GEK-14995B

INSTRUCTIONS

GEREG*

voltage regulator

FOR USE WITH SYNCHRONOUS GENERATORS

3S7950GR400, 500, 600, 700, 800 AND 900

GENERAL ELECTRIC

TABLE OF CONTENTS

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company

FULL-WAVE REGULATORS 3S7950GR400, 500, 600, 700, 800 AND 900

INTRODUCTION

The function of the static voltage regulator is to control the AC generator terminal voltage. The excitation to the machine is adjusted by the silicon-controlled rectifiers in the regulator. The operating function of the regulator is completely static with no moving parts or vacuum tubes used to perform the regulating function. A build-up relay is used for start-up.

RECEIVING, HANDLING AND STORAGE

Immediately upon receipt, the regulator should be carefully unpacked to avoid damage. Particular care should be exercised to prevent small parts or documents from being discarded with the packing material.

As soon as the equipment is unpacked, it should be examined for damage that might have occurred during shipment. If damage or rough handling is evident, a damage claim should be filed immediately with the transportation company. The nearest General Electric Sales Office should be notified promptly of the damage.

If the equipment is not 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 taken to avoid storing the equipment in an area where construction work is in progress.

IDENTIFYING REGULATOR FUNCTIONS (Figures 1 and 2)

This instruction book covers all the functions available on regulators having either the standard or provisional base. In order to ascertain whether a regulator has a certain option, refer to the diagrams accompanying the equipment or to Figures 1 and 2 of this instruction book.

The standard base and provisional base can have the following variations:

(1) The power transformer may or may not be chassis mounted.

(2) Three phase sensing uses three magnetic components two transformers and a reactor or single phase sensing uses a single transformer.

(3) If the underfrequency limit circuit is not present, the area indicated on Figure 1 or 2 will be void of components.

(4) The thermal overload relay, if present, will be mounted on the side of the Automatic module as shown. Only the provisional base can have either or both of the following two variations.

(a) Manual control module.

(b) Fault current support module.

INSTALLATION

The regulator should be mounted so that it is accessible. If furnished without enclosure, the regulator should be mounted in a restrained area to protect personnel from exposed voltages and to prevent tampering with the initial adjustments. The mounting location should allow an unrestricted circulation of air to keep the regulator ambient temperature below 55°C (131°F). If the ambient temperature is more than 55°C (131°F), the regulator should be derated per factory instructions.

The panel should be mounted in an upright position as indicated on the outline drawings furnished with the unit. Make connections to the panel according to the *connection diagram furnished with the regulator.* Read <u>all</u> notes on the diagram furnished for possible changes in the application.

CAUTION

THE HEAT SINKS ON THE PANEL ARE ABOVE GROUND POTENTIAL AND ARE ELECTRICALLY HOT.

NEVER ASSUME THE GENERATOR WILL NOT BUILD UP. THE GENERATOR RESIDUAL VOLTAGE MAY BE SUFFICIENT TO INITIATE BUILD UP.

ALWAYS OPEN INPUT TO REGULATOR BEFORE SERVICING.

GROUND ONLY AT THE LUG PROVIDED ON THE BASE.

ADJUSTMENTS (Figures 3 and 4)

<u>INITIAL ADJUSTMENTS</u>

All the following directions, unless otherwise stated, assume there is <u>no load</u> applied to the generator.

<u>Before starting the prime mover:</u>

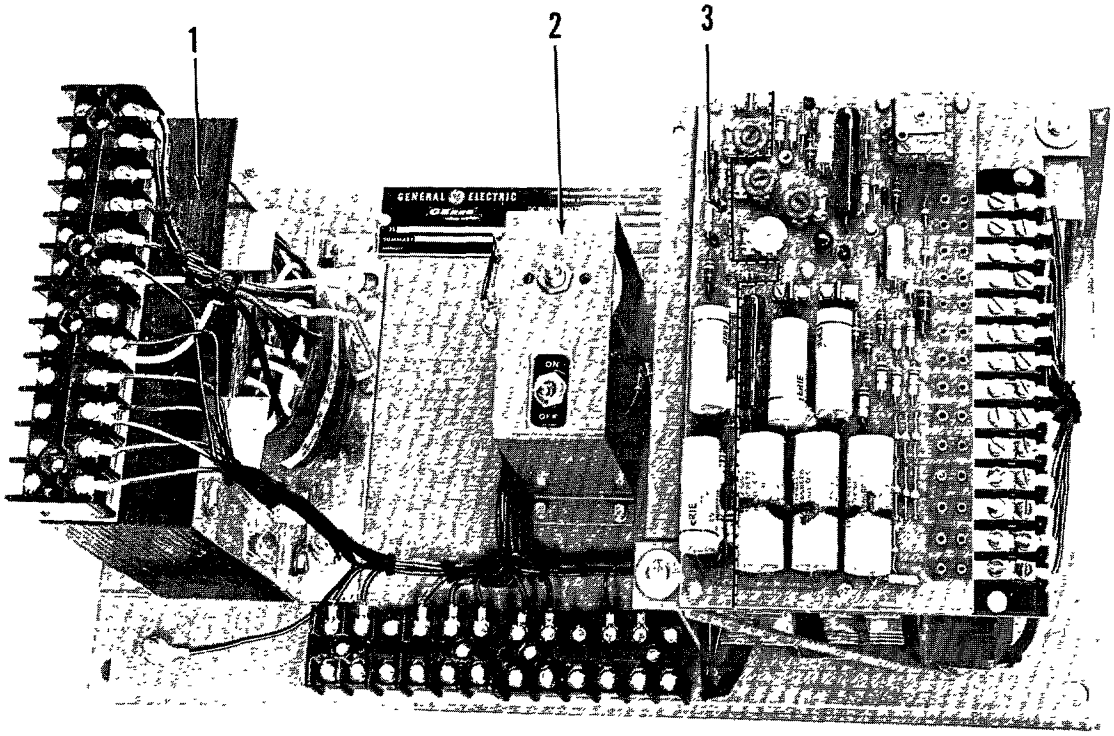
Check all connections to the regulator.

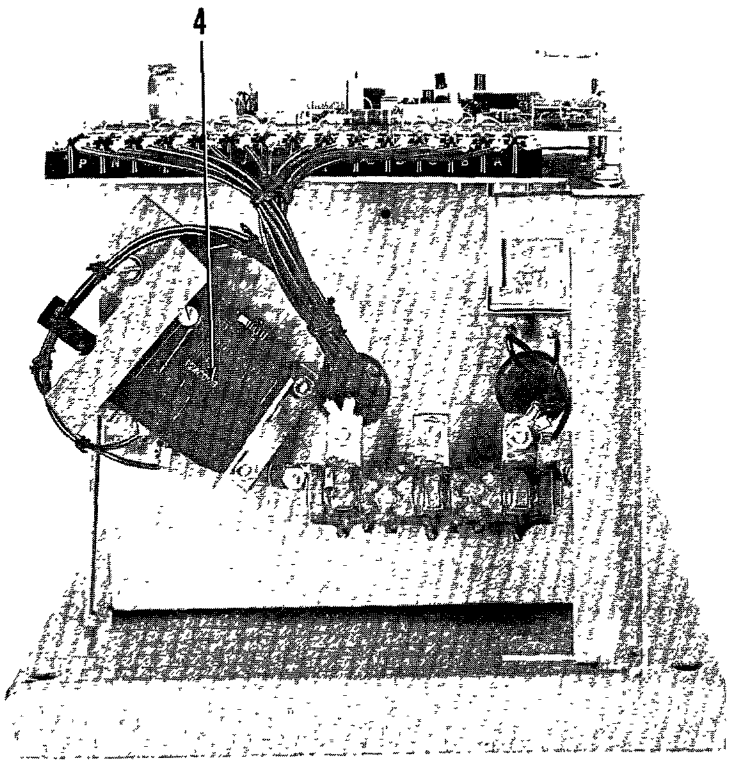
Check the transformers for proper voltage setting.

Turn the ON-OFF switch to the OFF position.

<u>Adjustments on the Automatic Regulator Module</u>

Turn AUTOMATIC VOLTAGE ADJUST rheostat fully counterclockwise.





OPTIONAL FUNCTIONS

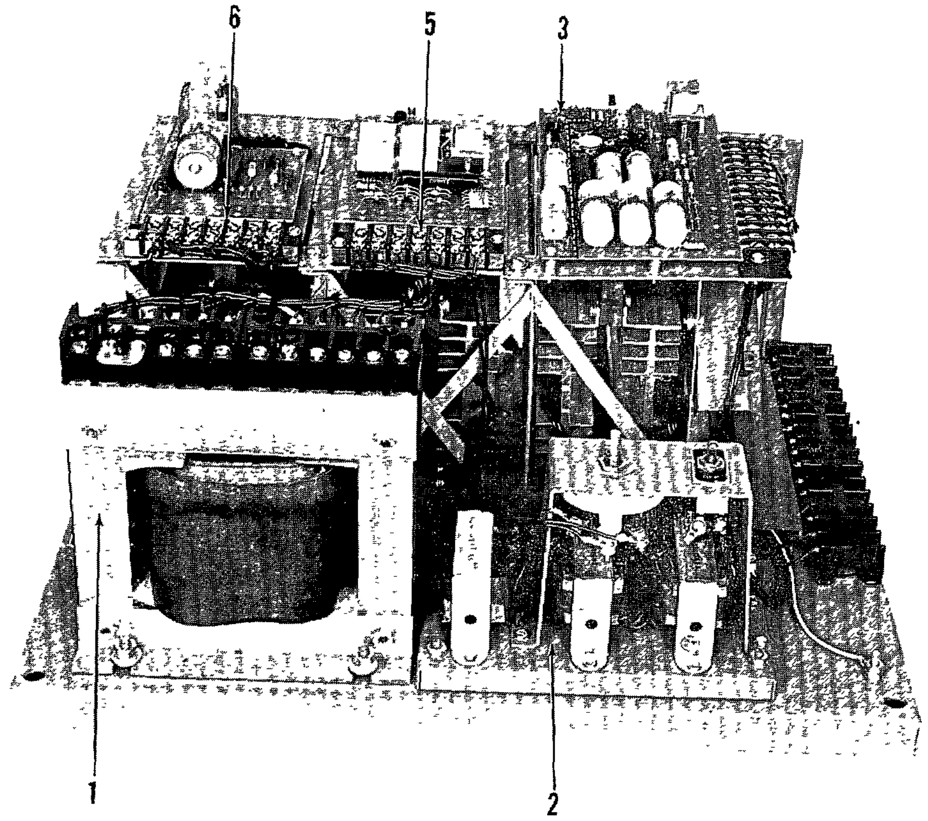
1 Power Transformer

2 1Ø or 3Ø Sensing Panel

3 Underfrequency Limit Circuit

4 Thermal Overload Relay

Figure 1. Standard Base Identifying All Optional Items



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5 Manual Control Module

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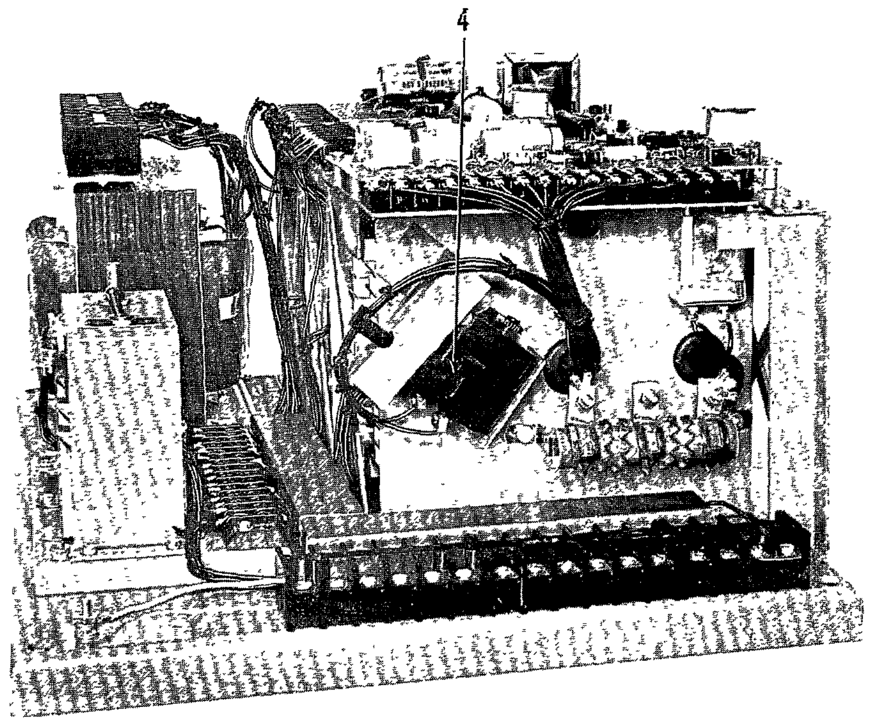


Figure 2. Provisional Base Regulator Identifying All Optional Items

Set the AUTOMATIC/MANUAL switch, if present, in AUTOMATIC position.

Make the following adjustments to the automatic regulator control board (Figure 3):

Set the white FINE STABILITY Rheostat midscale.

Set the blue BIAS ADJUST Rheostat midscale.

Turn the green GAIN Rheostat fully counterclockwise.

Turn the red UNDERFREQUENCY LIMIT ADJUST Rheostat (if present) fully counterclockwise.

Put the COARSE STABILITY jumpers in the maximum stability configuration.

Min. Stab.	Med. Stab.	Max. Stab.	Jumpers J1 & J2 on ICB
x			2 to 3
	x		1 to 2
		x	1 to 2, 3 to 4

Start the prime mover and bring it up to the proper speed.

Turn the ON-OFF switch to the ON position.

The generator should build up. If not, turn the regulator ON-OFF switch to the OFF position and flash the exciter field or generator field, if slip ring type, with a battery source carefully observing the polarities which are positive (+) to line 18 and negative (-) to line 17. Turn the ON- OFF switch to the ON position. If the generator still does not build up, refer to the TROUBLESHOOTING section.

Set the AUTOMATIC VOLTAGE ADJUST Rheostat for proper generator terminal voltage.

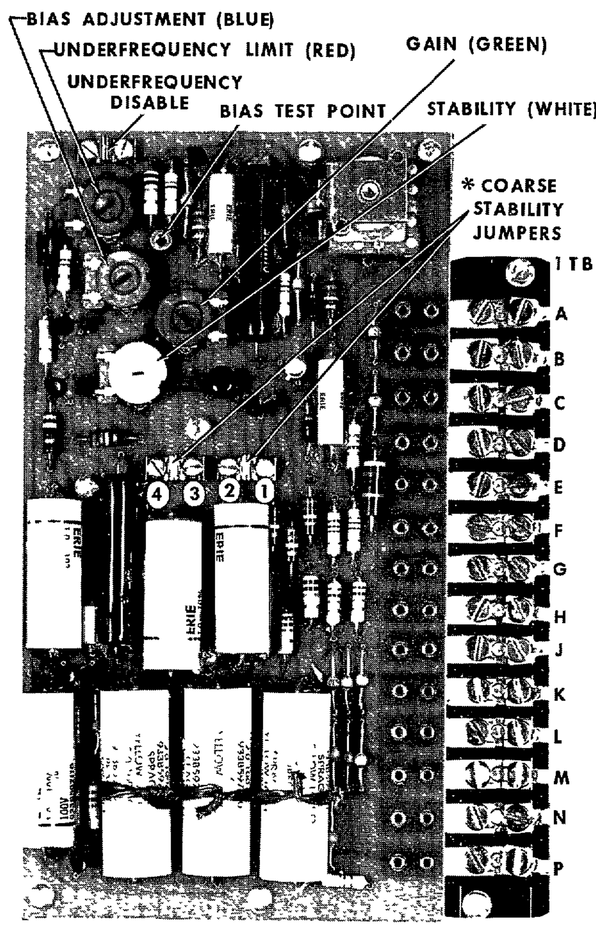
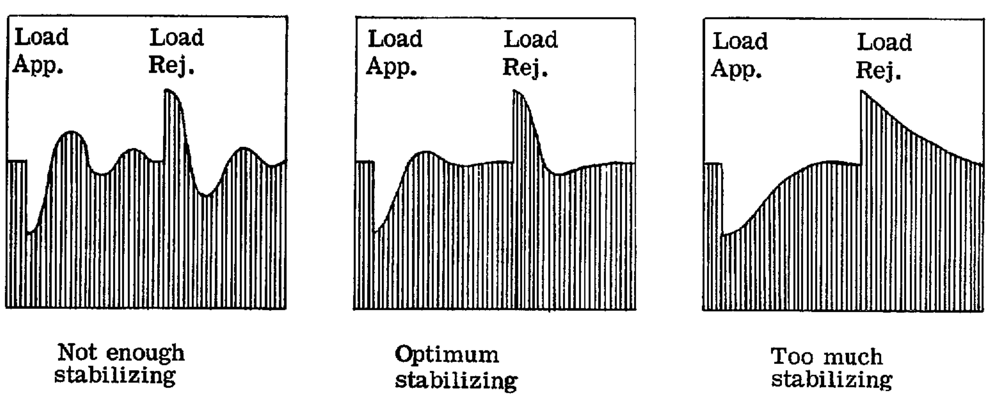


Figure 3. Identification of Test Points and Adjustments on the Automatic Regulator Control Board



Typical oscillograms or recordings looking at amplified portion of generator a-c voltage.

Figure 4. Stabilizing Adjustment

On automatic regulator control board:

Put a DC voltmeter (VOM), 10 volt DC scale or greater, between the BIAS TEST POINT (+) and point 1TB-J (-) on the automatic module control board.

Set the blue BIAS ADJUST Rheostat for 10 volts DC on the meter; then remove the meter.

Set the green GAIN Rheostat about midscale while observing the generator terminal volts for instability. Stop and back off slightly, if instability occurs.

The best method to adjust the stability of the system is to observe the peaks of the generator terminal voltage waveform with an oscilloscope and adjust for the optimum performance as shown in Figure 4. Observing the deflections of the needle of the generator terminal voltmeter is another way. In order to obtain a system disturbance to check stability, apply and reject load or turn the ON-OFF switch quickly OFF then ON and observe system response.

Adjust the white FINE STABILITY Rheostat for optimum response.

Recheck Bias Voltage. Readjust if required.

If the Underfrequency Limit Circuit is present, adjust the red UFL as follows:

1. Preferred Method

Turns the red UNDERFREQUENCY LIMIT Rheostat clockwise slowly until the generator terminal volts drop. Then back off until voltage returns.

Turn the prime mover off or throttle back watching the frequency meter and voltage meter until voltage drop occurs.

Readjust the red UNDERFREQUENCY LIMIT Rheostat until the generator terminal voltage drop occurs approximately 5 Hz under running frequency.

Recheck the BIAS voltage. Readjust, if required.

2. If Frequency Meter is not Avaliable

Turn the red Rheostat clockwise until terminal volts drop.

Turn the red Rheostat counterclockwise until terminal volts return.

When turning counterclockwise, turn in just enough Rheostat to get voltage to return. If Rheostat is set on the edge of holding voltage you will be set for a trip of approximately 5Hz. The further counterclockwise you set the Rheostat the lower the frequency will be before tripping.

If system is over-damped:

Turn the ON-OFF switch to OFF.

Put the COARSE STABILITY jumpers in the next lower stability configuration.

Set the FINE STABILITY midscale.

Turn the ON-OFF switch to ON.

Readjust the white FINE STABILITY Rheostat for optimum response.

Repeat the previous five steps if required.

Increase the GAIN Rheostat until no-load to full load regulation is adequate. If instability occurs, back off until the system is stable. The GAIN adjust affects the generator terminal voltage set point. Readjust the AUTOMATIC VOLTAGE ADJUST Rheostat as required.

The system stability and gain oppose one another. To obtain low no-load to full load regulation, a slower system response may be required.

The paralleling circuitry requires adjustment only if the generator is to operate together with other generators to supply system power.

Check phase rotation of the system or other generator (s) it is to be paralleled with. It must be the same.

If the generator is to parallel with a utility:

Set the DROOP Rheostat fully clockwise and the initial adjustments are complete.

If the generator is to parallel with other generators:

Set the DROOP Rheostat of all units at midpoint.

CONDITION 1: Where there is no system load that has to be sustained during paralleling but a load of sufficient inductance to see the KVAR distribution is available.

Set all generator terminal voltages (at no-load) equal prior to paralleling. Parallel the generator without readjusting the voltage. (Refer to PARALLELING PROCEDURE.)

Apply the load and adjust the KVAR distribution with the DROOP Rheostat only. The DROOP Rheostat from this point on should not be readjusted. When paralleling in the future, the KVAR's should be adjusted with AUTOMATIC VOLTAGE ADJUST.

CONDITION 2: Where the system load cannot be interrupted.

Remove one generator at a time from the system.

Set the off system generator's terminal volts to the rated voltage and do not readjust until all DROOP Rheostats are set.

Parallel the generator with the system without readjusting the generator terminal voltage.

Adjust the KVAR load as required with the DROOP Rheostat.

Remove a different generator from the system and repeat the four previous steps. The DROOP Rheostat from this point on should not be readjusted. When paralleling in the future, the KVAR's should be adjusted with the AUTOMATIC VOLTAGE ADJUST.

Manual Control (optional):

No initial adjustments are required for manual regulation other than determining that the circuit is operational.

Turn the ON-OFF switch to OFF.

Turn the MANUAL VOLTAGE ADJUST Rheostat fully counterclockwise.

Turn the AUTOMATIC/MANUAL selector switch to MANUAL.

Turn the ON-OFF switch to ON.

Adjust the MANUAL VOLTAGE ADJUST Rheostat for the desired generator terminal voltage.

PERIODIC ADJUSTMENTS

Periodic checks would consist of checking the voltage level, voltage regulation, and performance as required for the particular application.

START-UP, PARALLELING, AND SHUT-DOWN PROCEDURES

The regulator is an electronic device designed to control the generator. Its full power capability is limited to a frequency band of 45 Hz to 65 Hz. Even with all the protective and safety devices built into the unit, good operating procedures are the best assurance for long and trouble-free performance.

Start-Up Procedure

The suggested system start-up should be as follows:

See that the voltage regulator is turned off. Start the prime mover and bring the generator up to speed. Turn the regulator on. It does not matter whether it is in the AUTOMATIC or MANUAL mode, but if the proper position for the particular voltage adjust Rheostat is in question, turn it counterclockwise. If necessary; adjust the voltage to the proper value, then apply load.

Paralleling Procedure

When paralleling the regulator in AUTOMATIC with another machine or an AC bus; first, make sure that the phase sequence of the generator and the other source match. (This is done at the initial set up and any time the generator cabling is disconnected.) Second, match the voltage between the generator output and the other power source, and last, match the frequency with the governor controls.

As the two systems slowly move (6 cycle/min) into phase synchronism, close the paralleling breaker. Assuming the droop has been set, adjust the governor controls for proper sharing of real load and the AUTOMATIC VOLTAGE ADJUST Rheostat for reactive distribution. The regulator and governor automatic controls will then handle the system changes.

It is general practice to have about 3% droop in terminal volts from no-load to full load at 0.8 pf. With too little droop, the generator will circulate reactive current. With too much droop, the resulting regulation will become annoying.

The droop circuit holds the generators reactive current in proportion to the DROOP Rheostat setting once the proportion is set by the AUTOMATIC VOLTAGE ADJUST Rheostat.

In order to remove a machine from the parallel operating mode, transfer its real power to the other machine (s) with the governor controls. Transfer the reactive load with the AUTOMATIC VOLTAGE ADJUST Rheostat. Then open the breaker to the main bus.

Shut-Down Procedure

When shutting down the machine, the start-up procedure is reversed. Remove the load, turn the regulator off; then shut down the prime mover.

TROUBLESHOOTING GUIDE

Problems in Automatic Regulator

I. Generator voltage will not build up in the AUTOMATIC mode.

   A. Check connections.

      1. Between the exciter and the generator (if not brushless).

      2. Between the rotating machinery and the regulator panel.

      3. On the power and sensing transformer tap setting.

B. Check generator residual voltage at power input; it should be approximately 5% or more of the nominal primary setting of the regulator power input requirements.

   1. Flash the exciter field (or generator field if slip ring type) observing the polarity on the elementary diagram. Residual voltage may be lost due to long idle time.

   2. May require separate flashing source for dependable buildup if less than 5%.

C. Check the THERMAL OVERLOAD RELAY (optional); if tripped, determine cause.

D. Check the build-up relay (clean contacts if required).

E. Check the main component board.

   1. Remove jumper, J3. If regulator builds up, but not necessarily to nominal voltage; replace Component Board 1CB.

   2. Lift wires to 1TB-G and H; measure voltage from G or H to 1TB-J. It should measure greater than 2 volts DC for 34 volt regulators, and more than 4 volts DC for 67 volt and 117 volt. If not, replace the AUTOMATIC regulator circuit board.

   3. If in the previous step it has adequate voltage, troubleshoot the SCR's and rectifiers for broken leads or open devices.

II. Generator voltage goes to ceiling in AUTOMATIC.

A. Check connections.

   1. Between the rotating machinery and the regulator panel.

   2. On the power and sensing transformer tap setting.

B. Isolate problem to AUTOMATIC CIRCUITRY or FAULT CURRENT SUPPORT circuitry (optional).

   1. Short 5TB-15 to 5TB-16; if generator still goes to ceiling, the problem is not in the FAULT CURRENT SUPPORT circuitry. If it does, refer to "Problems in Fault Current Support Circuitry".

C. Troubleshoot the AUTOMATIC regulator.

   1. Short 1TB-G and 1TB-H to 1TB-J. If the generator still goes to ceiling, change the automatic regulator SCR.

   2. Measure the voltage between 1TB-P and 1TB-J. If greater than 36 volts DC change AUTOMATIC control board.

   3. Turn the AUTOMATIC VOLTAGE ADJUST potentiometer fully counter-clockwise. Measure the voltage 1TB-N and 1TB-P. If greater than 0.5 volts DC, check potentiometer and wiring to it.

   4. Check the single phase sensing panel. Measure the voltage between 1TB-L and 1TB-M. If it is greater than 57 volts, AC, replace the automatic regulator circuit board.

   5. If in the previous step the voltage is less than 57 volts, check the wiring and transformers on the sensing panel.

   6. Check the three phase sensing panel. Measure voltage between 1TB-K and 1TB-L; 1TB-L and 1TB-M; and 1TB-K and 1TB-M. If they are equal and if they exceed 38 volts, change the automatic regulator circuit board.

   7. If in the previous step they are unequal or do not exceed 38 volts AC, check the connections to the main terminal board.

III. Poor voltage regualtion.

A. Loss of system gain.

   1. Adjust the green Gain Rheostat per "Initial Adjustments".

   2. Check the rotating rectifiers if it is a brushless generator.

   3. Check to see if the Droop is in effect. (Regulation should be checked with this circuit shorted out.)

   4. Change the AUTOMATIC REGULATOR CONTROL board.

B. Distorted input to sensing circuit.

   1. Unbalanced load on generator.

   2. Generator wave shape distorted.

IV. System unstable - Excess system transient gain.

A. Repeat "Initial Adjustments".

B. Exciter field resistance too low; add resistance if necessary.

C. Raise the "Coarse Stability" adjustment.

V. Slow system response - Low transient system gain.

A. Repeat "Initial Adjustments".

B. Refer to III, part A.

VI. Paralleled generators will not divide reactive current.

A. Increase the DROOP adjustment.

B. Check the polarity of the droop CT with respect to the phase rotation of the generator.

C. Check against the elementary diagram for proper polarity and phase rotation.

Problems in manual control (optional):

I. Generator will not build up in manual control.

A. Check the residual voltage; it should be approximately 5% or more of (nominal) power input voltage.

B. Check the MANUAL control build up relay; clean contacts if required.

C. Check to see if MANUAL VOLTAGE ADJUST Rheostat is short circuited.

D. Replace the MANUAL CONTROL circuitboard.

II. Generator voltage goes to ceiling in manual control.

A. The MANUAL VOLTAGE ADJUST Rheostat may be open circuited.

B. Remove the wires on 2TB-E and 2TB-F. If the generator does not go to ceiling, change the MANUAL CONTROL board.

C. If removing the wires does not cure the problem, change the MANUAL CONTROL SCR's.

Problems in FAULT CURRENT SUPPORT circuitry (optional):

I. Generator goes to ceiling.

A. Troubleshoot the FAULT CURRENT SUPPORT circuitry (optional).

B. With the 5TB-15 shorted to 5TB-16, and the nominal voltage set on the generator output, measure 3TB-D to 3TB-E and 3TB-D to 3TB-C; both voltages should be 9 volts AC or greater; if not, check 2T connections.

C. With the regulator in the off position, remove the short from 5TB-15 to 5TB-16 and jumper 3TB-A to 3TB-B with a 100 ohm to 500 ohm resistor. If the generator goes to the ceiling, check the wiring to SCR 5CD for opens. If none are found, replace the SCR.

D. If the generator does not go to the ceiling in the previous steps, replace the FAULT CURRENT SUPPORT circuit board.

II. Sustained short circuit current too low.

A. If the CT is not delivering enough voltage, increase the fault current CT secondary turns.

B. If the CT is not delivering enough current, decrease the fault current CT secondary turns.

C. If the exciter output is too low, check the rotating rectifiers if the exciter is a brushless type or check the brushes if the exciter is a DC type.

III. Sustained short circuit current is too high.

A. If the CT is delivering too much voltage; decrease forcing CT secondary turns.

B. Faults other than 3 phase are not unusual. The unit is designed to support a desired per unit forcing with a 3 phase fault.

IV. System collapses under short circuit.

A. 5CD is failing to commutate off.

1. Short 3TB-B to 3TB-D with load on the generator; the voltage should rise. If it does not, check 5CD.

B. CT secondary current is too low.

1. Decrease the CT secondary turns.

PRINCIPLES OF OPERATION

GENERAL

The voltage regulator is made up of four major circuits. The power circuit with the capability of handling the voltage and current for the exciter field. The control circuit to determine how much excitation to supply. The stabilizing feedback circuit to limit the rate at which the system returns to equilibrium after a disturbance. The sensing circuit which produces a DC voltage proportional to the terminal voltage of the generator.

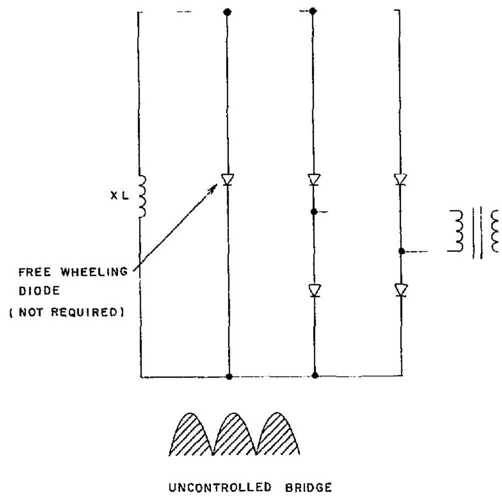


FIG. 5A - WAVEFORM ACROSS XL

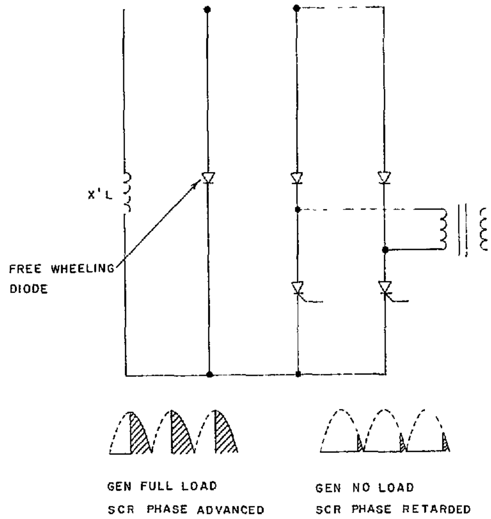


FIG. 5B - WAVEFORMS ACROSS X'L

POWER RECTIFIER CIRCUIT - (Figures 5 and 6)

The power for the exciter field is furnished by a full wave rectifier bridge consisting of power rectifiers and silicon controlled rectifiers (SCRs). If the SCRs were replaced by power diodes, the output would be that of a full-wave bridge (Ref. Figure 5A).

However, when the SCRs are used in the bridge circuit they allow control of the output voltage by delaying the point on the supply voltage cycle at which the leg conducts (Figure 5B). If the SCRs are fired early during the cycle, the average output voltage is higher than if they are fired near the end of the cycle. The later in the cycle the SCRs are fired, a lower average voltage will be applied to the exciter field. By phase-controlling the SCRs, the average DC voltage can be controlled from nearly zero to just slightly less than that of an uncontrolled full-wave bridge.

As the SCR firing angle is retarded, there is no current path provided by the controlled bridge prior to the firing of the SCR (Ref. Figure 5B). Since the exciter field is highly inductive and the current flowing in it is unidirectional and assumed continuous, an auxiliary circuit must be provided to carry this current. The auxiliary circuit is the freewheeling diode.

The power rectifier circuit is designed to operate at a particular voltage level. When the generator terminal voltage does not correspond, a transformer must be provided.

FIRING CONDITIONS

An SCR is a unidirectional current switch which remains non-conductive until a firing pulse of current is passed through its gate to cathode junction. If the anode voltage is positive with respect to the cathode when the pulse is applied, the SCR will conduct and will remain conducting until the anode to cathode current goes to zero or attempts to reverse. By delaying the firing pulse, during the period when the anode is positive, the SCR is phase-controlled.

CONTROL CIRCUIT - (Figures 7 and 16)

The control circuit provides the regulator's reference, gain, and the firing pulses for firing the SCR in the power circuit. At the start of a half cycle, the control circuit is gated on, and the amplifier compares the signal from sensing against the reference. The difference between the signal and reference is summed into a capacitor until the voltage generated reaches the trip point of the unijunction transistor. When the unijunction transistor fires, a pulse is applied to both SCRs. The SCR with the positive voltage on its anode will turn on and the other SCR will absorb the energy of the pulse. The instant the SCR is turned on its anode to cathode voltage will drop to near zero removing the power from the control circuitry until the next half cycle.

The control circuitry is turned on by the current flowing through one of diodes 100D or 101D, depending on which half cycle it is. The voltage will rise rapidly across the pair of reference zeners, 100ZD and 101ZD.

When the zener diodes begin to conduct, the voltage across them becomes relatively constant. The error voltage is the difference between the positive side of zener 100ZD and the base of transistor 102Q. Transistor 102Q is used as an emitter-follower which means there is no voltage gain in this stage. It is used to prevent loading the previous stages. The emitter of transistor 102Q is the input to the amplifier stage, transistor 101Q.

The GAIN ADJUST Rheostat (101P) is in the emitter leg of transistor 101Q. The action of the circuitry is to place the error voltage across Rheostat 101P. The error voltage across Rheostat 101P will produce

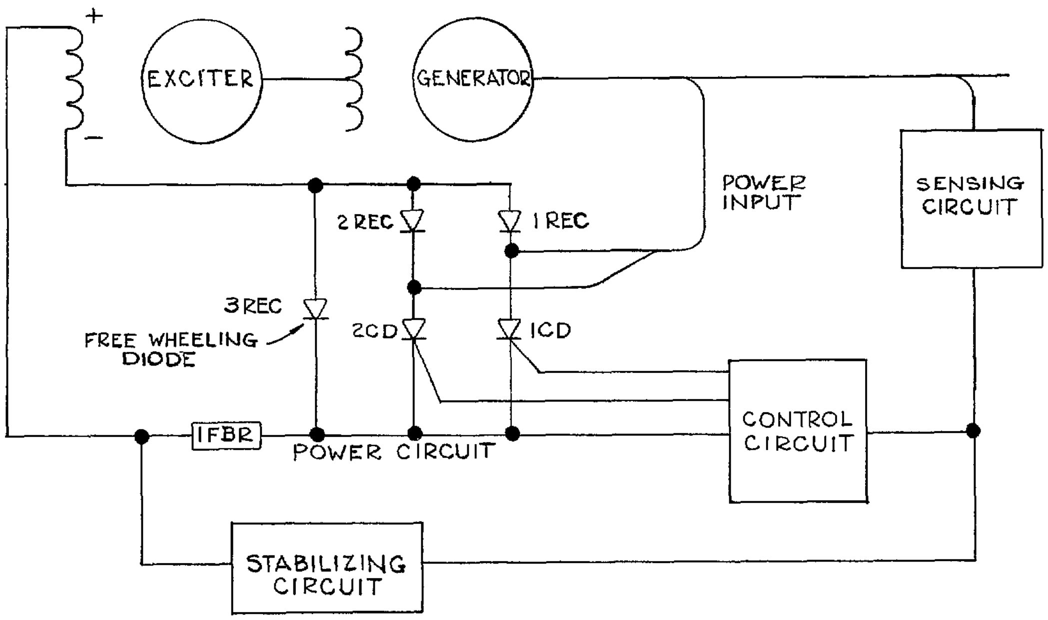


Figure 6. SCR Bridge

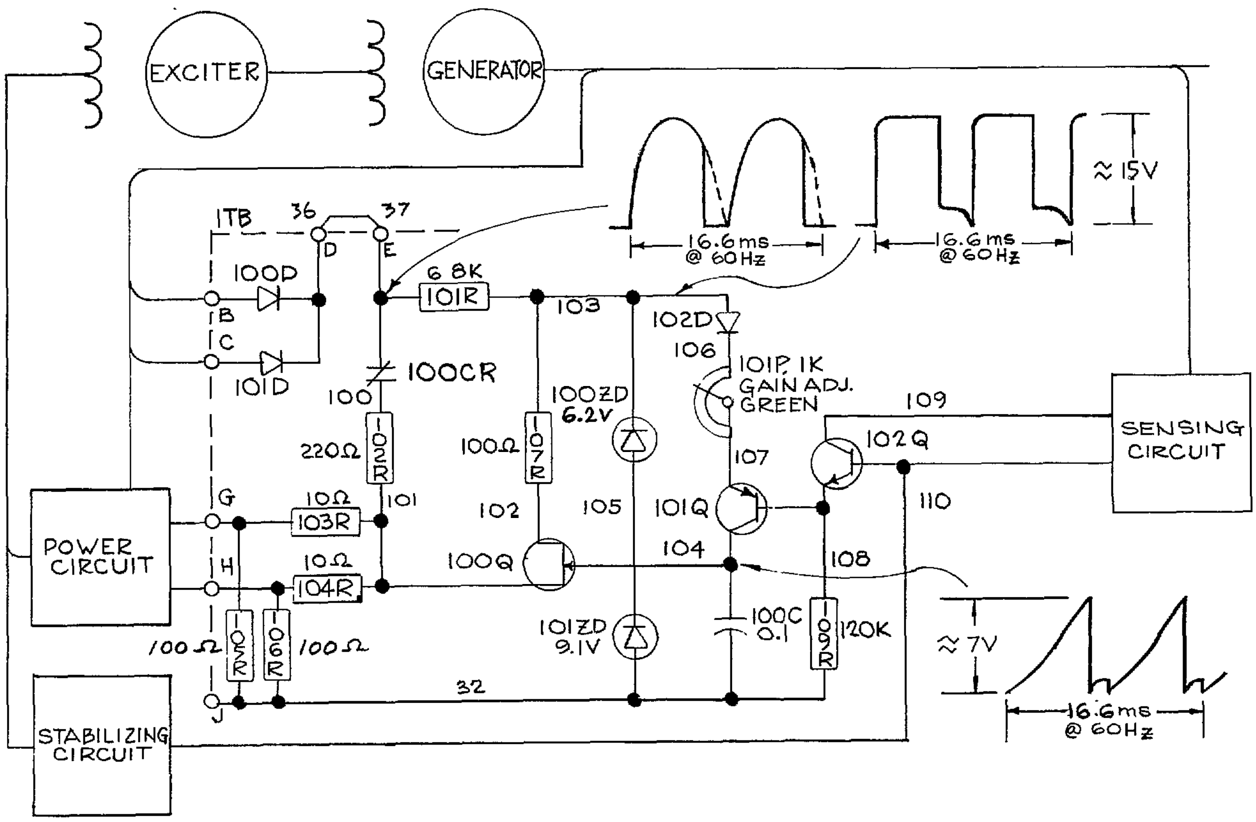


Figure 7. Control Amplifier

a current which will flow through transistor 101Q from emitter to collector. This current flows into capacitor 100C charging it until it reaches the threshold of unijunction transistor 100Q. When the threshold of unijunction transistor 100Q is reached, it will fire. The voltage accumulated across capacitor 100C is discharged into the gates of the SCRs through resistors 103R, 104R. The instant the SCR with the positive anode fires the voltage is removed from the control section.

The action of the normally-closed contact of relay 100CR is to assist the system to build up. Resistor 102R is used to protect the SCRs from excessive gate current.

STABILIZING FEEDBACK CIRCUITRY - (Figures 8 and 15)

In all high gain systems a means must be provided to prevent the system from over-correcting. The method used here is current feedback stabilization.

The exciter field current is sampled by the feedback resistor (FBR). The voltage across this resistor is amplified by transistor 103Q. The bias point, initially adjusted to 10 volts, is set by BIAS ADJUST Rheostat 103P. The amplified output of transistor 103Q is filtered to remove the higher frequency noise present in the field circuit by resistor 116R and capacitor 106C. The output of the filter is then coupled back to the input of the control circuit, through the STABILITY ADJUST Rheostat 102P, and capacitors 104C and 105C. Jumpers (J1 and J2) associated with capacitors 104C and 105C are used in series, singularly, or in parallel to give a coarse adjustment of the stabilizing circuit. In series, the capacitors give the minimum amount of stabilizing feedback, singularly they give the medium amount of stabilizing and in parallel they offer the maximum amount of stability feedback. The STABILITY ADJUST Rheostat 102P, allows a fine adjustment of the stability feedback.

SENSING CIRCUIT - (Figures 9 and 15)

The sensing circuit accomplishes the rectification and filtering necessary to provide a sufficiently smooth DC voltage proportional to the average AC generator terminal voltage. This DC voltage is compared by the control circuitry to its reference and the resultant error signal is used to control the power bridge.

The input voltage, either single-phase or three-phase, is rectified by the diode bridge circuit 104D, 105D, 106D, 107D, 108D, and 109D. The output of the diode bridge is applied across the adjustable divider, the AUTOMATIC VOLTAGE ADJUST Rheostat 100P, resistor 115R, and the coil of relay 100CR. The AUTOMATIC VOLTAGE Rheostat, 100P, allows adjustment of the generator terminal voltage. A percentage of the total voltage which appears between Node 26 and Node 32 is held constant by the voltage regulating action of the automatic circuitry. Therefore, the larger the portion of Rheostat 100P

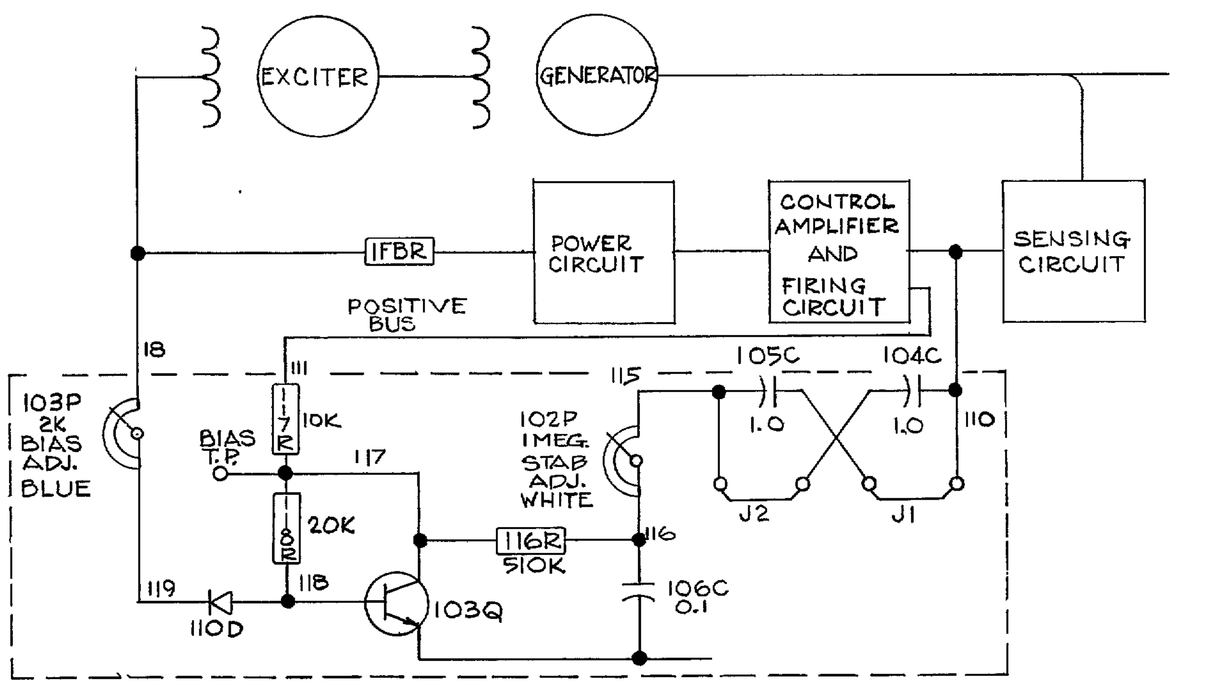


Figure 8. Stabilizing Feedback Circuit

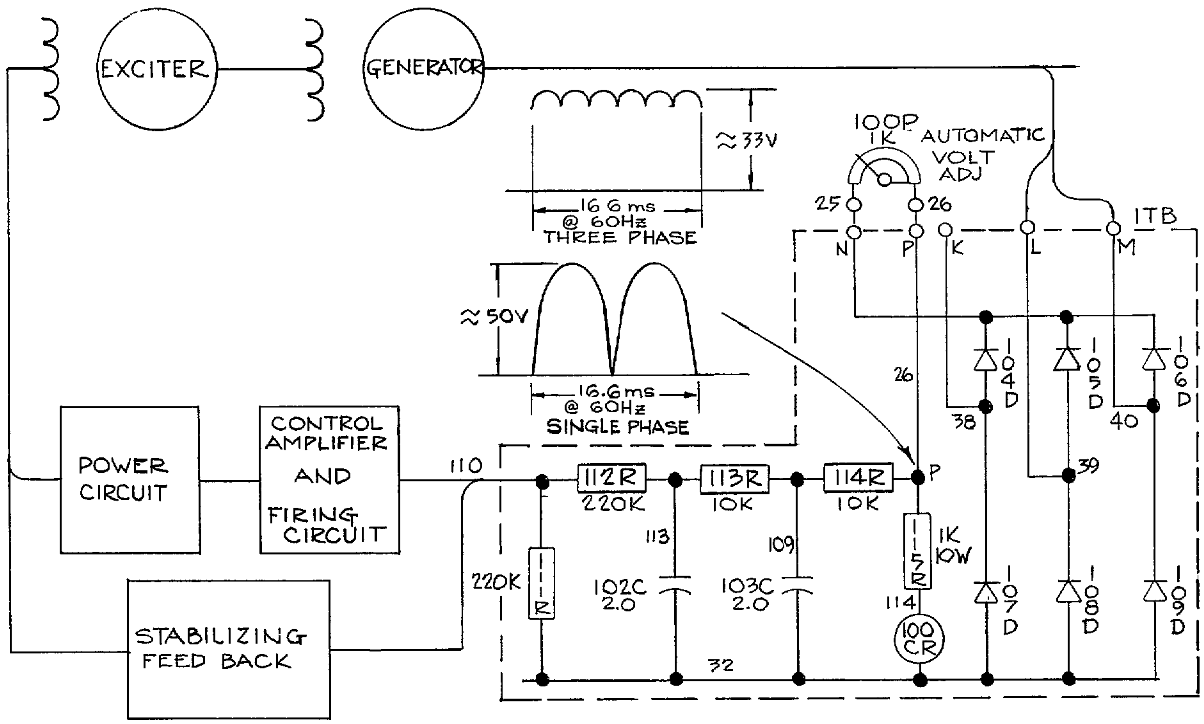


Figure 9. Sensing Circuit

in the divider, the smaller the percentage of the total voltage at junction (P), and the higher the terminal voltage of the generator. The relay coil senses the terminal voltage of the generator. When the generator voltage reaches a sufficiently high level, it picks up, removing the buildup circuit from the power bridge. The filter which is made up of resistors 113R and 114R and capacitors 102C and 103C removes most of the ripple from the rectified input.

PARALLELING CIRCUITRY - (Figure 10)

In order to tie two machines to the same power bus, some provisions must be made to prevent the generators from circulating reactive current. The method used is to cause the generator's terminal voltage to drop proportionally with reactive load. This is called the voltage droop method.

The presence of a lagging or reactive load current develops a voltage across DROOP Rheostat 2P, Fig. 10D, in phase with the terminal voltage so as to make the terminal voltage of the generator appear larger than it really is. The action of the regulator is to reduce this voltage to the proper preset level; thereby, reducing the generator voltage by an amount proportional to the voltage across DROOP Rheostat 2P.

The voltage developed by the real load current across DROOP Rheostat 2P is 90° out of phase with the generator terminal voltage (Figure 10c). As a result it has little effect on the actual magnitude of the sensing voltage.

UNDERFREQUENCY LIMIT CIRCUIT (optional)
(Figures 11 and 15)

One cause of static regulator failure results from the operator's failure to remove the regulator from service during shutdown. If the regulator is not removed from service, it will attempt to hold terminal voltage constant. However, the input sensing transformer (s), SCR's and diodes, although adequately sized for 45/65 Hz, cannot tolerate lower frequencies at full generator terminal voltage for extended periods.

The basic function of the underfrequency protection circuit is to sample the generator output frequency and, to reduce the regulator output sufficiently to prevent damage to the regulator if the frequency drops below the preset level. The underfrequency protection circuit samples the frequency of the generator once each cycle. When this frequency drops below a preset value, the reference to the regulator is shorted out causing the terminal voltage of the generator to drop.

This function can be overridden by removing jumper J3 from the automatic regulator control board.

This circuit operates as follows:

A constant current source is obtained by putting a constant voltage across the series combinations of resistor 123R, Rheostat 104P, and the base to emitter junction of transistor 106Q by zener diode 102ZD. The collector current flowing out of

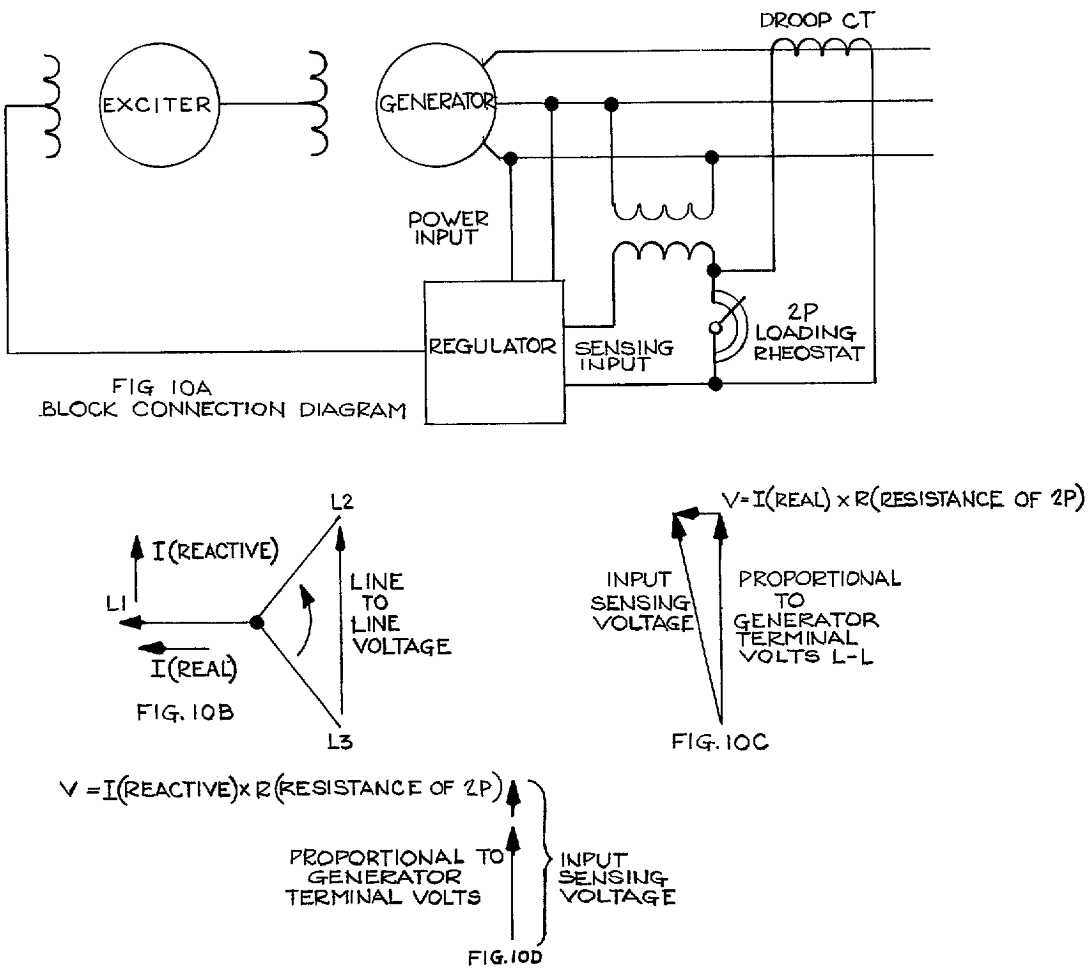


Figure 10. Paralleling Circuit

transistor 106Q is constant for any setting of Rheostat 104P. When diode 108D is forward biased and transistor 107Q is turned off, the current flowing out of transistor 106Q flows into capacitor 108C. The current flowing into capacitor 108C causes its voltage to rise in a linear manner. When diode 108D is reverse biased and transistor 107Q is turned on, the accumulated voltage across capacitor 108C is shorted out and the current flowing from transistor 106Q is shunted to circuit 32.

If the system frequency drops, the duration which diode 108D is forward biased is increased and the voltage across capacitor 108C rises to the point where the silicon unilateral switch 105Q will trip. Once the silicon unilateral switch trips, the charge on the first capacitor 108C is shared with the second capacitor 107C. This results in a voltage on capacitor 107C which supplies base drive to transistor 104Q and shorts out the control amplifier reference diodes. This causes the generator terminal voltage to drop protecting the frequency sensitive components. Until the desired frequency is reestablished, the system will remain at reduced voltage.

MANUAL CONTROL SECTION (optional) - (Figures 12 and 16)

The manual control circuitry is provided basically as an emergency backup to the main automatic regulator. It contains power bridge elements identical to those of the automatic regulator. It's control circuitry provides a manually adjustable voltage level for the exciter field.

The MANUAL VOLTAGE ADJUST Rheostat 200P adjusts the percentage of the applied exciter field voltage to the filter (201C, 202C, and 211R).

As the voltage begins to rise in line 6 with respect to line 11, the same voltage will exist between line 6 and line 19. This is due to the continuous current in the field and the action of 6REC and 4REC. As the voltage across zener diode 200ZD reaches its clamping point, the amplifier (201Q, 202Q) becomes activated.

Transistors 201Q and 202Q produce from the error signal (the voltage between line 201 and line 19) a current signal into capacitor 200C. The accumulation

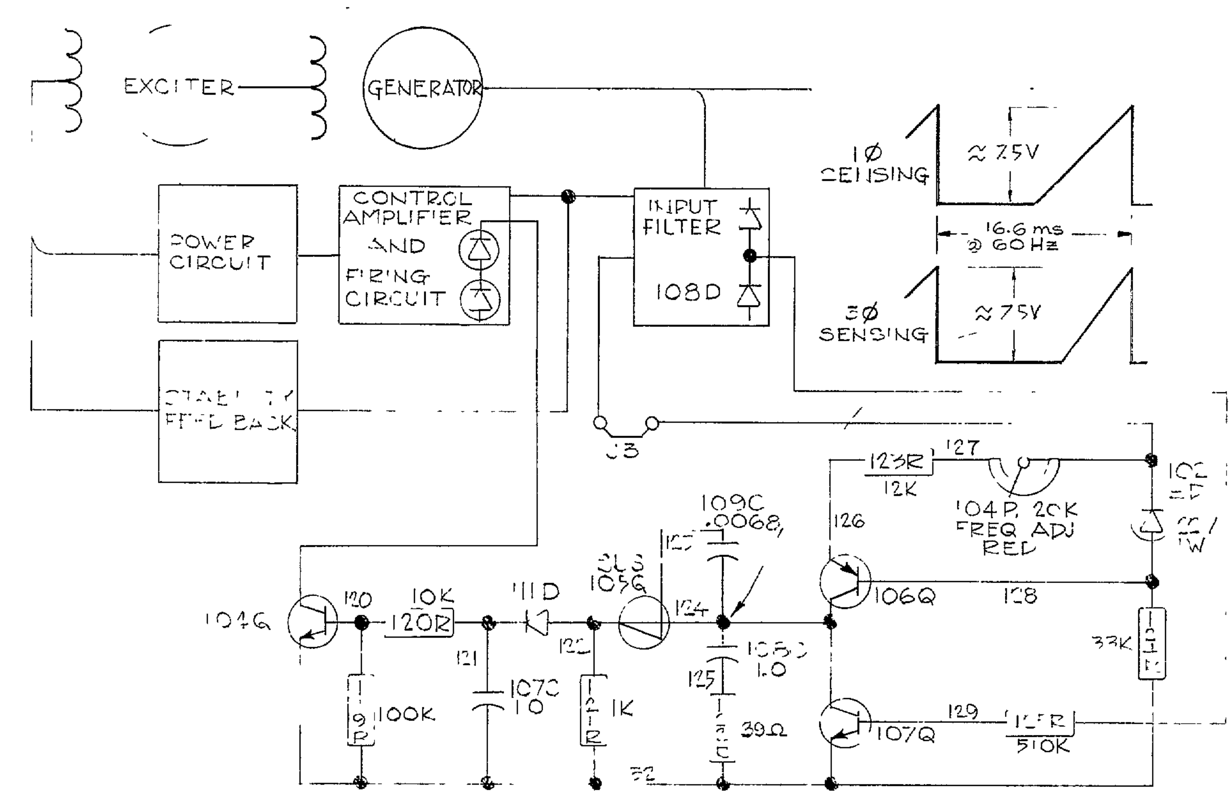


Figure 11. Underfrequency Limit Circuit

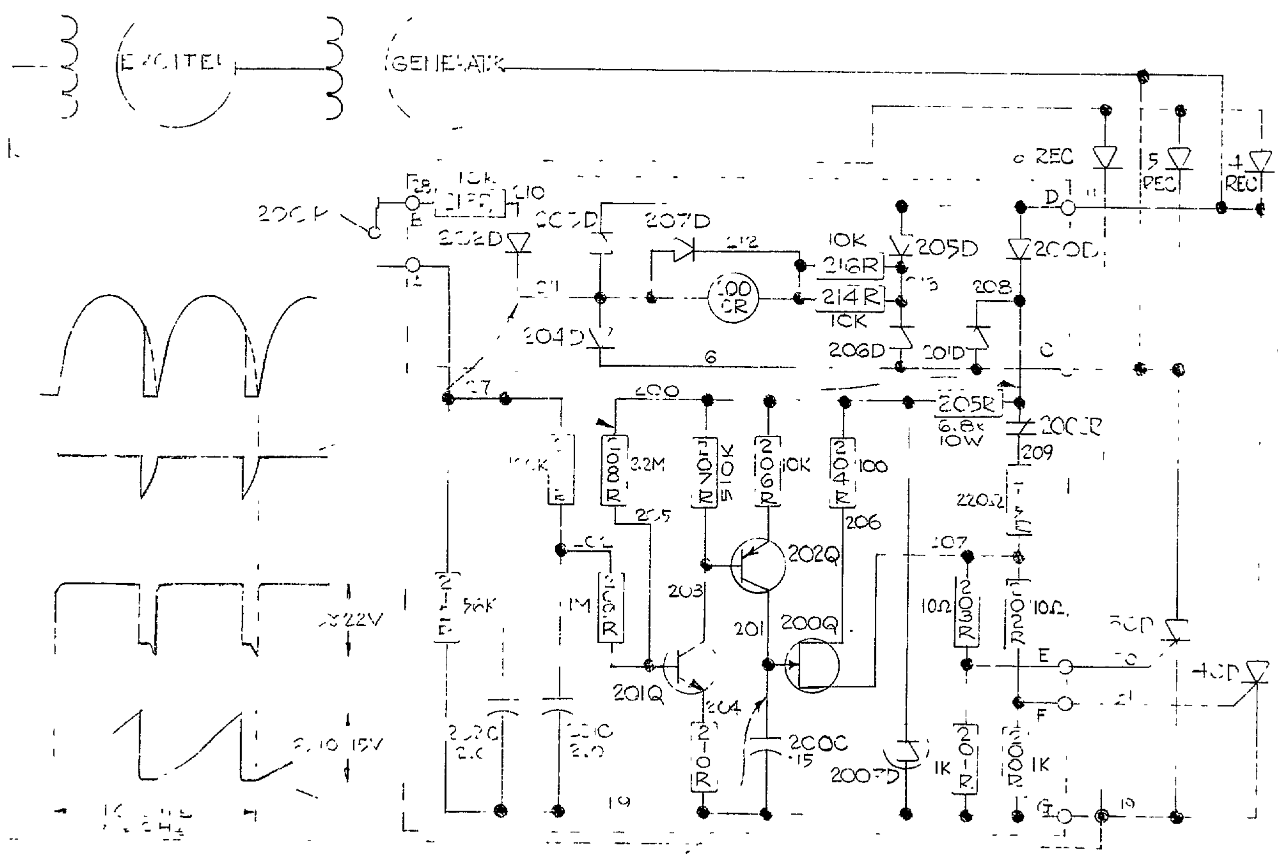


Figure 12. Manual Control Circuit

of the current signal produces a voltage. When this voltage reaches the trip point of unijunction transistor 200Q, the unijunction fires,putting a pulse of voltage on the gates of the 2 SCR's. The SCR with the positive anode will fire and remove the voltage from the amplifier and SCR firing circuit until the next half cycle when line 11 becomes positive with respect to line 6.

The build-up relay is used to insure positive build up. It supplies gate power to the SCRs only during build up. Then it is no longer part of the active circuit.

The manual control circuitry has no feedback from the output terminal of the generator; therefore, it cannot correct for changes of voltage due to load changes. An operator is required to make all changes.

FAULT CURRENT SUPPORT CIRCUITRY (optional)

(Figures 13, 14 and 17)

The automatic regulator is dependent on the terminal voltage of the generator for its power as well as the power supplied to the field of the exciter. A fault (short) on the generator output will cause loss of excitation to the machine. Depending on the severity of the fault, it could prevent the machine from clearing the fault or opening the protective breakers which would isolate the fault. The fault current support circuitry is used to provide forcing to open the proper breakers.

The circuitry derives its power from two saturable current transformers (1SCT and 2SCT). When in the normal mode of operation they are shorted by

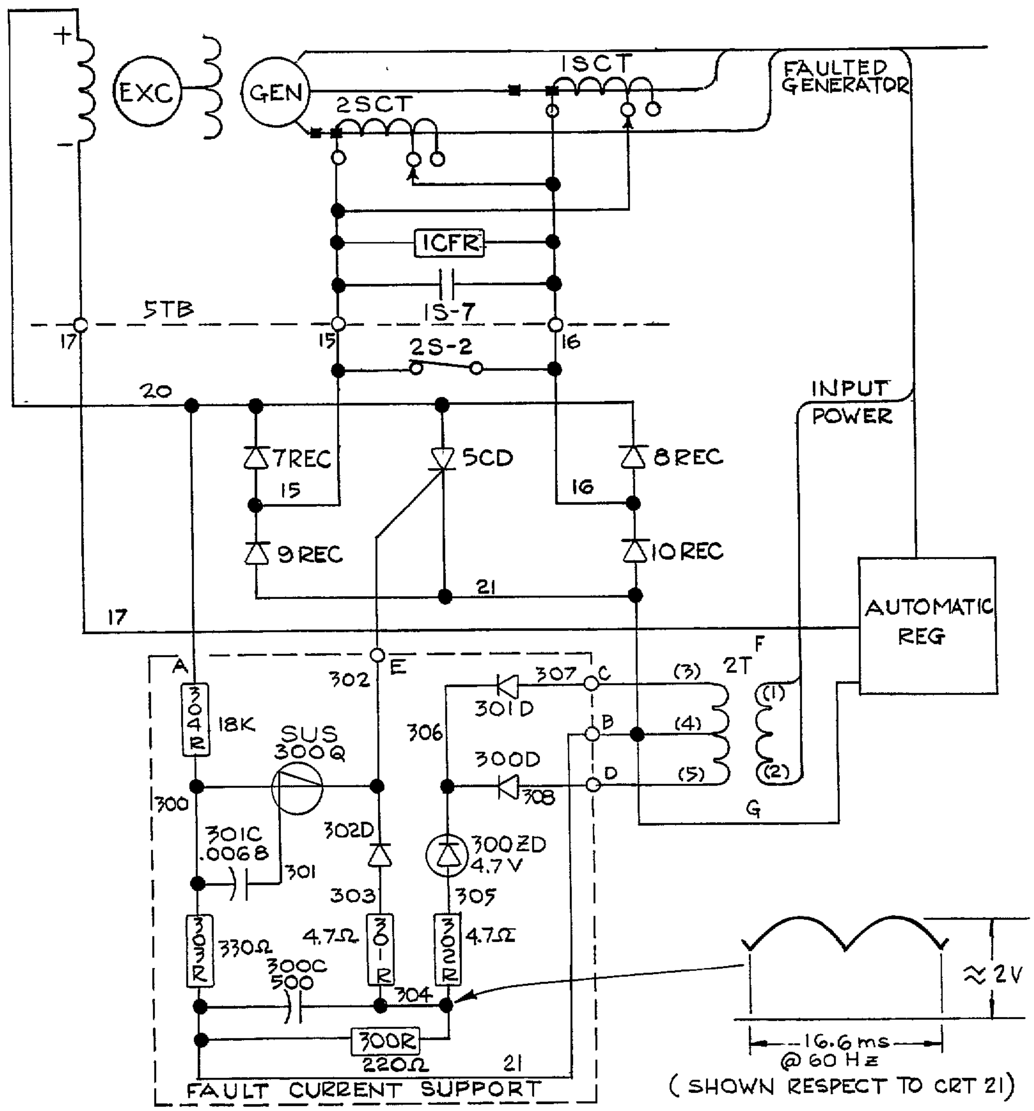


Figure 13. Fault Current Support Circuit

SCR 5CD to prevent them from interfering with the automatic regulator performance. When a fault occurs, the shorting SCR 5CD releases the 1SCT and 2SCT to provide field excitation. SCR 5CD is normally made to conduct by the secondary voltage of transformer 2T. The voltage is rectified by diodes 300D and 301D and passed through zener diode 300ZD to insure a sharp cutoff and average voltage across capacitor 300C. The average voltage is applied to the gate of SCR 5CD by resistor 301R and diode 302D. The resistor divider 304R and 303R and the silicon unilateral switch SUS300 are used to protect SCR 5CD from high forward voltage by turning it on.

When the generator terminal voltage fails, the potential source driving the gate of SCR 5CD fails. The SCR commutates off and 1SCT and 2SCT drive the field.

The SCT's (1SCT and 2SCT) are designed to saturate at a voltage sufficient to supply the per unit forcing required. The tap setting for the regulator connections to the externally mounted 1SCT and 2SCT is supplied on the summary sheet which accompanies the regulator. Also included is resistor 1CFR to be mounted with 1SCT or 2SCT. This resistor provides a burden for 1SCT or 2SCT since the field is highly inductive and its current is basically a DC value. If insufficient or too much forcing is provided by 1SCT or 2SCT, the tap setting on the transformer connected to the regulator may be changed. (Refer to the SCT drawing for the next lower or higher tap change.)

The setting of the CT secondary turns can be established analytically as shown in Figure 14. For a particular generator, the value of exciter field current can be established for sustaining a specified line current into a specified fault. (Usually a three phase line-to-line fault, the worst condition, is specified). Knowing exciter field current and field resistance, the required exciter field voltage can be established and the critical excitation line drawn for a specified fault. (See Figure 14.)

The maximum CT turns ratio can be established for the respective line current and exciter field requirements. If the CT turns ratio were greater, the CT would deliver less than the required excitation and the system would collapse. The CT turns ratio used must be less than the critical value, so that the system will tend to overexcite. The CT is then designed to saturate at a voltage level that will provide the proper excitation.

Varying the CT secondary turns also varies its voltage saturation level, thus the choice of CT turns provides an adjustment. A proper turns ratio can be established as shown in Figure 14 by picking the CT turns curve that crosses the critical excitation line nearest the required excitation point X.

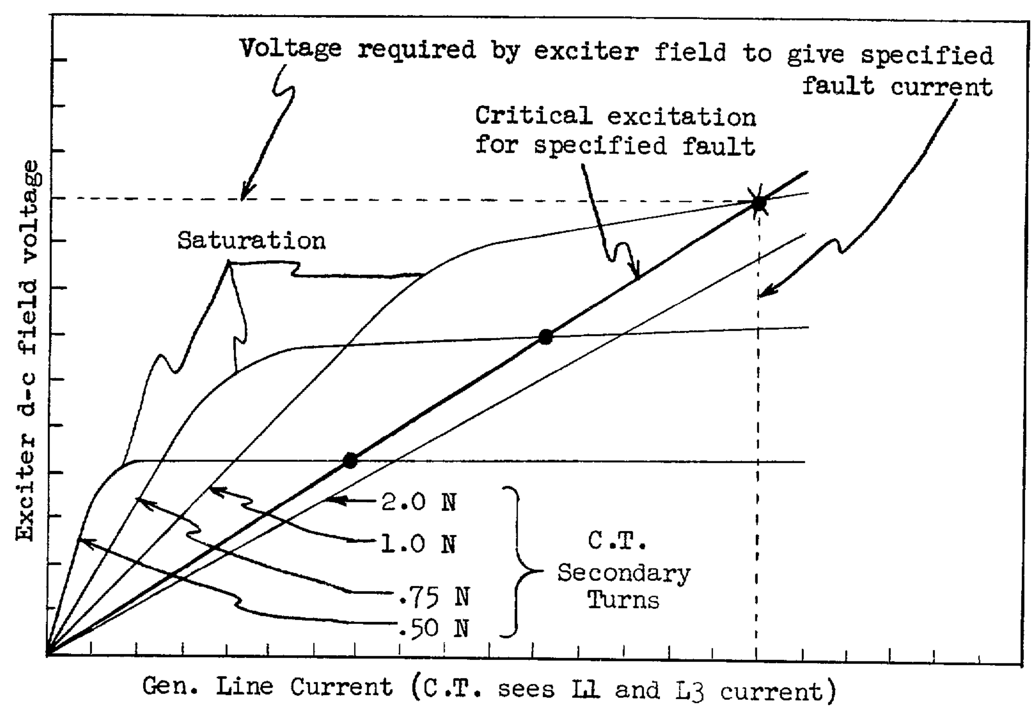


Figure 14. Action of Saturating CT on Faults

THERMAL OVERLOAD RELAY (optional)

The Manual Reset thermal overload relay serves to protect the rotating equipment field from excessive heating due to a prolonged over current condition.

The internal heater in the overload relay activates a bimetallic sensing element in an over current condition to open a normally closed contact. The device exhibits an inverse time vs current characteristic. Therefore, short term overloads do not trip the device which allows the regulator to force the rotating machine for short durations allowing the generator to pick up large loads. The sensing element is in the exciter field circuit and the normally closed trip contacts are in the control circuitry. This contact in the normally closed state allows the control circuitry to turn on 1CD or 2CD.

The device is adjustable from 85% to 115% of the heater rating which may be varied at the discretion of the operator. No adjustment is generally required.

MAINTENANCE

Since there are no moving parts in the regulator, very little maintenance is required. The regulator should be cleaned with an air hose periodically to prevent accumulation of dirt and dust.

RENEWAL PARTS

Should a component fail, a replacement part can be ordered from the nearest sales office of the General Electric Company. When ordering renewal parts, specify the quantity required, give the catalog number and describe the required parts in detail. In addition, give the 3S model number and the complete nameplate rating of the equipment. A principal renewal parts list is furnished with each equipment.

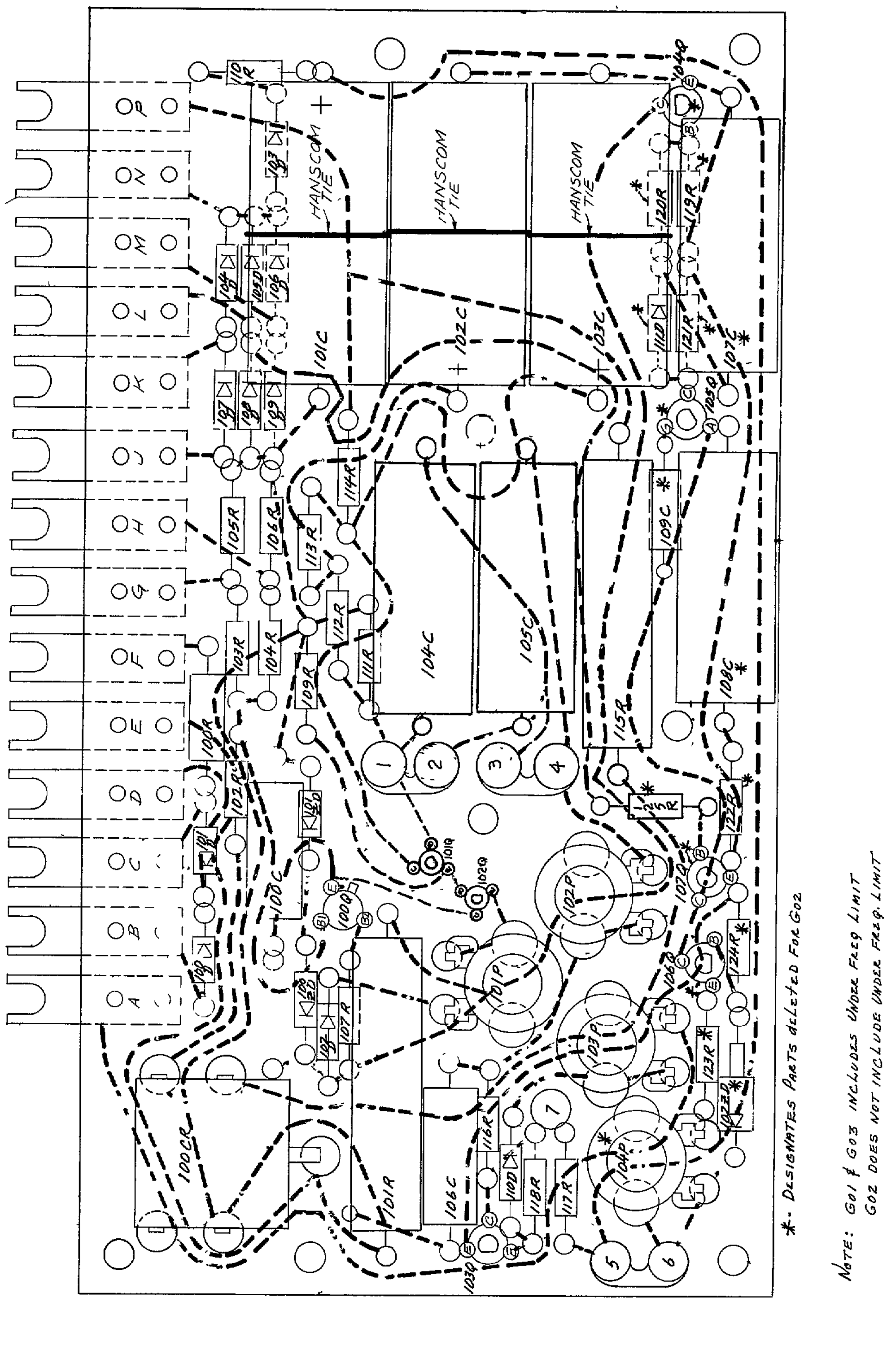


Figure 15. Automatic Control Component Board Layout

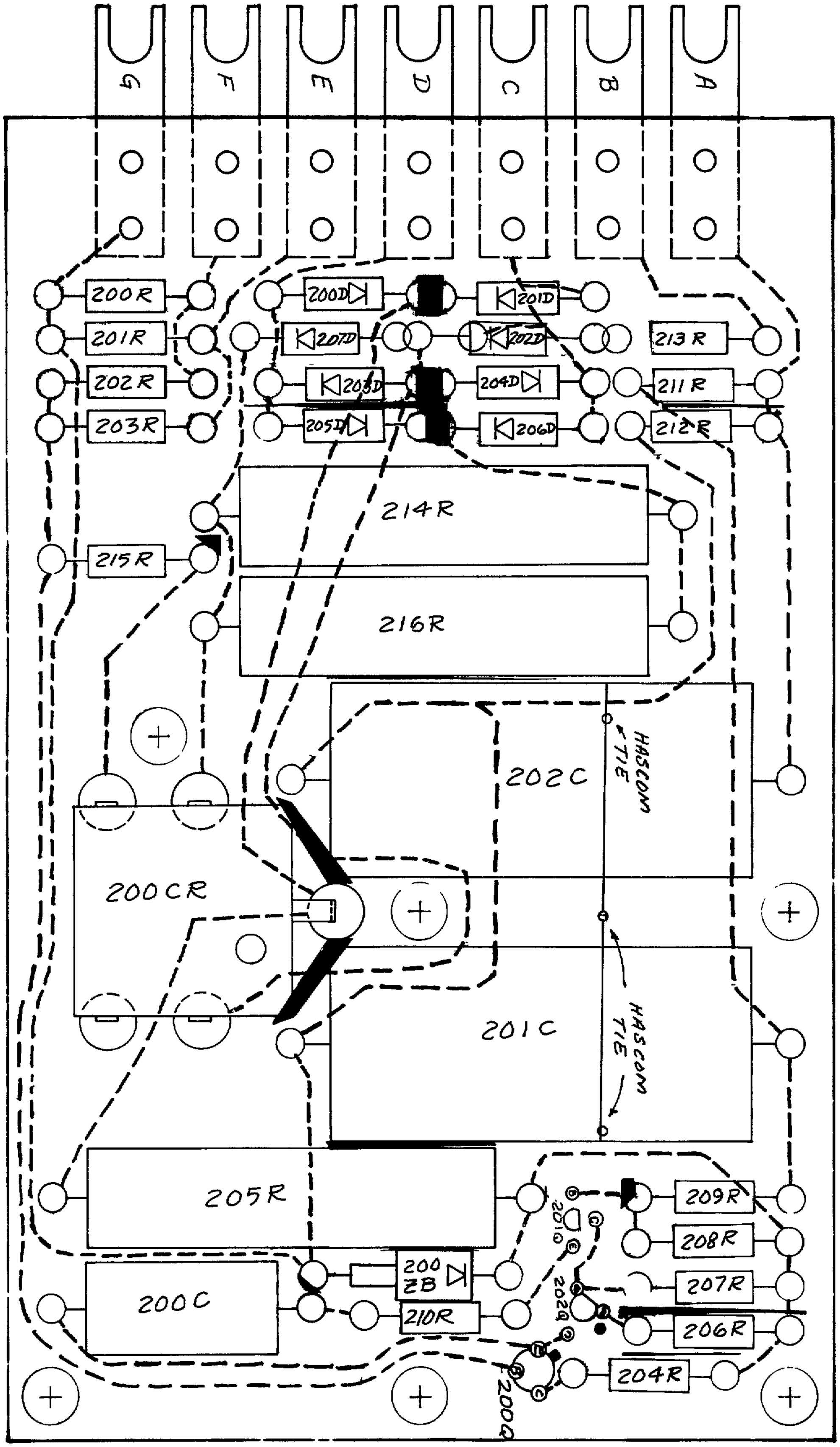


Figure 16. Manual Control Component Board Layout

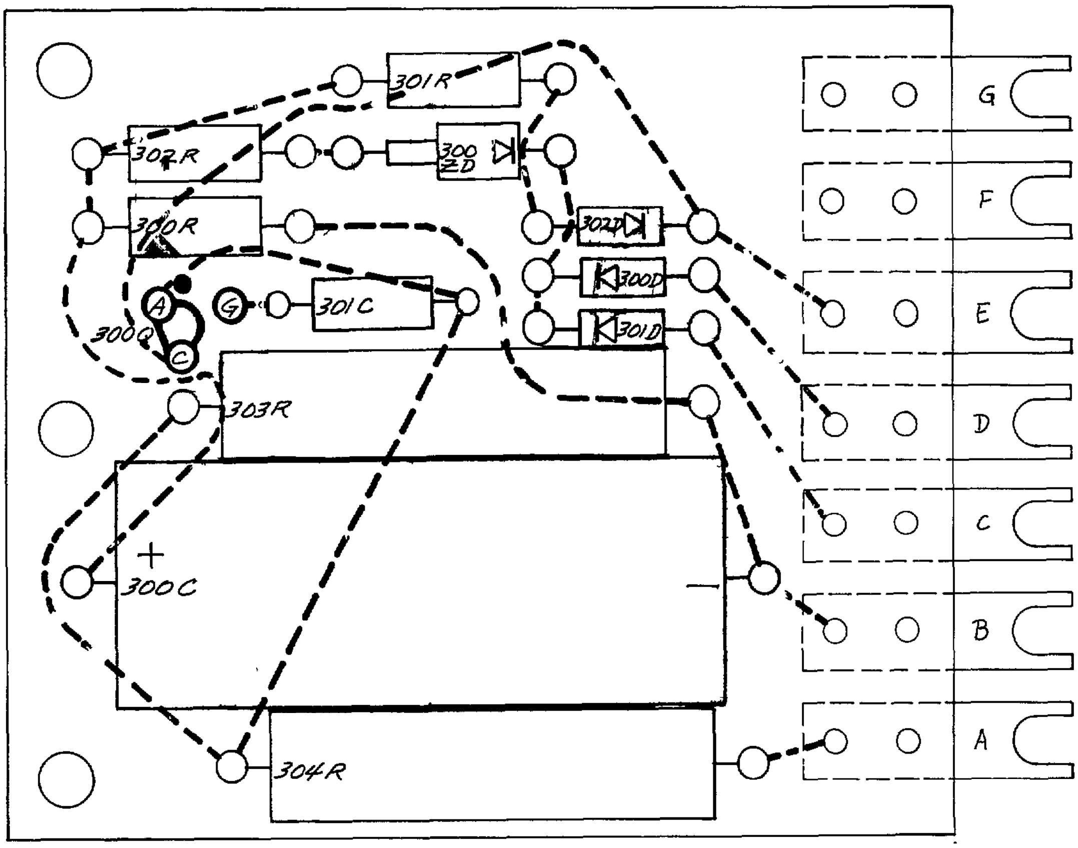
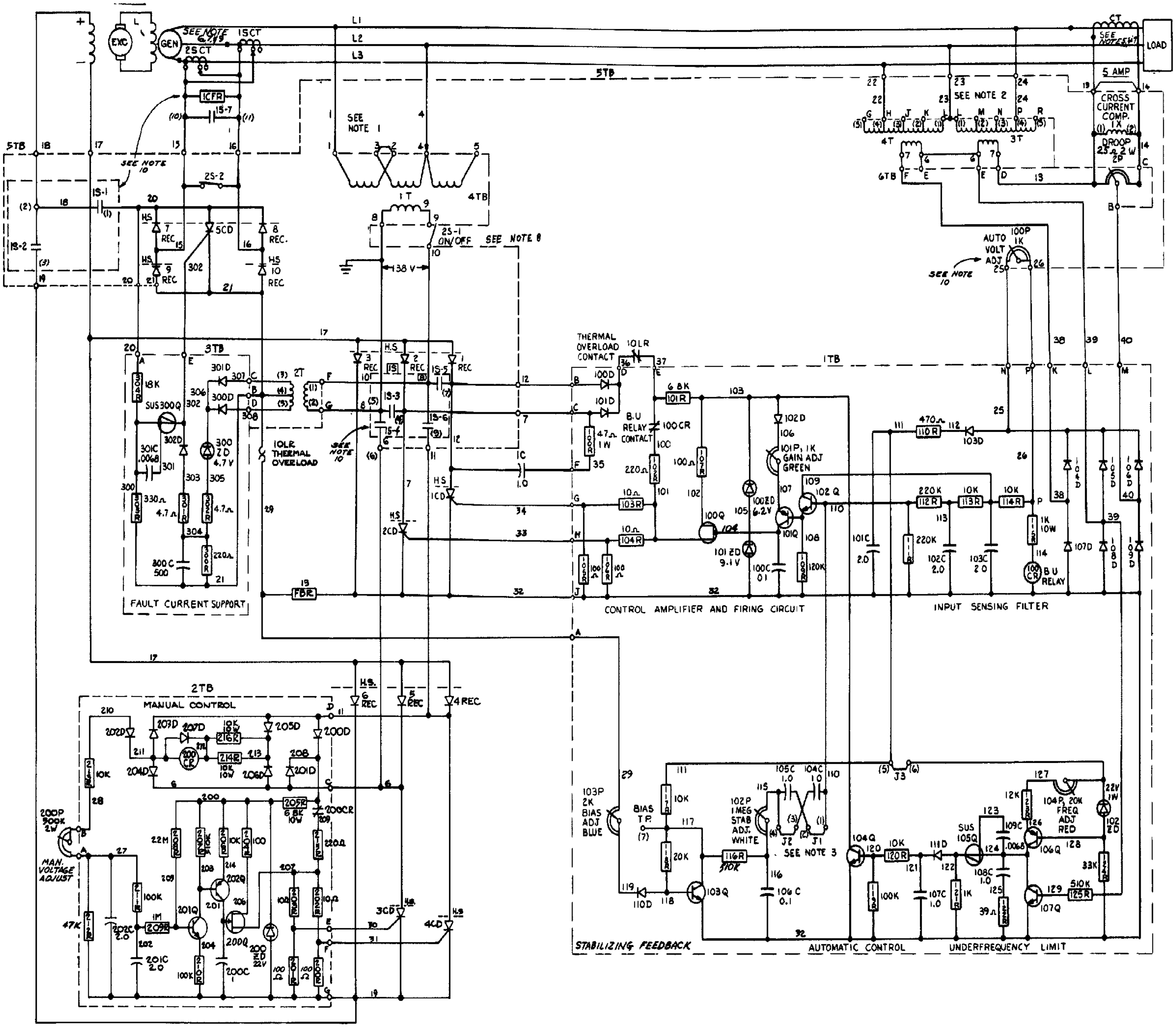


Figure 17. Fault Current Support Component Board Layout



NOTES.

1. INPUT CONNECTIONS FOR POWER TRANSFORMER 1T

INPUT VOLTAGE			CONNECT		JUMPERS
240	480	600	CIR 1 TO	CIR. 4 TO	ON 4TB
X			4TB-1	4TB-4	1 TO 3, 2 TO 4
	X		4TB-1	4TB-4	2 TO 3
		X	4TB-1	4TB-5	2 TO 3

1B. TAPS 4 TO 5 ON 1T ARE USED WITH 600 VOLT INPUT. DO NOT USE FOR 120 VOLT INPUT

2. INPUT CONNECTIONS FOR SENSING TRANSFORMER 3T

INPUT VOLTAGE				CONNECT		
120	240	480	600	CIR. 22 TO	CIR. 23 TO	CIR. 24 TO
X				6TB-K	6TB-L	6TB-M
	X			6TB-J	6TB-L	6TB-N
		X		6TB-H	6TB-L	6TB-P
			X	6TB-G	6TB-L	6TB-R

3. JUMPERS ON COMPONENT BOARD ARE COARSE. STABILITY ADJUSTMENT RHEOSTAT IS FINE ADJUST.

MIN STAB	MED STAB.	MAX. STAB.	JUMPERS J1 & J2 * ON 1CB
X			2 TO 3
	X		1 TO 2
		X	1 TO 2, 3 TO 4

* SEE FOR LOCATION

4. ALL RHEOSTATS AND POTENTIOMETERS ARE SHOWN INCREASE IN CLOCKWISE DIRECTION.

5. FOR REACTIVE CURRENT DIVISION WHEN PARALLELING GENERATORS, REMOVE JUMPER AND CONNECT CT AS SHOWN.

6. LINE 6 IS THE REGULATOR GROUND POINT. NO OTHER GROUNDS ON THE REGULATOR ARE ALLOWED.

7. CT POLARITY IS SHOWN FOR PHASE ROTATION 1, 2, 3. REVERSE CT POLARITY FOR 3, 2, 1 ROTATION.

8. SWITCH 2S MAY BE REMOVED FOR REMOTE MOUNTING.

9. 1SCT & 2SCT SECONDARY CONNECTIONS MAY BE VARIED TO OBTAIN VARIOUS AMOUNTS OF FORCING. INCREASING SECONDARY TURNS INCREASES FORCING. SEE CT DRAWING FOR VARIOUS TURN RATIOS. SEE REGULATOR SUMMARY FOR SECONDARY CONNECTION FOR VARIOUS GENERATORS SEE REGULATOR SUMMARY FOR PARTICULAR APPLICATIONS.

10. COMPONENTS PROVIDED FOR CUSTOMER MOUNTING.

1S AUTO/ MAN SWITCH

CONTACTS	MAN.	INTER	AUTO
1S-1		X	X
1S-2	X	X	
1S-3			X
1S-4	X		
1S-5			X
1S-6	X		
1S-7	X		

2S ON/OFF

	ON	OFF
2S-1	X	
2S-2		X

X DENOTES CLOSED CONTACTS

Figure 18. Typical Elementary Diagram for the 3S7950GR400, 500, 600, 700, 800 and 900 Full-Wave Voltage Regulators (44D301319 Rev. 3)

1/75 (150)

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