GEK-36430

INSTRUCTIONS

OBSOLETE

ALTHYREX* EXCITATION SYSTEM

3S7931SA412 - 416 SERIES

3S7931SA420 - 424 SERIES

GENERAL ELECTRIC

AUGUST, 1973

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ALTHYREX EXCITATION SYSTEM

INTRODUCTION

This Excitation System controls the voltage (or reactive volt-amperes) of an AC generator by controlling its excitation. This system uses a smaller AC generator as a power source for excitation. The AC voltage from this smaller AC generator is controlled by parallel banks of the thyristors (SCRs) to furnish DC current for the main generator field. For clarity, the small AC generator will be called the Exciter and the larger AC generator will be called the Generator.

The exciter terminal voltage, or generator excitation source voltage, is maintained at a constant value by a static voltage regulator. A portion of the exciter output is fed back to a thyristor bridge to supply exciter field current excitation. The exciter field current is varied by controlling the exciter thyristor bridge output by a static voltage regulator. The exciter regulator automatically maintains a constant voltage at the exciter terminals.

The generator field current is also varied by controlling the generator thyristor bridge output by a static voltage regulator. The generator regulator includes both Auto and Manual control functions to regulate generator terminal voltage or generator field voltage respectively.

This Excitation System is completely static, with the exception of the exciter, which is a small AC generator. No moving parts or vacuum tubes are used to perform the regulating function. Relays are used only for start-up, changing mode of operation, and protective functions. The regulator voltage adjustor potentiometer may be motor driven in some installations. The system may also include various limit circuits, compensator circuits, start-up circuits, and relaying.

RECEIVING, HANDLING AND STORAGE

RECEIVING AND HANDLING

Immediately upon receipt, the equipment should be carefully unpacked to avoid damage. Particular care should be exercised to prevent small parts from being mislaid or thrown away in the packing material.

As soon as the equipment is unpacked, it should be examined for any damage that might have been sustained in transit. If injury or rough handling is evident, a damage claim should be filed immediately with the transportation company and the nearest General Electric Sales Office should be notified promptly.

STORAGE

If the equipment is not to be used as soon as it is unpacked, it should be stored in a clean, dry place and protected from accidental damage. Particular care should be exercised to avoid storing the equipment in locations where construction work is in progress. If the equipment is to be stored for more than three months, it should be kept heated to at least 5°C above ambient temperature to keep out moisture.

DESCRIPTION

The 3S7931SA412 and 3S7931SA420 are exciter regulator cubicles furnished with tandem compound turbine generators and may include the following:

1	3S7932CD147	Control Panel
1	3S7932CD148	Protective Panel
1	3S7932FA106	Disconnect Panel
2	3S7932FA107	Fuse Panel
1	44C318148	Exciter Master Firing Power Circuit
2	3S7932JA111	Volts per Hertz Regulator
1	3S7932JA112	Maximum Excitation Limit Panel
1	3S7932LA202	Power System Stabilizer
1	3S7932MA265	Volts per Hertz Protection Panel
2	3S7932MA268	AC Voltage Regulator
1	3S7932MA280	Exciter Master Firing Panel
2	3S7932MA282	Resistor Panel
1	3S7932MA283	Filter Panel
1	3S7932MA284	Potential Transformer Panel
1	3S7932MA285	Test Panel
1	3S7932MA318	AC Voltage Regulator Failure Alarm
1	3S7932MD200	Meter Panel
2	3S7932MD125	Shaft Voltage Suppressor Panel

1	3S7932MD155	Field Flashing Panel
1	3S7932MD162	Resistor Panel
2	3S7501FS250	Exciter Thyristor Bridge
1	3S7932MD175	Thyrite* Panel

The two generator regulator cubicles are distinguished by the designations left and right, as observed at the exciter, facing the generator. Furthermore, each generator regulator cubicle is divided into a top and a bottom section.

The 3S7931SA413 and 3S7931SA421 are top sections of left generator regulator cubicles and may include the following:

	3S7501FS200	Upper Bridge Assembly
2	3S7932FA107	Fuse Panel
1	44C318148	Generator Master Firing Power Circuit

The 3S7931SA414 and 3S7931SA422 are top sections of right generator regulator cubicles and may include the following:

	3S7501FS200	Upper Bridge Assembly

The 3S7931SA415 and 3S7931SA423 are bottom sections of left generator regulator cubicles and may include the following:

	3S7501FS200	Lower Bridge Assembly
1	3S7932CD147	Control Panel
1	3S7932MD162	Resistor Panel
1	3S7932MA285	Test Panel
1	3S7932FA106	Disconnect Panel
2	3S7932MA280	Master Firing Panel
1	3S7932MA281	Transfer Panel
2	3S7932MA283	Filter Panel
2	3S7932MA282	Resistor Panel

The 3S7931SA416 and 3S7931SA424 are bottom sections of right generator regulator cubicles and may include the following:

	3S7501FS200	Lower Bridge Assembly
1	3S7932MD159	DC Voltage Regulator
2	3S7932HA128	Motor Operated Voltage Adjustor
1	3S7932MA268	AC Voltage Regulator
1	3S7932MD200	Meter Panel
1	3S7932MA273	Maximum Current Limit Panel
1	3S7932JA112	Maximum Excitation Limit Panel
1	3S7932KA120	Underexcited Reactive Ampere Limit Panel
1	3S7932MA189	Voltage Matching Panel
1	3S7932AT100	Automatic Tracking Panel
1	3S7932MA202	Reactive Current Compensator and Active Reactive Current Compensator

*Registered trademark of General Electric Co., USA

INSTALLATION

LOCATION AND MOUNTING

The exciter regulator cubicle should be mounted so that it is accessible from both front and rear. This enclosure should be installed in a well-ventilated, clean dry location where normal ambient temperature is less than 50°C (122°F). Cooling water is not required for the exciter regulator cubicle . Make all wiring connections to control per diagrams furnished for particular installation.

The generator regulator equipment is supplied in cubicles designed for mounting in the exciter housing, adjacent to the exciter. Detailed information for mounting the generator regulator cubicles is supplied by the Generator Department of General Electric Company.

The cooling water for the generator thyristor bridges is furnished by the de-ionized cooling water system used to cool the generator conductors. This is a high purity water supply which should have a conductivity, as measured by a standard conductivity cell, of 0.5 microhms per centimeter or less. The cooling water supply for the thyristor bridges should be capable of supplying 8 gallons per minute per double bridge. Make all wiring and bus connections to the generator regulator cubicles per diagrams furnished for each particular installation.

During the period of time the regulator equipment is being installed, the disconnect switches which disconnect the individual thyristor bridges should be opened to insure no voltage which could damage the thyristors is accidentally applied to them.

Care must be exercised to determine that all wiring connections are correct to avoid damaging the equipment. The size of the interconnecting wires, cables, and buses will vary with the rating of the equipment.

CONNECTIONS

1. Wire check all external connections to all regulator equipment cubicles.

2. Check CT and PT polarities (on generator output) connecting to the generator regulator. RCC current transformer must be in proper phase. The PT burden is approximately 300 VA maximum total. The CT burden is approximately 500 VA maximum.

3. Check all connections from the BR terminal board in the exciter regulator cubicle to 4CT, 5CT, 6CT, and the exciter armature output.

4. Check generator and exciter phase sequence.

5. Check all clamp on type thyristors with ohmmeter (in exciter and generator field circuits).

6. Check all thyristor gate leads for connection to the proper trigger circuits.

7. Check all trigger circuit disconnect plugs for connection.

8. Check wire size of interconnecting wiring per diagram furnished with control.

CAUTION

ALL THYRISTOR HEAT SINKS ARE AT "ABOVE GROUND" POTENTIAL. ANY WIRING OR CIRCUITS TO BE HI-POTTED MUST FIRST BE DISCONNECTED FROM THE REGULATOR CUBICLES. DO NOT HI-POT ANY CIRCUITS IN CONTROL OR THYRISTOR CUBICLE.

INITIAL OPERATION

All controls have been preset at the factory. If any of the calibration procedures described below are not performed following installation, the factory setting of the pertinent control should be retained. The factory setting should be recorded in Figure 1 for future reference.

Except in unusual operating circumstances, the factory setting should agree with that obtained in the calibration procedures described below.

PRELIMINARY CHECKS

The following steps must be performed before running the generator or exciter:

a. Energize DC for relay power. Check polarity.

b. Check operation of exciter field breaker.

c. Check operation of motor operated voltage adjustors -- generator manual control and auto control.

d. Check operation of 43CS switch and all associated relays. (See Principles of Operation -- Relay and Control Circuit.)

e. Check that flashing circuit will apply DC to exciter field circuit.

f. Check operation of all protective relays.

g. Check field ground detecting relays.

h. Check operation of over-temperature circuits (lights, relays, and alarms).

i. If ventilation fans are provided, check fan operation and air flow alarm circuit.

j. Perform dummy load tests on all exciter and generator thyristor bridges.

SETTINGS BEFORE OPERATING GENERATOR

a. Turn water flow ON for generator thyristor bridges. Open generator field thyristor bridge disconnect switches.

b. Turn exciter cubicle ventilation fans ON. Close exciter field thyristor bridge disconnect switches.

c. Set exciter auto voltage adjustor (A1P) fully CCW. Set A2P VOLTAGE RANGE at midpoint. Set A3P VOLTAGE LEVEL fully CCW. Set A4P GAIN at midpoint. Set A5P STABILIZING at midpoint. On terminal board 2TB, use metal jumpers supplied to jumper terminals B-C, D-E, and G-H. Set A6P PHASE BACK LIMIT fully CW.

d. Set generator auto voltage adjustor (A201P) fully CCW (full lower if motorized). Set A204P VOLTAGE RANGE at midpoint. Set A205P VOLTAGE LEVEL fully CCW. Set A203P GAIN fully CCW (minimum gain). Set A202P STABILIZING at midpoint. On terminal board 2TB, use metal jumpers supplied to jumper terminals B-C, D-E, and G-H. Set A206P PHASE BACK LIMIT fully CW.

e. Set generator manual control voltage adjustor (D201P) in full LOWER position. Adjust regulator pre-position limit switches LS5 and LS6 as required. Set D202P fully CCW.

f. Leave all other adjustments per factory setting.

g. Disconnect and isolate lead to terminal B11, output of U.R.A.L. panel.

FUNCTION	DEVICE	FACTORY SETTING	FIELD SETTING
EXCITER			
AC Voltage Regulator #1			
Volt Adjust	A1P		
Volt Range	A2P		
Volt Level	A3P		
Gain	A4P		
Stability	A5P		
Phase Back Limit	A6P		
Transient Gain Reduction	2TB		
AC Voltage Regulator #2			
Volt Adjust	A1P		
Volt Range	A2P		
Volt Level	A3P		
Gain	A4P		
Stability	A5P		
Phase Back Limit	A6P		
Transient Gain Reduction	2TB		
Regulator #1 Volts per Hertz Takeover	L1P		
Regulator #2 Volts per Hertz Takeover	L1P		
AC Regulator Failure Alarm Deadband	RFAP		
Maximum Excitation	59E		
Maximum Excitation Time Delay	59ETD		
GENERATOR			
AC Voltage Regulator			
Stability	A202P		
Gain	A203P		
Volt Range	A204P		
Volt Level	A205P		
Phase Back Limit	A206P		
Transient Gain Reduction	2TB		
DC Voltage Regulator Limit	D202P		
Maximum Excitation	59G		
Maximum Excitation Time Delay	59GTD		
Fault Suppression	76		
Fault Suppression Time Delay	76TD		
Maximum Current Limit	R750P		

Figure 1. Calibration Record

h. Apply all auxiliary power to excitation system; DC relay power, and all AC power for lights, relays, etc.

OFF LINE TESTS, GENERATOR RUNNING

a. Set 43CS to MANUAL position.

b. Set excitation control to START.

c. Close exciter field breaker. Exciter voltage should build up to a voltage proportional to the generator speed (if below rated speed).

d. Set excitation control to MANUAL. Operating exciter AC regulator RAISE-LOWER CONTROL (70E) should raise and lower exciter output voltage. Be careful not to exceed an output voltage of 1.0 per unit volts/hertz below rated speed.

The exciter thyristor bridge output can be monitored by connecting an oscilloscope across the exciter field voltmeter. All six thyristors should fire as shown in Figure 4. There should be no jitter or instability.

e. Operate 43PB to transfer from DC to AC regulator. The voltage range can be adjusted using A2P and the level can be adjusted using A3P. If stabilizing is required, see Exciter AC Regulator Stabilizing.

f. Set excitation control to STOP and close all generator thyristor bridge disconnect switches.

g. Set excitation control to START. Close exciter field breaker. Exciter terminal voltage and generator terminal voltage should build up to a low value, or a value proportional to speed if not at rated speed.

h. If the exciter fails to maintain voltage after field flashing, increase the exciter setting. Care should be taken not to exceed an output voltage of 1.0 per unit volts/hertz below rated speed on the generator or exciter.

i. With the excitation control set to MANUAL, the generator DC voltage regulator RAISE-LOWER control should raise and lower the generator field voltage.

j. At rated speed only, the generator can be transferred to the generator AC regulator. With the generator at rated terminal voltage and the excitation control in TEST, zero the 2VM transfer voltmeter by using the generator AC regulator RAISE - LOWER control. It should be possible to obtain a meter deflection to either side of zero. If the meter deflection cannot be obtained, adjust A204P, A205P, and A203P. Do not attempt initial transfer with 2VM at a meter reading other than zero.

k. Setting the excitation control to AUTO transfers the generator from the DC to the AC regulator. The generator and the exciter voltage should remain as before. The voltage range can be adjusted using A204P and the level can be adjusted using A205P. If stabilizing is required, see Generator AC Regulator Stabilizing.

l. To transfer back to manual control, zero the 2VM transfer voltmeter using the generator DC regulator RAISE-LOWER control. Setting the excitation control to either TEST or MANUAL transfers control from the AC regulator to the DC regulator.

m. Before synchronizing the generator with the system, record all potentiometer settings for future reference.

EXCITER AC REGULATOR STABILIZING

a. Set A2P VOLTAGE RANGE fully CW for maximum voltage range adjustment. Set A3P VOLTAGE LEVEL fully CCW for minimum voltage level. Set A4P GAIN at midpoint. Resistor A18R on amplifier board should not be shorted. On terminal board 2TB, use metal jumpers supplied to jumper terminals B-C, D-E, and G-H. Set A5P STABILIZING at midpoint.

b. Connect a normally open (NO) pushbutton or switch across potentiometer A3P VOLTAGE LEVEL.

c. Monitor the exciter terminal voltage with an oscilloscope or recorder. If an oscilloscope is used, a low sweep frequency should be used and the vertical positioning should be adjusted to monitor the peak AC voltage. See Figure 2.

d. Set 43CS and use A1P VOLTAGE ADJUSTOR to zero 10VM TRANSFER VOLTMETER. Operate 43PB to transfer to AC regulator.

e. Adjust A1P VOLTAGE ADJUSTOR for 90% exciter terminal voltage. Turn A3P VOLTAGE LEVEL CW to increase terminal voltage to 100%.

f. As the pushbutton or switch across A3P is operated, a 10% change in the voltage reference will be introduced and an oscillation in terminal voltage will occur. Adjusting STABILIZING A5P will dampen this oscillation. Increasing GAIN A4P will improve response. For stabilizing, A5P acts as a fine adjustment and the combination of jumpers on 2TB acts as a coarse adjustment. Increase GAIN gradually, continually adjusting the stabilizing RC (A5P and jumpers on 2TB) until optimum response is obtained. See Figure 2 for illustration of optimum response. As gain is increased, the voltage adjustor should be

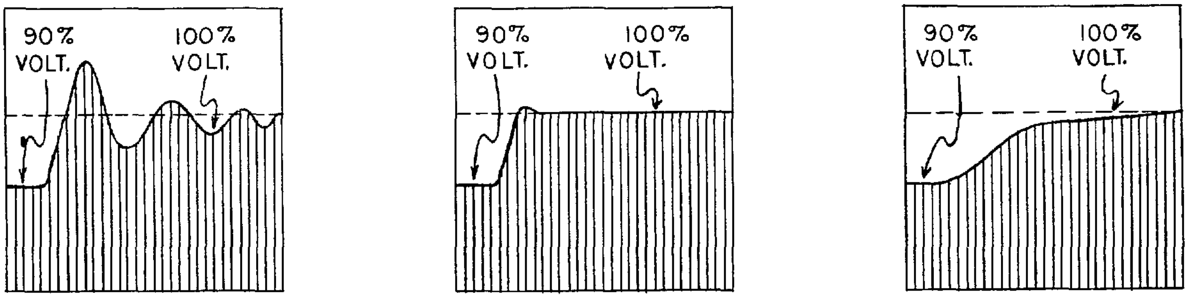


Figure 2. Oscillograms For Stabilizing Adjustment.

readjusted to maintain the desired terminal voltages.

Too much GAIN may make stabilizing impossible. In this case, decrease GAIN slightly.

g. Monitor the exciter field voltage with an oscilloscope or recorder. All six thyristors should fire as shown in Figure 4. There should be no jitter or instability.

h. Lock all potentiometer dials, taking care not to disturb the potentiometer setting. Record the dial setting in Figure 1 for future reference.

GENERATOR AC REGULATOR STABILIZING

a. Operate the generator at rated terminal voltage on generator DC regulator with the excitation control in MANUAL. The exciter should be operated on the exciter AC regulator. If stabilizing of both AC regulators is required, the the exciter AC regulator should be stabilized before attempting to stabilize the generator AC regulator.

b. Set A204P VOLTAGE RANGE fully CW for maximum voltage range. Set A205P VOLTAGE LEVEL fully CCW for minimum voltage level. Set A203P GAIN fully CCW. Resistor A218R on amplifier board should be shorted. On terminal board 2TB, use metal jumpers supplied to jumper terminals B-C, D-E, and G-H. Set A202P STABILIZING at midpoint.

c. Connect a normally open (NO) pushbutton or switch across potentiometer A205P VOLTAGE LEVEL.

d. Monitor the exciter terminal voltage with an oscilloscope or recorder. If an oscilloscope is used, a low sweep frequency should be used and the vertical positioning should be adjusted to monitor the peak AC voltage. See Figure 2.

e. Set the excitation control to TEST and use A201P VOLTAGE ADJUSTOR to zero 2VM TRANSFER VOLTMETER. Set the excitation control to AUTO to transfer to AC regulator.

f. Adjust A201P VOLTAGE ADJUSTOR for 90% generator terminal voltage. Turn A205P VOLTAGE LEVEL CW to increase terminal voltage to 100%.

g. As the pushbutton or switch across A205P is operated, a 10% change in the voltage reference will be introduced and an oscillation in terminal voltage will occur. Adjusting STABILIZING A202P will dampen this oscillation. Increasing gain A203P will improve response. For stabilizing, A202P acts as a fine adjustment and the combination of jumpers on 2TB acts as a coarse adjustment. Increase GAIN gradually, continually adjusting the stabilizing RC (A202P and jumpers on 2TB) until optimum response is obtained. See Figure 2 for illustration of optimum response. As gain is increased, the voltage adjustor should be readjusted to maintain the desired terminal voltage.

Too much GAIN may make stabilizing impossible. In this case, decrease GAIN slightly. For low gain settings, the jumper may be removed from resistor A218R.

An alternate method of introducing a step change is to set the DC regulator for 90% voltage and the AC regulator for 100% voltage. Regulator transfer will then introduce a 10% step change.

h. Monitor the exciter terminal voltage with an oscilloscope or recorder while stabilizing the generator AC regulator. When a step change is introduced in the generator voltage, the exciter voltage should respond without instability. The main thyristor bridge firing will appear as commutation notches in the exciter terminal voltage. All six thyristor bridge legs should fire without jitter or instability.

i. Lock all potentiometer dials, taking care not to disturb the potentiometer setting. Record the dial setting in Figure 1 for future reference.

ON-LINE TESTS, GENERATOR RUNNING

a. With generator operating on TEST and synchronized with system, pick up as much as 10% load if possible.

b. Raise MANUAL control (D201P) to cause generator to supply 5 or 10% of its rating as VARs (over-excited).

c. Set reactive current compensator (RCC) and active-reactive current compensator (ARCC) settings on zero (G1SW and G2SW).

d. Zero 2VM TRANSFER VOLTMETER using AC regulator voltage adjustor.

e. Turn G2SW COURSE on RCC to "5". VM voltage (AC regulator output) should decrease. If reading increases, short B1CT (generator current transformer) by opening CT switch at terminals 3S-25 and 3S-26, and reverse the wires to the compensator.

CAUTION

MAKE SURE THE PROPER TYPE OF SWITCH HAS BEEN SUPPLIED BEFORE OPENING IT. IT SHOULD SHORT THE INCOMING TERMINALS BEFORE OPENING THE OUTGOING TERMINALS.

Final adjustment of the compensator can be made only after considerable experience with the generator operating under control of the regulator. It is desirable to keep the amount of compensation to the minimum required for proper division of VARs between generators to avoid excessive voltage regulation. As an initial adjustment, it is advisable to turn the fine-adjustment knob to position 5 with the coarse knob at zero. Adjustments may be made with the compensator current transformer energized (CT switch closed).

f. Turn G2SW COURSE on ARCC to "5". VM voltage (AC regulator output) should increase. If reading decreases, short B1CT (generator current transformer) by opening CT switch at terminals 3S-25 and 3S-26 and reverse R and X on ARCC by reversing leads to terminals G x R and G x X. Return the reactance-adjusting knob to zero, and turn the resistance-adjusting knob, G1RH, to the right to increase resistance; this should also increase the A1VM voltage.

Final adjustment of the compensator must be made on the basis of experience. Preliminary adjustment may be made in accordance with the known values of resistance and reactance for that portion of the system over which compensation is desired. If the voltage at the point which is to be compensated decreases as the power factor becomes more lagging and increases as the power factor becomes less lagging, more reactance and possibly less resistance may be required.

Return generator excitation to desired VARs and zero the transfer voltmeter with the AC regulator voltage adjustor. Transfer to AC regulator by setting the excitation control to AUTO. Generator VARs should not change. The generator AC regulator should now control generator excitation and VAR output.

UNDER-EXCITED REACTIVE AMPERE LIMIT ADJUSTMENT

After satisfactory operation of the AC (AUTO) regulator has been obtained, the under-excited reactive ampere limit should be tested. Return the U.R.A.L. to service by turning the URAL GAIN potentiometer to "0" (fully CCW) and reconnect the lead to terminal B11. See separate instructions GEK-4716 for adjusting the U.R.A.L. panel.

CURRENT LIMIT ADJUSTMENT

a. Operate generator on MANUAL control.

b. To set CURRENT LIMIT, first check calibration of current limit circuit. Read generator field current at no load. Read voltage across R750C (terminals CL-7 and CL-8) at no load. Calculate calibration of current limit feedback circuit as follows:

$$K = \frac{E_{CL7\text{-}8\ (NL)}}{I_{FLD\ (NL)}} \ \frac{\text{Volts}}{\text{Amp}}$$

c. Calculate generator field current limit I_{CL}:

$$I_{CL} = \frac{1.6 \times \text{E Gen Rated Fld Volts}}{\text{Resistance at Gen Fld } 125°C}$$

d. Open current limit CT feedback switch at terminals 3S-22, 23, 24. Connect a variable DC power supply (0-200 V DC) across terminals CL-7 and CL-8 (be sure to connect the positive side to terminal CL-7) and set for the following voltage:

$$E_{CL} = K \times I_{CL}$$

e. With this voltage across R750C, set the excitation control to TEST, and zero the transfer voltmeter (2VM). Then turn the current limit potentiometer (R750P) until the current limit takes over. This will be indicated by the transfer voltmeter moving off zero. Lock R750P and record the dial settings. The current limit is now set at 160% AFFL (amperes field full load). Remove the power supply and close the CT feedback at terminals 3S-22, 23, 24.

FAULT SUPPRESSION ADJUSTMENT

a. Open current limit CT feedback switch at terminals 3S-22, 23 and 24. Open current limit power supply switch at terminals 3S-20 and 3S-21. Remove the outgoing lead from terminal FA-4.

b. Connect a variable DC power supply (0-200 V DC) across terminals FA-4 and FA-5 (be sure to connect the positive side to terminal FA-4) and set for the following voltage:

$$E_{FS} = 2 \times E_{CL}$$

Adjust the 76 relay per instruction GEI-30971 to pick up at the calculated voltage. The fault suppression is now set to sense a current twice the expected ceiling current.

c. Adjust the 76TD time delay relay, if required.

d. Remove the power supply and reconnect the lead to terminal FA-4, close all switches to the current limit circuit.

MAXIMUM EXCITATION LIMIT ADJUSTMENT

a. To set the maximum excitation limit first determine the maximum continuous voltage required by the exciter or generator field:

$$V_{FD} = I_{FD}\,(\text{Full Load}) \times R_{FD}\,(\text{Hot})$$

This can be determined from the exciter or generator data.

b. Calculate the maximum excitation relay pick up current.

$$I_{LIMIT} = \frac{\text{VFD} \times (\text{Per Unit Ceiling Limit})}{\text{R Series} + 115}$$

Where 100 ma < I_{LIMIT} < 300 ma

The resistance in series with each relay can be determined by referring to the elementary diagram furnished with each installation. Adjust the series resistance as required to keep the pick up current between 100 and 300 ma.

c. To set the exciter maximum excitation limit, isolate the 59E relay by removing the outgoing lead from terminal 2J-1. To set the generator maximum excitation limit, isolate the 59G relay by removing the outgoing lead from terminal 1J-1.

CAUTION

THE MAXIMUM EXCITATION LIMIT CIRCUITS ARE CONNECTED DIRECTLY ACROSS THE EXCITER AND GENERATOR FIELD CIRCUIT. DO NOT INTERRUPT THE MAXIMUM EXCITATION LIMIT CIRCUIT OR CONNECT A VARIABLE POWER SUPPLY ACROSS THE 59E OR 59G RELAY WHILE EXCITATION IS BEING APPLIED TO THE EXCITER OR GENERATOR FIELD.

d. Connect a variable DC power supply (0-30 V DC) across the maximum excitation relay (59E or 59G) with the negative lead on the side of the relay that has been interrupted and set for the following voltage:

$$E_{Relay} = 115 \times I_{LIMIT}$$

Adjust the relay per instruction GEI-30971 to pick up at the calculated voltage. Remove the power supply.

e. Adjust the series resistance to the value required to keep the pick up current between 100 and 300 ma at the limit voltage. Reconnect the lead to terminal 1.

f. Determine the permissible time at the per unit ceiling limit, at which the maximum excitation limit relay (59E or 59G) has been set, from the exciter or generator data. Adjust the time delay relay (59ETD on the exciter or 59GTD on the generator) for the required time delay.

OPERATION

PRELIMINARY CHECKS

a. Apply all auxiliary and control power to excitation system.

b. Exciter field breaker open.

c. 43CS on OFF.

d. Excitation system control on STOP.

e. All thyristor bridge disconnect switches closed.

f. Cooling water on. Ventilation fans on.

OPERATING SEQUENCE

a. When excitation is required, set 43CS to MANUAL.

b. Set excitation control to START.

c. Apply excitation by closing field breaker.

d. To adjust field voltage set excitation control to MANUAL. Adjust field voltages using DC regulator RAISE-LOWER control taking care not to exceed 1.0 per unit volts per hertz.

e. Bring generator voltage up to rated using generator DC regulator voltage adjustor (D201P).

f. Set excitation control to TEST.

g. Zero 2VM TRANSFER VOLTMETER with generator AC regulator voltage adjustor (A201P).

h. Set excitation control to AUTO. Then proceed with synchronizing procedure to put generator on the line.

i. When operating on AUTO, the generator AC regulator voltage adjustor, A201P is used to set level of generator terminal voltage; thus, it controls the reactive load on the generator.

   Adjustor D201P can be changed as often as required to keep 2VM reading zero volts, so that excitation will remain constant if the AUTO regulator should trip. Some users may desire to set D201P at some predetermined position while operating on AUTO regulator.

j. If it is necessary to operate on MANUAL, the generator DC regulator voltage adjustor, D201P, will control reactive load on the generator. Potentiometer A201P should always be adjusted to zero 2VM before going to AUTO.

PRINCIPLES OF OPERATION

This Excitation System controls the voltage (or reactive volt-amperes) of an AC generator by controlling its excitation. This system uses a smaller AC generator as a power source for excitation. The AC voltage from this smaller AC generator is controlled by parallel banks of thyristors (SCRs) to furnish DC current for the main generator field. For clarity, the smaller AC generator will be called the Exciter and the large AC generator will be called the Generator.

The exciter terminal voltage, or generator excitation source voltage, is maintained at a constant value by a static voltage regulator. A portion of the exciter output is fed back to a thyristor bridge to supply exciter field current excitation. The exciter field current is varied by controlling the exciter thyristor bridge output by a static voltage regulator. The regulator includes an AUTO control function to regulate exciter terminal voltage.

The generator field current is also varied by controlling the generator thyristor bridge output by a static voltage regulator. The regulator includes both AUTO and MANUAL control functions to regulate generator terminal voltage or generator field voltage respectively.

The excitation system is illustrated by the block diagram, Figure 3. The exciter is self-excited since power is taken from its output terminals (through an anode transformer and thyristor bridge circuit) to furnish DC for its field. The DC field current flowing through the Diode Rectifier Bridge Circuit is normally more than the input AC current from the current-boost CTs so the Diode Rectifier Bridge Circuit develops no voltage. Exciter field current control is the result of phase-controlled output from the Exciter Thyristor Bridge Circuit.

The generator is separately excited since power is taken from the exciter output (through the generator thyristor bridge circuit). Generator field current control is the result of phase-controlled output from the Generator Thyristor Bridge Circuit.

When thyristors are used in parallel, as in the case of multiple bridges, the parallel thyristors must be controlled from a common source. The purpose of the Master Firing Circuit is to generate a signal that will fire, or turn-on, each parallel thyristor simultaneously. This simultaneous firing provides for good current division between the two parallel legs and also good voltage division across the series thyristors in the generator bridge.

The Generator Regulator Transfer panel selects the Master Firing Circuit controlled by the DC regulator which holds a constant machine field voltage or the Master Firing Circuit controlled by the AC regulator which holds a constant machine terminal voltage. A transfer voltmeter is used for matching signals to provide for smooth transfer between the two generator regulators. Exciter regulator transfer is automatic.

The input to the DC Regulator on the generator is a filtered feedback signal from the machine field voltage. The output is a control signal to the corresponding master firing circuit.

The input to the Exciter AC Regulator is a feedback signal from the exciter terminal voltage. The output is a control signal to the corresponding master firing circuit.

The inputs to the Generator AC Regulator include a feedback signal from generator terminal voltage, and compensating signals from the reactive current compensator (RCC) and the active-reactive current compensator (ARCC), if supplied. If a power system

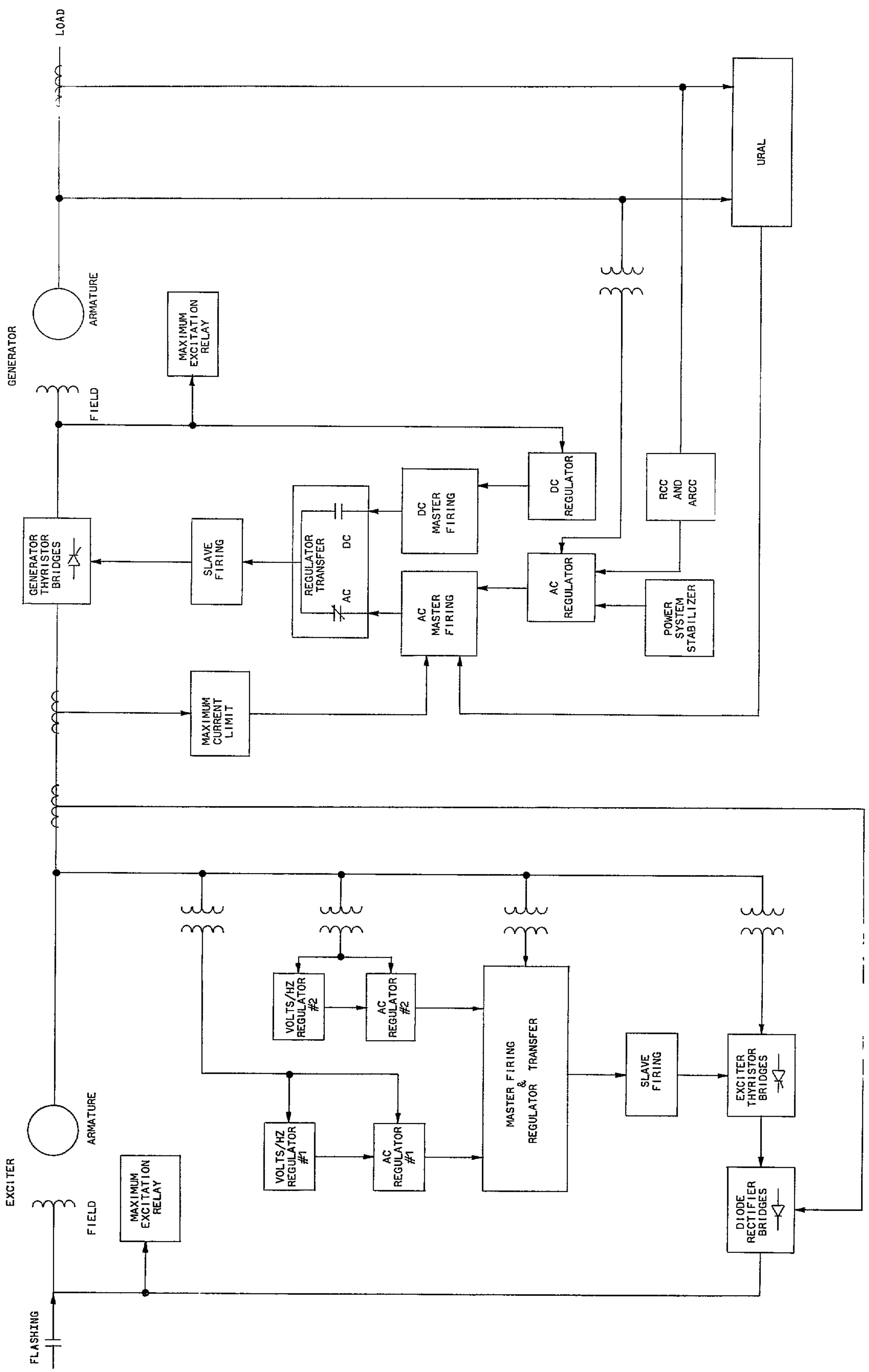


Figure 3. Excitation System Block Diagram.

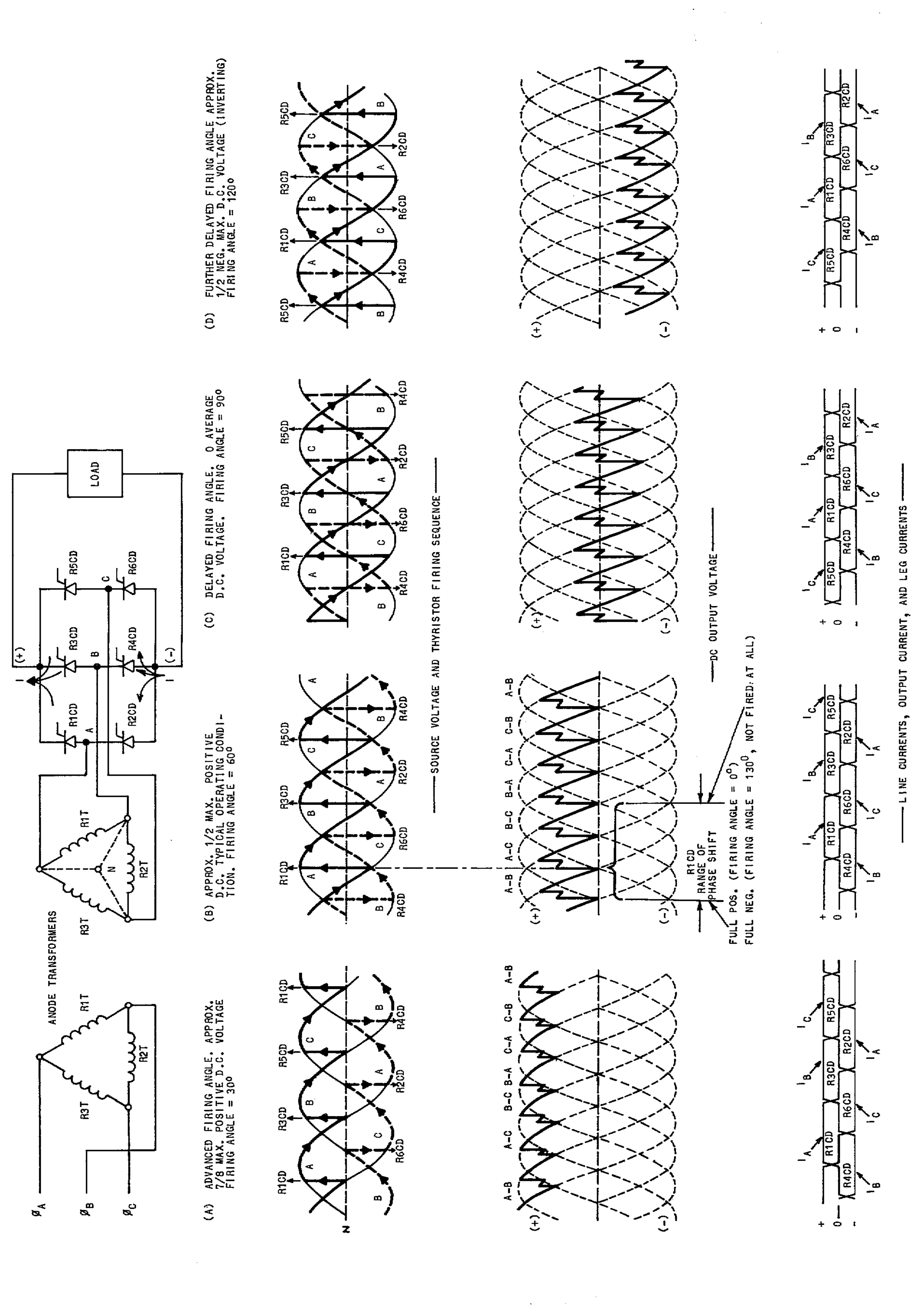


Figure 4. 3-Phase Full-Wave Thyristor Bridge Circuit (Inverting Type).

stabilizer is used, then a stabilizing signal is fed into the AC regulator. The output is a control signal to the corresponding master firing circuit.

The Underexcited Reactive Ampere Limit (URAL) provides a TURN-ON take-over signal to the master firing circuit controlled by the generator AC regulator if the underexcited reactive current increases beyond a safe value.

The input to the Maximum Current Limit circuit is a feedback signal from the exciter output current. The output is a TURN-OFF take-over signal to the master firing circuit controlled by the generator AC regulator.

The Fault Suppression Circuit senses a collector ring fault by comparing feedback signals from the generator field voltage and generator field current. The output is a signal that trips the exciter master firing circuit power supply.

The Reactive Current Compensator (RCC) provides a signal to modify the generator voltage input signal as required to achieve good paralleling of the generator with the power system. The Active-Reactive Current Compensator (ARCC) provides a signal (to one or several generators) to modify the generator voltage input signal as required to compensate for line drop; thus, it regulates voltage at some remote point in the power system.

The Maximum Excitation Limit circuits will transfer regulator control from AC regulator to DC regulator if the field voltage is maintained in excess of the pick up voltage of the 59 relay. Regulator transfer occurs after a preset time delay. A maximum excitation limit is furnished for both the exciter and generator.

A volts/hertz relay circuit may be provided to remove the AC regulators from service at 90% speed by transferring control to the DC regulators. A DC regulator voltage adjustor run back circuit may be included as a part of the excessive volts/hertz protection.

EXCITER FIELD BRIDGE

The exciter field current is furnished by two parallel rectifier circuits, each including a 3-phase full wave Diode Bridge Circuit and a 3-phase full wave Thyristor Bridge Circuit. See typical elementary diagram, Figure 23. Either of the parallel rectifier circuits can be disconnected for maintenance during operation, by an eight-pole switch. Either rectifier circuit will provide full load exciter field current without limitations while the other circuit is out of service. The Thyristor Bridge Circuit normally provides controlled DC voltage for the exciter field while the Diode Bridge Circuit provides DC voltage only during transient conditions.

Each bridge circuit has a single element, diode or thyristor, between the AC source and the DC output. This type of bridge is usually referred to as a single bridge. That is, each bridge has a single path in each leg.

Thyristor Bridge Circuit

The thyristor circuit operates as a phase-controlled variable DC voltage source to control exciter field current as required by the AC and DC regulator. Refer to Figure 4.

The input voltage to the thyristor circuit is taken from the exciter output through the anode transformers R1T, R2T, and R3T, which are connected delta-delta. Depending upon the secondary tap setting, the anode transformer supplies a source voltage that will allow an exciter field ceiling voltage from 120% to 200% of the exciter full load field voltage. Five secondary taps are provided for a 20% step in ceiling voltage adjustment. The 140% tap setting is normally used.

In Figure 4 the top waveforms illustrate the source voltage and thyristor firing sequence. The center waveforms illustrate the output DC voltage. The bottom waveforms indicate current flow in the various thyristors.

The circuit used to turn-on, or FIRE the thyristors is covered in detail under Firing Circuit. Refer to Figure 4 (b), a typical steady-state operating condition. Note that the positive (+) side of the circuit follows the solid line as it is switched from line B to C to line A, etc. The negative (-) side of the circuit follows the broken line as it is switched from line A to line B, etc. The three-phase source voltage (A-B-C) is referenced to a neutral (zero) voltage point. Arrows pointing up indicate thyristors firing to connect source voltages to the positive bus, while arrows pointing down indicate thyristors firing to connect source voltage to the negative bus.

Note that the neutral voltage point is not provided in an installation, and is usually not necessary for purposes other than discussion. If it is required to obtain this point, however, a small (low wattage or low VAR) balanced load may be wye-connected to the exciter output terminals.

The net DC output voltage is a plot of the difference between the positive and negative bus, as indicated by the center waveforms. This is the voltage that would be seen on an oscilloscope connected, "standing on" the negative bus and "looking at" the positive bus. The bottom waveforms indicate instantaneous current as it flows from the AC lines, through the positive thyristors through the load (DC), back through the negative thyristors to the AC lines. The current is constant between commutation intervals because the large inductance of the load (the exciter field winding) will not allow current to change appreciably during a thyristor's conducting interval.

Current does not transfer instantly from one thyristor to another but builds up in one thyristor while it decays in the previous conducting thyristor. This is due to the commutating reactance in the source preventing instantaneous changes in current. This same commutating reactance causes the notch in the output DC voltage, following thyristor firing.

The result is that while current is decaying in the thyristor being TURNED OFF and current is building up (to the constant load current value) in the thyristor which has just been FIRED, the voltage at this commutating bus is the average of the two thyristor voltages.

The firing angle of the thyristors can be measured from the fully phased-on condition (α) or from the fully phased-off condition (β). In this discussion, the firing angle is measured from the fully phased-on condition (α). For $\alpha = 0°$, the thyristors are turned full-on and the output corresponds to that obtained from a diode rectifier bridge. This angle may also be referred to as the ANGLE OF DELAY in firing.

If the AC regulator error signal calls for more excitation, the thyristors will be phased-on (α decreases) to furnish more positive DC output voltage. See Figure 4 (a). If the AC regulator error signal calls for less excitation, the thyristors will be phased-off (α increases) to furnish less positive DC output voltage, or even negative DC output voltage. See Figure 4 (c) and (d).

When the thyristors are phased-off, the inductance of the load (exciter field winding) will force the instantaneous output voltage to follow the connected source voltage negative until the next thyristor fires to connect a more positive phase source.

This "inverting" action causes the net output DC voltage to swing negative transiently (as long as positive current is flowing in the inductive load). This inverting action provides both positive and negative voltage output from the thyristor circuit for forcing exciter field current both up and down. During normal operation Figure 4 (b) - power is flowing from the source to the exciter field. During inverting operation Figure 4 (d) - power is flowing from the exciter field back into the source.

In actual operation, the exciter output voltage waveform becomes distorted by commutation. For comparison to the theoretical wave shapes of Figure 4, the actual exciter field voltage is shown in Figure 5. In this figure, the firing angle for the generator thyristor bridge is greater than the firing angle for the exciter thyristor bridge. Also, since the generator field resistance is much less than the exciter field resistance, the commutation period is much greater in the generator thyristor bridge. Thus, the generator thyristor commutation shows up as a notch in the exciter field voltage waveshape. The exciter terminal voltage is shown in Figure 6.

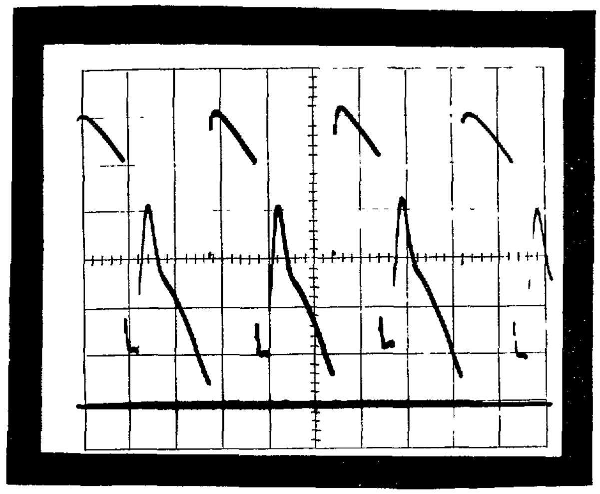


Figure 5. Exciter Field Voltage Oscillogram.

Vertical: 20.0 Volts/Division
Horizontal: 1.0 Millisec/Division

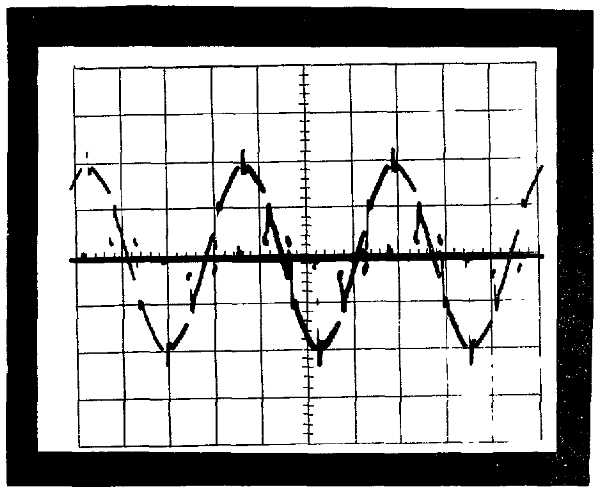


Figure 6. Exciter Terminal Voltage Oscillogram.

Vertical: 50.0 Volts/Division
Horizontal: 5.0 Millisec/Division

For further comparison, Figure 7 is the exciter field voltage with the exciter operating no load, i. e., not connected to the generator thyristor bridges. Since the field current requirement has decreased for no load operation, the thyristors have been phased back to a greater firing angle for the same exciter terminal voltage. Since the field inductance causes the instantaneous voltage to follow the source voltage, the net DC output voltage is the difference of the areas under the positive and negative instantaneous voltages.

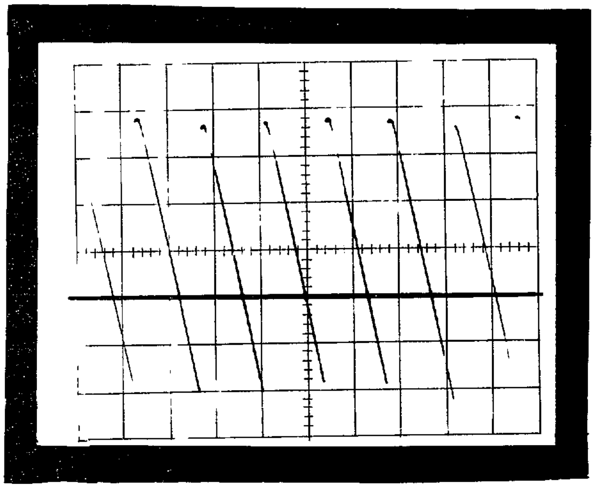


Figure 7. No Load Exciter Field Voltage Oscillogram.

Vertical: 20.0 Volts/Division
Horizontal: 2.0 Millisec/Division

Each thyristor has an indicating neon light connected between its anode and cathode. Normally both sides of the bulb should glow. Should a thyristor short or its fuse blow, the associated light will go out. When the firing angle is advanced, the electrode of the neon bulb connected to the thyristor anode will glow brighter than the other electrode. When the firing angle is retarded, the electrode of the neon bulb connected to the cathode of the thyristor will glow brighter.

The orientation of the lamp is such that when the top electrode is brighter, a positive voltage is being applied to the field. A single bridge leg (the section of the bridge from the AC source to the DC output) is shown in Figure 8.

There is an RC circuit across each phase (line-to-line) of source voltage. This RC filter absorbs or furnishes current sufficiently to prevent source voltage transients from occurring during thyristor commutation.

In addition to the RC line filter, each thyristor is paralleled by an RC filter. The purpose of this RC filter is to suppress voltage transients across the thyristor being commutated off.

Each bridge leg has a series reactor. The purpose of this reactor is to limit the rate of change of current during commutation (di/dt) and to assist in bridge paralleling.

To further assure good current division in the parallel bridges, current balancing CTs are used in the anode transformer primary.

Diode Rectifier Circuit - Current Boost

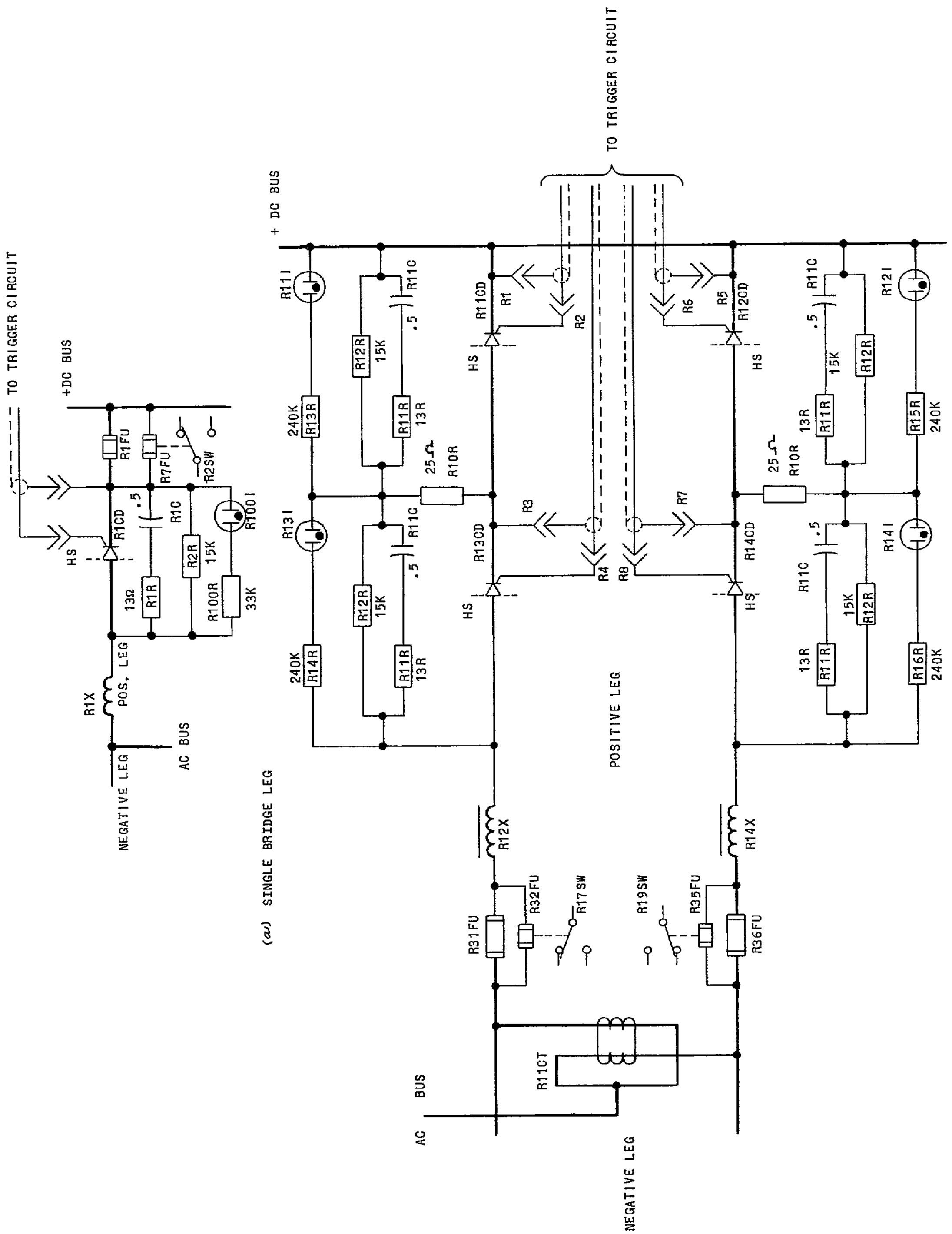
Current Boost is provided in order to prevent collapse of the excitation system during fault conditions. Exciter field power is taken from the exciter output terminals; however, exciter field current must be maintained even when exciter terminal voltage is low.

Shown in Figure 9 is a diagram illustrating the current boost function and the relationship between exciter field current and exciter line current for two limit conditions. One of these conditions is steady-state load represented by the generator field supplied through the main field rectifier from the exciter terminals. The other is a short circuit on the exciter output lines. There are, of course, an infinite number of possible load conditions that would fall between the two shown in Figure 9.

Current transformers in the exciter output lines supply power to the current boost diode bridge. The ratio of these transformers is selected such that for any point (such as point A) on the steady-state load curve of Figure 9, the current produced at the output of the current boost bridge (OD) is less than the field current required (OF) to supply the exciter line current (OE).

The current transformer ratio is selected so that in addition to meeting the requirements just described, the current produced under the short circuit condition for the same exciter line current at the output of the current boost bridge (OD) is more than the field current required (OG) to supply the exciter line current (OE).

For steady-state load conditions, the current boost feedback at any particular line current is less than the field current required to produce that line current. In this case, however, there is exciter line voltage with the result that the thyristor regulator is in control and supplies the required field current which flows through the current boost diodes and on into the exciter field. The current boost current also flows in the current boost bridge. Since current boost current is less than field current, the extra field current supplied from the thyristors flows across the current boost diode bridge. All six diodes in the current boost bridge are conducting continuously - the current transformer secondary line current modulates the steady exciter field current, divided among the three legs. Under this steady-state



(a) SINGLE BRIDGE LEG

(b) DOUBLE BRIDGE LEG

Figure 8. Typical Thyristor Bridge Leg.

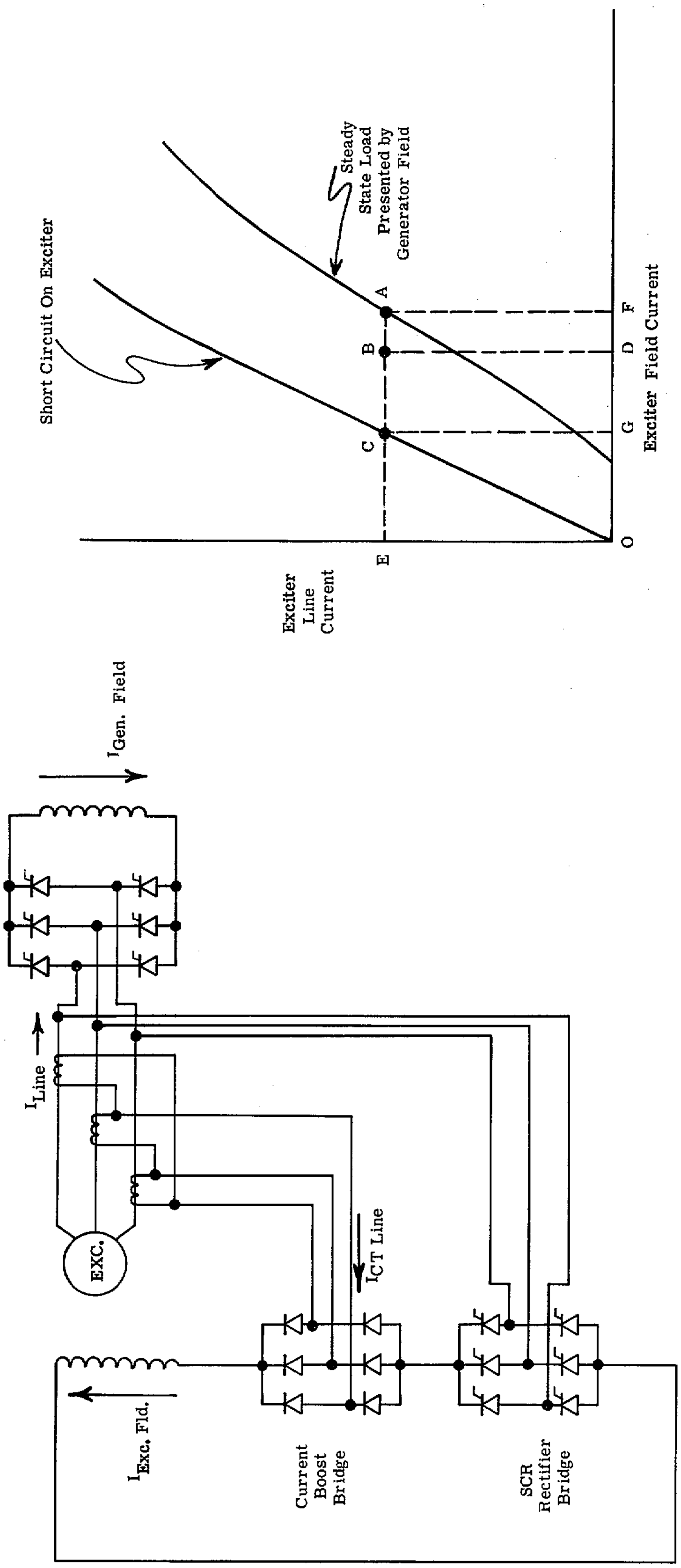


Figure 9. Current Boost Diagram and Excitation Requirements.

load condition, the voltage across the bridge is only the forward drop of two diodes in series. The thyristor bridge has control and is almost totally unaffected by the presence of the current boost bridge in the circuit.

For the short-circuit load condition, the current boost feedback at any particular line current is more than the field current required to produce that line current. During a short-circuit condition, voltage to the thyristor bridge is zero; thus, its output voltage is zero, but the last thyristors to be conducting prior to the application of the short-circuit, will continue to conduct. Because of the fact that current boost under the short circuit condition is regenerative, and since a thyristor path remains conducting, exciter field current will build up until the current transformers saturate. The transformers are designed so that at the point of saturation, the current boost circuit will be supplying rated full-load field current to the exciter field.

Depending on the actual ratio selected for the current boost current transformers, the current boost circuit will also take over control of the field, and maintain excitation for transient load conditions considerably less extreme than a short circuit.

GENERATOR FIELD THYRISTOR BRIDGE

The generator thyristor bridge operates as a phase-controlled variable DC voltage source to control generator field current as required by the AC and DC regulator.

The input to the thyristor bridge is taken directly from the exciter output rather than being reduced by an anode transformer. The maximum DC output voltage (generator field ceiling voltage) is determined directly by the exciter terminal voltage.

The theory of operation of the generator thyristor bridge is the same as that for the exciter thyristor bridge and has been covered in detail under Thyristor Bridge Circuit. For comparison, Figure 10 is the generator field voltage. The most significant difference is the increased commutation period.

The physical arrangement differs from the exciter bridge in that the generator thyristor bridges are "Double Bridges". That is, each bridge leg has a parallel thyristor path from the AC source to the DC output bus. In addition, each leg has two thyristors in series. Refer to Figure 8 (b).

As in the exciter bridges, each thyristor is paralleled by an RC filter to suppress voltage transients during commutation. The divider circuit formed by the individual resistors across each thyristor forces equal division of reverse voltage across each thyristor during the negative (blocking portion) of the voltage cycle.

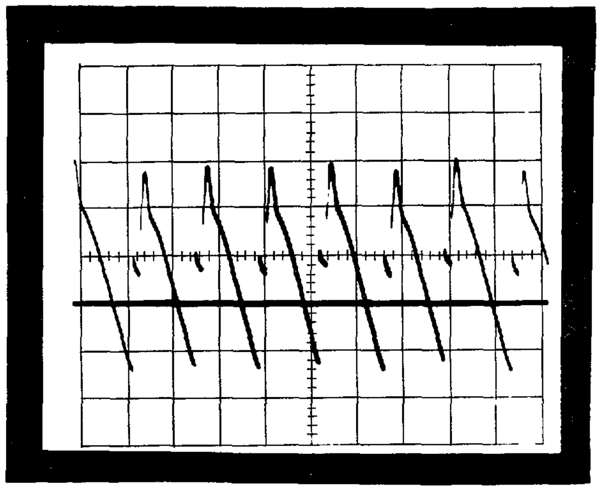


Figure 10. Generator Field Voltage Oscillogram.

Vertical: 200.0 Volts/Division
Horizontal: 2.0 Millisec/Division

Line-to-line RC filters are used to suppress source voltage transients during commutation.

Fast clearing protective fuses are included in each thyristor path assembly. A fuse is connected in series with each path of each positive and each negative leg to clear the leg in the event two thyristors in series in the leg fail by shorting.

FIRING CIRCUIT

A thyristor remains non-conductive until a firing pulse of current is applied through its gate-to-cathode junction. If the anode is positive with respect to the cathode when the pulse is applied, the thyristor will conduct and remain conducting until the anode voltage goes negative with respect to the cathode and the anode current goes to zero. By delaying the firing pulse during the period when the anode to cathode voltage is positive, the thyristor is phase controlled as described in Figure 4.

For thyristors operating in series, it is essential to fire them simultaneously to assure transient voltage division across the thyristors. When operating thyristors in parallel, it is essential to fire them simultaneously to assure transient current division among parallel paths. To provide simultaneous firing, all four thyristors in the same leg of a double thyristor bridge unit are fired from a common pulse transformer in the trigger circuit. In addition, all parallel leg trigger circuits are pulsed from the same source, the master gating thyristors in the master firing circuit.

The firing sequence for a thyristor bridge is shown in Figure 11. Both primary and secondary firing pulses are used during each thyristor conduction period. When the bridge is in an initial non-conducting state, the forward current path and the return current path must be fired simultaneously in order to get current build-up in the machine field. Referring to Figure 11, if the firing circuit is turned on at t = 0, the first firing pulse is the primary pulse for 1CD. A secondary pulse also fires 4CD to complete the circuit through the field and back to the source voltage. Current build-up is then obtained and the bridge continues to function by firing each thyristor leg on the primary pulse.

The firing circuit for only one bridge leg will be explained since the firing for all 6 bridge legs is identical, but occurring at different times (Figure 11).

Master Firing Circuit

The master firing circuit uses a saturable reactor type firing and phase control circuit. This circuit is shown in Figure 12, which describes the firing of G210CD. The supply voltage for G210CD is the voltage at A with respect to B (A-B) as shown in Figure 12 (a) and indicated on Figure 12 (b). The supply voltage for the saturable firing reactor, D201SX, is the voltage B' - B as shown in Figure 12 (a). This phase shift in the saturable firing reactor circuit prevents the master gating thyristor from firing past full-on. That is, the phase shift furnishes a firing angle delay to assure a positive voltage across the bridge thyristor before firing.

In Figure 12 (a)-(h), consider the primary (phase-controlled) firing circuit formed by D201SX and resistors G210R and G212R. Numbers in circles indicate points in time. At the beginning of the cycle (positive voltage B'-B), the firing reactor D201SX is unsaturated (1) ; thus its impedance is high and it allows only exciting current to flow through the resistors. This condition continues during (2) while the reactor is accumulating volt-seconds and its flux density B is increasing. At point (3) the reactor will saturate so that its impedance will drop sharply and cause most of the supply voltage to appear across the resistors. The core material is a square-loop type, so the rising voltage across the resistor is quite steep. See Figure 12 (e). Before saturation (2) , the voltage that does appear across G212R is blocked by G212REC and does not appear across the G210CD gate.

After D201SX saturates, the remainder of the positive half-cycle voltage appears across the voltage divider network formed by G210R and G212R, Figure 12 (d). The voltage across G212R is limited by the zener diode G210ZD, and the blocking diode, G212REC, in order to prevent overvoltage on the G210CD gate, Figure 12 (e). When voltage appears across the gate-to-cathode junction, G210CD will fire and generate a pulse to fire a bridge thyristor. The RC network formed by G213R and G210C form a filter to bypass high frequency noise that could cause erratic firing.

The foregoing explains the primary thyristor firing (1) - (2) - (3) in Figure 12. After G210CD is fired there is no change until (4) when the supply voltage (phasor B'-B across G4T and G5T) swings negative, and rectifier G210REC disconnects the gate winding on D201SX from the supply voltage. The flux then returns to the B_R point.

The regulator output applies a voltage to the control winding that causes exciting current to flow to produce a flux in the opposite direction from that resulting from the gate winding current, so the reactor begins accumulating volt-seconds on the opposite side of the B-H loop, (5) . At the end of the negative half-cycle (6) , the exciting current again transfers back to the gate winding (1) , which begins accumulating positive volt-seconds - (2) .

The volt-seconds that must be accumulated before D201SX again saturates at (3) is determined by how much the flux was driven down the B-H loop (reset) during the previous negative half-cycle - (5) .

If the regulator output (reset voltage) is small during the negative half-cycle, the flux will not be pushed far down the B-H loop so few volt-seconds need be accumulated during the next positive half-cycle before D201SX will saturate. See Figure 12 (I) - delayed firing angle. If the regulator output (reset voltage) is large during the negative half-cycle, the flux will be pushed far down the B-H loop, so more volt-seconds will need to be accumulated during the next positive half-cycle before D201SX will saturate. See Figure 12 (II) - advance firing angle.

Note in Figure 12 (b) that for a positive half-cycle of D201SX voltage, the area of the shaded portion (volt-seconds) must be equal to the preceding negative half-cycle volt-seconds. Thus, as regulator output increases, the firing angle of G210CD is advanced, and the output voltage from the thyristor bridge decreases (phased back). The above and Figure 4 illustrate the primary (phase-controlled) firing of G210CD. The master firing circuits for all other thyristor bridge legs are identical. The regulator output (reset voltage) is applied equally to all six firing reactors (D201SX through D206SX) so that all six thyristor legs in each thyristor bridge are firing at the same respective angle (balanced firing).

The inverting capabilities of a full-wave thyristor bridge depends upon delayed thyristor firing. See Figure 4 (d). If a high negative voltage is maintained on the control winding of the firing reactors, the master gating thyristors may be phased completely off. If a large reset voltage is applied during the negative half-cycle, the firing reactor may not saturate during the positive half-cycle. If this happens, the master gating thyristors would not fire and no thyristor bridge firing pulse would be generated. The load inductance would force the last thyristor that fires to continue to conduct current

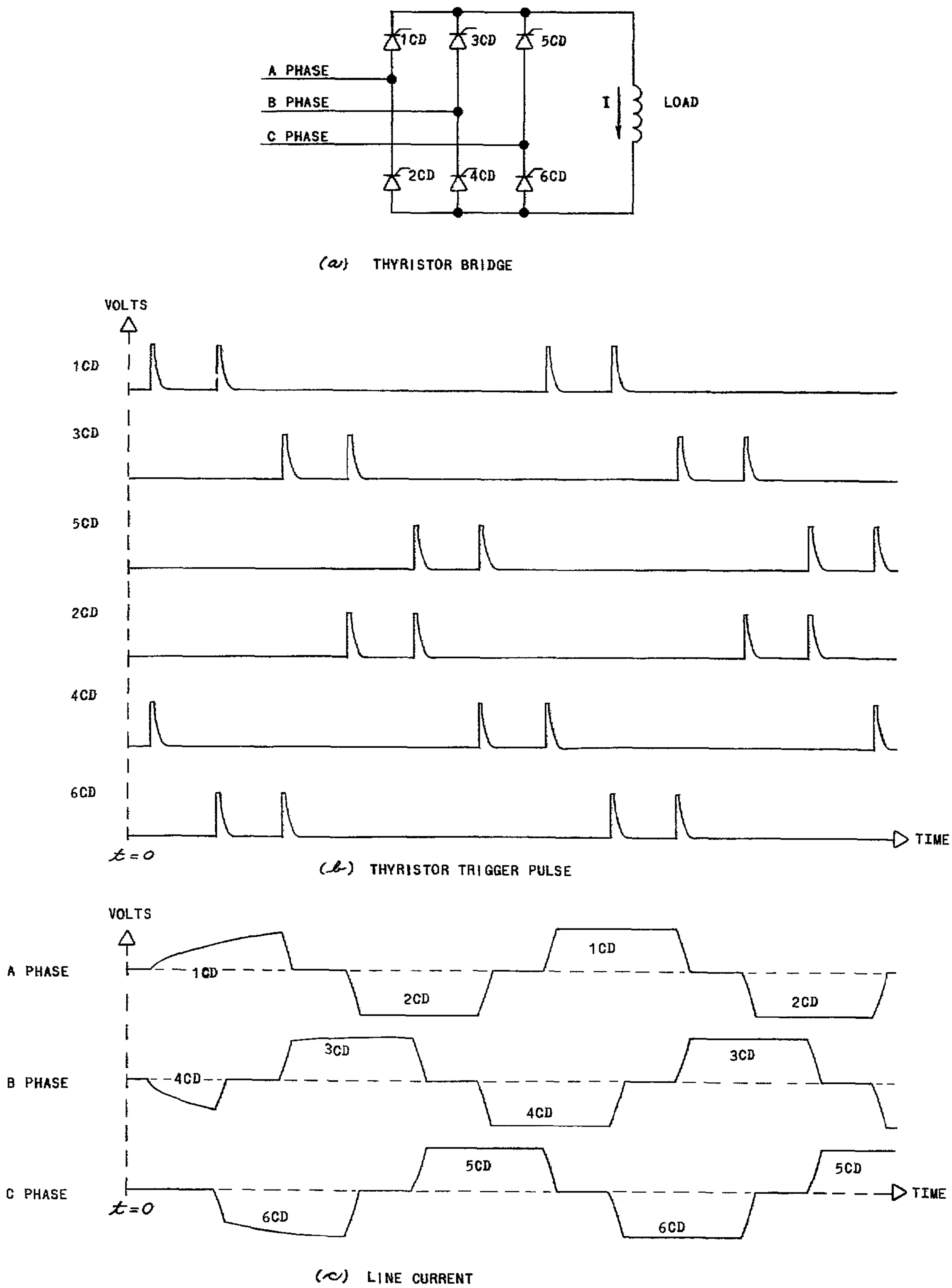


Figure 11. Thyristor Firing Sequence.

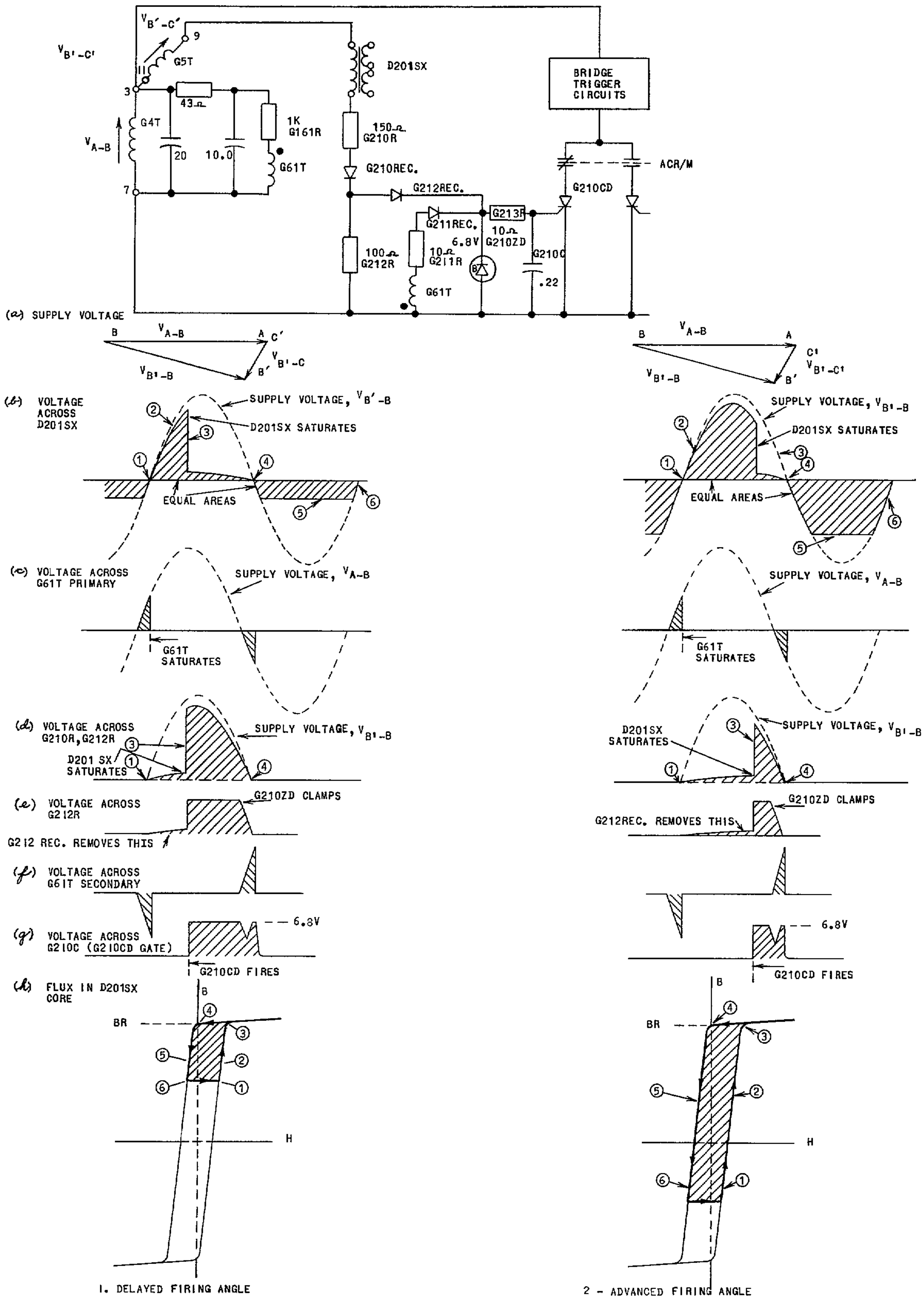


Figure 12. Thyristor Master Firing Circuit.

and the output voltage will follow the AC supply voltage, resulting in a zero average output voltage. The secondary (not phased controlled) firing circuit, G61T, is used to maintain control of the thyristors by supplying a reliable firing pulse during transient conditions of negative voltage forcing.

Transformer G61T has a limited volt-second capacity and reaches saturation during the first 15° of the supply voltage half-cycle, Figure 12 (c). The secondary winding of G61T is phased so that a positive voltage pulse will occur at the end of the primary gate pulse, Figure 12 (f). The positive voltage pulse is clamped by zener diode G210ZD and the negative pulse is blocked by G211REC. The resultant gate pulse from both the primary and secondary firing circuits is shown in Figure 12 (g). If the firing reactor does not saturate and generate a primary firing pulse, the secondary pulse from G61T will fire G210CD and generate a firing pulse to the thyristor bridge leg. Thus, it maintains bridge inversion until the regulator output reset voltage decreases, or until the field current goes to zero. The RC filter removes noise from the supply voltage to G61T.

Figures 13 and 14 show actual master gating thyristor voltages and gate voltages at two different firing angles.

Referring to the typical elementary, Figure 23, the DC regulator controls firing reactors D201SX through D206SX, thus controlling firing of G210CD, G230CD, G250CD, G270CD, G290CD and G310CD respectively. The AC regulator controls firing reactors A201SX through A206SX, thus controlling firing of G220CD, G240CD, G260CD, G280CD, G300CD, and G320CD respectively. If the AC regulator firing reactor, A201SX, is generating a firing pulse at the same angle as the DC regulator firing reactor, D201SX, regulator control transfer can be made by closing ACRMX without disturbing the thyristor bridge output. In Figure 15, voltmeter 5VM provides an indication for presetting the firing angle of the inactive regulator before transferring to the regulator with ACRMX. When the inactive circuit is firing at the same angle as the active circuit, the average DC voltage across 2VM will be zero, thus, the transfer can be made with ACRMX and no bump to the excitation system.

Trigger Circuit

Thus, when the master gating thyristor fires, all series and parallel thyristors in each bridge leg are fired simultaneously by the trigger circuit supplying a gate-to-cathode voltage pulse on each thyristor. Parallel bridges can be fired by connecting the trigger circuit for each bridge leg in parallel. In practice, the minimum gate voltage required to fire a thyristor may differ slightly in each thyristor. To further assure simultaneous firing, the trigger circuit provides a firing pulse with a very fast rise time. The difference in the time required for each trigger pulse to reach the minimum gate firing voltage is negligible because graded SCRs are used exclusively.

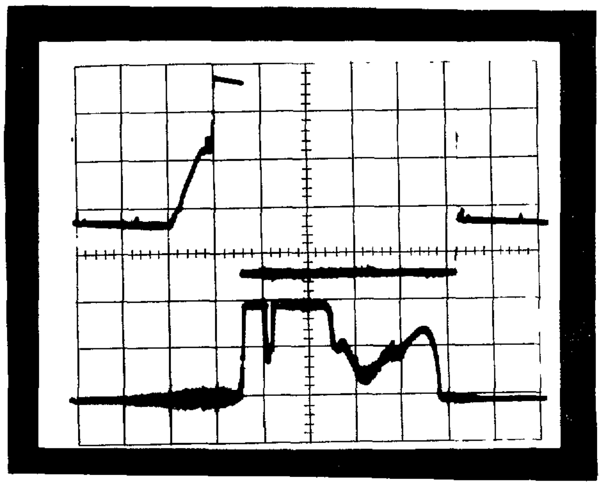


Figure 13. Master Firing Thyristor Oscillogram. (Advanced Firing)

Top: Thyristor Voltage - 50.0 Volts/Division
Bottom: Gate Voltage - 2.0 Volts/Division
Horizontal: 2.0 Millisec/Division

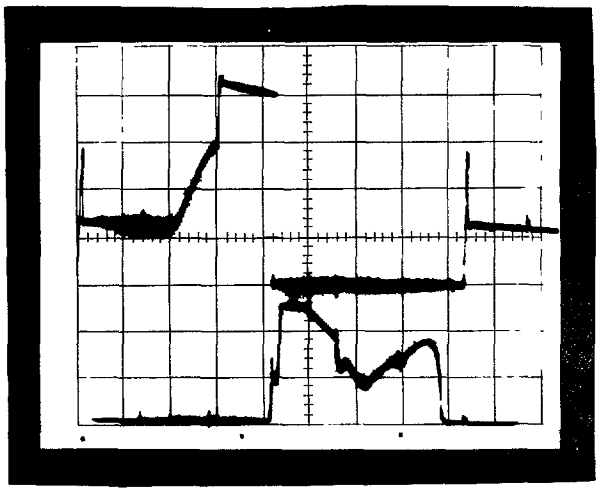


Figure 14. Master Firing Thyristor Oscillogram. (Delayed Firing)

Top: Thyristor Voltage - 50.0 Volts/Division
Bottom: Gate Voltage - 1.0 Volts/Division
Horizontal: 1.0 Millisec/Division

The circuit required to generate a primary firing pulse, Figure 16, will be explained in detail.

Master gating thyristor G210CD acts as an open circuit before firing and as a short circuit after firing.

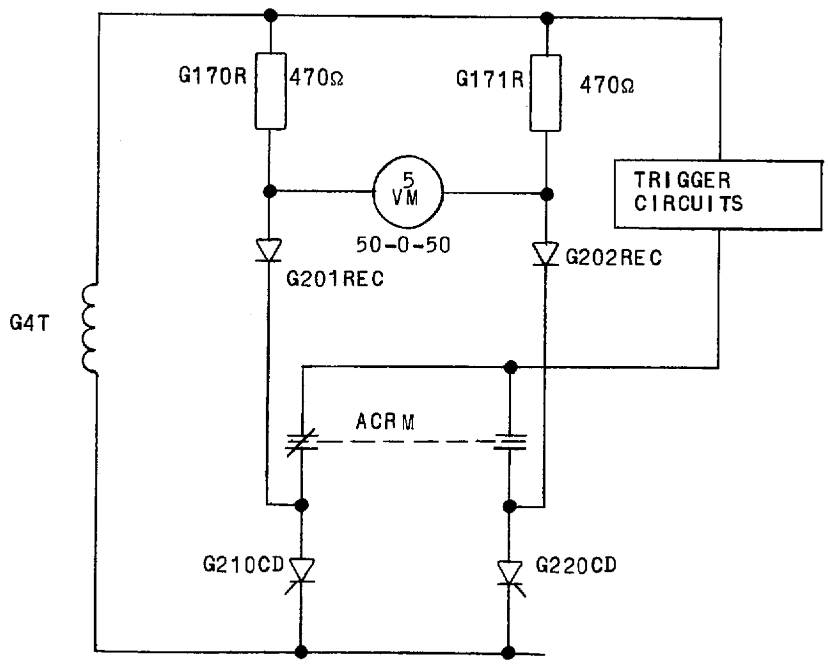


Figure 15. Regulator Transfer Circuit.

Refer to I - small firing angle, Figure 16 (b). The series capacitor, Z1C, assures that initially almost all of the supply voltage appears across the primary windings of G216T. Transformer G216T is a pulse transformer with only a small volt-second capacity. After approximately 100 micro-seconds G216T will saturate and the remainder of the supply voltage half-cycle will appear across Z201R. Transformer G216T thus provides a 100 microsecond pulse on all four secondaries when G210CD or G220CD fires. Zener diodes G215ZD, G216ZD, G217ZD, and G218ZD clamp the secondary voltage to produce a square pulse and to prevent gate overvoltage, Figure 16 (d).

If the firing angle is delayed, capacitor Z2C will charge to the peak AC supply voltage, Figure 16 (b), II - large firing angle. Without Z2C the voltage source for delayed firing would be so low that the pulse transformer could not deliver a substantial pulse to the bridge thyristors. With Z2C, firing can be maintained for bridge inversion even into the negative half-cycle of the master firing supply voltage.

During each bridge thyristor conduction period, Figure 11 shows a secondary gate pulse occurring at the same time as a primary pulse in another bridge thyristor leg. Pulse transformers are paralleled in each trigger circuit, Figure 17, to obtain secondary pulses. Transformer G216T supplies a primary pulse to R11CD and transformer G296T supplies a secondary pulse to the return path, R25CD. The top waveform in Figure 18 is the voltage across one bridge thyristor. The bottom waveform in Figure 18 is the gate to cathode voltage of this same thyristor.

GENERATOR AC VOLTAGE REGULATOR

The AC regulator provides automatic operation by controlling firing of the thyristor bridges to hold constant machine terminal voltage. Figure 19 shows the generator AC regulator.

The input to the AC regulator must be 3-phase with a line-to-line voltage between 100 and 125 volts AC. The exciter AC regulator has voltage step down transformers connected to the exciter terminals. The generator AC regulator must be supplied from potential transformers at the generator terminals. The input voltage to the generator AC regulator also contains a small component of voltage proportional to generator line current.

The regulator supply transformers, A201T, A202T, and A203T, reduce the input AC voltage to approximately 42 volts (at 120 volts input). Secondary transformer taps are provided for regulator range adjustment, if required. The transformer secondaries supply a three-phase full-wave diode rectifier bridge

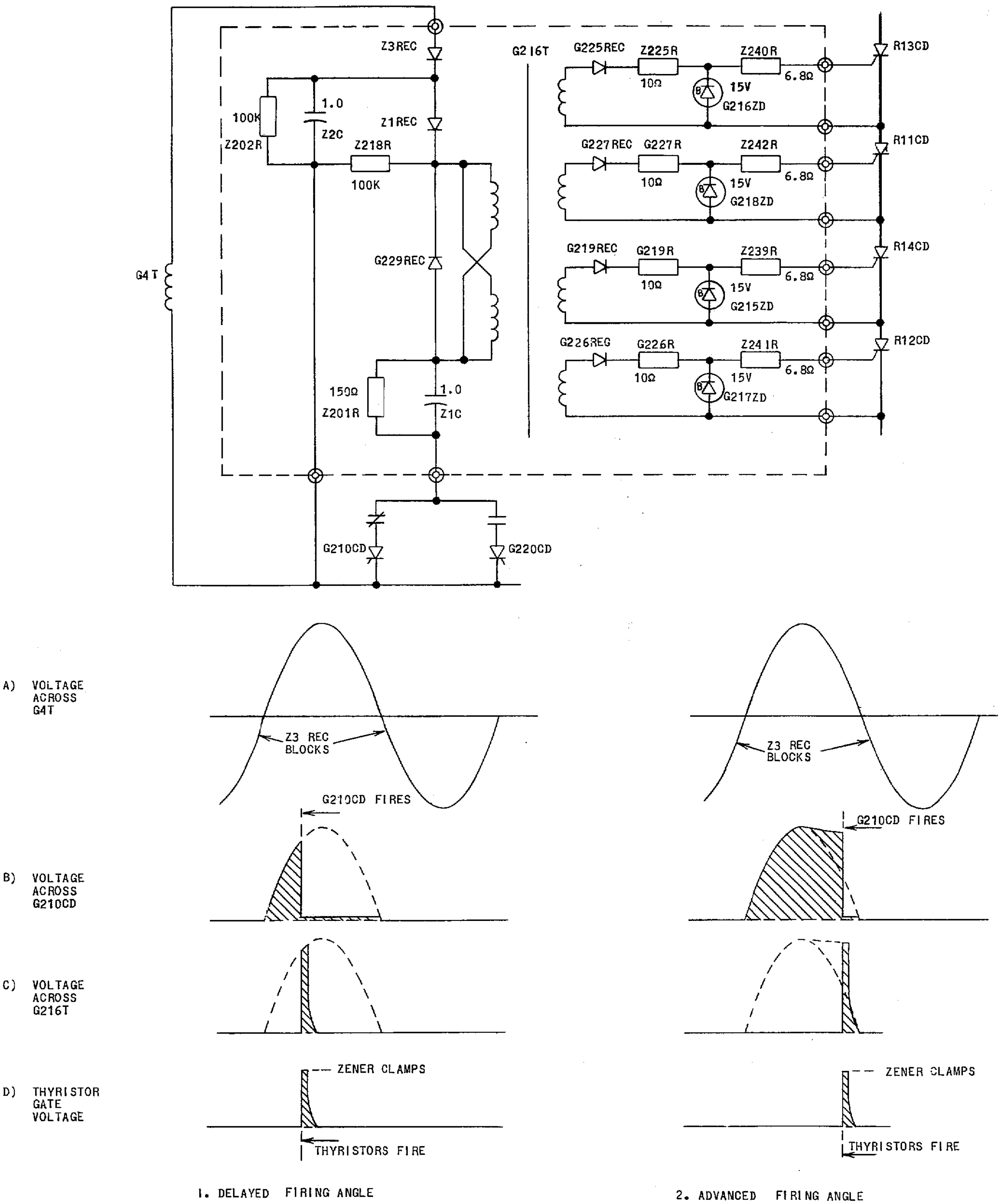


Figure 16. Bridge Thyristor Trigger Circuit (Primary Trigger Pulse).

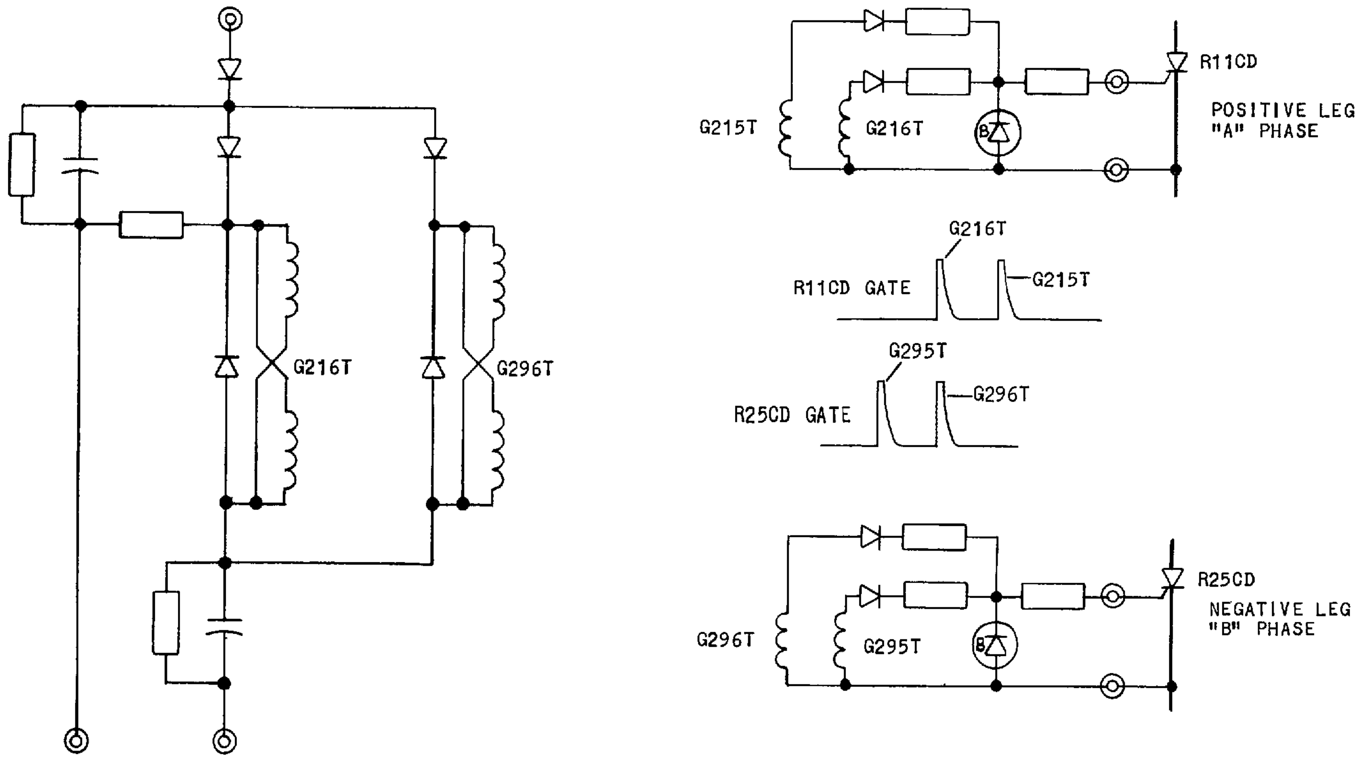


Figure 17. Bridge Thyristor Trigger Circuit.
(Primary and Secondary Trigger Pulse)

consisting of rectifiers A201REC through A206REC. The DC output of this bridge is used (1) to provide DC power for the transistor circuits, (2) to provide reference voltage for the AC voltage regulator by supplying power to zener diode A202ZD, and (3) to supply voltage feedback proportional to the generator terminal voltage (modified by the line current compensation signal).

The current compensation signal can be combined with the generator voltage feedback signal so as to add to it or to subtract from it, depending on whether it is desired to make the regulator decrease terminal voltage or to increase it, as a function of generator line current.

The bridge output is filtered by reactor A201X and capacitor A201C to supply a DC voltage proportional to generator terminal voltage to the sensing circuit and to the zener diodes A201ZD and A202ZD. Zener A201ZD provides a 24 V DC regulated supply and zener A202ZD provides a reference voltage for the voltage regulator. The zener diodes have a very low temperature coefficient so this regulated voltage will not drift.

The sensing circuit consists of resistors A202R, A203R, and A223R, potentiometers 90AP, A204P, and A205P, and zener A202ZD. The difference between the reference voltage and the feedback voltage produces an error current that flows through the base-to-emitter of A201Q. This error current is

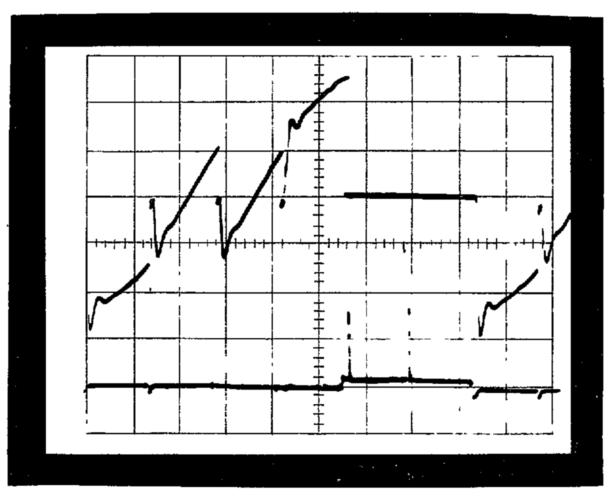


Figure 18. Bridge Thyristor Oscillogram.

Top: Thyristor Voltage - 200.0 Volts/Division
Bottom: Gate Voltage - 5.0 Volts/Division
Horizontal: 2.0 Millisec/Division

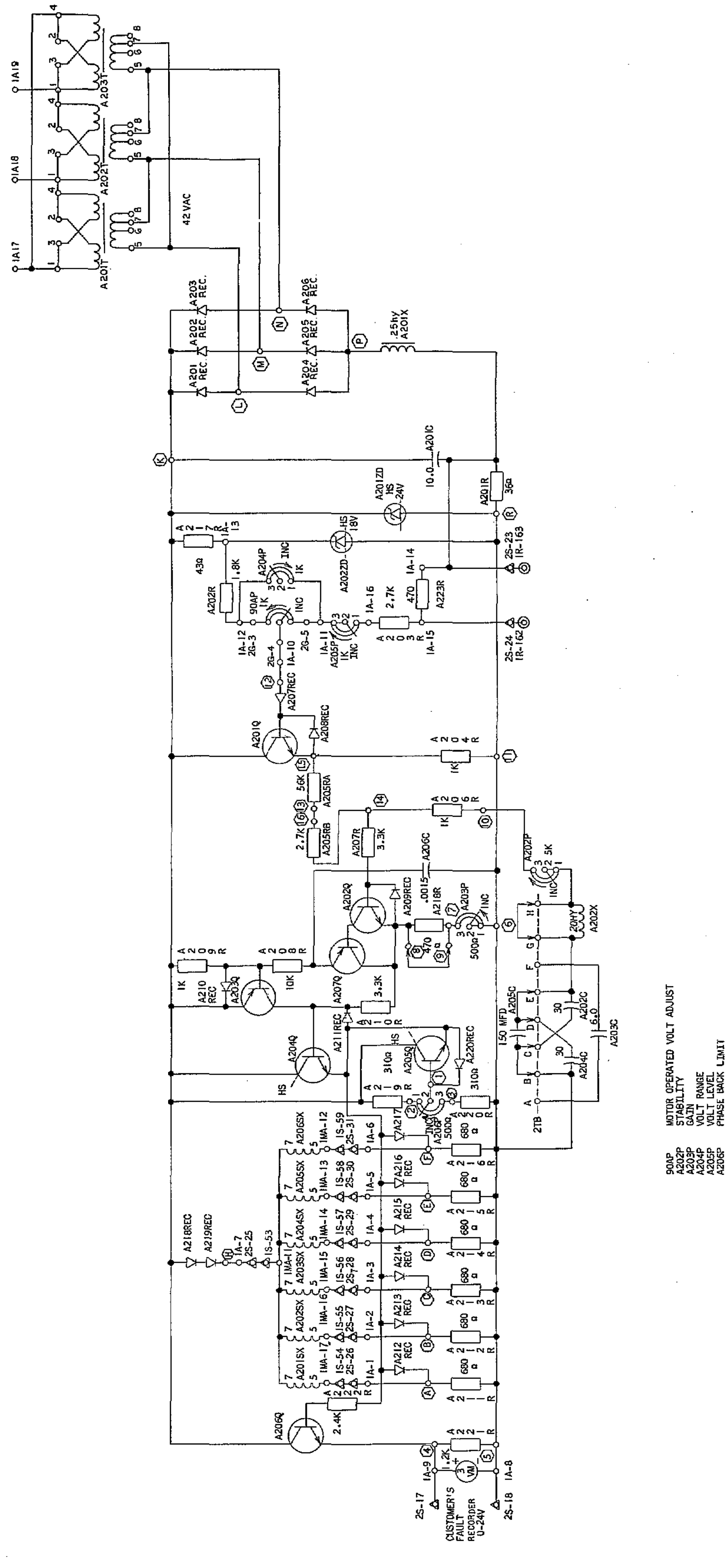


Figure 19. Generator AC Voltage Regulator.

amplified by A201Q; thus, any small change in A201Q base current produces a larger change in A201Q collector current. This amplified error current produces an amplified error signal across A204R. The voltage at the emitter of A201Q is applied through resistors A205RA, A205RB and A207R to the base of a second amplifier stage consisting of transistors A202Q, A207Q and A203Q. Components A205RA, A205RB, A206R, A202P, A202X, A202C A203C, A204C, and A205C constitute a lag-lead network in series between the output of the first stage amplifier and the input of the second stage amplifier. The values of the lag-lead network components and A207R are selected so that they are low in resistance compared to the input impedance of the second stage. This allows the input impedance to be neglected in calculating the behavior of the network.

Since the three-transistor second stage amplifier employs feedback from the third transistor A203Q into the emitter of the first transistor A202Q, the overall gain of this stage is very stable and is relatively unaffected by changes in the current gain of the individual transistors. Resistor A218R and potentiometer A203P provide a gain adjustment. The use of A218R decreases the gain sensitivity.

The collector of A203Q is supplied to the base of A204Q in an emitter follower arrangement in which the emitter load is the control windings of the thyristor firing reactors (A201SX through A206SX). The voltage at the emitter of A204Q determines the reset voltage applied to the reactor control windings and thereby establishes the firing angle of the thyristors, as previously described.

The emitter of A204Q is also applied to the base of A206Q which is an emitter follower for regulator output metering. The output metering is in the same sense as the regulator action. If the voltage across the emitter of A204Q increases (becomes more negative) with respect to R, the reset voltage across the firing reactor control windings decreases, the thyristor firing angle decreases (thyristors turn-on) and the field voltage increases.

During a sample case of the generator terminal voltage dropping, such as due to an increase in load, the diode rectifier bridge output will decrease. The voltage at the wiper of 90AP will then decrease, causing the emitter voltage of A201Q to increase. This increased voltage is applied to the base of A202Q, causing the emitter voltage of A204Q to increase. This decreases the reset voltage across the firing reactors, which in turn decreases the thyristor firing angle. As the thyristor firing angle decreases (phase-on), generator field voltage will rise, and generator terminal voltage will rise to correct the original error. During a change such as just described, the stabilizing circuit will transiently oppose the initial voltage error and allow the system to return to normal voltage smoothly without oscillating. Should the generator terminal voltage rise due to load rejection, the opposite of the above action would take place.

Phase Back Limit

The phase back limit, potentiometer A206P, can be used to limit the degree to which the thyristor bridge will invert, when it is supplying reverse output voltage during those times when the regulator acts to reduce the excitation rapidly. Resistors A219R and A220R and potentiometer A206P form an adjustable voltage divider for the base of transistor A205Q. If the regulator "turns off" the voltage from 7 to 16 will decrease. The emitter of A205Q is tied to point 16 so that if the emitter becomes negative with respect to the base A205Q will conduct and prevent point 16 from going more negative. If A206P is turned fully clockwise (dial setting ten) full negative ceiling will be attained.

EXCITER VOLTAGE REGULATORS

The exciter voltage regulator consists of two AC voltage regulators and two Volts per Hertz regulators. The operation of the Volts per Hertz regulators is explained in instruction book GEK-15021. The operation of the exciter AC voltage regulator is similar to that of the generator AC voltage regulator. The circuitry of an exciter AC voltage regulator differs from a generator AC voltage regulator in that: (1) there is provision for a Volts per Hertz Regulator, and (2) no equivalent of A207Q exists in the exciter.

The exciter's master firing circuit differs from the generator's master firing circuit in that transfer between regulators is accomplished electronically. The generator requires a relay, ACRM, to accomplish this function. The exciter master firing circuit examines the terminal voltage each AC voltage regulator attempts to hold, then selects the regulator which will maintain the lower voltage. Should either AC voltage regulator go above or below the range set by potentiometer RFAP, then the exciter AC Voltage Regulator Failure Alarm would be activated.

DC VOLTAGE REGULATOR (MANUAL)

The DC voltage regulator provides manual control by controlling firing of the thyristor bridges to hold constant machine field voltage. The DC voltage regulator provides constant excitation by regulating the average DC voltage to the machine field, regardless of AC line voltage changes. Figure 20 shows the generator DC regulator.

The output voltage from the thyristor bridge is fed into the DC regulator through seven reactors. This voltage is applied through D201R to D201ZD, setting the regulator reference voltage at 12.0 volts. The filtering action of reactors D201X, D202X, D203X, D204X, D205X, D206X, and D207X and potentiometers D201P and D202P produces a DC voltage across D201P that is proportional to the average DC field voltage.

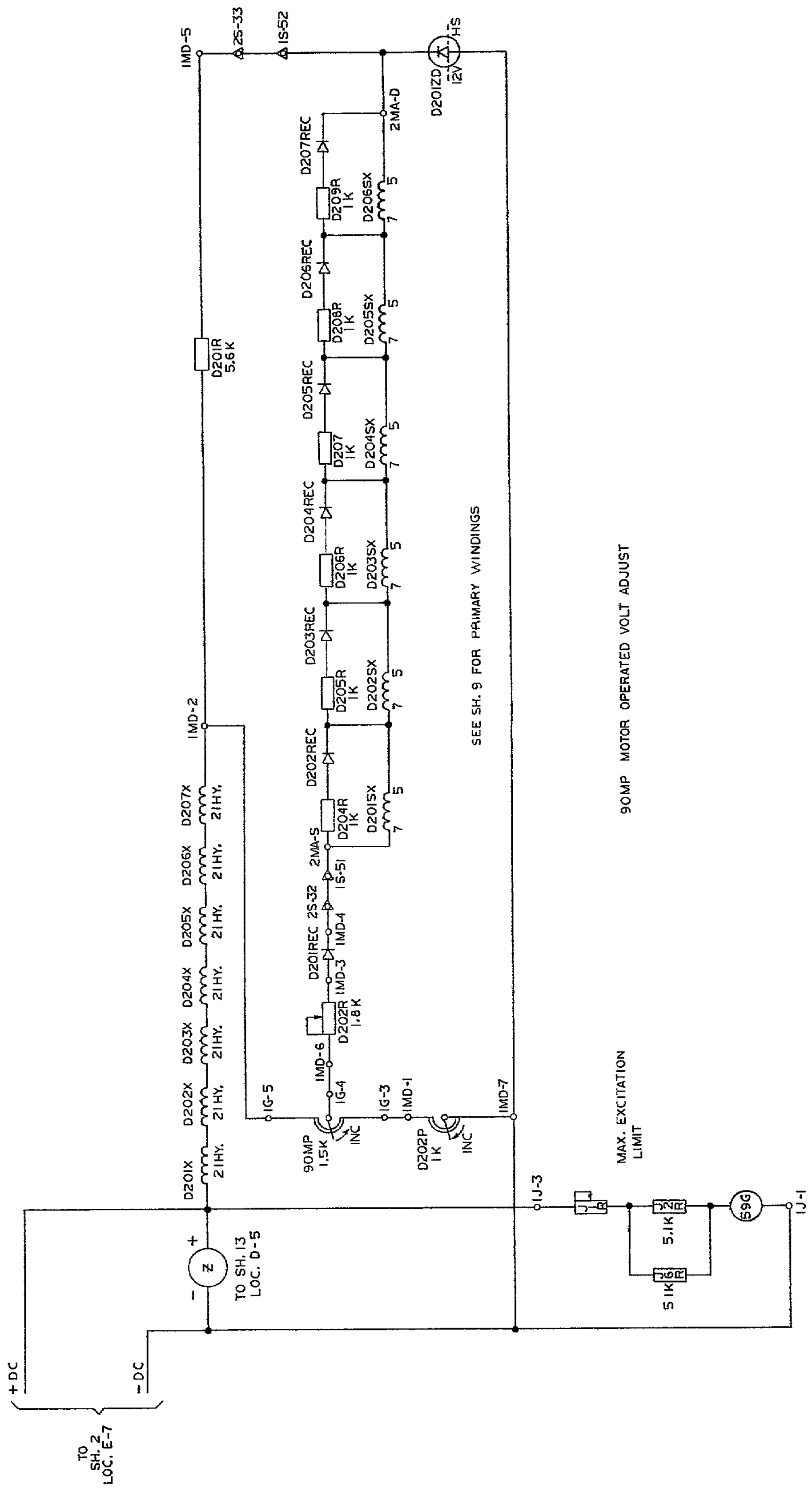


Figure 20. Generator DC Voltage Regulator.

The firing reactor control windings are connected from the cathode of the reference zener, D201ZD to D201P, which acts as a voltage divider. If the voltage from the anode of the reference zener point 1MD-7, to the anode of D201REC point 1MD-3 (which is proportional to field voltage), is too high, an error reset voltage will appear across the reactor control windings to reduce excitation. The DC regulator thus is a bridge type circuit.

The series resistor-rectifier, such as D204R and D202REC, equalize the reset voltage across each reactor control winding so that each master gating thyristor will be firing at the same respective angle (balanced firing).

Potentiometer D202P can be used to limit the ceiling field voltage of the DC regulator. Clockwise rotation of D202P increases the voltage across D201P and consequently its control range.

MAXIMUM EXCITATION LIMIT

The exciter and the generator both have maximum excitation limit circuits to protect the respective fields against sustained over-excitation while the field is controlled from the AC regulator.

Over-excitation is detected by a voltage sensitive relay (relay 59E on the exciter and 59G on the generator), with series voltage dropping resistors, that is connected across the field circuit. If the field voltage exceeds the proportional relay pick-up voltage, a time delay relay (relay 59ETD on the exciter and 59GTD on the generator) will be energized. If the over-excitation condition persists, the time delay relay will time out and excitation control will be transferred from the AC regulator (Auto) to the DC regulator (Manual).

The series voltage dropping resistors serve as a coarse adjustment for a voltage sensitive relay that has a pick-up voltage much less than the expected field voltage. The low voltage relay permits a closer setting of the pick-up point with a small differential between the pick-up and drop-out voltages.

The maximum excitation limits are independent and either the exciter field limit or the generator field limit may operate alone.

UNDER-FREQUENCY LIMIT

The AC regulators sense voltage and are insensitive to changes in frequency. A 14 frequency relay is used to provide protection from excessive volts/hertz on excitation equipment (such as power transformers) for underfrequency operation in AC regulator (Auto). If the generator is operated at reduced speeds, the 14 frequency relay will prevent operation in either the exciter or the generator AC regulator by transferring field control to the DC regulator.

MAXIMUM CURRENT LIMIT

The maximum current limit provides a ceiling or top limit to the DC current that can be applied to the generator field, and also protects the excitation system by limiting the current that can be supplied by the thyristor bridges when in generator AC regulator (Auto) control. See Figure 21.

A current transformer in each AC line to the thyristor bridge circuits provides a voltage proportional to current due to its fixed load resistor (R750R, R751R and R752R). This voltage is rectified by a three-phase full wave bridge (rectifiers R754REC through R759-REC). Capacitor R750C holds the bridge output voltage to near peak voltage of the highest single phase input. The voltage across R750C is thus nearly proportional to the highest AC phase current into the generator thyristor bridge circuits.

The DC voltage across R750C is also applied across R750P, which acts as a voltage divider, so that the voltage at point k is proportional to current. If this voltage exceeds the 6.8 volt level of R750ZD, current will flow from base-to-emitter through R750Q. This causes a larger current flow from collector-to emitter through R750Q. This emitter follower action of R750Q applies reset voltage to the firing reactor control windings (A201SX through A206SX) to decrease excitation, thereby reducing the overcurrent.

A separate power supply, R750T, allows R750P resistance to be high enough not to add extra burden on the CTs. Transformer R750T supplies a single-phase bridge, R750REC through R753REC, and the DC output is filtered by R753R and R751C. Zener R751ZD maintains a constant 36 volt supply.

FAULT SUPPRESSION CIRCUIT

In the event of a fault condition, such as a generator collector ring fault, the excessive field current will be sensed by the 76 relay. If the excessive field current is sustained, 76TD will operate to trip the master firing circuit on the exciter thyristor bridge. If the excessive current is a result of field forcing, 59GTD/X will will sense field voltage and operate to pick up 76X to lock out 76TD.

The 76 relay is connected across the R750C capacitor in the maximum current limit circuit. The relay then senses a voltage proportional to the highest single phase input.

REACTIVE CURRENT COMPENSATOR (RCC)

The RCC is used to equalize division of reactive kva between generators when two or more generators with individual regulators are operating in parallel. As shown in Figure 22, the adjustable reactor winding (G1T) is connected to the secondary of a current transformer in one of the generator lines, while the insulating winding is connected in one phase of the

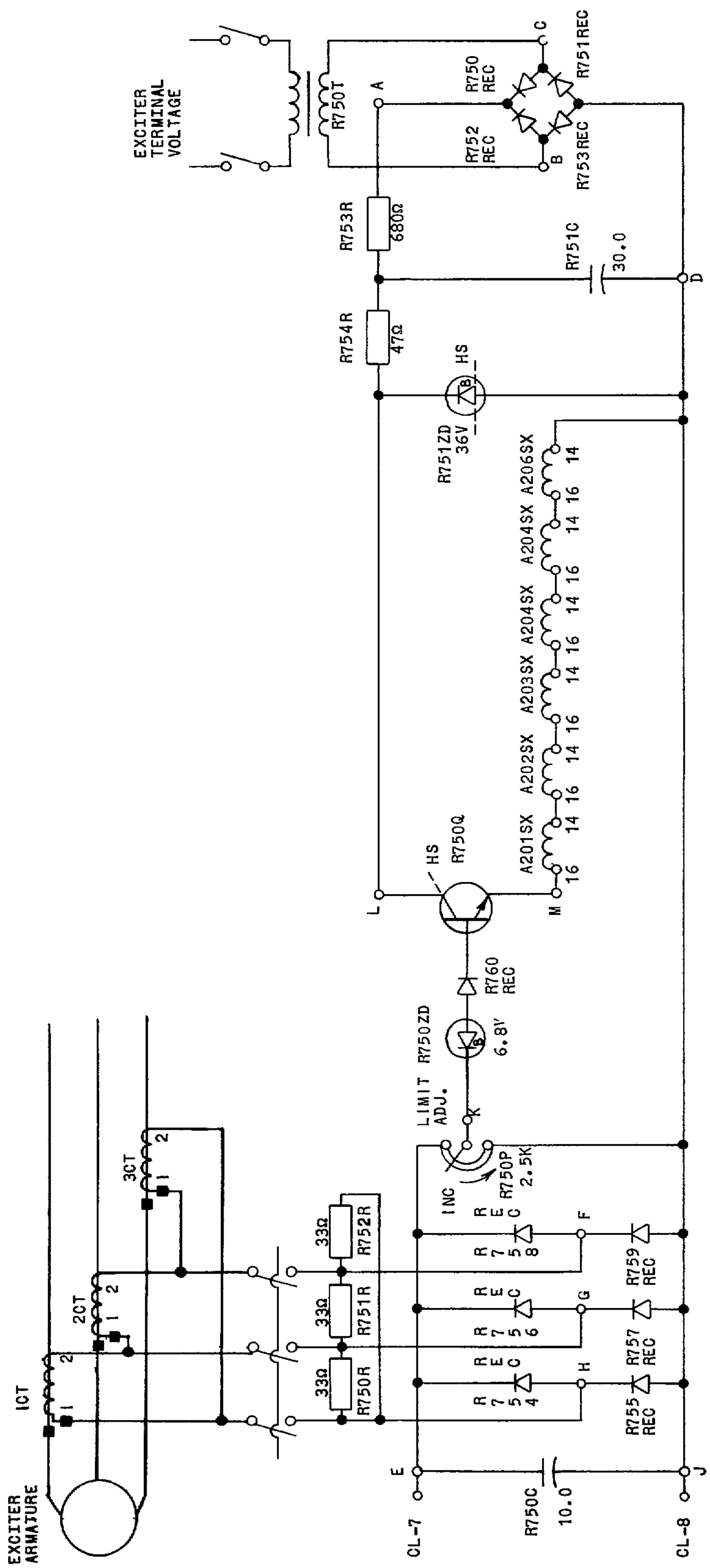


Figure 21. Maximum Current Limit Circuit.

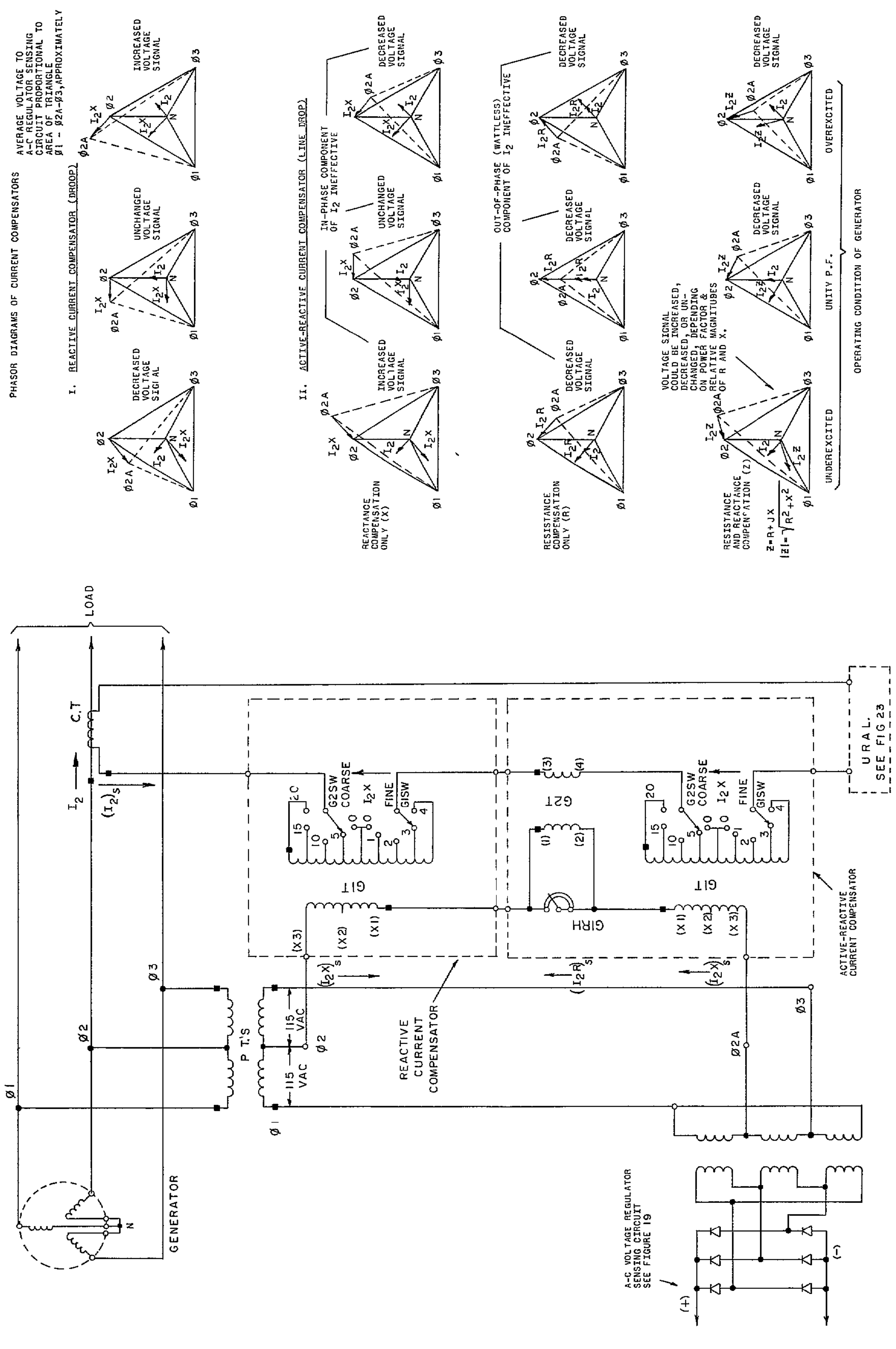


Figure 22. Reactive Current Compensator and Active-Reactive Current Compensator.

three-phase AC regulator feedback voltage.

CAUTION

IT IS ESSENTIAL THAT BOTH WINDINGS OF THE COMPENSATOR BE CONNECTED IN THE SAME GENERATOR PHASE - USUALLY PHASE 2.

The compensator will vary the AC regulator feedback voltage mainly as a function of the reactive current. See Figure 22-I. If overexcited reactive current increases, the average three-phase feedback voltage supplied to the AC regulator will increase. The regulator will act to decrease excitation, thereby decreasing the overexcited reactive current.

If underexcited reactive current increases, the average three-phase feedback supplied to the AC regulator will decrease, The regulator will act to increase excitation, thereby decreasing the underexcited reactive current. The effect of the compensator can be increased by increasing the reactance in the current-transformer secondary circuit with tap switches G1SW and G2SW.

If two generators are connected through transformers, one's winding may be reversed to obtain the opposite effect of that described above. This makes it possible to adjust the apparent transformer impedance to an optimum value (3 to 6 percent) improving system voltage regulation.

The compensator is adjustable in one-volt steps, on the basis of five amperes in the current-transformer secondary, by means of two manually operated tap switches. One of the tap switches gives coarse adjustment and the other gives fine adjustment. The voltage across this winding in the AC regulator feedback circuit is proportional to the current in the current transformer secondary winding. With five amperes flowing through the compensator and with the reactance all cut in, the total drop is 24 volts. This is equivalent to about 36 percent line-to-neutral voltage drop in one signal lead to the regulator, or an average effect of approximately 12 percent line-to neutral voltage drop on a three-phase basis (at zero power factor).

The compensator is built with two independent windings, as shown in Figure 22, so that the current and potential transfomer secondaries are electrically separate and both may be grounded.

ACTIVE-REACTIVE CURRENT COMPENSATOR (ARCC)

In certain special applications, an active-reactive current compensator is used to reproduce in miniature at the regulator, the resistance and reactance between the generator and some predetermined point in the system. The function of the compensator is to lower the signal voltage to the AC regulator as the generator load increases, thereby causing the regulator to maintain normal voltage at some predetermined point in the system, regardless of changes in the voltage drop over the system impedance between the generator and this point. See Figure 22-II.

Where line-drop compensation is required on several generators in a station, provision can be made to prevent interference between the compensators. This is accomplished by special connections of the current transformer and compensators.

The reactance of the compensator is divided into a number of equal sections. Taps are brought out from these sections and connected to independently adjustable tap switches, one having coarse adjustment and the other having fine adjustment. The reactance is variable in one-volt steps based on five amperes in the current transformer. It has a total of 24 steps, and will introduce a maximum of 24 volts total drop in the AC regulator signal voltage circuit, with five amperes in the current-transformer secondary. This voltage drop is proportional to the current flowing in the compensator. The resistance portion of the compensation is a 5 ohm rheostat which produces 25 volts drop in the regulator signal with five amperes in the CT secondary.

Figure 22 shows the connections for this device when used with a single generator. Insulating windings are provided for both the reactor and resistor to permit grounding the current and potential-transformer secondaries separately. It is essential that the current transformer be in the same phase as the single-voltage line in which the compensator is connected.

UNDER-EXCITED REACTIVE AMPERE LIMIT (U.R.A.L.)

This accessory is described by separate instructions GEK-4716.

POWER SYSTEM STABILIZER

This accessory is described by separate instructions GEK-36416.

RELAY AND CONTROL CIRCUIT

All essential relaying and control circuits are operated on a DC power source for maximum reliability. This DC is usually 125 volts DC. In some applications, the relaying may be at 250 volts DC. A typical application is illustrated in Figure 23. Most applications require different circuits to fit the user's practice; however, the general mode of operation is similar to the following description.

All essential relays are latched relays. Loss of DC control power will not disturb the mode of excitation system operation. During loss of DC power, the exciter field breaker can be tripped mechanically at the breaker.

SEQUENCE OF OPERATIONS

A typical sequence of operations for each of the four states Start, Manual, Automatic and Stop follows. It is assumed that the progression of states is from Start to Manual, Manual to Automatic, and Automatic to Stop.

Start

1. Turn SBM switch to Start.

2. Assume break before make operation of SBM switch.

3. Break

a. $\frac{\text{43CS}}{\text{Stop}}$ opens.

b. Relay 5 drops out.

(1) N.O. contacts of 5 open, causing Stop light to go out.

(2) N.O. contacts of 5 open, relay 5X2 drops out.

4. Make

a. $\frac{\text{43CS}}{\text{Start}}$ closes.

b. Relay 1 picks up.

c. Relay 43S picks up.

(1) N.O. contacts of 43S close, Start light illuminates.

(2) N.C. contacts of 43S open, removing power from 90AR, 90AL, 90MR and 90ML.

(3) N.O. contacts of 43S close, relay 9CR picks up.

(a) N.O. contacts of 9CR close to apply power to 90MR and 90ML to pre-position the manual voltage adjustor to AFNL.

d. Pre-positioning of the manual voltage adjustor causes OCRM to pick up.

(1) Contacts of OCRM cause relay OCRMX to pick up.

(2) N.O. contacts of OCRM close, relay OCR picks up.

(3) N.O. contacts of OCRM close, applying power to the Breaker Ready light through a normally closed contact of 41E AUX.

(4) N.O. contacts of OCRM close, relay OCR picks up.

(a) Contacts of OCR cause relay OCRX to pick up.

(b) N.O. contacts of OCR close, relay OCRY picks up.

e. Operator closes exciter field breaker 41E.

(1) N.C. contacts of 41E AUX open, causing Breaker Ready light to go out.

(2) N.O. contacts of 41E AUX close, relays 53 and 53TD pick up.

(a) N.O. contacts of 53 close, the exciter field is flashed until relay 53TD times out.

(b) N.C. contacts of 53TD open, relay 53 drops out.

f. Operator should now transfer to Manual.

<u>Manual</u>

1. Turn SBM switch to Manual.

2. Assume break before make operation of the SBM switch.

3. Break

a. $\frac{\text{43CS}}{\text{Start}}$ opens.

b. Relay 43S drops out.

(1). N.O. contacts of 43S open, causing Start light to go out.

(2) N.C. contacts of 43S restore power to 90AR, 90AL, 90MR and 90ML.

(3) N.O. contacts of 43S open and drop out 9CR.

(a) Power is removed from 90MR and 90ML, via N.O. contacts of 9CR. (Power remains applied to 90AR, 90AL, 90MR and 90ML through N.C. contacts of 43S.)

4. Make

a. $\frac{\text{43CS}}{\text{Manual}}$ closes.

b. Relay 43M picks up.

(1) N.O. contacts of 43M close. As a result, relay 43TR is picked up.

(2) N.O. contacts of 43M close, Manual light illuminates.

c. The manual raise-lower pushbuttons can now be used to control the generator terminal voltage by operating the DC voltage adjustor. The AC voltage adjustor may also be operated, but since the control is in Manual, operation of the AC voltage adjustor will have no effect on terminal voltage.

d. Exciter terminal voltage will build up proportional to frequency under the control of the Volts/Hertz regulators until 57 Hz.

e. Exciter AC regulators control exciter terminal voltage above 57 Hz.

f. Relay 14 picks up above 57 Hz.

(1) N.O. contacts of 14 close, relay 14 AUX picks up.

(a) N.O. contacts of 14 AUX close, relay 5CR picks up.

g. Before transferring to Automatic, the AC regulator should be adjusted to match the DC regulator as indicated by a null condition of the transfer voltmeter.

Automatic

1. Turn SBM switch to Automatic.

2. Assume break before make operation of SBM switch.

3. Break

a. $\frac{\text{43CS}}{\text{Manual}}$ opens.

b. Relay 43M drops out.

(1) N.O. contacts of 43M open, causing Manual light to go out.

4. Make

a. $\frac{\text{43CS}}{\text{Auto}}$ closes.

b. Relay 43A picks up.

(1) N.O. contacts of 43A close, Automatic light illuminates.

(2) N.O. contacts of 43A close. As a result, relay ACRM is picked up.

c. The AC regulator automatically adjusts the generator field voltage to obtain a constant terminal voltage. When in Automatic, the DC regulator should be tracked to keep the transfer voltmeter at zero. To transfer back to Manual, the DC regulator should be balanced to the AC regulator in order to avoid a system disturbance.

Stop

1. Turn SBM switch to Stop.

2. Assume break before make operation of SBM switch.

3. Break

a. $\frac{\text{43CS}}{\text{Auto}}$ opens.

b. Relay 43A drops out.

(1) N.O. contacts of 43A open, causing Automatic light to go out.

(2) N.O. contacts of 43A open. As a result, relay ACRM drops out.

4. Make

a. $\frac{\text{43CS}}{\text{Stop}}$ closes.

b. Relay 5 picks up.

(1) N.O. contacts of 5 close, Stop light illuminates.

(2) N.C. contacts of 5 open, relay 43TR drops out.

(3) N.O. contacts of 5 close, 1 trip coil is energized and relay 1 drops out.

(4) N.O. contacts of 5 close, OCRM trip coil is energized and relay OCRM drops out.

(a) Contacts of OCRM cause relay OCRMX to drop out.

(5) N.O. contacts of 5 close, relay 5X2 picks up.

(a) N.O. contacts of 5X2 close, OCR trip coil is energized and relay OCR drops out.

(1) Contacts of OCR cause relay OCRX to drop out.

(2) N.O. contacts of OCR open, relay 53TD drops out.

(b) N.O. contacts of 5X2 close, OCRY trip coil is energized and relay OCRY drops out.

c. Relay 14 drops out below 57 Hz.

(1) N.O. contacts of 14 open, relay 14 AUX drops out.

(a) N.O. contacts of 14 AUX open, relay 5CR drops out.

d. Operator should now open exciter field breaker 41E.

The following chart summarizes the preceding sequence of operations and is valid only for the previously specified progression of states.

RELAY	PICKED UP IN	DROPPED OUT IN
1	START	STOP
43S	START	MANUAL
Start Light	START	MANUAL
90AR	MANUAL	START
90AL	MANUAL	START
90MR	START, MANUAL	START, MANUAL
90ML	START, MANUAL	START, MANUAL
9CR	START	MANUAL
OCRM	START	STOP
OCRMX	START	STOP
OCR	START	STOP
Breaker Ready Light	START	START
OCRX	START	STOP
OCRY	START	STOP
41E	START	STOP
53	START	START
53TD	START	STOP
43M	MANUAL	AUTO
43TR	MANUAL	STOP
Manual Light	MANUAL	AUTO
14	MANUAL	STOP
14 AUX	MANUAL	STOP
5CR	MANUAL	STOP
43A	AUTO	STOP
ACRM	AUTO	STOP
Auto Light	AUTO	STOP
5	STOP	START
Stop Light	STOP	START
5X2	STOP	START

MISCELLANEOUS FUNCTIONS

Shaft voltage suppressor circuits are provided across exciter and generator field circuits to provide a ground path for AC currents. This prevents the ripple component of the field rectifier output voltage from inducing voltage in the rotor shaft. Shaft voltage tends to cause current flow across bearings, which could shorten bearing life.

Generator and exciter field ground detector relay panels are provided. These are described by separate instructions GEK-36424.

WARNING

WHEN REPLACING GENERATOR OR EXCITER SLIP RING BRUSHES, DISCONNECT GROUND (TERMINAL 1TB-C) FROM FIELD GROUND DETECTOR RELAY PANEL AND DISCONNECT GROUND FROM SHAFT VOLTAGE SUPPRESSION CIRCUIT.

Transducers may be provided to transmit an isolated low power level signal to indicate generator field current and voltage.

Control switches and a transfer voltmeter may be provided for mounting on the user's control board.

MAINTENANCE

This excitation system is static, having no moving parts except for relays and instruments, so little maintenance should be required. All cubicles should be cleaned regularly with a vacuum cleaner.

CAUTION

DO NOT USE A METAL NOZZLE ON THE VACUUM CLEANER. A METAL NOZZLE CAN CAUSE COMPONENT DAMAGE. USE A RUBBER NOZZLE.

If excessive vibration is present, then all screw connections should be checked periodically. Space heaters should be used to prevent an accumulation of moisture.

In some high ambient temperature applications, some cubicles may be equipped with ventilation fans. In unusually dusty conditions, ventilation filters may be used. If ventilation filters are supplied, they should be periodically cleaned by washing in warm, not hot, sudsy water.

All thyristors should be checked weekly. All neon lights on each thyristor bridge must be lit. A neon light out indicates a faulty thyristor, blown fuse or faulty lamp. The thyristors used in the bridges are of the silicon controlled rectifier type and are not known to age. Therefore, they are either good or faulty and if faulty they should be removed. Thyristors normally fail by short circuit and will have a very low and approximately equal forward and reverse resistance. No exact values can be given as different ohmmeters use different battery voltages and will, therefore, give different readings. The best way to obtain a calibration of what the forward and reverse resistance should be for a given meter is to actually measure these values on a thyristor known to be good.

When replacing or checking thyristors, no more than one bridge should be disconnected at a time. If a thyristor is to be replaced, care should be taken to insure the replacement is of an identical grade as the removed thyristor.

PROCEDURE FOR INSTALLING SCRs

The procedure for installing replacement clamp-on type SCRs is as follows:

1. Clean the heat sink surface and the rectifier base. Use alcohol, then wipe with a clean cloth.

2. Lightly coat the heat sink surface and the rectifier base with Dow Corning #3 silicon grease.

3. Using approximately eight light strokes, lightly buff the heat sink surface and the rectifier base with a clean fine wire brush.

4. Re-apply a smaller amount of silicon grease to the heat sink and the rectifier.

5. Place SCR on its heat sink. Place clamp on rectifier, insert 5/16" bolts, apply 3 drops of light machine oil (3 in 1 - SAE 20) to threads, and loosely attach clamp. Do not use lockwashers.

6. Attach the pigtail loosely to its terminal. This allows the pigtail to assume its natural lie, which should cause the cell to rotate to its preferred position. The cell, thus aligned, should be free from undue stress, pigtail distortion and header distortion.

7. Tighten the clamping bolts finger tight. Do not cock the clamp on the cell. Then, using a torque wrench, tighten each bolt alternately, one-half turn at a time.

8. Tighten each bolt to 35^{+0}_{-1} inch-pounds of torque. Do not exceed 35 inch-pounds.

9. Do not pull the clamp past flat.

If the generator thyristor bridges are to be out of service with the ambient temperature below freezing, the cooling water should be drained from the heat sinks and piping. A drain plug is provided in the lowest point in each bridge cooling water circuit. Care should be taken to replace drain plugs and restore water flow before the thyristor bridges are again energized.

The field breaker trip circuit indicating light should be checked weekly to indicate integrity of trip coil. Field ground detecting relays should be tested weekly. Alarm circuit relays, such as bridge overtemperature, have test pushbuttons to test relay pick-up and remote alarm and should be tested weekly.

The generator should be transferred to DC (manual) regulator periodically, to check circuit operation. This transfer should be smooth and control on MANUAL operation should be smooth. The transfer back to AC (Auto) regulator should also be smooth.

The U.R.A.L. output meter (B1VM) should be checked weekly. It should normally read slightly negative. User may choose to operate generator in the under-excited region periodically to check U.R.A.L. operation.

Magnetically operated contact-making devices should be inspected regularly in accordance with applicable instructions. Brushes in motors (for all motor-driven adjustments), all open rheostats, potentiometers and variable transformers should be inspected every six months under normal operating conditions. Where unusually dusty or other abnormal atmospheric conditions exist, they should be inspected every six weeks. If arcing occurs or if the brushes are badly worn, they should be replaced.

For planned outages, the following maintenance should be performed:

1. General cleaning--blower or vacuum cleaner.

2. Check all brushes, motors, and rheostats.

3. Inspect all relays--operation and contacts.

4. Check for any loose connections on large wire, bus, and large thyristors.

5. Check all large thyristors and rectifiers (those requiring heat sinks) and all large fuses with an ohmmeter.

TROUBLESHOOTING

The best aid for troubleshooting is a thorough study of the particular circuit in the "Principles of Operation."

RENEWAL PARTS

When ordering renewal parts, the following information should be given:

1. Catalog number stamped on the part, with complete description including use and location.

2. Complete nameplate data appearing on the assembly that included the component.

3. If possible, data on original order on which equipment was first supplied including all numerical references.

Drive Systems Product Department • General Electric Company,
Waynesboro, Virginia 22980

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GENERAL ELECTRIC

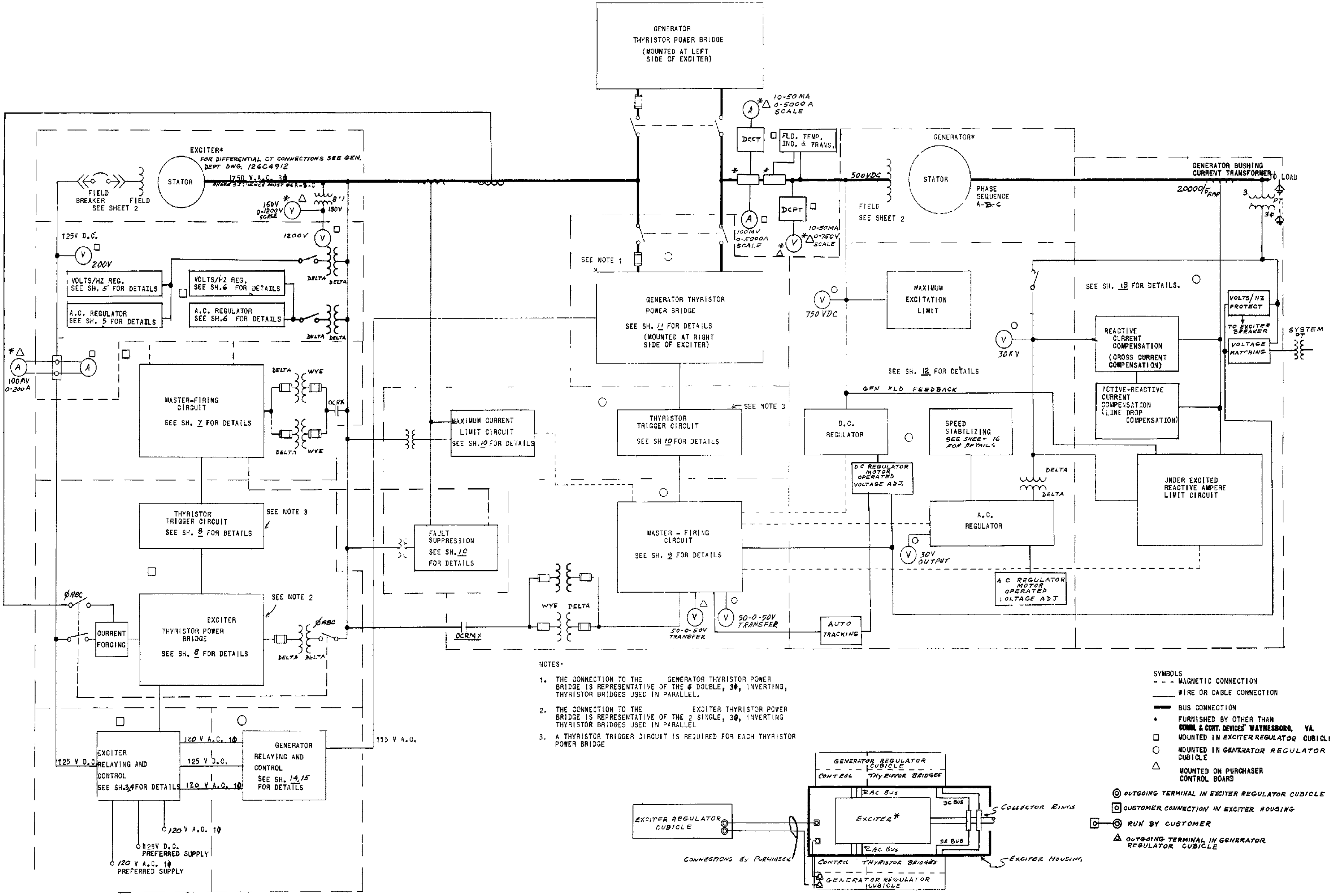


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 1 - Block Diagram

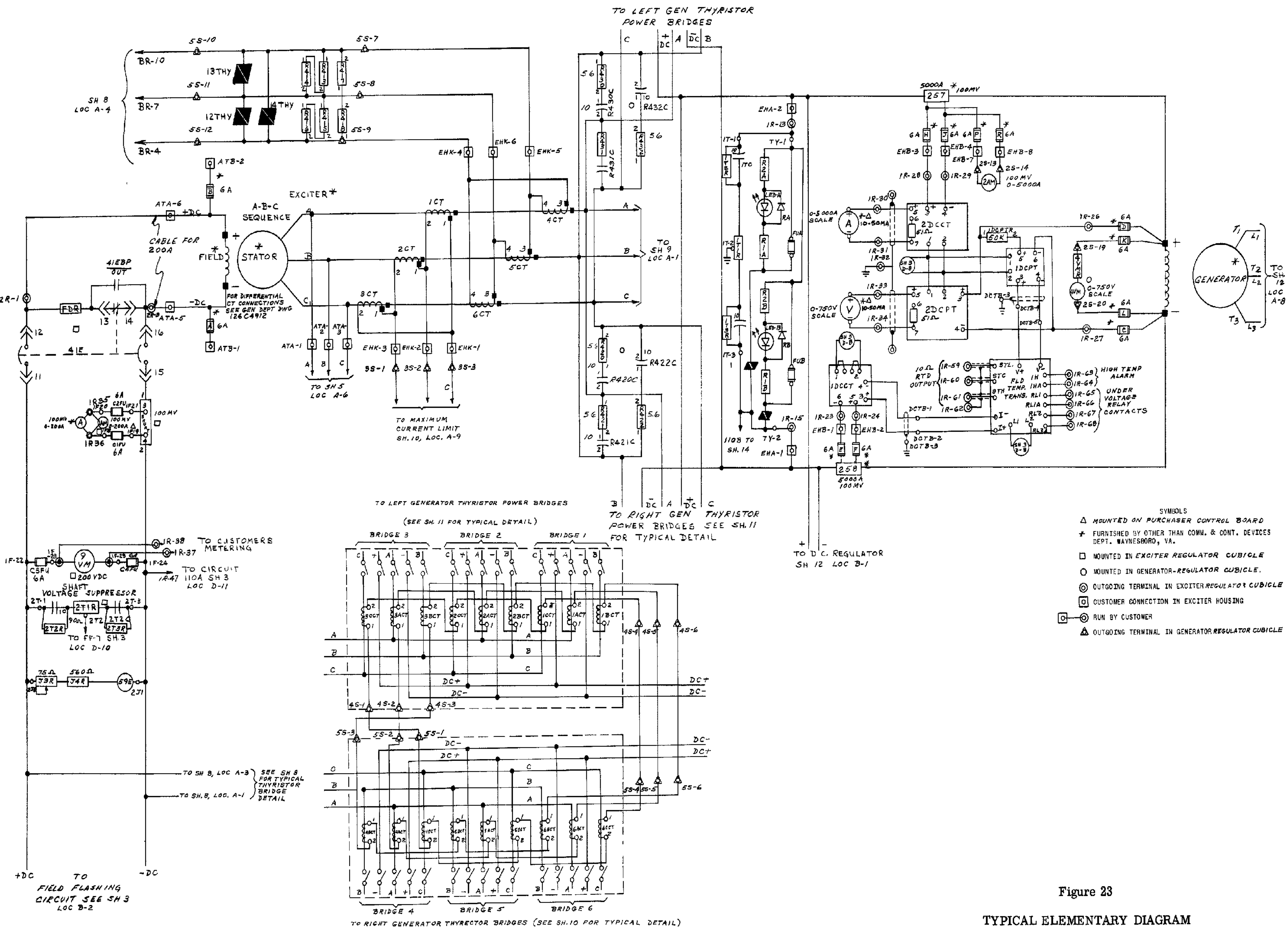


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 2 - Field Connections

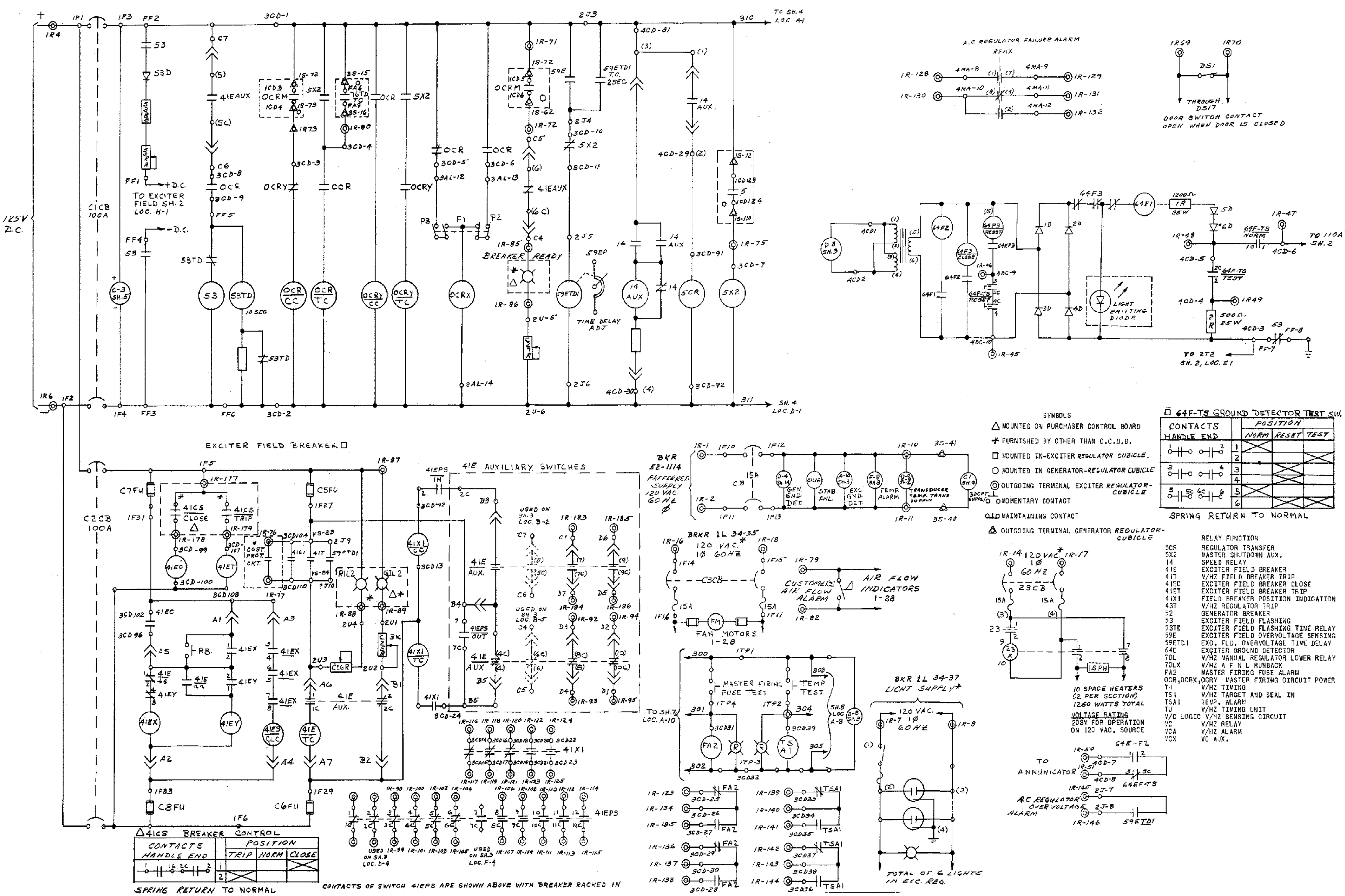
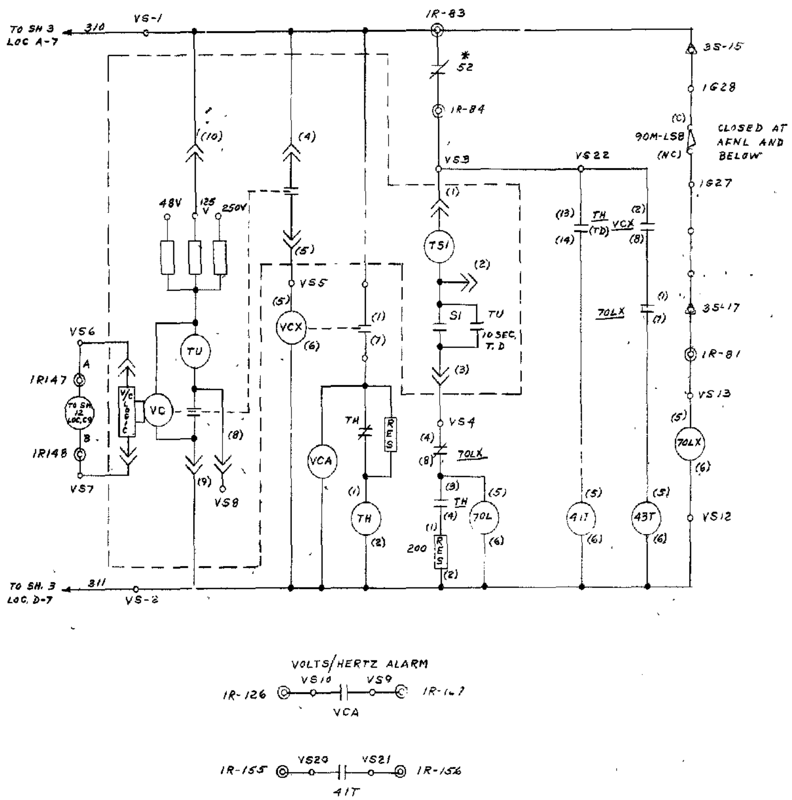


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 3 - Exciter Control



SYMBOLS

△	MOUNTED ON PURCHASER CONTROL BOARD
*	FURNISHED BY OTHER THAN CO.'N. & CONT. DEVICES DEPT. WAYNESBORO, VA.
□	MOUNTED IN EXCITER REGULATOR CUBICLE.
○	MOUNTED IN GENERATOR REGULATOR CUBICLE.
◎	OUTGOING TERMINAL IN EXCITER REGULATOR CUBICLE
⊡	CUSTOMER CONNECTION IN EXCITER HOUSING
⊡—◎	RUN BY CUSTOMER
⚠	OUTGOING TERMINAL IN GENERATOR REGULATOR CUBICLE

	RELAY FUNCTION
5CR	REGULATOR TRANSFER
5X2	MASTER SHUTDOWN AUX.
14	SPEED RELAY
41E	EXCITER FIELD BREAKER
41T	V/HZ FIELD BREAKER TRIP
41EC	EXCITER FIELD BREAKER CLOSE
41ET	EXCITER FIELD BREAKER TRIP
41X1	FIELD BREAKER POSITION INDICATION
43T	V/HZ REGULATOR TRIP
52	GENERATOR BREAKER
53	EXCITER FIELD FLASHING
53TD	EXCITER FIELD FLASHING TIME RELAY
59E	EXCITER FIELD OVERVOLTAGE SENSING
59ETD1	EXC. FLD. OVERVOLTAGE TIME DELAY
64E	EXCITER GROUND DETECTOR
70L	V/HZ MANUAL REGULATOR LOWER RELAY
70LX	V/HZ A F N L RUNBACK
FA2	MASTER FIRING FUSE ALARM
OCR,OCRX,OCRY	MASTER FIRING CIRCUIT POWER
TH	V/HZ TIMING
TS1	V/HZ TARGET AND SEAL IN
TSA1	TEMP. ALARM
TU	V/HZ TIMING UNIT
V/C LOGIC	V/HZ SENSING CIRCUIT
VC	V/HZ RELAY
VCA	V/HZ ALARM
VCX	VC AUX.

Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 4 - Generator Control

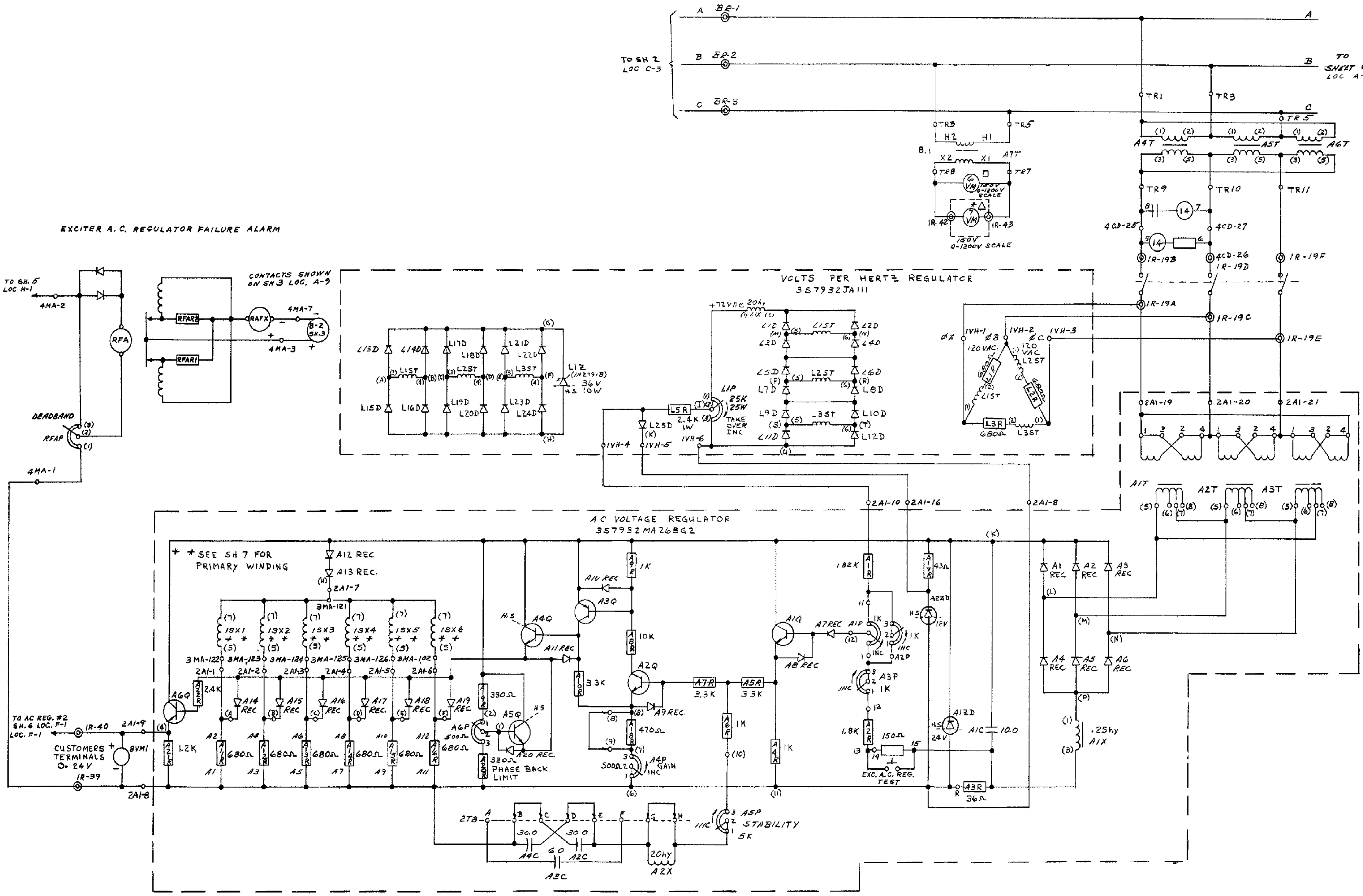


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 5 - Exciter Regulator #1

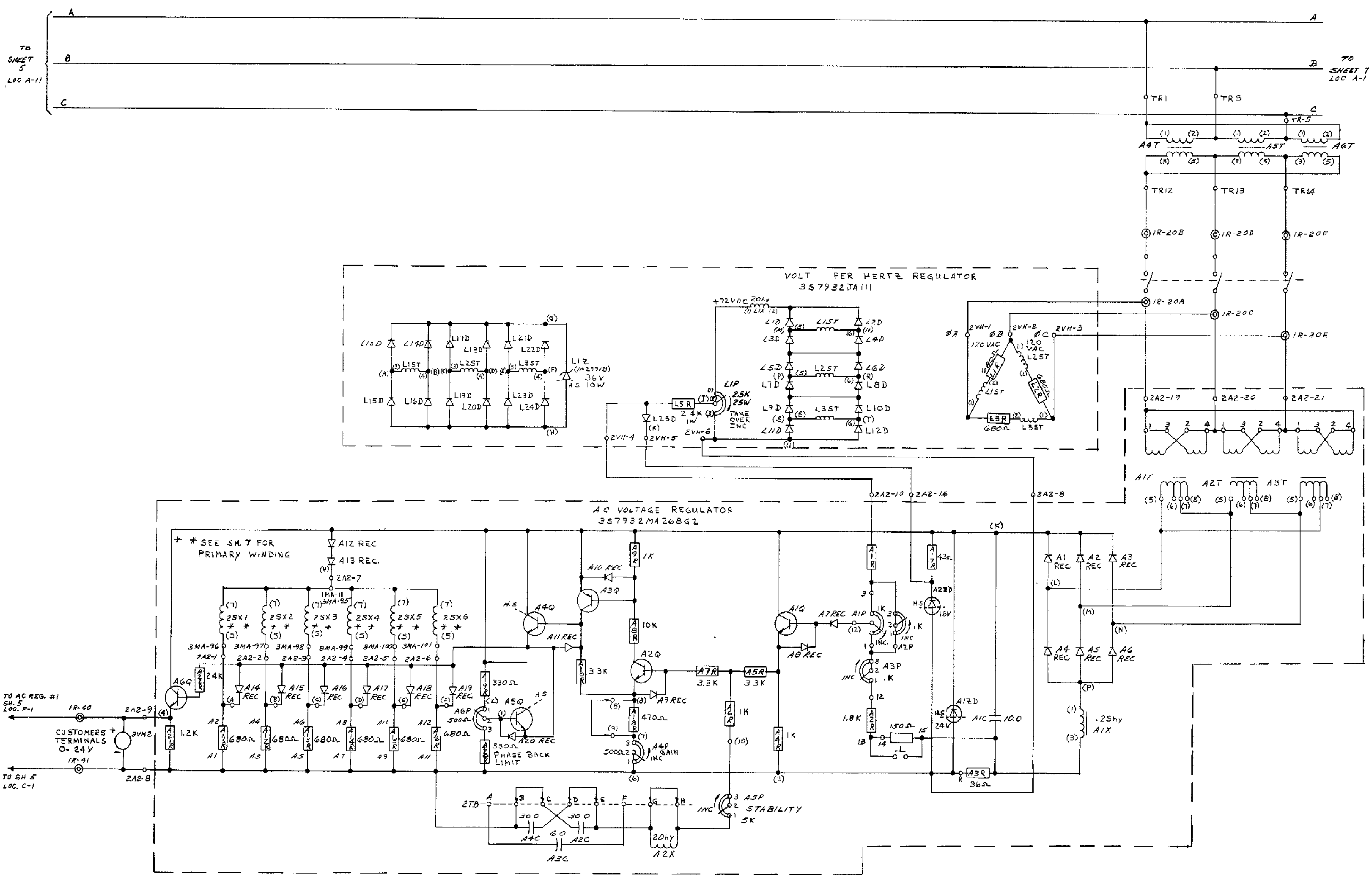


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 6 - Exciter Regulator #2

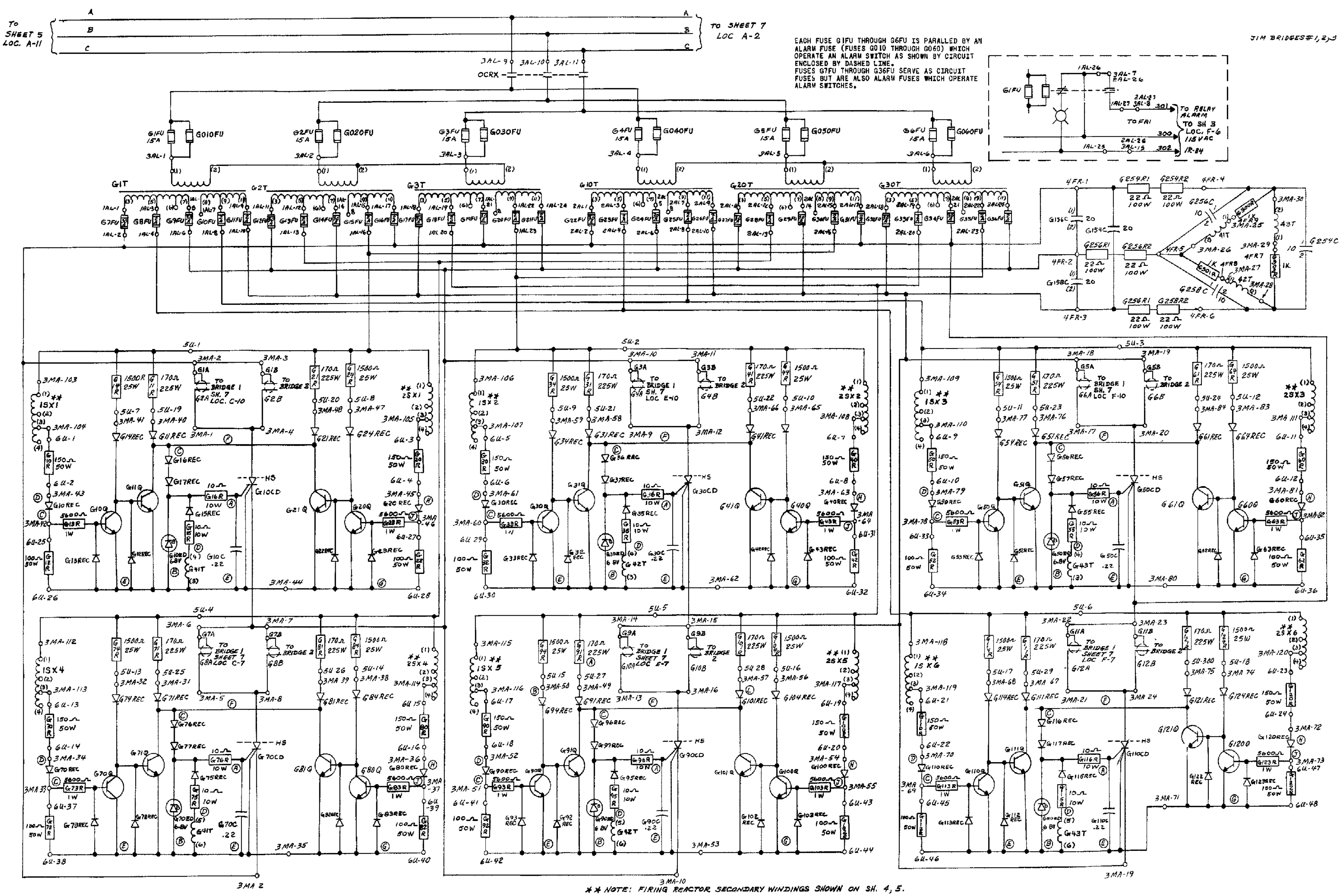


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 7 - Exciter Master Firing

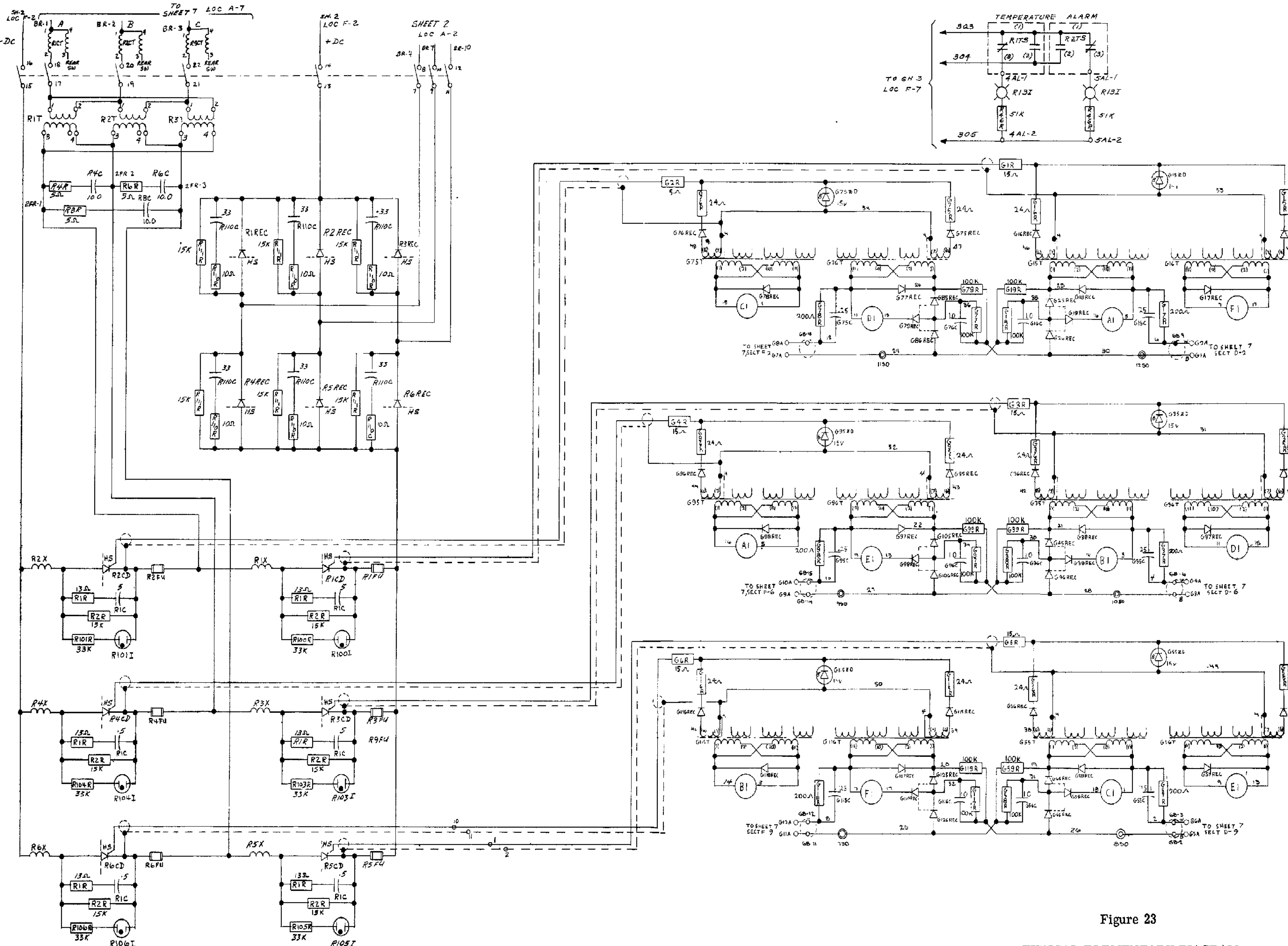


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 8 - Exciter Thyristor Bridge

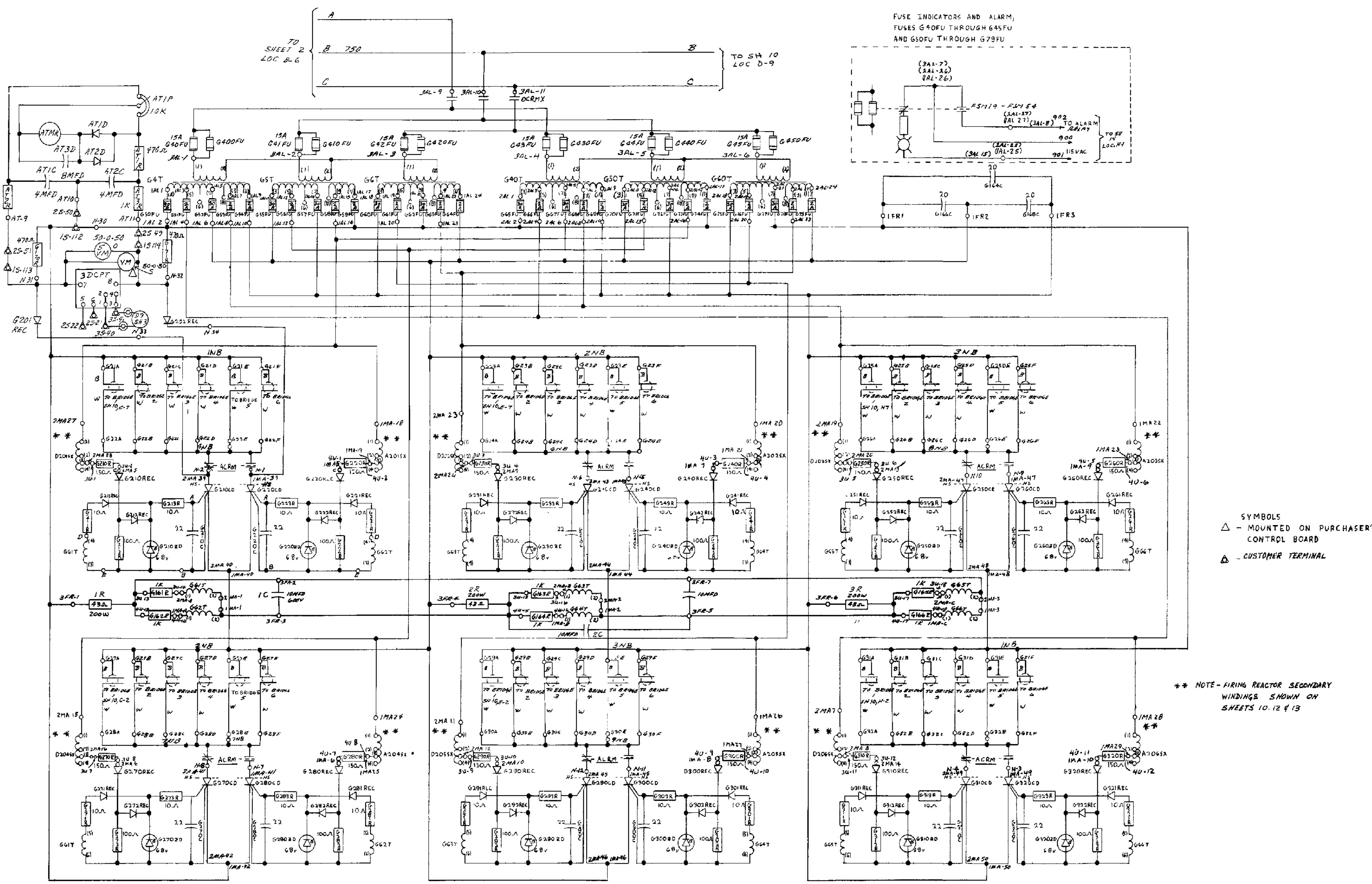


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 9 - Generator Master Firing

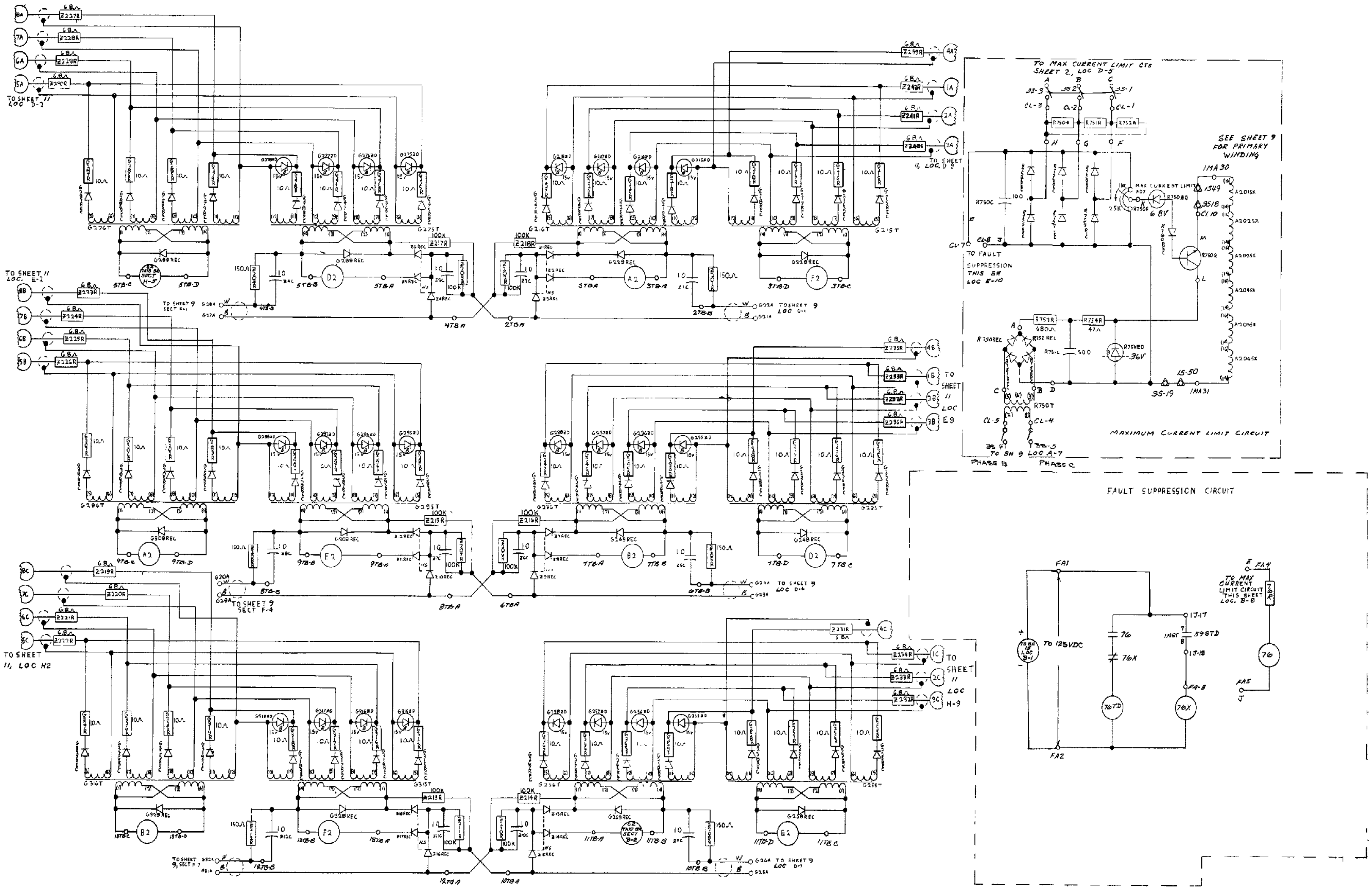


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 10 - Generator Bridge Trigger

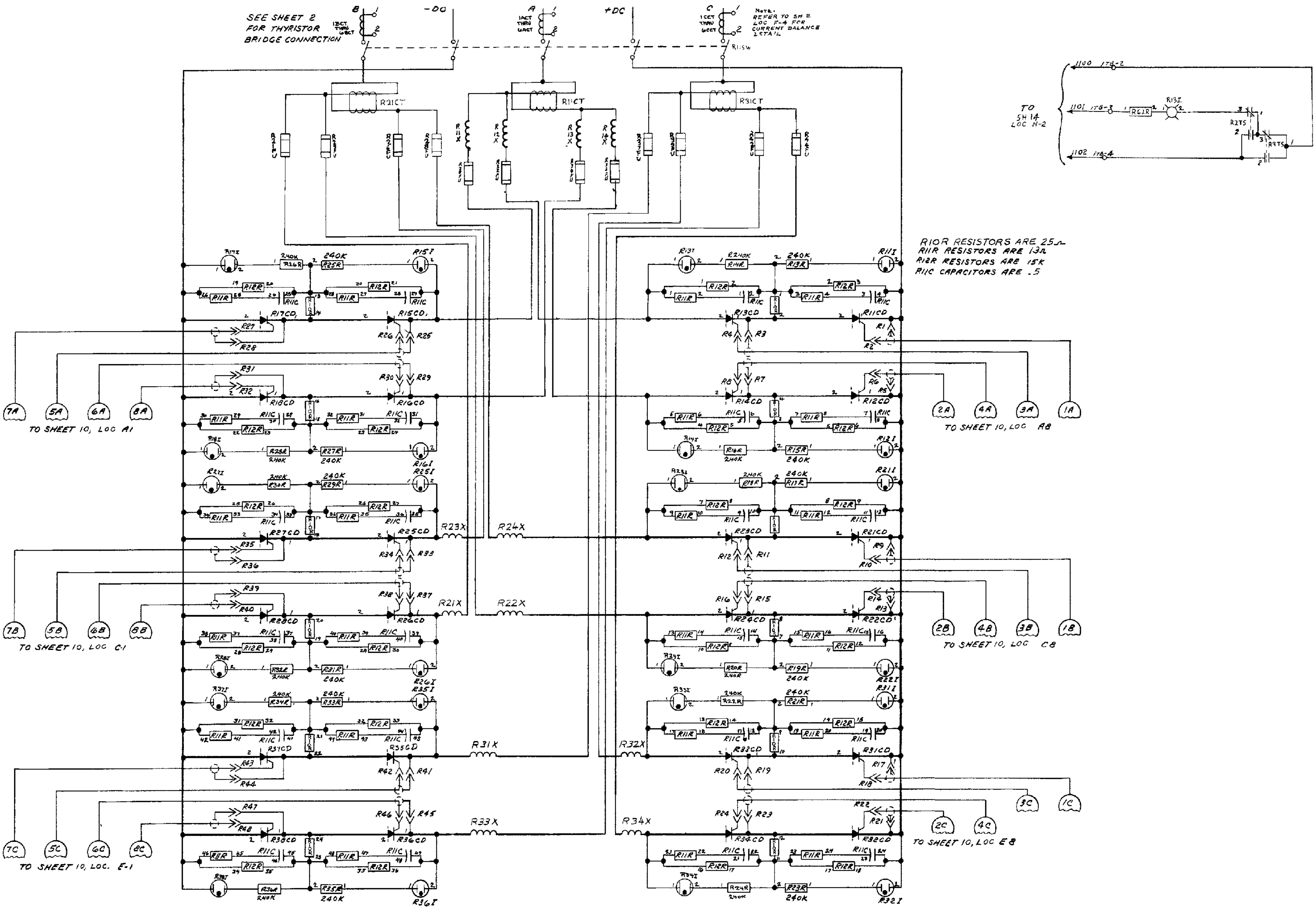


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 11 - Generator Thyristor Bridge

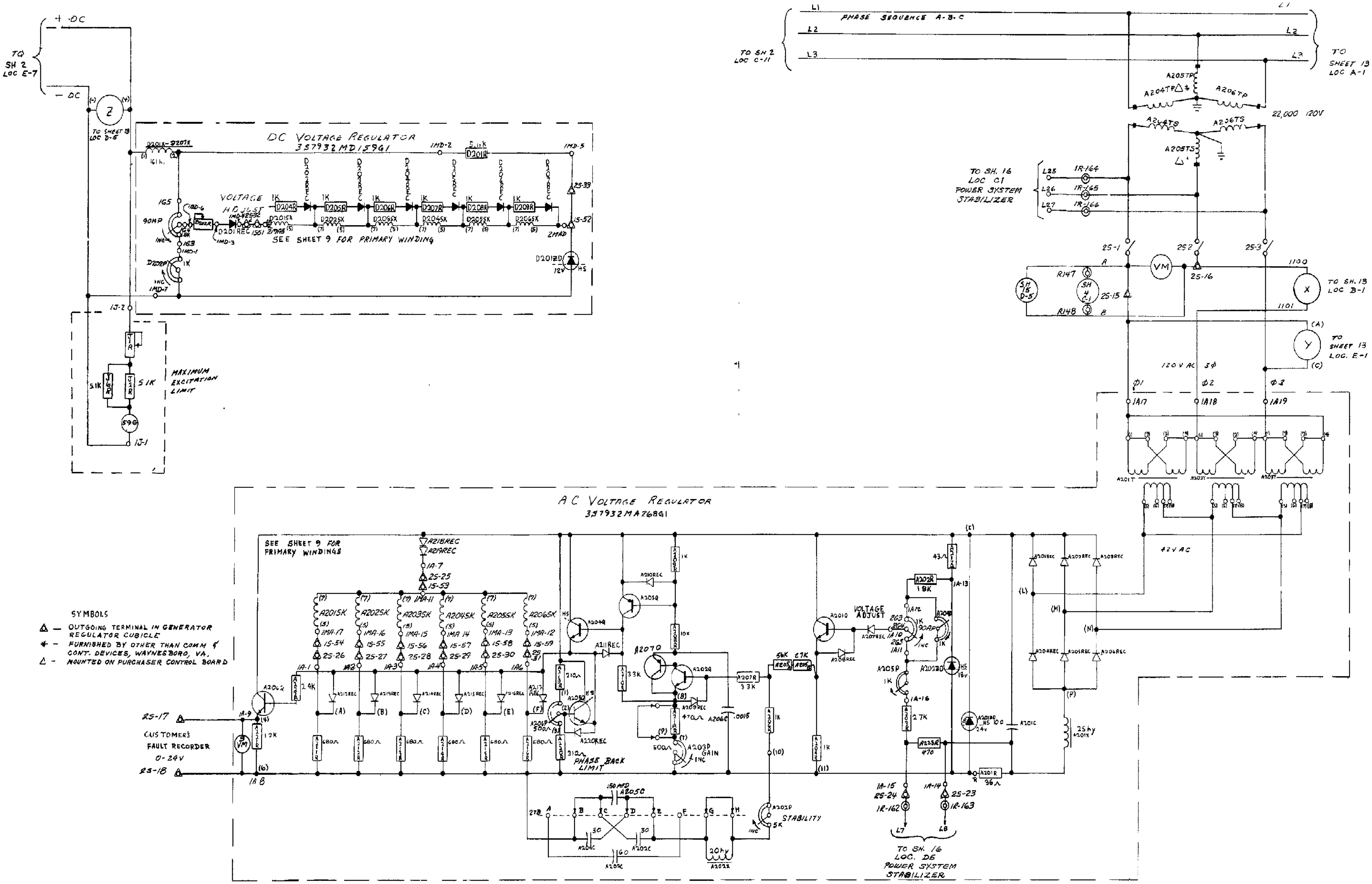


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 12 - Generator Regulator

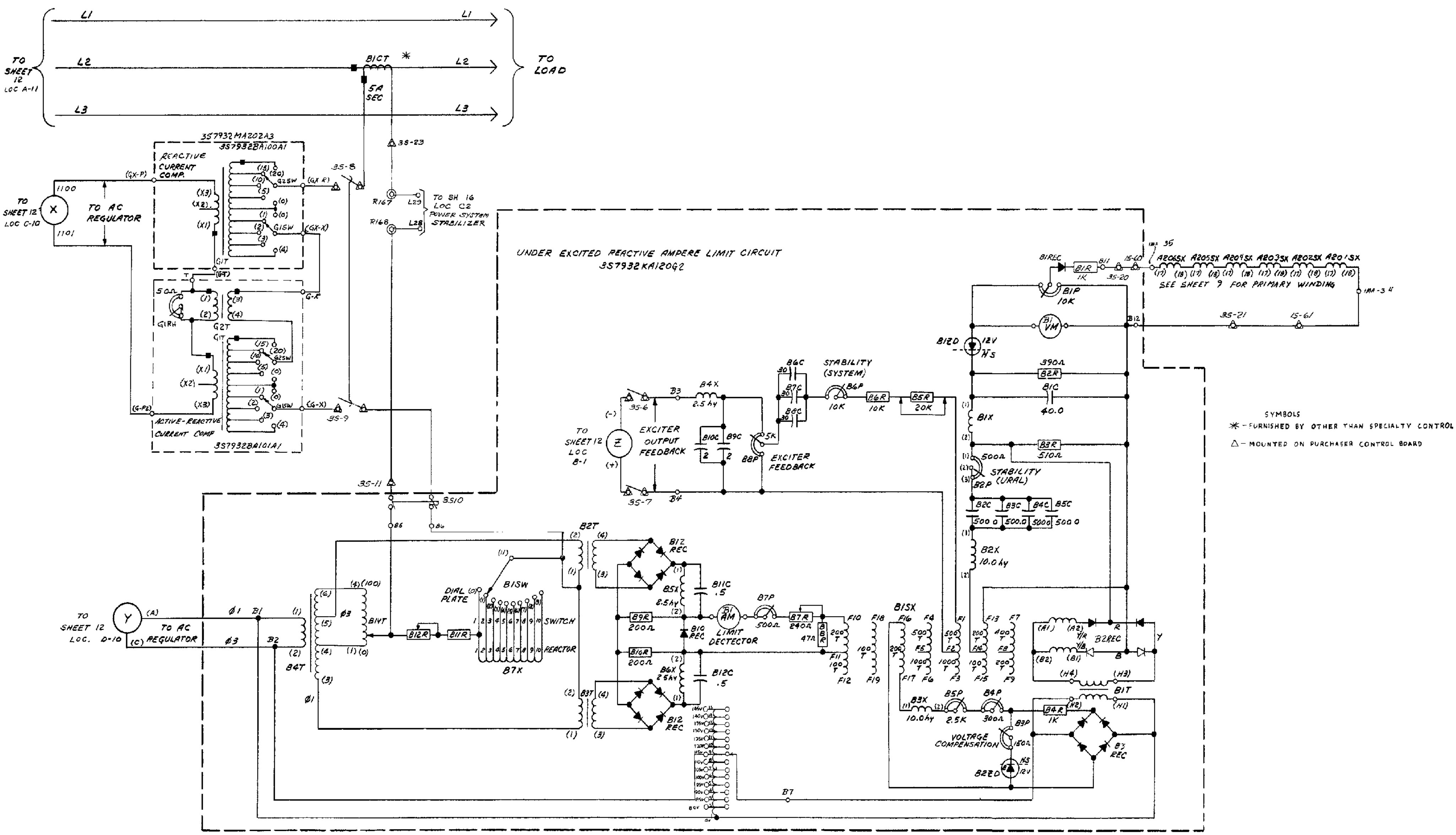


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 13 - U. R. A. L. and Compensation

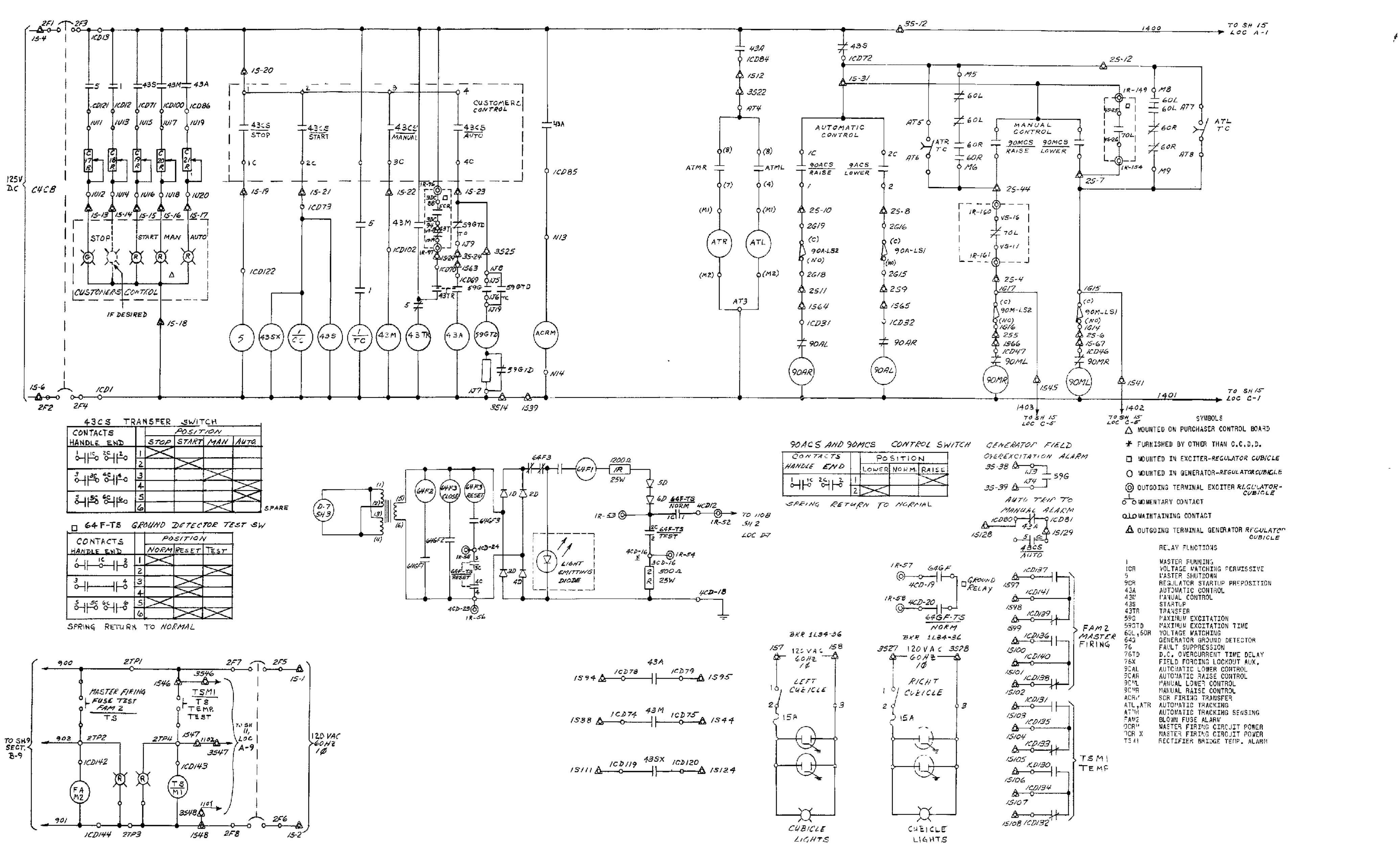


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 14 - Generator Control

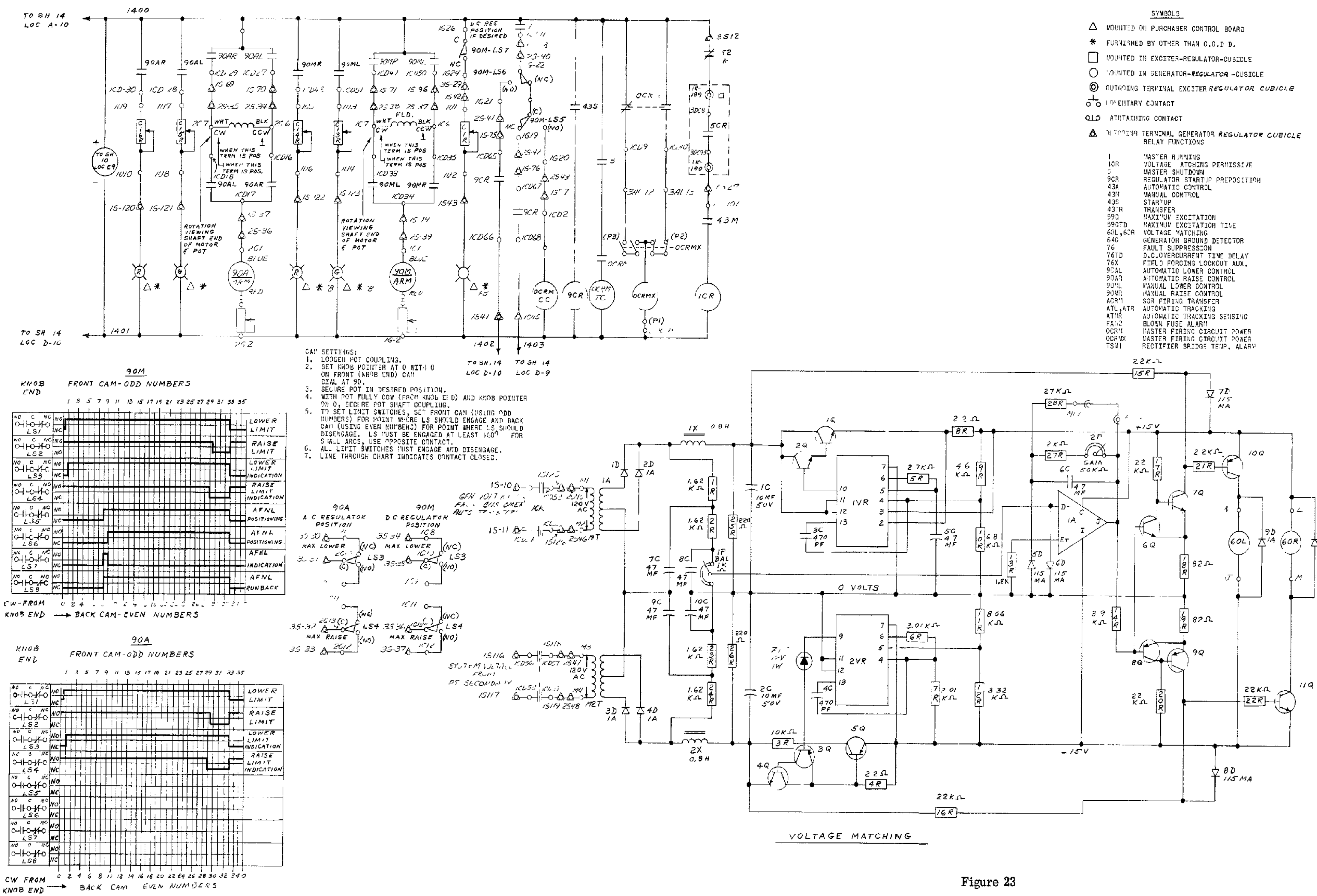


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 15 - Generator Control

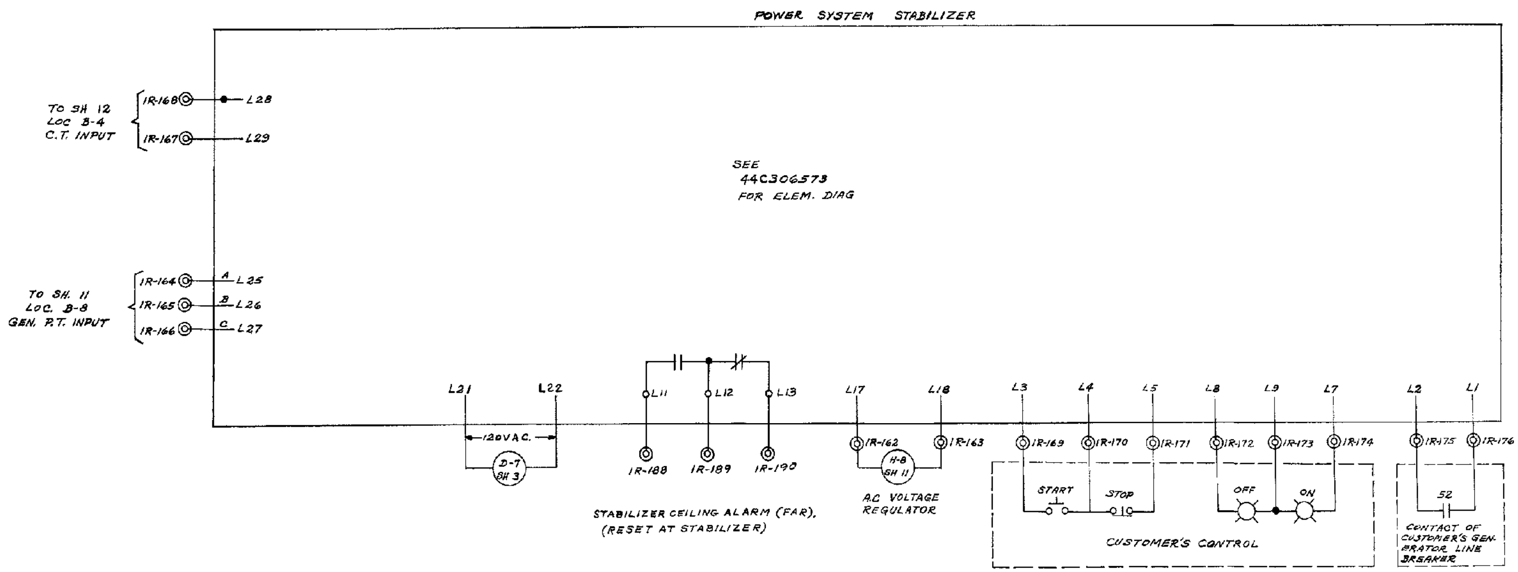


Figure 23

TYPICAL ELEMENTARY DIAGRAM
Sheet 16 - Power System Stabilizer

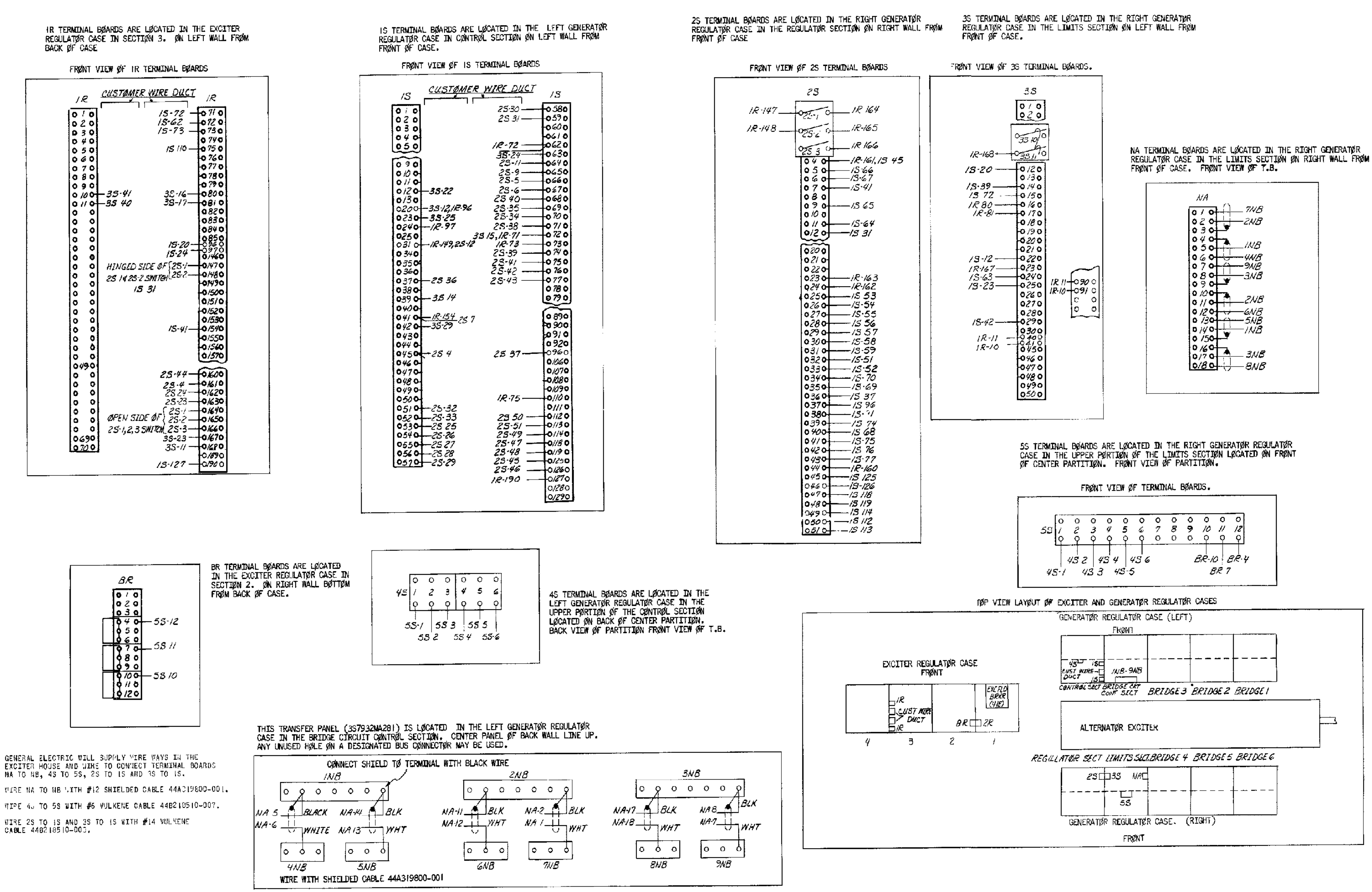


Figure 24

TYPICAL CASE TO CASE CONNECTION DIAGRAM

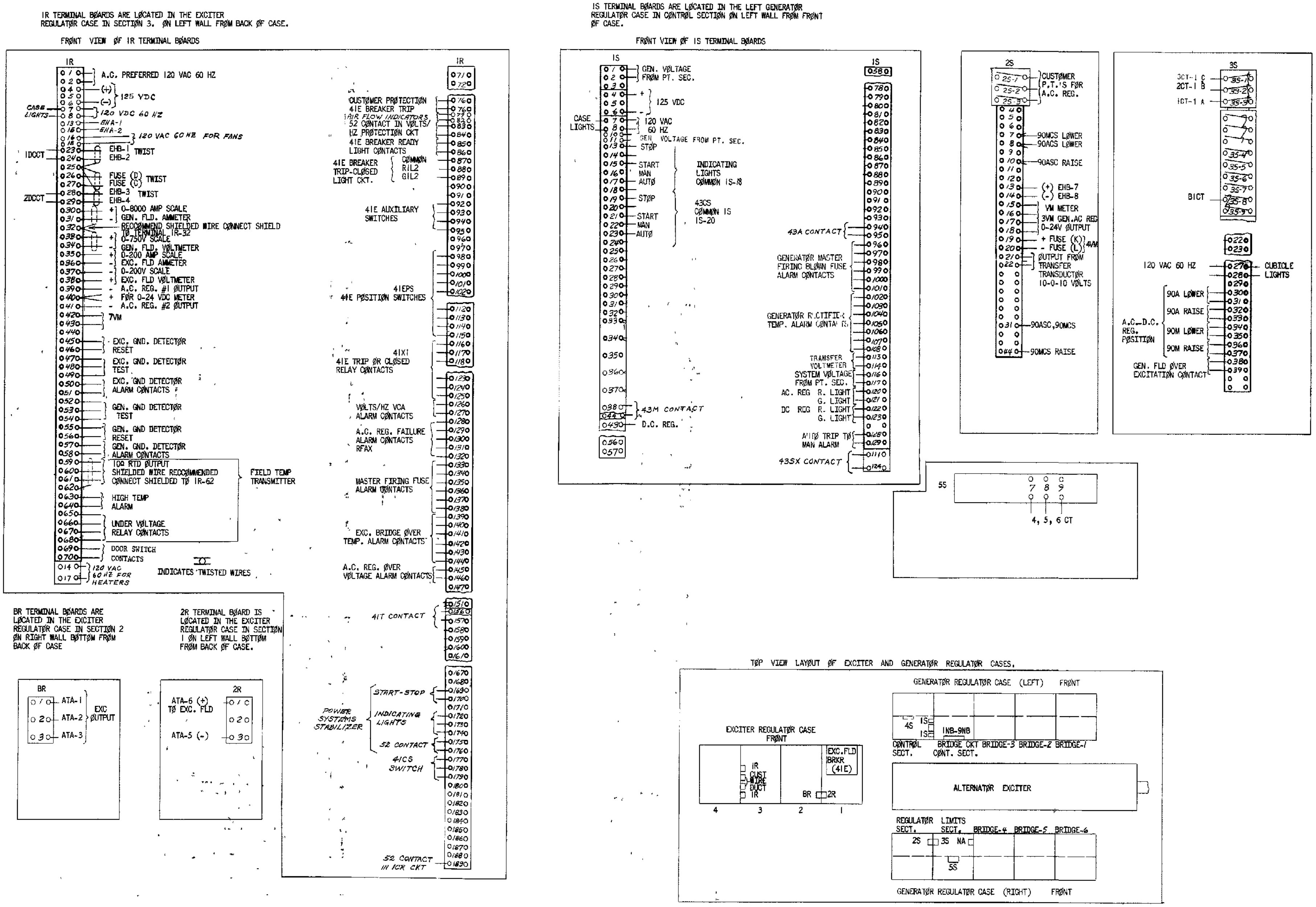


Figure 25

TYPICAL CASE TO CUSTOMER CONNECTION DIAGRAM

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8-73 (600)

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