Allen-Bradley

Brush-Type Synchronous Motor Controller

Bulletin 1912B, 36-inch, 400A
Single Phase Exciter

User Manual

Rockwell Automation

Important User Information

Read this document and the documents listed in the Additional Resources section about installation, configuration, and operation of this equipment before you install, configure, operate, or maintain this product. Users are required to familiarize themselves with installation and wiring instructions in addition to requirements of all applicable codes, laws, and standards.

Activities including installation, adjustments, putting into service, use, assembly, disassembly, and maintenance are required to be carried out by suitably trained personnel in accordance with applicable code of practice.

If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

	**WARNING:** Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
	**ATTENTION:** Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

Labels may also be on or inside the equipment to provide specific precautions.

	**SHOCK HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
	**BURN HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.
	**ARC FLASH HAZARD:** Labels may be on or inside the equipment, for example, a motor control center, to alert people to potential Arc Flash. Arc Flash will cause severe injury or death. Wear proper Personal Protective Equipment (PPE). Follow ALL Regulatory requirements for safe work practices and for Personal Protective Equipment (PPE).

Product Overview

Required Reference Manuals

This manual applies to the Bulletin 1912B synchronous starter in a 36-inch wide cabinet and a static exciter rated up to 13 kW. It is intended to provide information for installation and commissioning of the synchronous starter, maintenance for the field switch assembly and troubleshooting procedures. The publications listed below are required for detailed information on those components and procedures that are not covered in this manual. **Do not begin commissioning, installation or maintenance unless the following publications are available and understood:**

- User Manual, Medium Voltage Controller, Bulletin 1512, 400A, Two-high Cabinet, Publication 1500-UM055B-EN-P
- User Manual, Medium Voltage Contactor, Bulletin 1502, 400A, 2400-7200 volts, Publication 1502-UM052B-EN-P

Additional publications, depending on the controller used:

- Instruction Manual, SyncPro™, Bulletin 1901, Publication 1901-UM020B-EN-P
- Other third party products

Component Layout

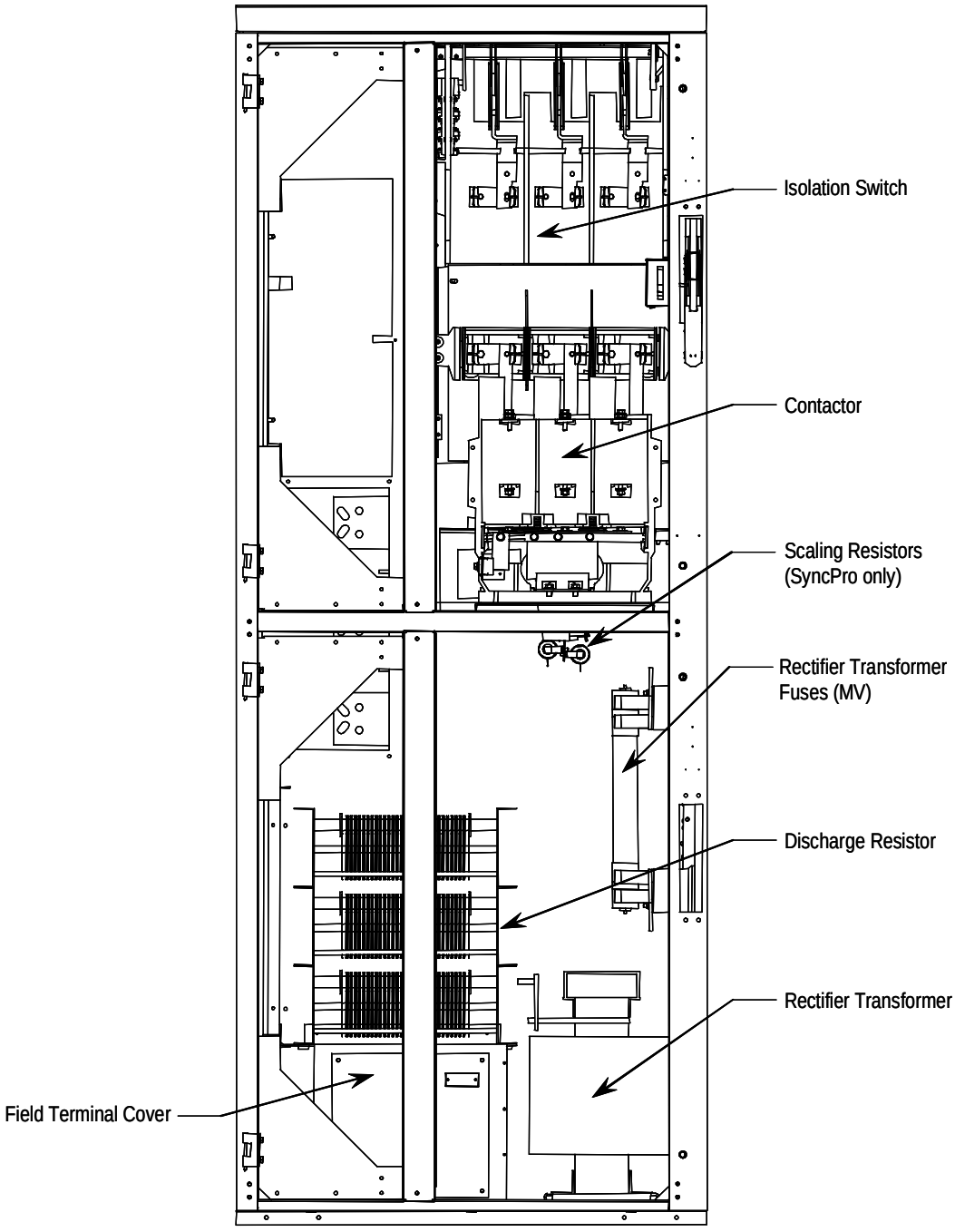


Figure 1.1 – Synchrounous Starter Component Layout

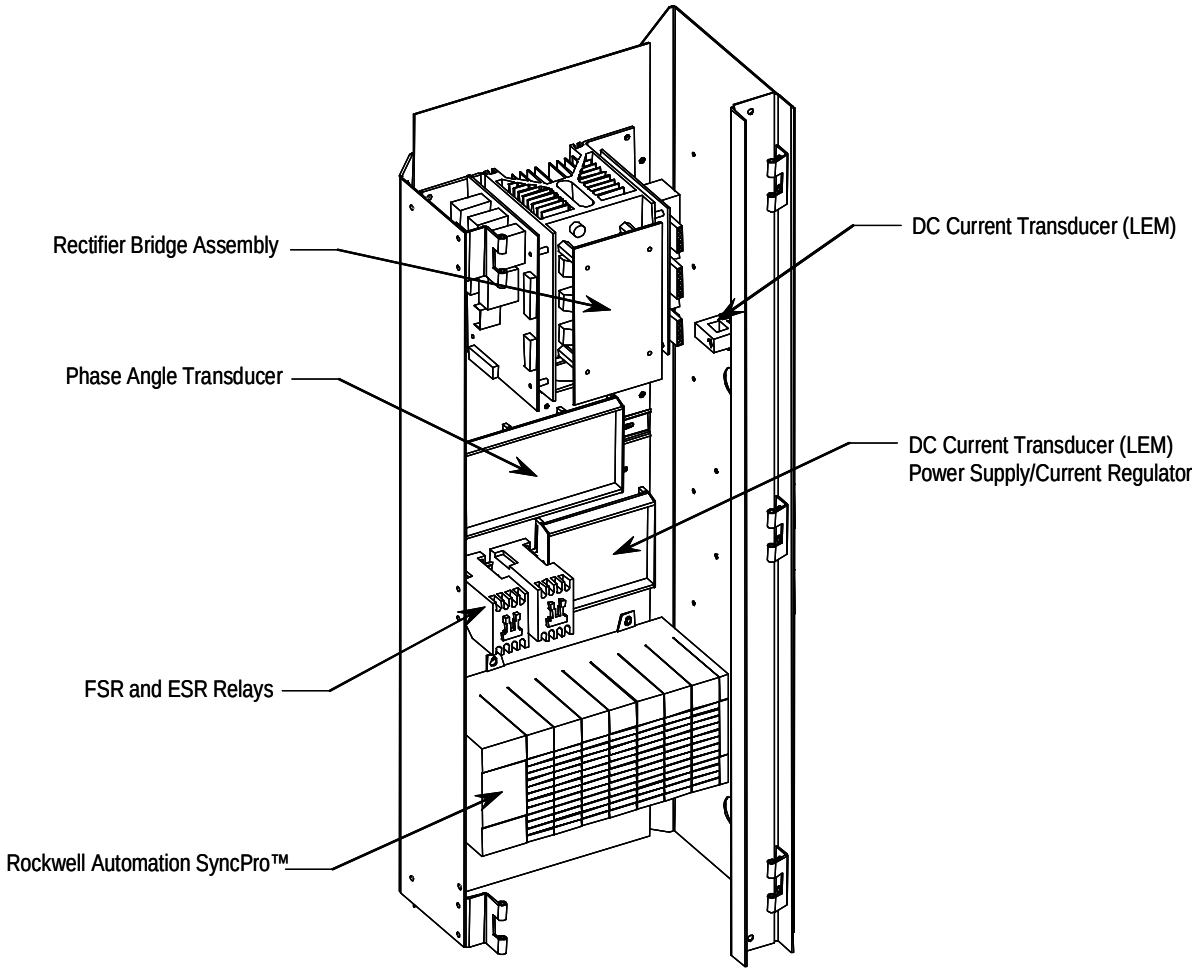


Figure 1.2 – Low Voltage Component Layout (with Sync Pro™)

Component Layout (Cont.)

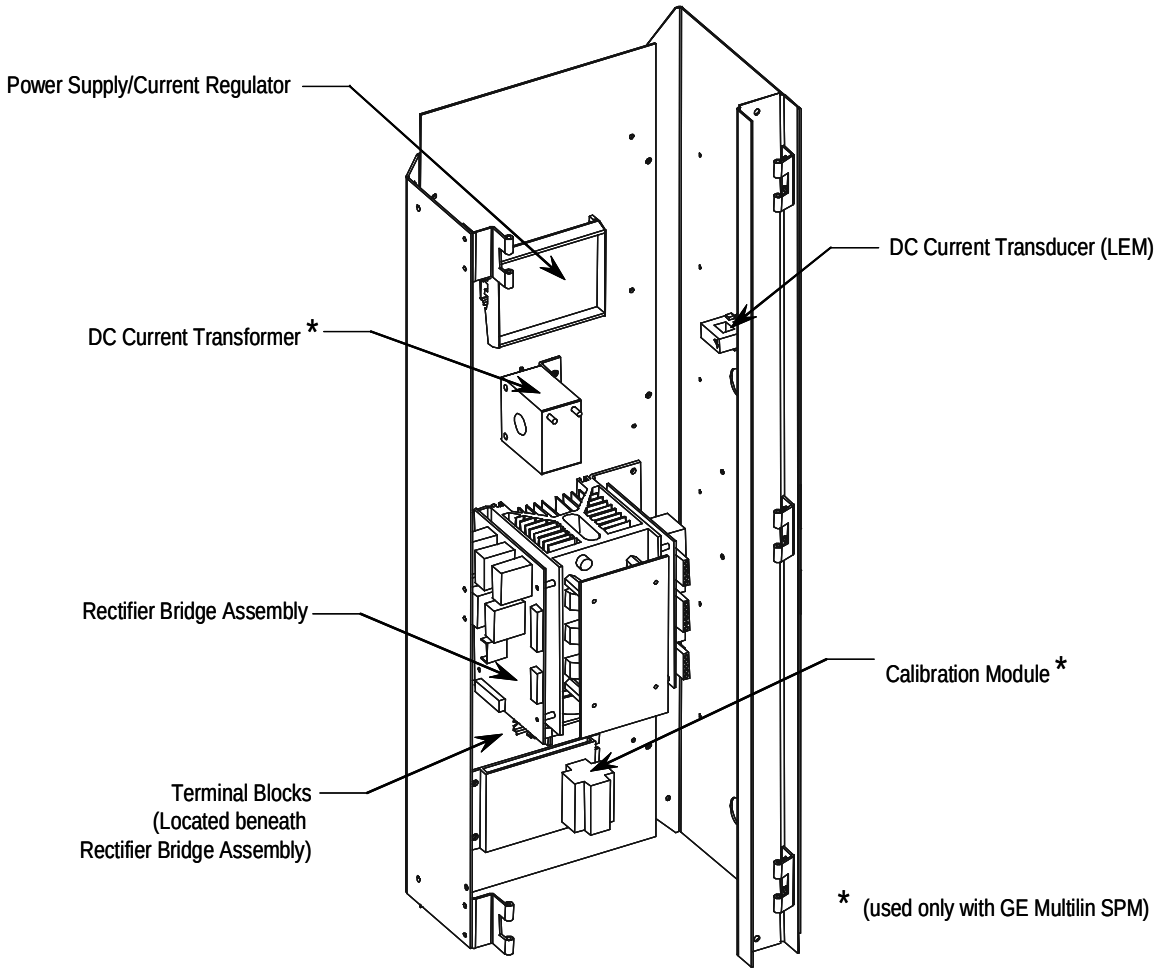


Figure 1.3 – Low Voltage Compartment Layout (with Multilin SPM)

Installation

Power Connections

Incoming Line Power

Refer to ***User Manual, Medium Voltage Controller, Bulletin 1512, 400A, Two-high Cabinet, Publication 1500-UM055B-EN-P*** for the procedure to connect incoming line power to the main bus of the Synchronous starter.

Load Cables and Field Connections

ATTENTION

To avoid shock hazards, lock out incoming power (see ***Power Lock-out Procedure in User Manual, Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P***) before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

a) Complete the Power-lock out procedure for the medium voltage power cell and the main power bus (see Publication 1500-UM055B-EN-P).
b) Remove the hinge pins from the medium voltage doors and remove the doors.
c) Open the low voltage power cell doors.

For Top Entry Field Cables and Top Exit Load Cables

1) Disconnect the control wiring harness from the wire plug at the lower left side of the contactor (see Figure 2.1).
2) Remove the two self-tapping screws from the upper and lower center vertical channels.
3) Pull on the center vertical channel to swing out the low voltage panel. Open both low voltage panels.

ATTENTION

Several wire bundles are routed around the low voltage panels. Excercise caution when swinging the panels open to avoid damaging the wires.

4) Remove the glass-polyester barrier located in front of the current transformers.
5) Remove the cable duct barrier and the field terminal cover from the lower power cell (see Figure 2.2).

Power Connections (cont.)

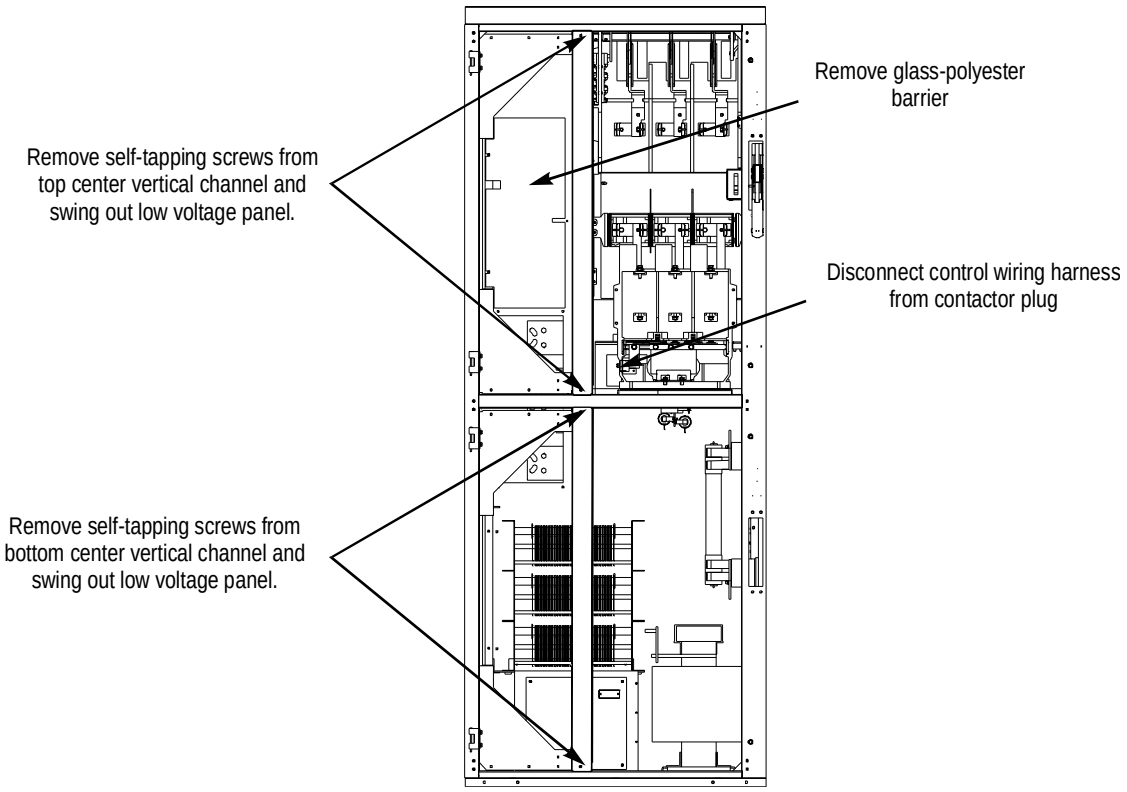


Figure 2.1 – Access to Cable Terminals (Low voltage panels not shown)

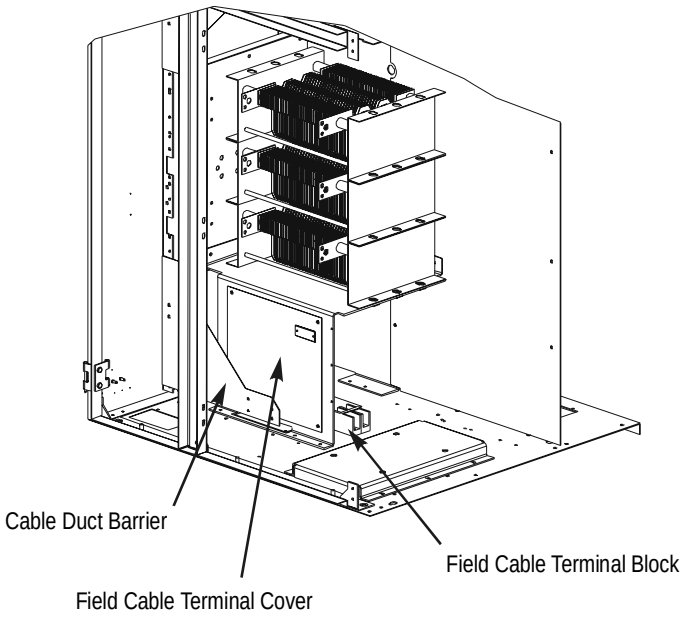


Figure 2.2 – Access to Field Cable Terminal Block (Cutaway view - Power cell doors and side panel not shown)

For Top Entry Field Cables and Top Exit Load Cables (cont.)

6) Use conduit cover ‘D’ (shown in Figure 2.3) for field (DC) cable entry.

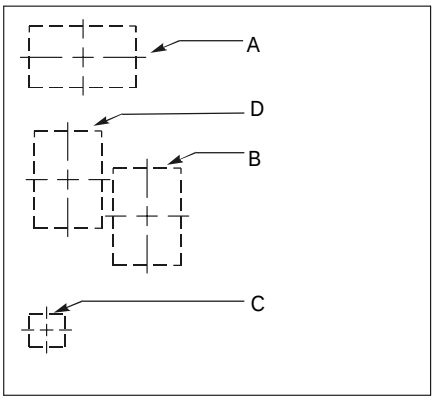


Figure 2.3 – Incoming Field Cable Conduit Cover (Top of cabinet shown)

7) Route the field cable (DC) into the cabinet through conduit D. Route the cables behind the current transformer mounting plate and into the lower power cell. You will need approximately 3 meters (10 feet) of cable.

8) Pull the cables into the lower power cell and route them behind the mounting plate to the floor of the cabinet. (See Figure 2.2)

9) Connect the cables to the field cable terminal block on the floor of the cabinet (see Figure 2.2). Connect the positive power cable to terminal F1 of the field cable terminal block. Connect the negative power cable to terminal F2. Torque the screws to 35-50 lb-in.(4.0-5.6 Nm).

10) Use conduit cover B (see Figure 2.3) for the load cables (AC).

11) Pull the load cables into the cabinet. You will need approximately 1.5 meters (5 feet) of cable.

12) Place lugs on cables and connect to the current transformers. Tighten the connections to 48 ft·lb (65 Nm).

13) Connect the cable shields to the ground lug.

14) Reassemble the cabinet. Re-install all barriers removed in previous steps.

ATTENTION

Ensure that all barriers are replaced before energizing the equipment. Failure to do so may result in electrical faults and cause damage to the equipment or serious injury to personnel.

Power Connections (cont.)

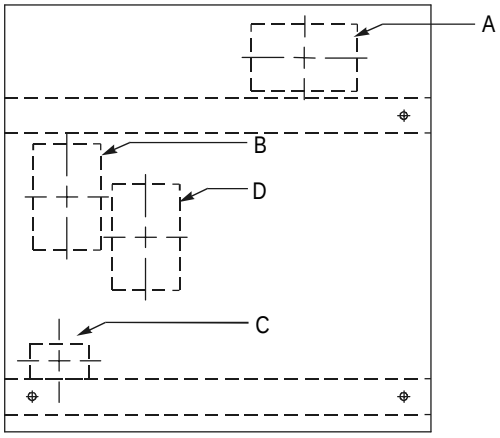
For Bottom Entry Field Cables and Bottom Exit Load Cables

1) Remove the two self-tapping screws from the bottom center vertical channel (see Figure 2.1).
2) Pull on the center vertical channel to swing out the bottom low voltage panel.
3) Remove the cable duct barrier and the field cable terminal cover from the lower power cell (see Figure 2.2).

ATTENTION

Several wire bundles are routed around the low voltage panels. Excercise caution when swinging the panels open to avoid damaging the wires.

4) Use conduit cover 'D' (shown in Figure 2.4) for field (DC) cable entry.



Front

Figure 2.4 – Conduit Covers (Bottom of Cabinet Shown)

5) Route the field cables (DC) into the right of the cabinet. You will need approximately 1 meter (3 feet) of cable.
6) Connect the cables to the field cable terminal block on the floor of the cabinet (see Figure 2.2). Connect the positive power cable to terminal F1 of the terminal block on the floor of the cabinet. Connect the negative power cable to terminal F2. Torque the screws to 35-50 lb-in. (4.0-5.6 Nm).
7) Use conduit cover B (see Figure 2.4) for the load cables (AC).
8) Pull the load cables into the cabinet.
9) Route the cable behind the panel to the left of the discharge resistor and connect the cables to the current transformer. Tighten the connections to 48 ft·lb (65 Nm).

10) Connect the cable shields to the ground lug.

11) Reassemble the cabinet. Re-install all barriers removed in the previous steps.

ATTENTION

Ensure that all barriers are replaced before energizing the equipment. Failure to do so may result in electrical faults and cause damage to the equipment or serious injury to personnel.

Control Connections

Refer to the wiring diagrams provided with your order and complete the connection of any remotely located control devices indicated. The Typical Wiring Diagrams (Appendix A) can be used as an additional reference for those orders using a SyncPro controller.

Commissioning

Pre-energization Checks

ATTENTION

To avoid shock hazards, lock out incoming power (see **Power Lock-out Procedure** in User Manual, **Medium Voltage Controller, Bulletin 1512, *Publication 1500-UM055B-EN-P***) before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

Verify that:

1) All mechanical interlocks are functioning properly. The medium voltage doors must not open when the isolation switch handle is in the ON position.
2) All protective barriers are in place and correctly fastened.
3) All fuses are correct class, type and rating.
4) The interior of the cabinet is free from dirt, loose hardware, tools or metal chips. Vacuum clean if necessary.
5) The control plug is securely connected to contactor plug.
6) All power cables are firmly secured and connections are torqued to proper specifications. (Refer to Table 3.A)
7) Any remote wiring to starter is properly connected and torqued to the recommended specifications.
8) The starter is properly grounded to the system ground grid.
9) Where a starter is joined to other enclosures, all ground splices and power bus splices are properly connected (see the section covering **Bus Splicing** in User Manual, ***Medium Voltage Controller, Bulletin 1512,Publication 1500-UM055B-EN-P***).

Table 3.A – Recommended Torque

Hardware	Recommended Torque
1/4 in.	6 ft·lb (8 N·m)
5/16 in.	11 ft·lb (15 N·m)
3/8 in.	20 ft·lb (27 N·m)
1/2 in.	48 ft·lb (65 N·m)
Wire terminal screws	2.0 – 3.3 in·lb (2.5 – 4.0 N·m)

Pre-energization Checks (cont.)

10) With the motor stopped, measure the DC field windings resistance directly at the slip rings of the motor or at the field wiring entering the synchronous starter. Ensure that there are no parallel resistances when taking the measurement. Isolate the brushes on the slip ring as they add additional resistance. Direct measurement at the slip rings is the preferred method.

11) Record the measurement from the previous step R_{field}= _____ Ω.

12) Compare the resistance from the previous step to the value recorded in the motor Information Sheet, Table 3.B. Any discrepancies must be within tolerable limits (refer to motor manufacturer's data sheets).

13) All plug-in connectors on the static exciter are firmly secured.

14) Measure the discharge resistance in the starter. Ensure that no parallel resistances are present by disconnecting the appropriate wiring. Check that this value is the same as the motor manufacturer's specifications or is the same value as the previous starter (for retrofit applications). Ensure that all wires are reconnected.

ATTENTION

Confirm that there is continuity through the discharge resistor and that the discharge resistor is the correct value, especially with retrofit applications. Severe damage to the motor and /or controller may occur if the wrong discharge resistor is selected.

15) If the starter has a SyncPro module installed, proceed to the section titled *Programming the SyncPro*.

16) If the starter has a Multilin SPM module installed, then proceed to the section titled *Programming the Multilin SPM*.

Motor Information

Table 3.B – Motor Information Sheet

CUSTOMER INFORMATION					
Customer					
Location					
Application					
RA/AB Job Number (Series Number)					
Customer Starter Tag/ID Name					
Commissioned By					
Commissioned Date					
SYNCHRONOUS MOTOR NAMEPLATE DATA					
Manufacturer		Serial Number		Date of Manufacturing	
Frame		Model		Type	
kVA		hp/kW		RPM	
Rated Stator Volts		Full Load Amps		Power Factor	
Frequency		I Field (A DC)		Efficiency	
V Field (V DC)		Phases		R field ( )	@ °C
Insulation Class - Rotor		Insulation Class - Rotor		Max. Ambient Temp. (°C)	
Temp. Rise Stator (°C)		Temp. Rise Stator (°C)		Time Rating	
Service Factor		Enclosure		Locked Rotor kVA/hp	
Acceleration Time to Full Speed (asynchronous speed)					
Time allowed at:	0% speed: _____ s		50% speed: _____ s		95% speed: _____ s
	Allowable starts per hour		Hot _____		Cold _____
STATIC EXCITER DATA					
Voltage DC rating			I DC rating		
DC CT	_____ A @ _____ mV				
FIELD WINDING INDUCED CURRENT DATA					
Induced Amps rms at 0% rpm		Induced Amps rms at 50% rpm		Induced Amps at 95% rmp	
FIELD DISCHARGE RESISTOR					
Discharge Resistor (___)	_____ at _____ °C				

Other information (load type, how load is applied (during acceleration/after acceleration/manual/automatic), new or existing motor, retrofit or new starter installation …):

SyncPro

Refer to ***Instruction Manual, SyncPro Bulletin 1901, Publication 1901-UM020B-EN-P, Chapter 4*** for the SyncPro setup and commissioning procedures.

Programming the SyncPro

The SyncPro must be programmed prior to use to ensure synchronization and protection of the synchronous motor.

Refer to ***Instruction Manual, SyncPro Bulletin 1901, Publication 1901-UM020B-EN-P, Chapter 5*** for the complete procedure to enter the setpoints into the control module.

The following is a brief summary outlining the procedure to enter the setpoints.

Use the data table access module (DTAM) to enter the setpoints into the SyncPro. Place the DTAM into the MODIFY mode by using jumpers at terminals 1 and 2 through the access port at the rear of the DTAM. Once all the setpoints are entered into the control module, record the data in Table 3.C.

Table 3.C – Setpoints

		Firmware Revision Level:
	Setpoints	
1.	Minimum percent Synchronous Slip Frequency	
2.	Power Factor Trip (lagging PF)	
3.	Power Factor Trip Time Delay	
4.	Squirrel Cage Protection Trip Time at 95% Speed	
5.	Squirrel Cage Protection Trip Time at 50% Speed	
6.	Squirrel Cage Protection Trip Time at 0% Speed (stall)	
7.	Function Number	
8.	Incomplete Sequence Trip Time Delay	
9.	Diagnostic Fault Mask	
10.	System Frequency (N23:1)	

Notes:

- The information from Table 3.B can be used to determine setpoints 4, 5, 6 and 8.
- Setpoints 4, 5 and 6 are used to protect the squirrel cage winding of the motor during starting. The motor manufacturer must specify the maximum allowed time at 95%, 50% and 0% speed. Setpoints 4, 5 and 6 should be set to a value lower than the manufacturer specified allowed time to protect the squirrel cage winding.
- Setpoint 8 is the maximum allowable time for synchronization before the controller aborts the starting sequence. This parameter should be set higher than the normal acceleration time of the motor recorded on the Table 3.B.

Tap Settings for R_{F1} and R_{F2}

Scaling resistors (R_{F1} and R_{F2}) make safe and sufficient voltage available to the A/D pulse generator board for proper determination of the rotor speed. If the settings for R_{F1} and R_{F2} are too low, the voltage that appears at the terminals for the A/D pulse generator board may be high enough to damage the board.

If the settings for R_{F1} and R_{F2} are too high, the voltage that appears at the terminals of the A/D pulse generator board may be prematurely blocked and falsely indicate an up-to-speed condition.

1) Determine the following information before proceeding
   - Induced current at 0% speed - I_0 (amps rms);
   - Induced current at 95% speed - I_{95} (amps rms);
   - Resistance of discharge resistor - R_{DIS} (Ω).
2) If I_0 and I_{95} are known, proceed to Determining the Tap Settings, page 3-9.
3) If I_0 and I_{95} are not known, proceed to Measuring the Induced Current.

For the complete procedure refer to ***Instruction Manual, SyncPro, Bulletin 1901, Publication 1901-UM020B-EN-P,*** Chapter 4 – R_{F1} and R_{F2} Resistor Setup.

Measuring the Induced Current

ATTENTION

To avoid shock hazards, lock out incoming power ***(see Power Lock-out procedure*** in ***User Manual, Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P)*** before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

1) Disconnect all connections on the discharge resistors from the circuit.
2) Jumper across the trip output on the SyncPro (0:3/01) or GE Multilin SPM.

ATTENTION

The protection features of the SyncPro will not function while the jumper wire is across trip output 0:3/01. Be prepared to stop the motor using the emergency stop if necessary. Failure to do so may result in personal injury and/or damage to the equipment.

Measuring the Induced Current (cont.)

3) Using a resistance measuring device accurate to at least one decimal place, measure the resistance of point R1 and R3 to obtain a resistance of 1Ω (refer to Figure 3.1). Ensure that there are no parallel resistances while taking this measurement.

Important: The 1Ω value was chosen to provide sufficient reduction of the total voltage that will appear across the discharge resistor using the voltage divider rule. If the discharge resistor has a value of 2 Ω, the tap selection of 1Ω may not be low enough to provide the necessary reduction in voltage. Select a more suitable tap selection such as 0.2 Ω. Use care in selecting the taps since the strip chart recorder or oscilloscope ratings must not be exceeded.

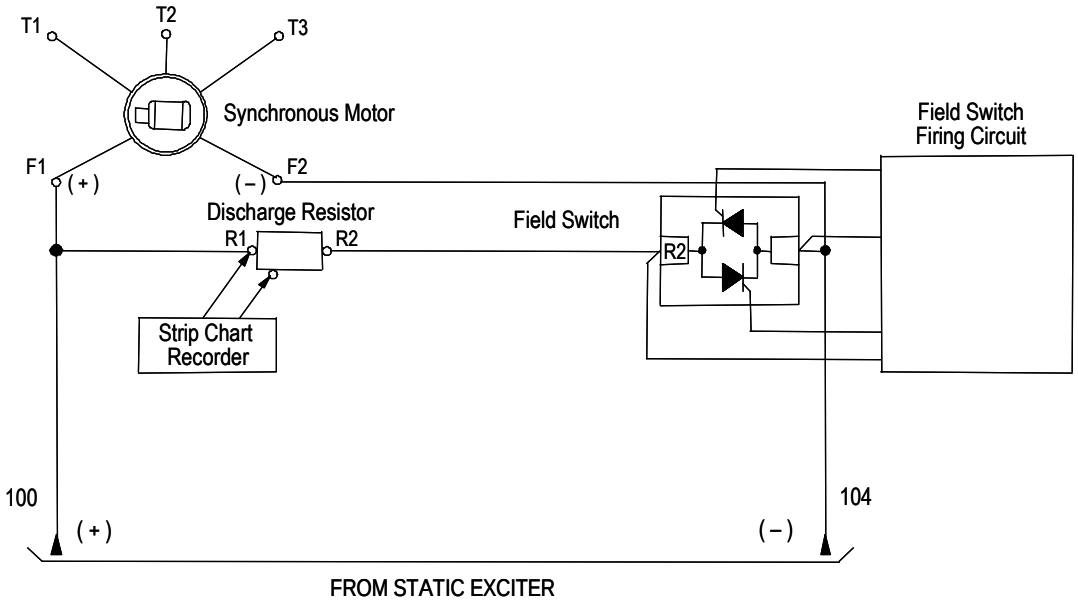


Figure 3.1 – Final Connections to Discharge Resistor

4) Reconnect all wires removed (in Step #1) from the discharge resistor to the circuit.
5) Verify that all wiring is correct.
6) Connect a strip chart recorder or oscilloscopes to point R1 and R3. The recorder must be peak-to-peak indicating at frequencies of 1 Hz to 60 Hz and be able to read 1000 V AC.
7) Start the motor as during normal operation (i.e. full voltage starting, reduced voltage starting, etc.). See **Applying Medium Voltage**, page 3-11.

Note: An induced current (with an initial frequency the same as the supply) is generated in the field circuit when the motor is started. The induced current develops a voltage across points R1 and R3 during motor acceleration.

8) The induced current and voltage readings across points R1 to R3 will vary as the motor speed increases. The frequency of the induced voltage will drop to about 3 Hz as the motor reaches near synchronous speed (95% speed).

9) The strip chart printout (or captured waveform on oscilloscopes) should show voltage readings between 0% speed and 95% speed, the point of motor synchronization. It should also show the normal acceleration time of the motor. Conduct a few test runs to determine the best use of the chart width to obtain accurate results. Ensure that time and voltage scales are indicated on the printout (see Figure 3.2). Do not exceed the starting duty of the motor.

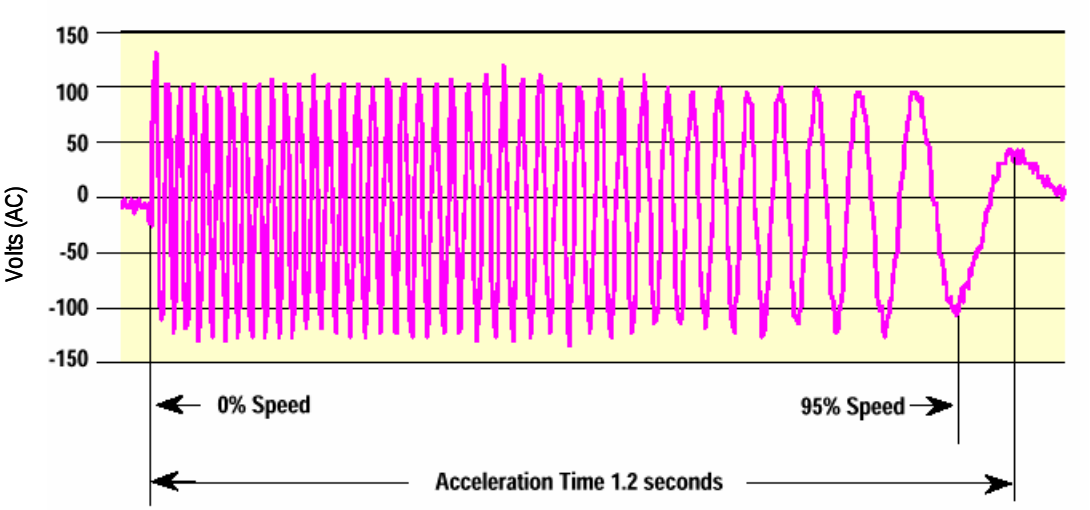


Figure 3.2 – Sample Strip Chart Recording

10) Remove the two jumper wires that were installed in Step 2 and 3.

11) The waveform provides the induced current values at 0% and 95% speed, but further calculations are required to obtain the RMS value. Follow the example below and reference Figure 3.2 to determine the I_0 and I_{95} Amps rms.

EXAMPLE: (Refer to Figure 3.2)

$$V_{RMS} = \frac{V_{pk\text{-}pk}}{2\sqrt{2}}$$

$V_{0pk\text{-}pk}$ – the peak-to-peak voltage at 0% speed is approximately 240V
$V_{95pk\text{-}pk}$ – the peak-to-peak voltage at 95% speed is approximately 190V

V_0 – the rms voltage at 0% speed is $V_{0pk\text{-}pk} \div 2\sqrt{2}$

$= 240V \div 2\sqrt{2}$
$= 84.9$ Vrms

V_{95} – the rms voltage at 95% speed is $V_{95pk\text{-}pk} \div 2\sqrt{2}$

$= 190V \div 2\sqrt{2}$
$= 67.2\ V_{RMS}$

Since the voltage was captured across a 1 Ω resistance, then according to Ohm's law the voltage waveform equals the current waveform.

$$I_0 = \frac{V_{RMS}}{R_{R1\text{-}R3}}$$

$R_{R1\text{-}R3} = 1\ \Omega$ in this example

Therefore, $I_0 = 84.9$ A rms, and $I_{95} = 67.2$ A rms.

For your specific set up, determine I_0 and I_{95} then proceed to determining the Tap Settings, page 3-9.

Determining the Tap Settings

1) Use Ohms law to determine the corresponding induced voltages:
   a) Voltage Induced @ 0%speed – V_0 (V rms) = I_0 x R_{DIS}
   b) Voltage Induced @ 95%speed – V_{95} (V rms) = I_{95} x R_{DIS}

2) The value of V_0 and V_{95} must fall within the lower and upper limits on the same row of Table 3.D.

Table 3.D – Usable Voltage Range

R_{fi} and R_{f2} (kΩ)	Usable Voltage Range	
	Lower Limit (V_{95} rms)	Upper Limit (V_0 rms)
2.5 60		160
5.0 120		320
7.5 170		480
10.0 230		640
12.5 290		800
15.0 350		950
17.5 400		1100
20.0 460		1300

3) The value of R_{F1} and R_{F2} (R_{F1}=R_{F2}) corresponds to the row in which V_0 and V_{95} were placed.

4) Make the necessary connections on both R_{F1} and R_{F2} in the starter to achieve the resistance as determined from the previous steps. Refer to ***Instruction Manual, SyncPro Bulletin 1901, Publication 1901-UM020C-EN-P, Chapter 4.***

EXAMPLE:

Given: I_0 = 30A, I_{95} = 18A, R_{DIS} = 20 Ω

Then V_0 = 600V rms and V_{95} = 360V rms

The table shows that a lower limit of 230V and upper limit of 640V is the most appropriate selection. Thus, R_{F1} and R_{F2} must be 10 kΩ each. The value of 10 kΩ is the resistance between the tap setting on the resistor and the A/D Pulse Converter board.

If the value of V_0 and/or V_{95} do not fall within the specified range shown in Table 3.D, please contact Rockwell Automation Medium Voltage Product Support Division for further assistance.

Multilin SPM

Refer to ***Multilin SPM Instruction Manual*** for the setup and commissioning procedures for the Multilin SPM.

Programming the GE Multilin SPM

The SPM must be programmed before use to ensure synchronization and protection of the synchronous motor. Refer to ***GE Multilin SPM Instruction Manual*** for the procedure to enter the setpoints into the control module. Complete Table 3.E once the setpoints are entered.

Table 3.E – SPM Setpoints

Configuration	Settings
Motor Type (Brush or Brushless)	
Line Freq (Hz)	
PF Voltage Reference	
Statistics Protection	
Password	
Calibration	
FS EXC VOLT	
FS EXC AMPS	
FS MTR AMPS	
Function Motor	
Power Factor Trip (lag)	
Power Factor Trip Delay (seconds)	
Power Factor Suppression % of full load amps	
Power Factor Mode	
FAR Delay (seconds) — (Brushless motors only)	
FCX Delay (seconds)	
AC CT Rating /5	
Full Load Amps (amperes)	
Locked Rotor Amps (amperes)	
Sync. Slip %	
Stall Time (seconds)	
Run Time x ST	
DC CT Primary (amperes)	
High (Exciter) Field Ohms (ohms)	
(Exciter) Field Amps (amperes)	
(Exciter) Field Volts (volts)	
Incomplete Sequence Delay (seconds)	
Regulator Power Factor Option Power Factor	
Regulator Gain Option X	
Regulator Stability Option cycles	
Regulator Output Option volts	
Floor Volts Option volts	

1) Ensure that the Pre-energization Check (see page 3-1) have been completed.
2) Verify that all tools, loose hardware and debris is removed from the interior of the starter.
3) Make a final check of all medium voltage sections in the starter for any damage that may have occurred during installation.
4) Recheck the field discharge resistor to ensure that it is connected in the field discharge circuit (see *Field Discharge Resistor Wiring Check*, page 5-9).
5) Close all doors and tighten the door locking bolts. The application of medium voltage is now possible.

ATTENTION

If the unit is equipped with a Multilin SPM, do not touch any connection points at the rear of the SPM. Potentials of up to 1000 volts may be present across the inputs VF+ and VF-. Failure to avoid touching the connections may result in injury or death.

6) Check for correct rotation of the motor. Momentarily give the controller a start command, once rotation of the motor is positively noted, remove the start command and/or issue a stop command.
7) If the rotation is not correct switch the two motor cables at the motor terminals.

Important: The phase rotation of the incoming power is important for accurate power factor measurements. Reversing two incoming power connections may result in nuisance tripping and/or no protection against loss of synchronization. The phase sense on the phase angle transducer board must be voltage Va-b and current Ic.

Important: At this point in the procedure, the motor can operate under normal load conditions. If possible, avoid running the motor at no load and unity power factor. This causes large oscillations in power factor as the regulator attempts to maintain the unity power factor setting. This is an inherent behaviour of synchronous motors.

8) Monitor the power factor when the motor is started and is accelerating. The power factor must be lagging during the acceleration stage. If the power factor is not lagging, check the connections from the CT and PT secondary to the SPM. Verify the phase rotation of the medium voltage power supply.

Programming the GE Multilin SPM (cont.)

9) While running at a leading power factor and at a constant load, verify that as DC field current is increased the stator current also increases, and the motor power factor becomes more leading.

10) While running at a leading power factor and at a constant load, verify that as DC field current is decreased the stator current decreases and the motor power factor becomes more lagging.

11) To verify the power factor reading the following options can be used:

    a) If it is possible to run the motor at rated load and rated DC field excitation current, the displayed power factor should be the rated power factor of the motor.

    b) Compare the power factor displayed on the DTAM to any of the other power factor measurement devices in the motor circuit.

    c) If an oscilloscope is available that can measure current (clamp-on probe), use the first channel to measure line voltage Va-b, and the other channel to measure current in phase A. Phase A current is available from the current transformer in phase A, where the secondary is brought to the low voltage panel.

12) Confirm that the power factor protection functions at the desired trip setting. This is achieved by running at a constant load and then slowly reducing the DC field excitation until the power factor goes below the PF TRIP LEVEL for the duration entered in the PF TRIP DELAY. When this occurs, the starter must open the main contactor, which removes medium voltage to the motor.

13) Set the maximum DC current that can flow into the DC field windings. For the procedure, refer to page 5-12, *Field Current Maximum Settings Adjustment*.

Troubleshooting

Table 4.A – Troubleshooting

Problem	Cause	Diagnosis
No DC output	Excitation source interrupted	• Check low voltage and medium voltage fuses.

	No power to Firing Card	• Check firing card for power – indicated by a green LED on card
		• Verify that control (source) power is on.
		• Check all connections and fuses.
		  • To check fuses, disconnect J3 and measure from Pin 1 to Pin 5 with an ohmmeter. The resistance should be less than 500 Ohms.
		  • If resistance is too high, replace the firing card

	No power to DC Current Transducer (LEM) Power Supply/Current Regulator	• Check card for power – indicated by a green LED on card.
		• Verify that control (source) power is on by measuring at TB1- pin 5 and at TB1-pin 4. (see Figure 4.1)
		• Verify the correct position of SW1 (Voltage Selector Switch) if so equipped (see Figure 4.1).
		• Check Fuse F1
		  • Remove plug in TB1
		  • Remove fuse and visually inspect or check with an ohmmeter.
		• If LED is still not illuminated, replace power supply current regulator, P/N 80198-200-xx. (See Table 6.A)

	No current command	• Check door pot for proper setting – refer to Field Current Maximum Setting Adjustment, page 5-12.
		• Check the connection at TB3 on the DC Current Transducer (LEM) Power Supply (see Figure 4.1)
		• Check J4 (firing board) for proper connection
		  • Check the voltage at TB3-pin 9 and TB3-pin 10 on the DC Current Transducer (LEM) Power Supply (see Figure 4.1)
		  • If 5V present but not functioning, perform Firing Board Check (see page 5-10) – replace components if required

	Faulty Firing Card or faulty SCRs	• Perform Firing Board Check (see page 5-10) to determine faulty component • Replace faulty Firing Board or SCR
Unable to vary DC output between 0 and 100%	DC Current Transducer not connected or faulty	• Check the panel-mounted meter. If it is functioning, then the DC Current Transducer (LEM) Power Supply/Current Regulator is faulty – replace the component. • Check connections on the DC Current Transducer (LEM) Power Supply (TB2) and on the DC Current Transducer (LEM) (see Figure 4.1) • If the panel-mounted meter is not functioning, measure the voltage at TB2-pin 3 with reference to TP1 (see Figure 4.1). • Check adjustment of R56 – see Field Current Maximum Setting Adjustment (see page 5-12). • If the voltage is less than 0.25V when the current is flowing and the door pot is set to 100%, then the DC Current Transducer (LEM) is faulty – replace the component, P/N 80026-1230xx. (See Table 6.A)
Insufficient current at 100% pot setting	Maximum current setting not properly adjusted	• Perform Field Current Maximum Setting Adjustment (see page 5-12)
	Firing card not properly adjusted	• BIAS(R6) and SPAN(R7) pots should both be set to 100% and Resistor Network 2 (RN2) should be labeled 47k
Rectifier over-temperature trip	Bridge Rectifier Stack has overheated	• Note: Manually reset the thermistor (see Figure 5.1) • Verify ambient temperature does not exceed 40°C (104°F) • Check for control power at fan • Verify air movement • Replace the fan if it is not functioning
	Loose connections to snubber field switch board	• Verify proper connection at J7, J8, and J9

Troubleshooting (Cont.)

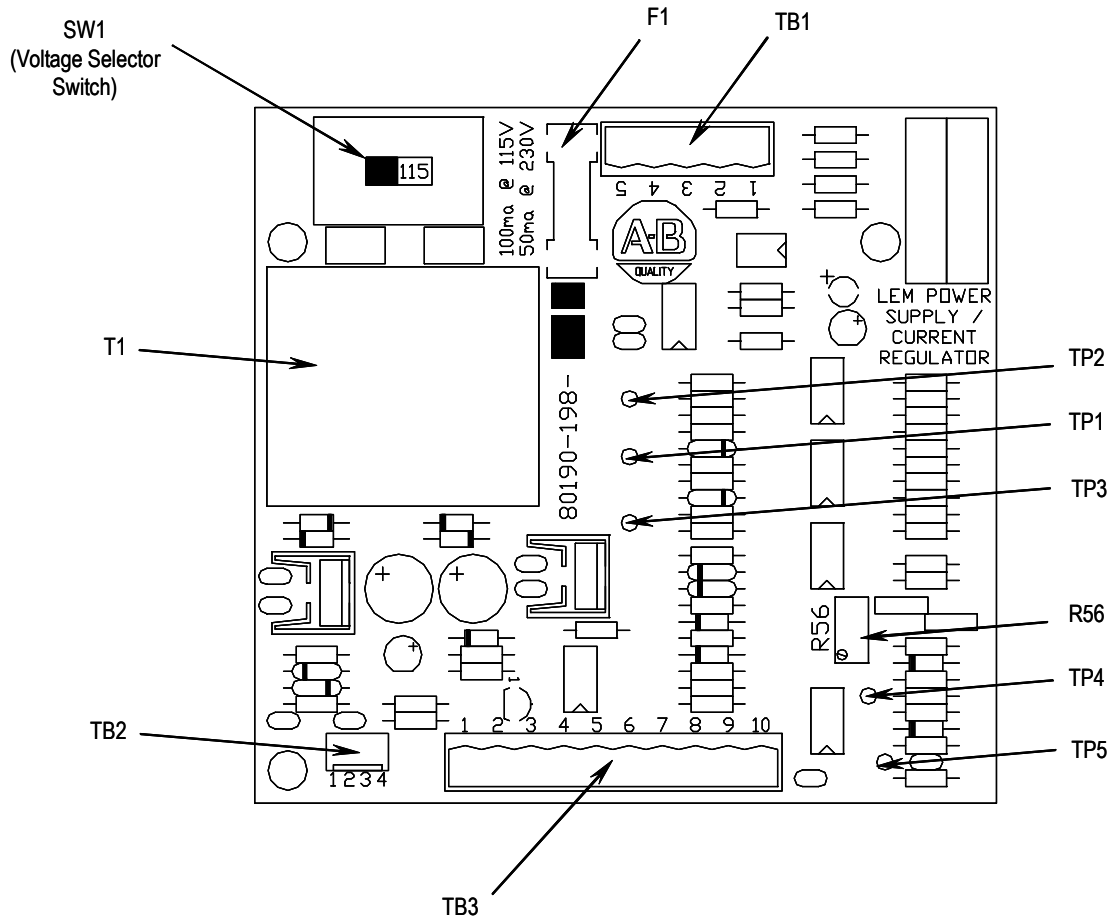


Figure 4.1 – LEM Power Supply/Current Regulator

Maintenance

Removal of Rectifier Bridge Assembly

ATTENTION

To avoid shock hazards, lock out incoming power *(see **Power Lock-out Procedure** in User Manual, **Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P**)* before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

1) Open the main medium voltage isolation switch for the starter.
2) Verify that the control power is off by testing the terminal blocks beneath the cooling fan (see Figures 1.2 or 1.3) with a hot stick or appropriate voltage measuring device.
3) Verify that the excitation source is off by testing points X1 and X2 (see Figure 5.1) with a hotstick or appropriate voltage measuring device.
4) Verify that there is no voltage on the positive and negative terminals of the DC bus (see Figure 5.1) with a hot stick or appropriate voltage measuring device.
5) Remove the retaining screws from the safety shield and remove the safety shield.

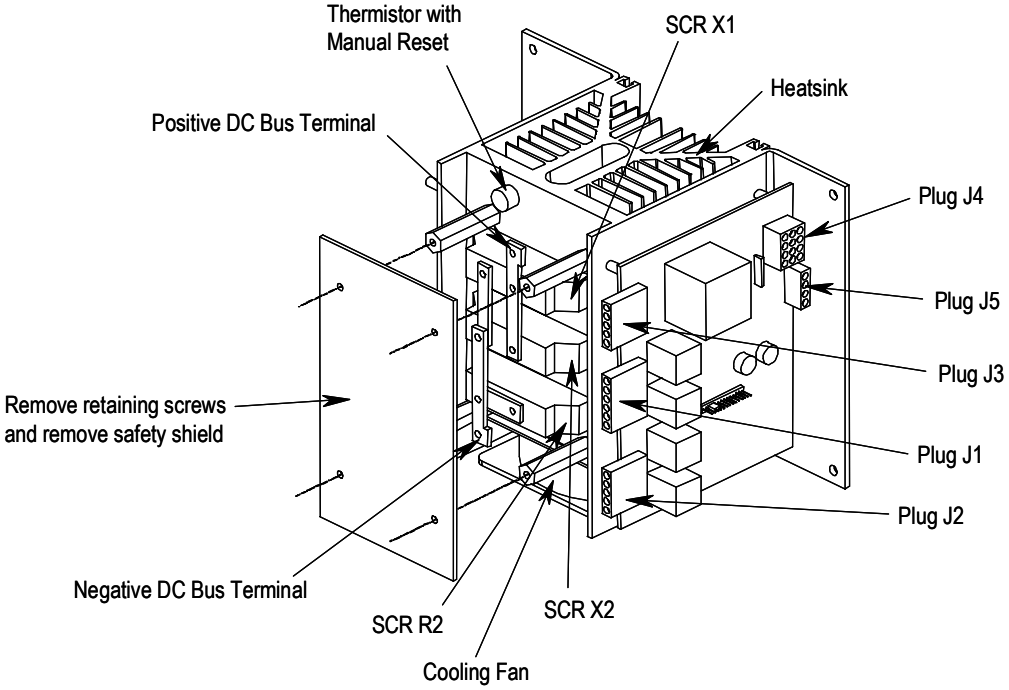


Figure 5.1 – Electrical Connections to Rectifier Bridge Assembly

Removal of Rectifier Bridge Assembly (cont.)

6) Loosen the wire retaining screws from SCRs X1, X2 and R2, and remove the wires. Remove the wires from the terminals on the positive and negative terminals of the DC bus. Mark the wires as they are removed to ensure proper reconnection.

7) Remove the wire plugs at points J3, J4, (see Figure 5.1) J9 (see Figure 5.3), and at the cooling fan.

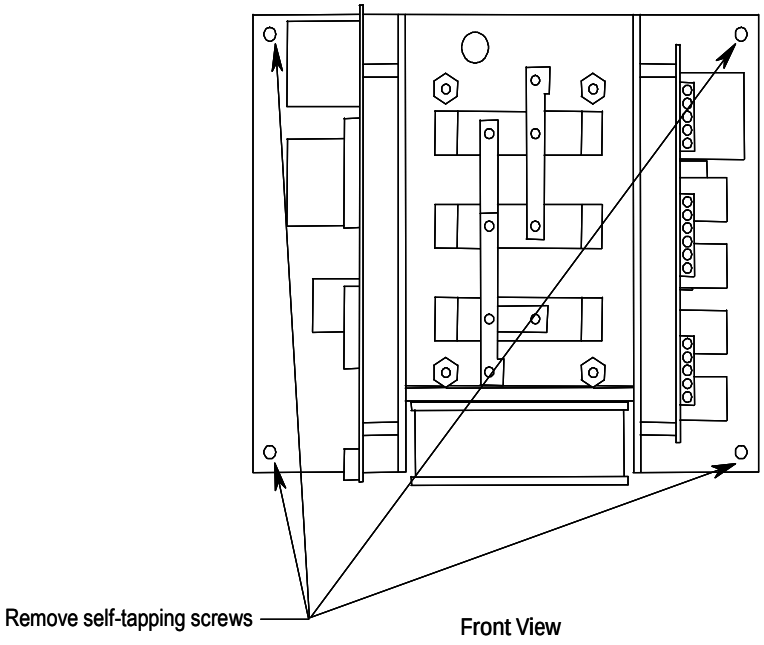


Figure 5.2 – Removing the Rectifier Bridge Assembly

8) Remove the self-tapping screws that secure the rectifier bridge assembly to the mounting plate. Remove the bottom two first, support the rectifier bridge assembly while removing the top two (see Figure 5.2)

9) Reverse the procedure to reinstall the rectifier bridge assembly.

10) Torque the wire retaining screws at X1, X2 and R2 to 2.0 – 3.3 in./lbs. (2.5 to 4 N/m).

11) Torque the wire terminal screws at the positive and negative terminals of the DC bus to 2.0 – 3.3 in./lbs. (2.5 to 4 N/m).

12) If any components were replaced, conduct the appropriate tests to verify proper functioning.

ATTENTION

Ensure all barriers are replaced before energizing the equipment. Failure to do so may result in electrical faults and cause damage to equipment or serious injury to personnel.

Snubber/Field Switch Board Replacement

ATTENTION

To avoid shock hazards, lock out incoming power (see ***Power Lock-out Procedure*** in *User Manual,* ***Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P***) before working on the equipment. Verify with a hot stick or approppriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

1) Open the main medium voltage isolation switch for the starter.
2) Verify that the control power is off by testing the terminal blocks beneath the cooling fan (see Figures 1.2 or 1.3) with a hot stick or appropriate voltage measuring device.
3) Verify that the excitation source is off by testing points X1 and X2 (see Figure 5.1) with a hotstick or appropriate voltage measuring device.
4) Verify that there is no voltage on the positive and negative terminals of the DC bus (see Figure 5.1) with a hot stick or appropriate voltage measuring device.
5) Verify that the part number of the replacement board matches that of the existing board.
6) Disconnect the wire plugs from J7, J8 and J9 (see Figure 5.3).
7) Remove the four retaining screws.

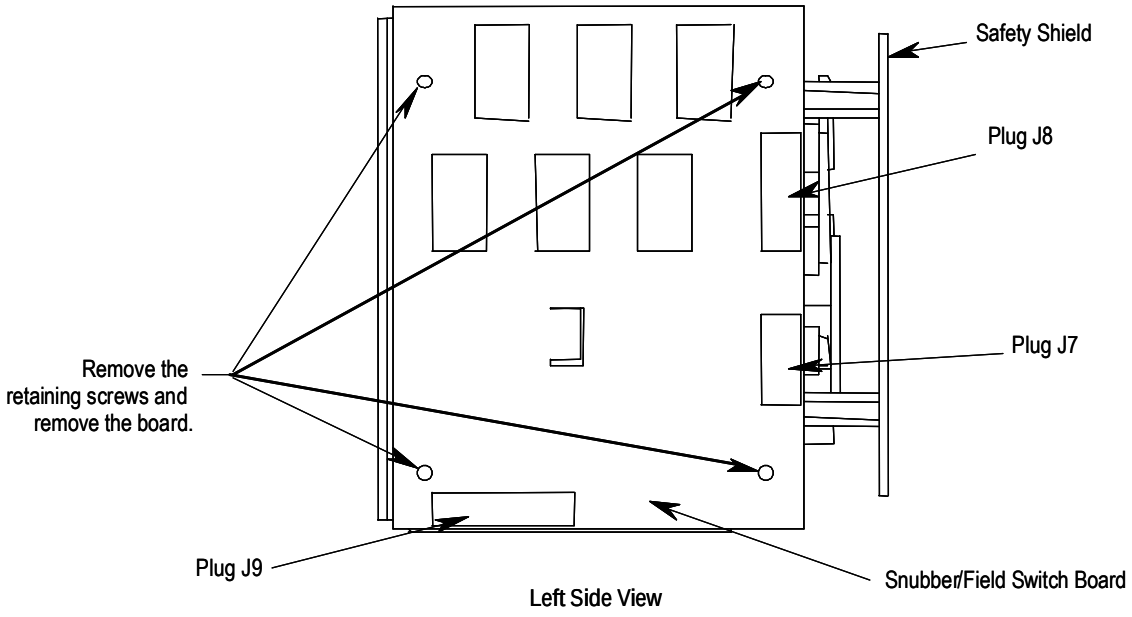


Figure 5.3 – Snubber/Field Switch Board Replacement

8) Remove the board.
9) Install the new board.
10) Install the four retaining screws.
11) Reconnect the plugs to J7, J8, and J9.

Firing Board Replacement

ATTENTION

To avoid shock hazards, lock out incoming power (see ***Power Lock-out Procedure*** in ***User Manual, Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P***) before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

1) Open the main medium voltage isolation switch for the starter.
2) Verify that the control power is off by testing the terminal blocks beneath the cooling fan (see Figures 1.2 or 1.3) with a hot stick or appropriate voltage measuring device.
3) Verify that the excitation source is off by testing points X1 and X2 (see Figure 5.1) with a hotstick or appropriate voltage measuring device.
4) Verify that there is no voltage on the positive and negative terminals of the DC bus (see Figure 5.1) with a hot stick or appropriate voltage measuring device.
5) Remove the plugs in J1, J2, J3, and J4 (see Figure 5.4).
6) Remove the four retaining screws from the board.
7) Remove the board.
8) Using the existing board as a reference, verify that the 50/60Hz jumper (marked J8) is set correctly on the replacement board. Pins 2 and 3 should be connected for 60Hz operations. The jumper should be removed for 50Hz operation.
9) Use a screwdriver to turn both pots (R6 and R7 on the FCR4100 firing board) fully clockwise. Seal the pots in the fully clockwise position with Loctite adhesive or equivalent.

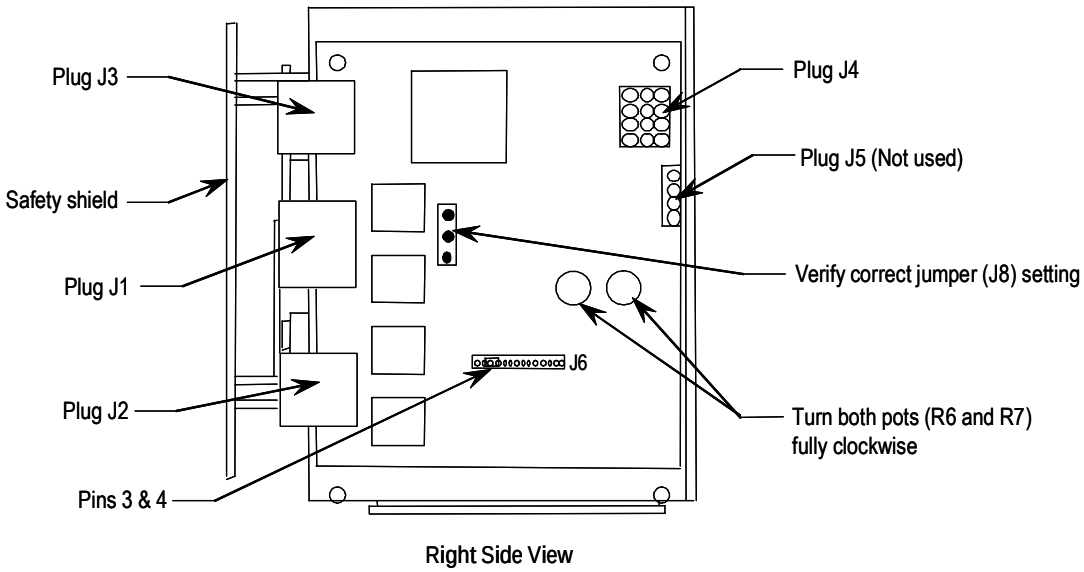


Figure 5.4 – Firing Board Replacement

10) Verify that pins 3 and 4 on J6, located on the card, are jumpered. (Refer to Figure 5.4)
11) Install the new firing board assembly.
12) Reconnect all connectors.
13) Perform the Firing Board Firing Check, page 5-10.
14) Perform the Field Current Maximum Setting Adjustment, page 5-12.

SCR Replacement

ATTENTION

To avoid shock hazards, lock out incoming power (see ***Power Lock-out Procedure*** in ***User Manual, Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P)*** before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

1) Open the main medium voltage isolation switch for the starter.
2) Verify that the control power is off by testing the terminal blocks beneath the fan (see Figure 1.1 or 1.2) with a hot stick or appropriate voltage measuring device.
3) Verify that the excitation source is off by testing points X1 and X2 (see Figure 5.1) with a hotstick or appropriate voltage measuring device.
4) Verify that there is no voltage on the positive and negative terminals of the DC bus (see Figure 5.1) with a hot stick or appropriate voltage measuring device.
5) Remove the retaining screws from the safety shield and remove the safety shield.
6) Remove the screws from the DC bus and remove the DC bus bars.

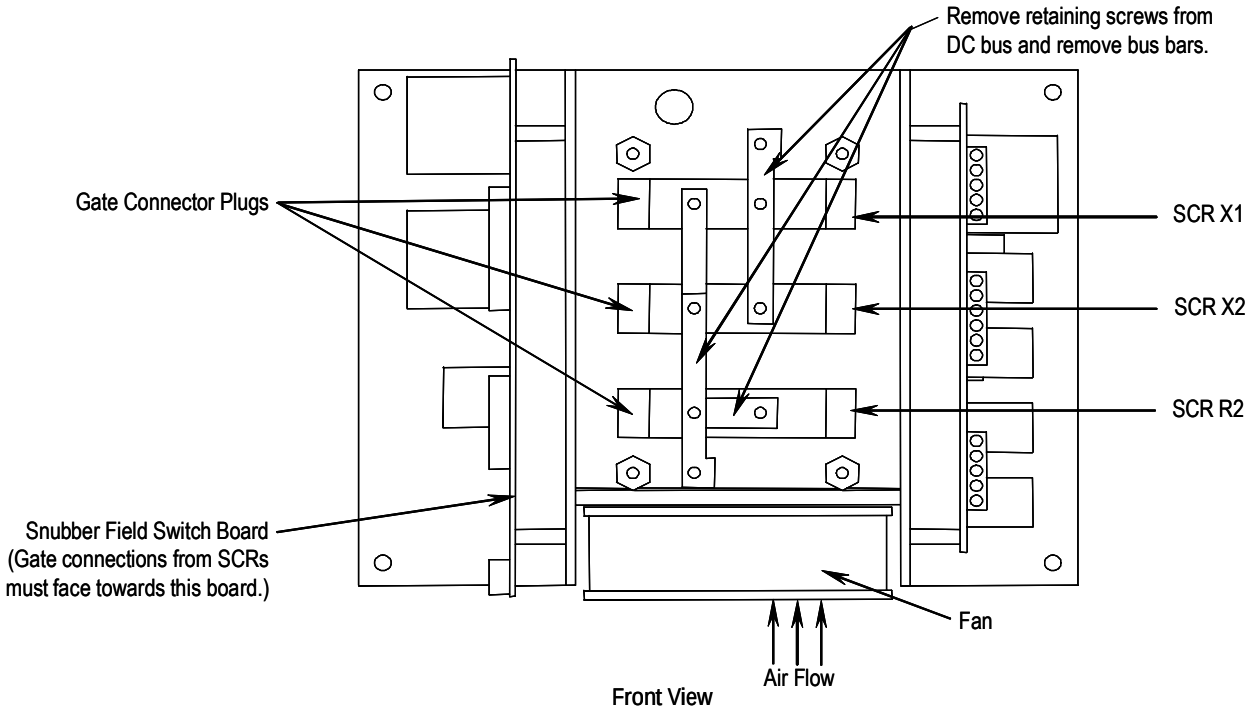


Figure 5.5 – SCR Replacement

7) Remove the gate connector plug from the SCRs that will be replaced (see Figure 5.5).

8) Remove the retaining screws from the SCR that will be replaced. Mark the wires to ensure proper reconnection.

ATTENTION

Replace SCRs X1 and X2 together. The failure of either SCR may damage the other. Failure to replace both SCRs (X1 and X2) may result in premature failure of the components. SCR R2 operates independently of the others and may be replaced separately.

9) Remove the SCR and replace it with the new one. When installing new devices, start at the top (X1) and work down. (Refer to Figure 5.5)

Important: The SCRs must be positioned with the Gate Connections located toward the snubber/field switch (SFS) board.

10) Reinstall the bus bars. Do not completely tighten the screws.

11) Position the SCR and bus bar assembly on the stack in the same position as the original devices.

12) Tighten SCR retaining screws to 2.0 – 3.3 in./lbs. (2.5 to 4 N/m).

13) Tighten bus bar screws to 2.0 – 3.3 in./lbs. (2.5 to 4 N/m).

14) Replace the safety shield.

15) Perform the Firing Board Firing Check Procedure, page 5-10.

Fan Removal and Replacement

ATTENTION

To avoid shock hazards, lock out incoming power *(see **Power Lock-out Procedure*** in ***User Manual, Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P)*** before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

1) Open the main medium voltage isolation switch for the starter.
2) Verify that the control power is off by testing the terminal blocks below the fan with a hot stick or appropriate voltage measuring device.
3) Verify that the excitation source is off by testing points X1 and X2 (see Figure 5.1) with a hotstick or appropriate voltage measuring device.
4) Disconnect the fan power plug.
5) Remove the four fan mounting screws and remove the fan. Make note of air flow direction on fan.
6) Verify that the voltage rating of the new fan matches that of the unit's control voltage.
7) Install the new fan. Check air flow direction on fan.
8) Replace all connections.
9) Apply test power. The fan should function as soon as power is restored. Airflow should be towards the top of the rectifier bridge assembly. Check wiring if the fan does not operate.

Field Discharge Resistor Wiring Check

ATTENTION

To avoid shock hazards, lock out incoming power (see ***Power Lock-out Procedure*** in ***User Manual, Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P)*** before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

1) Open the main medium voltage isolation switch for the starter.
2) Verify that the control power is off by testing the terminal blocks below the fan with a hot stick or appropriate voltage measuring device.
3) Verify that the excitation source is off by testing points X1 and X2 (see Figure 5.1) with a hotstick or appropriate voltage measuring device.
4) Remove retaining screws from safety shield and remove safety shield (see Figure 5.1).
5) Do a visual check to verify that all field related wiring appears correct. Use the supplied electrical drawings for reference.
6) Record the following information.
   - Motor Rotor Resistance
   - Installed Field Discharge Resistor Resistance
7) Measure the resistance from the exciter stack's positive DC bus to the negative DC bus. The resulting reading should be approximately equal to the connected motor's rotor resistance Refer to the R_{field} measurement in Table 3.B.

   If the readings are not close, check the wiring at the motor field terminals for tightness and proper connection points.
8) Measure the resistance from R2 to the negative DC bus. The reading should be nearly equal to the sum of the measured rotor resistance and the measured field discharge resistor resistance.
9) Measure the resistance from the positive DC bus to the negative DC bus (Rotor Resistance). Place a jumper across the negative DC bus terminal to the R2 SCR terminal. This will short the SCR and the reading should decrease. Record the resulting reading. The reading should be equal to the equivalent parallel resistance of the measured rotor resistance and the measured field discharge resistor resistance. The equivalent resistance can be calculated as
   ER = 1/(1/Rotor Resistance + 1/FDR).

Firing Board Check

ATTENTION

To avoid shock hazards, lock out incoming power (see ***Power Lock-out Procedure*** in ***User Manual, Medium Voltage Controller, Bulletin 1512, Publication 1500-UM055B-EN-P)*** before working on the equipment. Verify with a hot stick or appropriate voltage measuring device that all circuits are voltage free. Failure to do so may result in severe burns, injury or death.

1) Verify that the control power is off by testing the terminal blocks beneath the cooling fan (see Figures 1.2 or 1.3) with a hot stick or appropriate voltage measuring device.
2) Verify that the excitation source is off by testing points X1 and X2 (see Figure 5.1) with a hotstick or appropriate voltage measuring device.
3) Remove the secondary rectifier fuses F1 and F2 (see Figure 5.6)

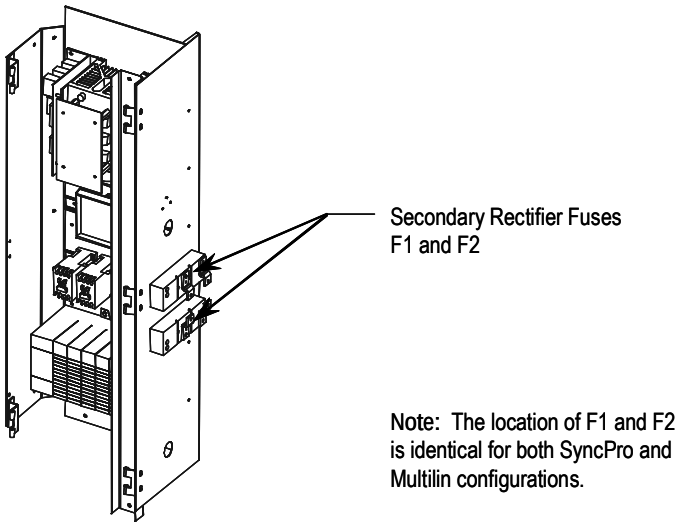


Figure 5.6 – Secondary Rectifier Fuses (SyncPro configuration shown)

4) Install a jumper across J4 Position 4 and J4 Position 6 on the FCR4100 Firing Board (refer to Figure 5.4). This defeats the operation of the protection package.
5) Connect an external power source to the auxiliary power receptacle on “Normal-Off-Test” switch control panel.
6) Set the field current potentiometer on the front door to 100% by turning it fully clockwise.
7) Move the selector switch on the control panel to the “TEST” position.

8) Use an AC voltmeter to measure the following voltages for each SCR. **Do not remove the plug for this procedure**. Check the voltages from the back of the plug. Pin #1 is marked on the firing card and indicated on the plug by a small protrusion. Measure the voltage between:
   - Plug J1, pins 1 and 2
   - Plug J1, pins 5 and 6
   - Plug J2, pins 1 and 2
   - Plug J2, pins 4 and 5

   (Refer to Figure 5.4)

   The measured voltage should be 0.5 Volts +/- 0.25 Volts.

Table 5.A – Troubleshooting Chart

Voltage	Diagnosis
Less than 0.25 V	• No control power • FSR not bypassed (Step 3) • J1/J2 not installed correctly • Door pot not set to 100% • Faulty firing board ❶ • SCR shorted ❶
0.26 – 0.75 V	• Normal device and firing circuit
0.76 V and over	• Incorrect gate connections • Gate open

❶ To verify whether firing board has failed or SCR is shorted, remove the plug from the position where the voltage was measured. Use a voltmeter to measure the voltage at the plug on the board.
- If the voltage is greater than 0.5 V, the corresponding SCR has failed and must be replaced.
- If the voltage is less than 0.5 V, replace the firing board.

9) Return the selector switch to the “OFF” position and disconnect the external power source. Remove all jumpers.

10) The following steps are optional, but provide an additional check for proper functioning of the firing board.

11) Remove the rectifier transformer secondary fuses (refer to supplied electrical drawings for location).

12) Remove the safety shield.

13) Connect a jumper from wire #12 to X1 (refer to electrical drawings in Appendix A for location).

14) Connect a jumper from wire #1 to X2 (refer to electrical drawings in Appendix A for location).

15) Disconnect the motor field connections at the field terminals

16) Connect an appropriate load in place of the motor field. 200-300 watts of incandescent bulbs make a good load.

17) Connect an external power source to the auxiliary power receptacle on the control panel. Move the selector switch on the control panel to the TEST position.

Firing Board Check (cont.)

18) Adjust the field current POT in the door. There should be some variation in the the lamp brightness (or voltage across the load) as the POT is rotated. There will only be minimal control as the load current is a fraction of the rated load current.

19) Move the selector switch on the control panel to the OFF postition and disconnect the external power source.

20) Remove the test load.

21) Reconnect the motor field terminals.

22) Remove the jumpers to X1 and X2.

23) Reinstall the safety shield.

24) Reinstall the rectifier transformer secondary fuses.

25) Perform the Field Discharge Resistor Wiring Check, page 5-9.

Field Current Maximum Setting Adjustment

ATTENTION

Hazardous voltages will be present in the low voltage power cell during this procedure. Use the appropriate protective equipment and work practices to avoid shock hazard. Failure to do so may result in severe burns, injury or death.

1) Open the low voltage door.

2) Start the motor and allow it to reach synchronous speed.

3) Set the door-mounted field current control to 100%.

4) Adjust the R56 resistor on the LEM power supply board (see Figure 4.1) to the desired maximum field current.

   Note: The factory setting is approximately 110% of the motor rating. Monitor the field current with the door-mounted field current meter. Turn the resistor clockwise to increase the current and counter-clockwise to decrease the current.

5) Stop the motor if required.

6) Close the low voltage door.

Spare Parts

Table 6.A – Spare Parts

Part Number	Description
80026-135-01	SCR pack (dual) used for rectification and field switch
80026-141-01	FCR4100 firing card
80026-142-01	Bridge Rectifier Fan (120V, 50/60 Hz)
80026-142-02	Bridge Rectifier Fan (230V, 50/60 Hz)
80174-902-11	Fuse, 100mA for 120V
80174-902-12	Fuse, 50 mA for 230 V
80190-200-01-R	DC Current Transducer (LEM) Power Supply/Current Regulator (120V)
80190-200-02-R	DC Current Transducer (LEM) Power Supply/Current Regulator (230V)
80026-285-51	Single phase rectifier bridge assembly with snubber/field switch board (120V, 60 Hz Control) – up to 67 VDC
80026-285-52	Single phase rectifier bridge assembly with snubber/field switch board (120V, 60 Hz Control) – up to 125 VDC
80026-285-53	Single phase rectifier bridge assembly with snubber/field switch board (120V, 60 Hz Control) – up to 250 VDC
80026-285-54	Single phase rectifier bridge assembly with snubber/field switch board (230V, 60 Hz Control) – up to 67 VDC
80026-285-55	Single phase rectifier bridge assembly with snubber/field switch board (230V, 60 Hz Control) – up to 125 VDC
80026-285-56	Single phase rectifier bridge assembly with snubber/field switch board (230V, 60 Hz Control) – up to 250 VDC
80026-285-57	Single phase rectifier bridge assembly with snubber/field switch board (110V, 50 Hz Control) – up to 67 VDC
80026-285-58	Single phase rectifier bridge assembly with snubber/field switch board (110V, 50 Hz Control) – up to 125 VDC
80026-285-59	Single phase rectifier bridge assembly with snubber/field switch board (110V, 50 Hz Control) – up to 250 VDC
80026-285-60	Single phase rectifier bridge assembly with snubber/field switch board (220V, 50 Hz Control) – up to 67 VDC
80026-285-61	Single phase rectifier bridge assembly with snubber/field switch board (220V, 50 Hz Control) – up to 125 VDC
80026-285-62	Single phase rectifier bridge assembly with snubber/field switch board (220V, 50 Hz Control) – up to 250 VDC

For additional synchronous starter spare parts, refer to the following documents:

- *User Manual, Medium Voltage Controller, Bulletin 1512, 400A, Two-high Cabinet, Publication 1500-UM055B-EN-P*
- *User Manual, Medium Voltage Contactor, Bulletin 1502, 400A, 2400-7200 Volts, Publication 1502-UM050B-EN-P*
- *Instruction Manual, SyncPro™, Bulletin 1901, Publication 1901-UM020B-EN-P*

Typical Electrical Diagrams

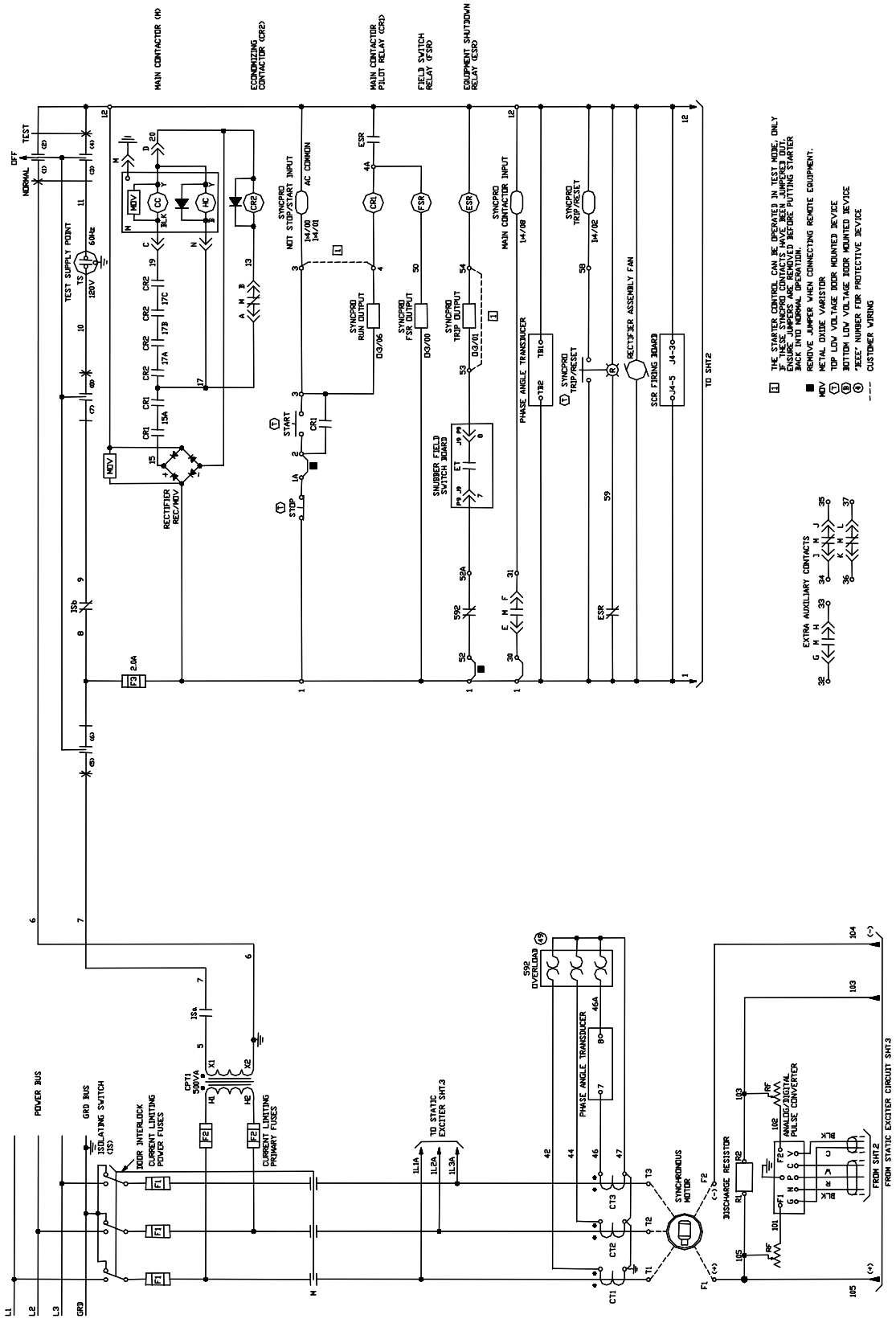


Figure A.1 – Typical Wiring Diagram (Sheet 1)

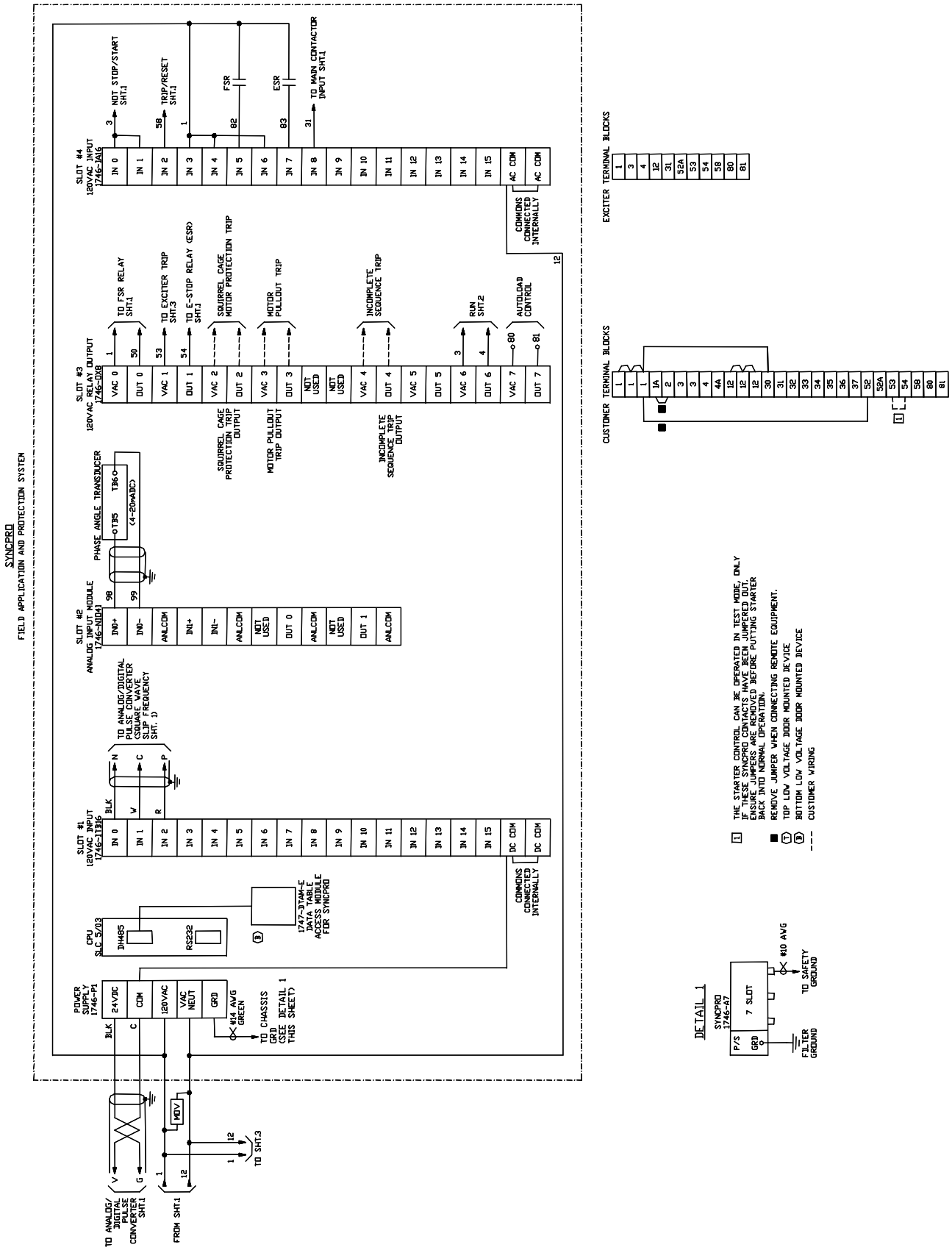


Figure A.2 – Typical Wiring Diagram (Sheet 2)

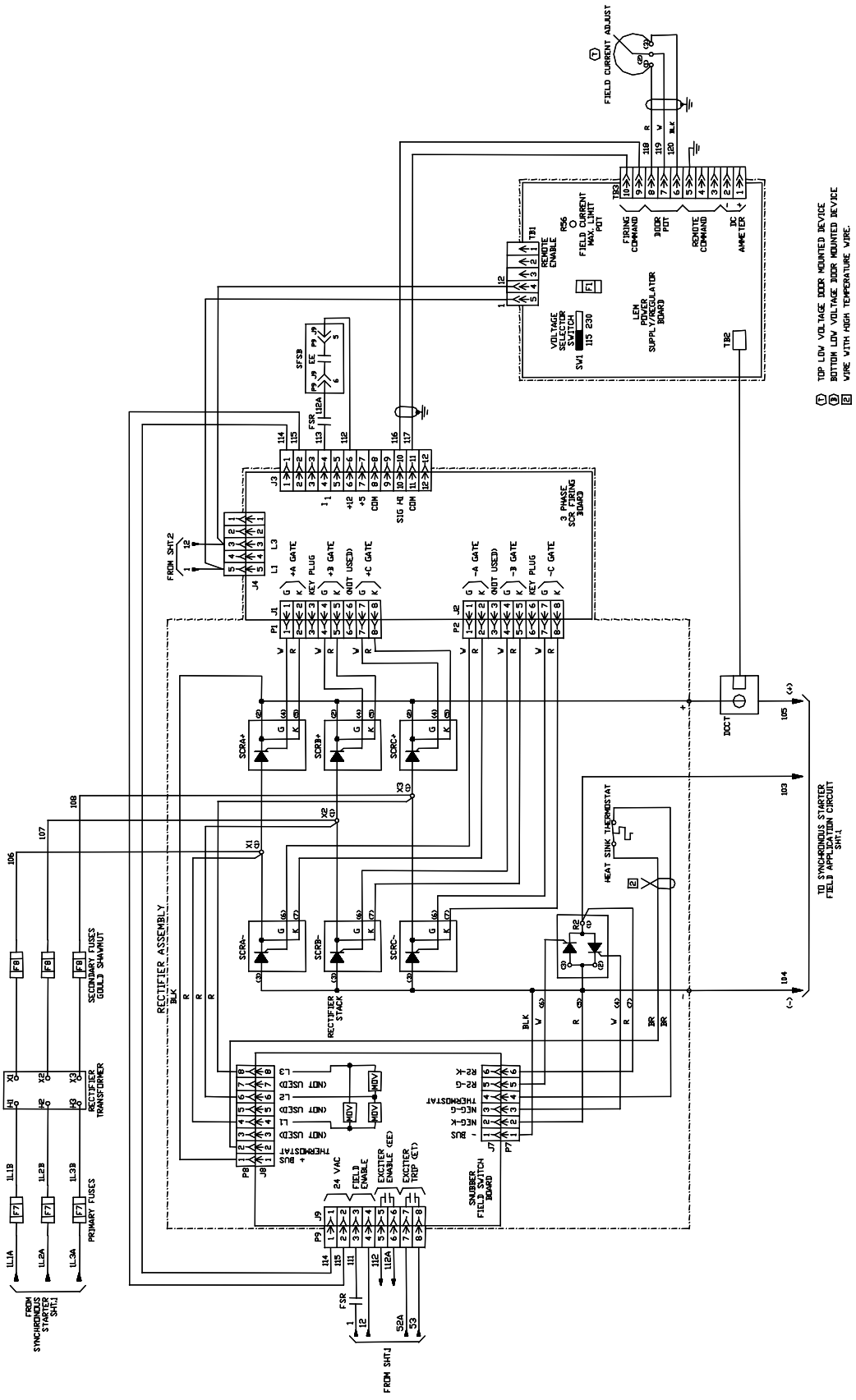


Figure A.3 – Typical Wiring Diagram (Sheet 3)

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