INSTRUCTIONS

STATIC VOLTAGE REGULATOR FOR AC GENERATORS 3S7930SA111D6

INTRODUCTION

The 3S7930SA111D6 voltage regulator controls the voltage of a 60 cycle AC generator by controlling the field current to the generator exciter. A silicon controlled rectifier controls power delivered to the exciter field. The regulator includes a current transformer forcing unit to provide excitation; thus, sustains short circuit current for selective relay tripping, where the voltage regulator input fails due to a fault on the system. The regulator is completely static, having no moving parts to perform the regulating function. A relay is used to assure initial voltage buildup.

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 may 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 after unpacking, 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.

DESCRIPTION

The 3S7930SA111D6 voltage regulator consists of a basic regulator, a current transformer forcing unit, a droop kit and miscellaneous components.

The basic voltage regulator consists of a 44B213985 encapsulated block assembly (including terminal board and adjustments) with rectifiers and heat sinks mounted on the block and on the supporting steel base. The reference element (a Zener diode) is contained in the bottom of the block.

The voltage adjusting rheostat is furnished unmounted for mounting by user.

The regulator includes a current transformer forcing unit. This unit is to provide excitation and sustained short circuit current for selective relay tripping during generator faults.

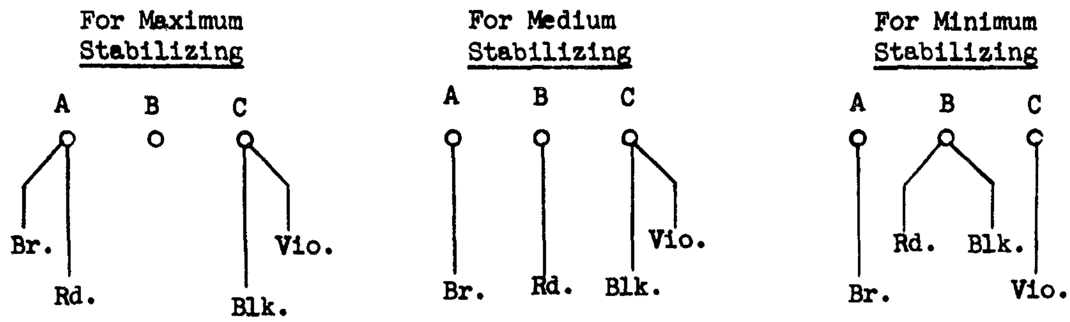
The regulator includes an under frequency limiter to protect the generator field from over current when idling generator or when shutting generator down.

The regulator includes a CR2790E100A72 relay to assure automatic voltage buildup during starting.

The regulator includes a droop kit for dividing reactive current when paralleling generators.

The regulator includes rectifier and circuitry for providing manual control of the generator. A manual-automatic selector switch and manual field rheostat are furnished with regulator.

The regulator also includes necessary transformers to provide operation from a 400 to 480 or 600 volt generator.



STABILIZING RANGE CONNECTIONS ON 2TB

INSTALLATION

The regulator should be mounted so that is is accessible. It should be mounted in an enclosure to protect personnel from exposed voltages. The enclosure should allow a reasonable circulation of air to keep the ambient temperature at 50°C or lower. The regulator must be mounted in an upright position as indicated on the outline drawing. The voltage adjusting potentiometer, manual control rheostat, current transformer for C. T. forcing, and the manual-automatic selector switch are to be remotely mounted by user. The current transformer for the droop kit (furnished by others) is also remotely mounted.

Make all connections to 1TB on regulator per diagram furnished with equipment. Connect all remotely mounted components per diagram furnished with equipment.

OPERATION

CAUTION

> The heat sinks on this regulator are at above ground potential.
>
> To prevent damage to regulator, exciter field resistance should not be less than 1.21 ohms.
>
> Always open current flow through 7CT primary before changing taps.

ADJUSTMENTS

Before starting prime mover, set "Voltage Adjust" (1P) and "Stabilizing" (3P) at their mid-points. Set "Gain" (2P) fully counterclockwise .

Start prime mover and bring up to rated-speed. Set "Voltage Adjust" to obtain proper line voltage. Turn "Gain" clockwise to improve regulation as generator is loaded. "Gain" should be set to allow approximately 1% voltage drop going from a no-load to a full-load condition on the generator. It will be necessary to correct voltage level with the "Voltage Adjust" each time the "Gain" is changed.

To obtain optimum transient response when applying and rejecting load, vary the "Stabilizing" (3P) and the connections of 2TB. The "Stabilizing" adjust (3P) acts as a fine adjustment; while the connection on 2TB act as a course or range adjustment.

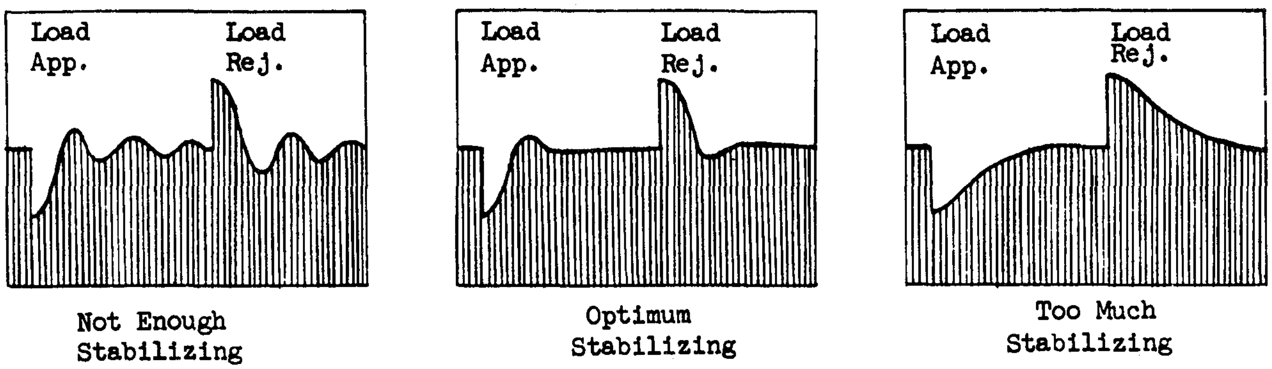
This regulator includes a choke (2X) and capacitor (4C) for increasing range of stabilizing circuit. Adjustment of this circuit can be done by moving jumper on 3TB. The settings are maximum, A to C; medium, B to C; minimum, A to B.

Figure 1 shows the effect of "Stabilizing" adjustment as seen on an oscilloscope or recorder when applying and rejecting loads.

It should not be necessary to test the current transformer forcing unit. The setting of the current transformer on the current transformer forcing unit should have already been arrived at analytically as described in "Principles of Operation".

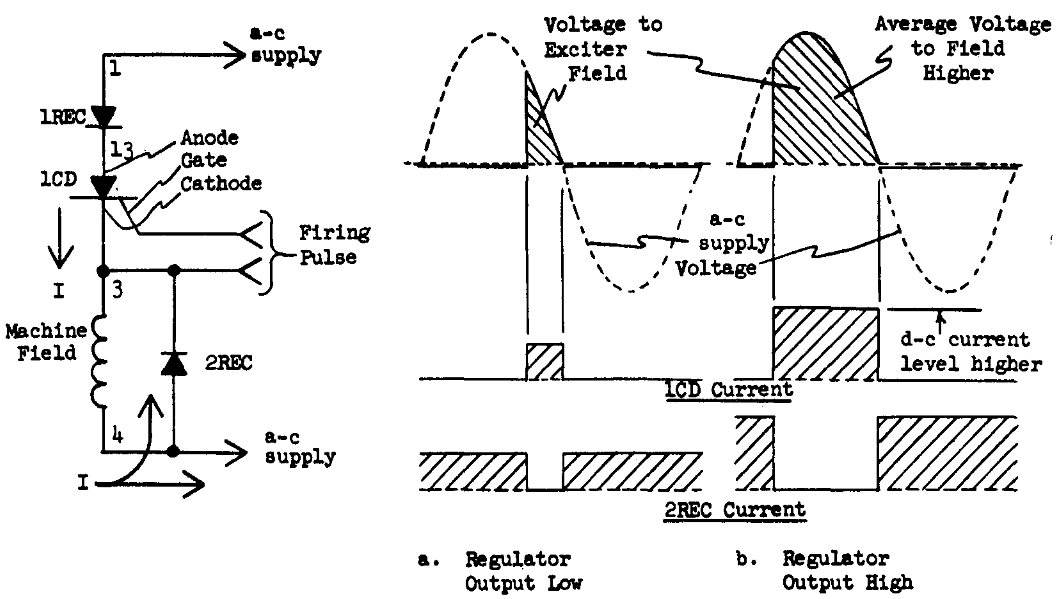
"Voltage Adjust" should be checked weekly, or monthly as required.

To adjust the under frequency limit bring generator up to rated speed and adjust lead 2 or reactor 8SX taps, 2 to 8 to position where AC volts begins to droop, then move to the next lower tap. Let generator coast to stop and observe field current which should not increase more than 30%. Observe gen-



TYPICAL OSCILLOGRAMS LOOKING AT AN AMPLIFIED PORTION OF GENERATOR A-C VOLTAGE

Figure 1



PHASE CONTROLLED OUTPUT OF SCR (1CD)

Figure 2

erator transient response by applying and rejecting load. Under Frequency limit should be set on tap where transient response is not affected.

PRINCIPLES OF OPERATION

GENERAL

The 3S7930SA111D6 voltage regulator operates by taking power from the generator output; and rectifying and controlling the power to furnish d-c excitation to the exciter field. Refer to Figure 7, Typical Elementary Diagram.

SILICON CONTROLLED RECTIFIER

The d-c excitation power for the exciter field is furnished by single phase half-wave silicon controlled rectifier (SCR). The SCR (1CD) is phase controlled to control the power delivered to the exciter field.

An SCR is similar to a Thyratron tube in that it remains non-conductive until a firing pulse is applied through its gate-to-cathode junction. If the anode is positive with respect to the cathode when a pulse is applied, the SCR will conduct and remain conducting until the anode goes negative and the current goes to zero.

The voltage regulator controls the exciter field voltage by controlling the firing of 1CD on each positive half cycle. See Figure 2. If 1CD fires early in each positive half cycle (Figure 2B) the regulator delivers a larger average voltage to the exciter field. If 1CD fires late in each positive half cycle (Figure 2A) the regulator delivers the smaller average voltage to the exciter field. Although the voltage applied to the exciter field is portions of a sine wave, the current through the field is continuous because of the inductance of the field winding. Since 1CD cannot supply voltage from the AC supply during the negative half cycle, the field current conducts through the "free-wheeling" rectifier 2REC.

SERIES RECTIFIER - 1REC

Rectifier 1REC is a series diode that takes most of the inverse voltage during the negative half cycle; thus, protects the SCR from permanent damage due to excess transient inverse voltage. Rectifier 1REC also furnishes the initial DC to the exciter field when the build-up relay contacts are closed during startup.

FIRING CIRCUIT

The SCR (1CD) firing pulse comes from a saturable reactor firing circuit in the encapsulated assembly. The encapsulated assembly also contains a sensing circuit, comparison circuit, feedback circuit, stabilizing circuit, and a zener diode reference in the bottom compartment. The sensing circuit is designed to regulate average line voltage; thus, on application where generator wave shape may be distorted, the regulator will more nearly regulate average voltage instead of rms voltage.

STABILIZING CIRCUIT

The stabilizing circuit consists of an RC combination of 3P and capacitors in the encapsulated assembly. See Figure 3.

Stabilizing capacity can be varied by changing the connections of 2TB. (See operation). This provides choice of 100, 200, and 400 MFD for stabilizing and should cover all normal machine characteristics. Should additional stabilizing be required, a 500 MFD - 50 W.V.D.C. polarized electrolytic capacitor may be added at 2TB (+ to A, - to C).

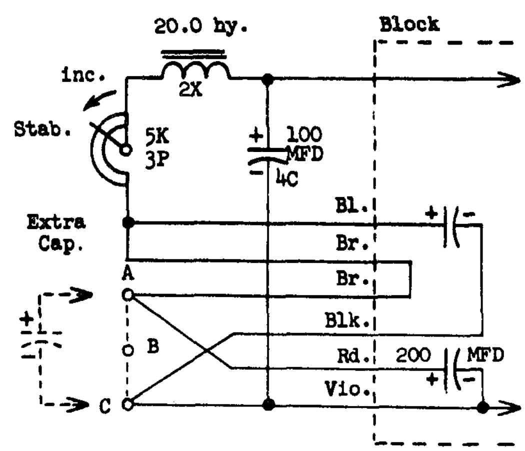
The addition of 2X and 4C is to provide greater range of stabilizing circuit for obtaining optimum response on larger machines.

CURRENT TRANSFORMER FORCING UNIT

The current transformer forcing unit switches in when associated voltage regulator power source fails, allowing its C.T. to supply excitation to the exciter field and thus sustain generator short circuit current as required for selective relay tripping.

Since the voltage regulator output and C.T. forcing unit output are in series, either can supply machine excitation. See Figure 4.

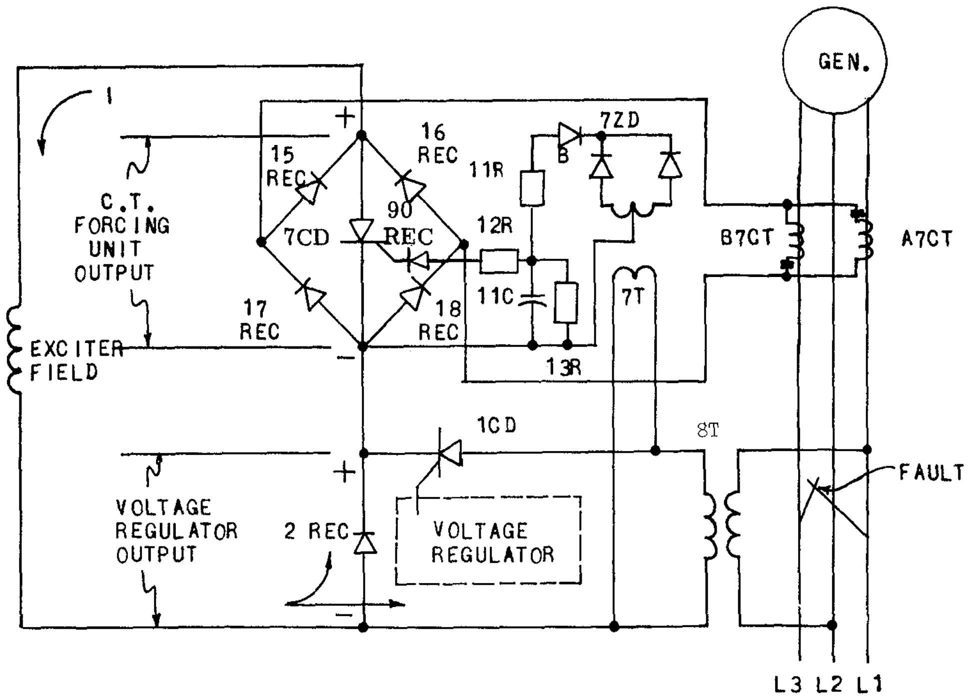
When regulator is operating normally the CT forcing unit output rectifier bridge (15, 16, 17 and 18REC) is shorted by 7CD silicon controlled rectifier. The voltage regulator therefore furnishes voltage to the exciter field normally and the CT current circulates through the shorted rectifier bridge.



Extra Range Stabilizing Circuit

STABILIZING CIRCUIT

Figure 3



C. T. FORCING UNIT OPERATION

Figure 4

When the voltage regulator power source fails, or drops below one-third normal voltage, 7CD will stop conducting and allow the CT to supply DC current to the exciter field to sustain excitation to the machine.

Since there is no control during the current forcing condition, if the CT output current is too small the system will collapse and not sustain short circuit excitation. If the CT output current is larger than a critical value, the excitation, and short circuit current, will increase until some part of the system saturates.

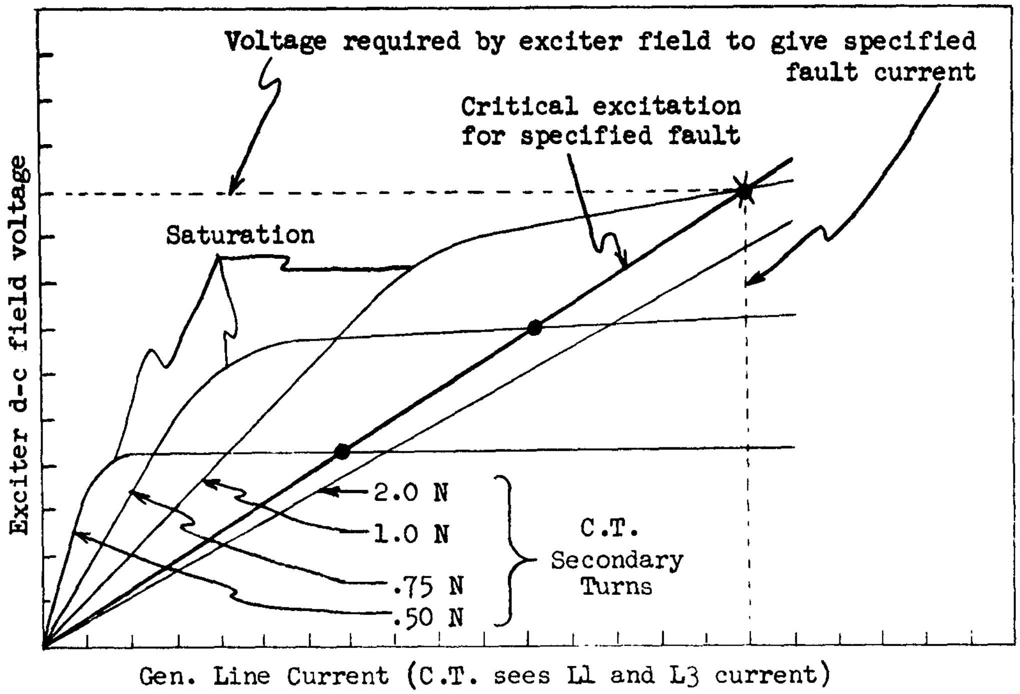
The forcing C. T. is designed to saturate at an output voltage level as required by the exciter field for maintaining a specified short circuit current out of the generator. Increasing the C. T. secondary turns increases the voltage level at which the C. T. will saturate; therefore, increases the current sustained into a short circuit. Since the increasing C. T. secdary turns decreases the C. T. secondary current, an excess number of secondary turns will decrease the C. T. secondary current below the critical value and the system will collapse. See Figure 5.

The setting of the C. T. secondary turns can be established analytically, as shown in Figure 5. 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 5).

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

Varying the C. T. secondary turns also varies its voltage saturation level, thus the choice of C. T. turns provides an adjustment. A proper turns ratio can be established as shown in Figure 5 by picking the C. T. turns curve that crosses the critical excitation line nearest the required excitation point X.

The C. T. output bridge is shorted to prevent forcing unless voltage source to regulator fails. The silicon controlled rectifier (7CD) is continuously conducting to short the bridge as long as the voltage regulator source is present. The DC firing voltage for the SCR (7CD) is supplied by a power supply consisting of 7T, 19REC, 20REC, 11C, and 13R. When



ACTION OF SATURATING C. T. ON FAULTS

Figure 5

the voltage regulator power source fails, the DC firing voltage drops to cease firing 7CD. The zener diode 7ZD provides a sharp cutoff of the firing at below one-third of normal voltage.

The C. T. fault current is extremely high at the first instant a fault occurs and a Thyrite resistor (THY) is used as a voltage suppressor and limits the excess voltage supplied by the C. T. This protects 7CD and the rectifier bridges from excess voltage.

MANUAL CONTROL

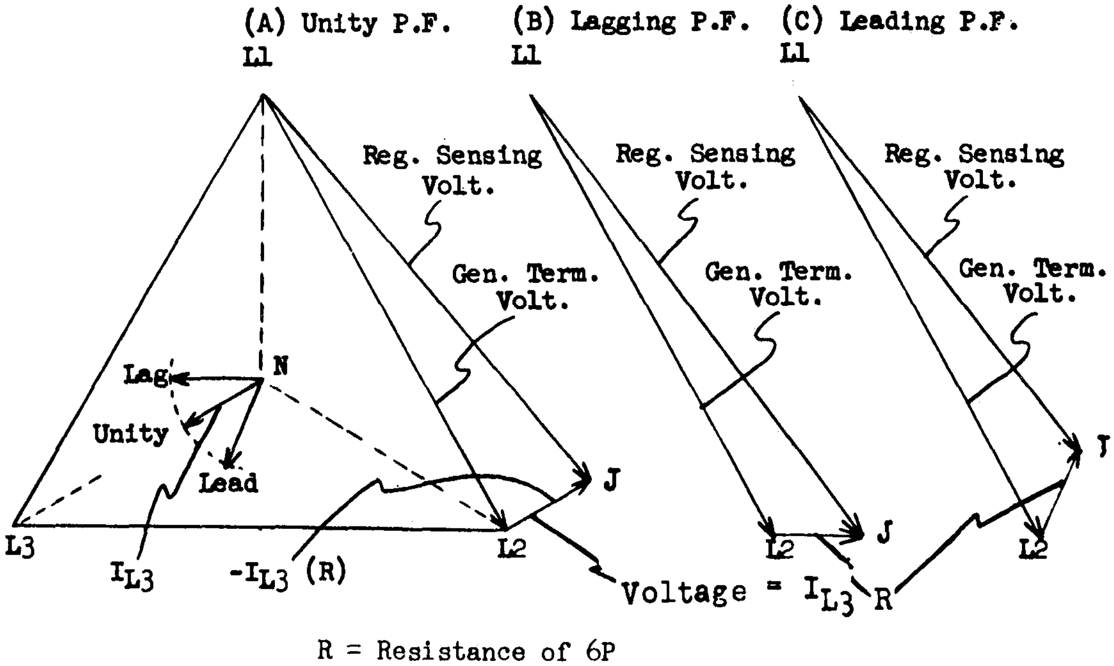
Manual control is provided by rectifiers 21REC and 22REC and the manual field rheostat. Rectifier 22REC provides half wave rectification to furnish DC through the manual field rheostat for excitation power for manual control. Rectifier 21REC acts as a free-wheeling rectifier to carry current during the negative half cycle during the manual control operation.

Selector switch 1SS provides for transferring from manual to test to automatic control. In the Auto position, excitation is furnished through the voltage regulator and C.T. forcing panel. During manual operation, excitation is furnished through the manual field rheostat, and the input to the voltage regulator is disconnected. In the test position, excitation is furnished through the manual field rheostat but the voltage regulator is connected so that its output may be checked. The output of the voltage regulator may be checked in the test position by placing a 250 ohm, 10 watt resistor across A to B on 10TB. The voltage output from the regulator can then be monitored with a voltmeter. As generator voltage is decreased (with manual control) regulator output voltage should increase. As generator voltage increases, regulator output voltage should decrease.

DROOP CIRCUIT FOR PARALLELING GENERATORS

A droop circuit is connected to the voltage regulator between transformer 9T and terminal J at the voltage regulator. The droop circuit consists of a loading rheostat (used with a standard 5 amp CT) and delivers an AC voltage that adds to the voltage going to the regulator sensing circuit. This added voltage may cause the sensing circuit voltage to increase or decrease depending on the phase relationship. See Figure 6.

When the generator is supplying unity power factor current, the voltage across the loading rheostat will add to the line voltage at a 90° angle such that the sensing circuit and line voltages will be practically the same. (Figure 6A). Should reactive current



OPERATION OF PARALLELING (DROOP) CIRCUIT

Figure 6

tend to increase in the lagging direction (Figure 6B) the regulator sensing circuit will see a higher than normal voltage, indicating overexcitation; thus, the regulator will decrease excitation to lower line voltage, thereby decreasing the lagging reactive current.

Should reactive current tend to increase in the leading direction (Figure 6C) the regulator sensing circuit will see a lower than normal voltage, indicating underexcitation; thus the regulator will increase excitation to raise line voltage, thereby decreasing the leading reactive current. Figure 6 illustrates circuit for phase sequence shown on elementary diagram. If phase sequence is reversed, reverse connections to N and P on 10TB.

POWER TRANSFORMER

Transformer 8T is provided to reduce the input voltage from the generator from 400-480 or 600 volts to 100-150 volts for operating the controlled rectifier.

Transformer 9T is provided to decrease the input voltage from the generator from 400-500 or 600 volts to 200-250 volts for input to the voltage regulator sensing circuit.

Resistor 20R is provided for limiting the excitation, thus limiting sustained short circuit currents. Relay 1CR bypasses 1CD to assure voltage build-up when starting, even when generator residual voltage is low.

UNDER FREQUENCY LIMIT

The Under-Frequency Limit is used to protect the exciter field and the regulator output stages during an under-frequency condition.

A voltage proportional to the generator output is applied to the bridge clipping circuit comprised of the four diodes (81, 82, 83, 84 REC) and the zener reference (8ZD) through a current limiting resistor (81R).

The result is an approximate 48 volts P.P. square wave measured between circuits 80 and 55. The frequency of the square wave is that of the generator output. The saturable reactor (8SX) will saturate after so many volt-seconds are accumulated and a pulse will then appear on its secondary (PTS. 9 and 10). This is adjusted to happen at some frequency under the normal running frequency by moving circuit 55 to one of the various taps on the reactor's primary (Ref. Figs. 7 and 8). The pulses which appear on the secondary winding during the under-frequency condition are rectified by the full wave bridge (85, 86, 87, 88 REC) and averaged by capacitor (8C). The transistor (8Q) is turned on when the averaged voltage becomes greater than approximately one volt. When the transistor is turned on, it reduces the voltage across the reference to a low value (1.5 volts ± .5 volt). This requires the regulator to phase back and reduce its output voltage. The resistor (85R) and rectifier (89 REC) are used to bias the transistor to insure proper turn off when the under-frequency condition does not exist.

MAINTENANCE

Since the regulator contains no moving parts, little maintenance should be required. Periodic checks should consist of checking the voltage level and regulation. The regulator should be cleaned with a blower as required to prevent an accumulation of dust and dirt.

TROUBLE SHOOTING

The following chart may be helpful for troubleshooting and locating faulty components; however, a thorough study of the "Principles of Operation" will be the greatest aid to troubleshooting.

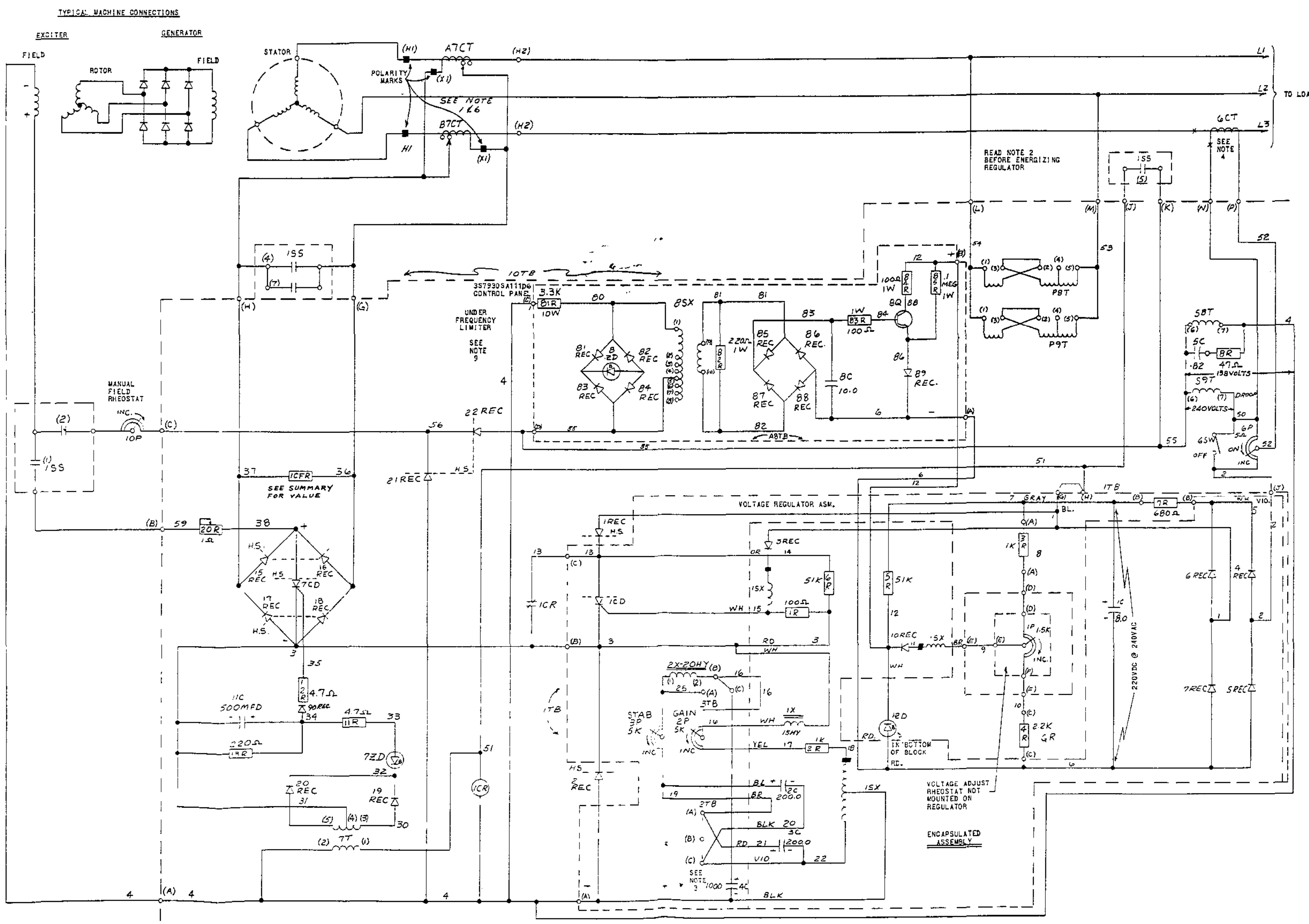
TROUBLE SHOOTING CHART

TROUBLE	PROBABLE CAUSE	CHECK
I. Generator Voltage will not build up	1. No power to generator field	a. Connections to regulator b. Connections between exciter and generator c. 1REC and 2REC d. 1CR
	2. No residual voltage out of generator	a. Reverse exciter field connections b. Try flashing field with battery (+ to B - to A)
II. Generator voltage goes to ceiling	1. No feedback voltage signal	a. "Droop" circuit connection b. 1P connections c. 1ZD
	2. No control of SCR	a. 1CD b. 1CR
III. Poor voltage regulation	1. Loss in system gain	a. "Gain" adjust per OPERATION b. Exciter output to generator field
	2. Distorted input to sensing circuit	a. For unbalanced 3 phase loads b. Generator wave shape

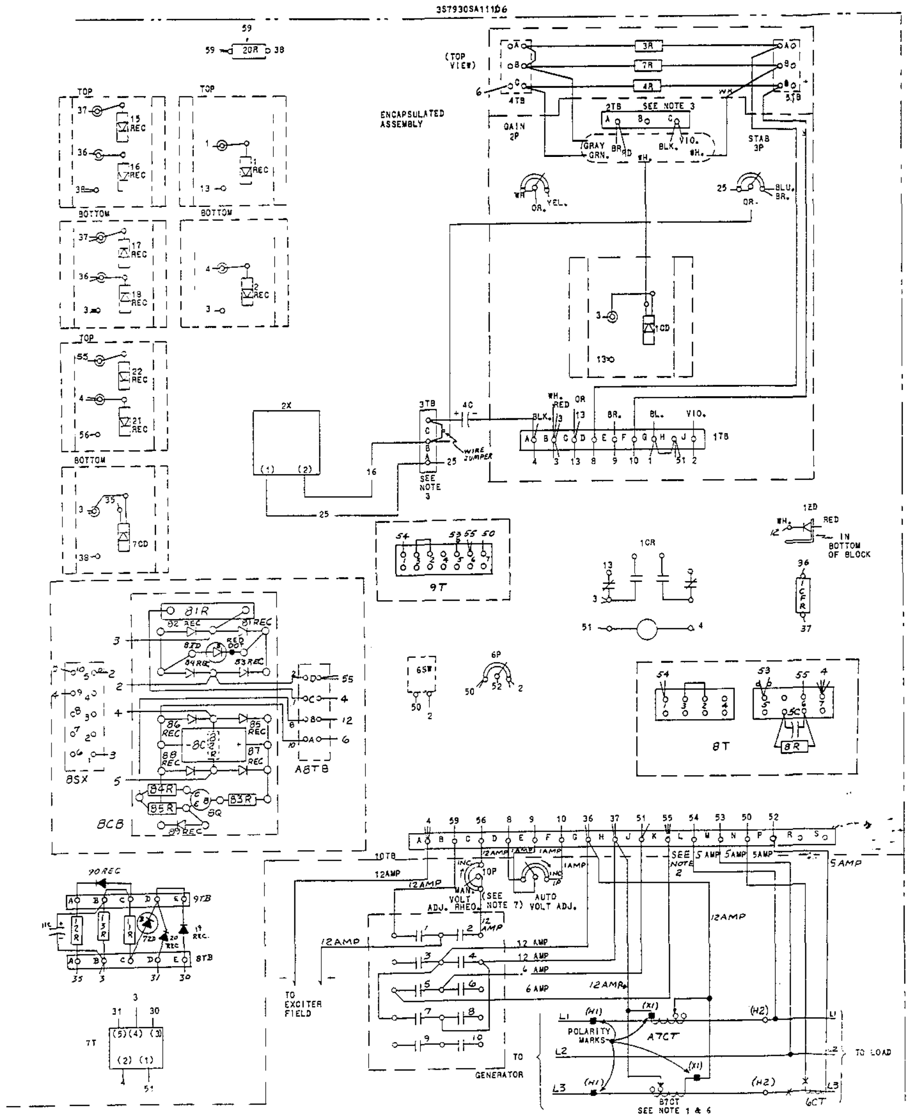
(Continued on page 9)

TROUBLE SHOOTING CHART CONTINUED

TROUBLE	PROBABLE CAUSE	CHECK
IV. Instability	1. Excess transient system gain	a. "Gain" adjust per OPERATION b. Exciter field resistance too low? c. "Stabilizing" per OPERATION
V. Slow system response	1. Low transient system gain	a. "Stabilizing" adjustments per OPERATION b. Loss in system gain Check Step III
VI. Paralleled generators will not divide reactive KVA	1. Droop circuit	a. Try reversing connections to loading rheostat b. Increase droop circuit C.T. loading resistance c. Check generator line phase sequence
VII. Sustained short circuit current too low	1. C.T. not delivering enough voltage	a. Increase C.T. secondary turns
	2. Exciter output low	a. Rotating rectifiers if exciter is brushless b. Brushes, if exciter is DC type
VIII. Sustained short circuit current too high	1. C.T. delivering too much voltage	a. Decrease C.T. secondary turns
	2. Other than a 3 phase fault	a. C.T. unit and C.T. design is for the worst faults, a 3 phase fault. For single phase faults short circuit currents will be higher
IX. System collapses under short circuits	1. 7CD not switching	a. Operation of 7CD when voltage is removed from A to B
	2. C.T. secondary current too low	a. Decrease C.T. secondary turns



TYPICAL ELEMENTARY DIAGRAM
Figure 7



NOTES:

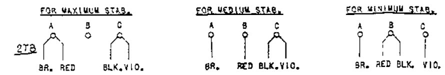
1. 7CT SECONDARY CONNECTIONS MAY BE VARIED TO OBTAIN VARIOUS AMOUNTS OF FORCING. INCREASING SECONDARY TURNS INCREASES FORCING. SEE C.T. DRAWING FOR VARIOUS TURNS RATIOS. SEE REGULATOR SUMMARY FOR SECONDARY CONNECTIONS FOR VARIOUS GENERATORS.

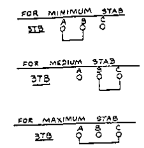
2(A) FOR INPUT LINE VOLTAGE BETWEEN 200 AND 250 VOLTS:
JUMPER 1 TO 3 & 2 TO 4 ON 8T & 9T.
CONNECT INPUT TO 1 & 4.

(B) FOR INPUT LINE VOLTAGE BETWEEN 400 AND 500 VOLTS:
JUMPER H2 TO H3 ON 8T AND 9T.
CONNECT INPUT TO 1 & 4.

(C) FOR INPUT LINE VOLTAGE BETWEEN 550 & 600 VOLTS JUMPER 2 TO 3 ON 8T & 9T. CONNECT INPUT TO 1 & 5.

3. STABILIZING RANGE MAY BE VARIED BY CHANGING CONNECTIONS AT 2TB & 3TB. REACTOR 2X AND CAPACITOR 4C ARE USED TO EXTEND THE STABILIZING RANGE FOR LARGE GENERATORS. MOVE JUMPER ON 3TB TO TERMINAL A TO B TO INCREASE PERFORMANCE ON SMALL GENERATORS.





4. FOR REACTIVE CURRENT DIVISION WHEN PARALLELING GENERATORS CONNECT 6CT AS SHOWN. PHASE SEQUENCE MUST BE L1-L2-L3. FOR REVERSE PHASE SEQUENCE, REVERSE CONNECTIONS TO N AND P.

6. FOR DETAILS ON 10P, 1SS, 6CT AND 7CT, SEE REGULATOR SUMMARY FOR PARTICULAR APPLICATION.

7. ALL RHEOSTATS SHOWN CONNECTED FRONT VIEW. USE #16 JUMPER WIRE BETWEEN STANDOFFS AND RECTIFIERS.

ALL WIRE TO BE #12 BLACK M-9729495P5A UNLESS OTHERWISE DESIGNATED. ALL WIRE MARKED 16 TO BE #16 BLACK M-9729494P2125. ALL WIRE MARKED 20 TO BE #20 BLACK M-9729494P1625.

CIR. NO.	WIRE SIZE	SEQUENCE OF CONNECTIONS
1		1REC, 1TB
2	16	1TB, 6P, 6SW
3		2REC, 18REC, 7CD, 1CR, 1TB, 1CD
3	16	18REC, 8TB
4		2REC, 21REC, 10TB, 8T, 1TB
4	16	8T, 1CR, A8TB(C)
6	16	4TB(C), A8TB(A)
8	16	1TB, 10TB
9	16	1TB, 10TB
10	16	1TB, 10TB
12	16	1ZD, A8TB(B)
13		1REC, 1CD, 1TB, 1CR
25	20	3P, 3TB
35	20	7CD, 8TB
36		16REC, 19REC, 10TB, 1CFR
37		15REC, 17REC, 10TB, 1CFR
38		20R, 16REC, 7CD
50	16	6SW, 6P, 10TB, 9T
51		1TB, 10TB
51	16	1TB, 1CR
52	16	6P, 10TB
53		9T, 8T, 10TB
54		9T, 8T, 10TB
55		22REC, 9T, A8TB(D), 10TB, 8T
56		21REC, 10TB(C)
59		20R, 10TB

2X CONNECTIONS

LEAD NO.	CIR. NO.	CONNECT TO
1	25	3TB
2	16	3TB

7T CONNECTIONS

LEAD NO.	CIR. NO.	CONNECT TO
1	51	10TB(J)
2	4	10TB(A)
3	30	8TB
4	3	8TB
5	31	8TB

8. CURRENT SHOWN BY EACH CIRCUIT IS MAXIMUM CURRENT EXPECTED FOR NORMAL OPERATION.

9. ADJUST LEAD 2, ON REACTOR 8SX TAPS 2 TO 8 TO POSITION WHERE AC VOLTAGE BEGINS TO DROOP, THEN MOVE TO NEXT LOWER TAP. LET GENERATOR COAST TO STOP AND OBSERVE FIELD CURRENT. FIELD CURRENT SHOULD NOT INCREASE MORE THAN 20 TO 30%.

OBSERVE GENERATOR TRANSIENT REPONSE BY APPLYING AND REJECTING LOAD. UNDERFREQUENCY LIMIT SHOULD BE SET ON TAP WHERE TRANSIENT REPONSE IS NOT AFFECTED.

1SS SEL. SWITCH		POSITIONS							
CONTACTS HANDLE END		*	OFF	*	AUTO	*	TEST	*	MAN
1 — 2	1	X	X	X	X	X			
	2	X				X	X	X	X
3 — 4	3	X	X	X	X	X			
	4	X				X	X	X	X
5 — 6	5				X		X		
	6				X		X		
7 — 8	7		X						
	8				X				
9 — 10	9						X		
	10								X

X DENOTES CLOSED CONTACT.

WIRE TABLE 8CB

LEAD NO.	CIR. NO.	CONNECT TO
1	4	A8TB(C)
2	55	A8TB(D)
2 *	55	8SX(5)
3	80	8SX(1)
4	81	8SX(9)
5	82	8SX(10)
8	12	A8TB(B)
10	6	A8TB(A)

*PIGTAIL ENOUGH TO REACH TERM. 2-8 ON 8SX.

TYPICAL CONNECTION DIAGRAM

Figure 8

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 principle renewal parts list is furnished with equipment.

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