GEK-12510

INSTRUCTIONS

3S7930SA216

STATIC VOLTAGE REGULATOR

FOR

AC GENERATOR

GENERAL ELECTRIC

CONTENTS

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INTRODUCTION

The 3S7930SA216, Voltage Regulator controls the voltage of a 50 or 60 cycle, AC generator by controlling its excitation; either directly on small machines, or through an exciter on large machines. Silicon controlled rectifiers control power delivered to the machine field. The regulator is completely static, having no moving parts to perform the regulating function. A relay is used to assure voltage build-up or for flashing.

RECEIVING, HANDLING AND STORAGE

RECEIVING AND HANDLING

Immediately upon receipt, the equipment should be carefully unpacked to avoid damaging the apparatus. 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.

DESCRIPTION

The 3S7930SA216, 8 amp voltage regulator is a flat panel and is usually applied as a static regulator to drive the field of a rotating exciter.

GENERAL

The 3S7930SA216, voltage regulator may be furnished in an enclosure. Some models may include various accessories and (or) instrumentation. Various means of assuring generator voltage buildup may be applied.

The voltage adjusting potentiometer on all models may be removed for remote mounting by user, as required. The regulator contains a 3S7932MA190 component board subassembly.

BUILD-UP RELAY

A 3S2791G138B4 relay is furnished on the 3S7930SA216 voltage regulator to assure automatic voltage build-up on generators with rotating exciters but with low residual voltage output.

The 3S7930SA216 voltage regulator has no provisions for flashing from external source.

PARALLELING GENERATORS

Droop compensation is furnished for dividing reactive current when paralleling generators, or for line drop compensation.

C. T. FORCING

Relay current forcing is furnished, on applications where it is necessary to maintain excitation and sustained short circuit current for selective relay tripping.

MANUAL-AUTO-CONTROL

Selector switch and manual field rheostat is furnished to facilitate "Manual" control as required per application.

UNDERFREQUENCY LIMIT

Under-frequency limit is provided to prevent over-excitation of the exciter field when generator is idled, or when starting up or shutting down generator.

TRANSFORMERS

Transformers may be furnished to provide proper input voltage to regulator where these voltages are not available directly from generator.

INSTALLATION

The regulator is normally furnished without an enclosure and should be mounted so that it is accessible, but so that personnel are protected from exposed voltages. If the regulator is to be mounted in an enclosure, a reasonable circulation of air must be allowed to keep the ambient temperature below +55°C. The regulator must be mounted upright as indicated on outline drawing furnished with equipment. Voltage adjusting potentiometer may be removed and remotely mounted, if required.

NOTE

MAKE CONNECTIONS TO REGULATOR PER DIAGRAM FURNISHED WITH PARTICULAR MODEL. CHECK POSSIBLE VARIATIONS OF APPLICATION PER NOTES ON REGULATOR CONNECTION DIAGRAM.

OPERATION

CAUTION

THE HEAT SINKS ON REGULATOR ARE AT ABOVE GROUND POTENTIAL.

ADJUSTMENTS

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

UNDERFREQUENCY LIMIT ADJUSTMENTS

To adjust underfrequency limit, start with lead 2 on reactor 8SX terminal 5. Start prime mover and bring up to speed. Flash generator field if required. Set "Voltage Adjust" to obtain proper voltage. See Figure 8.

Remove lead on tap 10 of 8SX; generator terminal voltage should not be affected. If voltage tends to rise when lead was removed, set lead 2 on next lower tap until generator voltage shows no effect. Replace lead and stop generator. Observe exciter field current as generator comes to rest. This current should not exceed 30%. If field current exceeds 30% or more, move lead 2 to higher tap on 8SX.

Observe generator transient response by applying and rejecting load. Underfrequency limit should be set on tap where transient response is not affected.

Turn "Gain" clockwise to improve regulation as generator is loaded. "Gain" should be set to allow approximately 1% voltage drop going from a noload to a full load condition on the generator. It will be necessary to correct voltage level with "Voltage Adjust" each time the "Gain" is changed.

To obtain optimum response when applying and rejecting load, vary the "Stabilizing" adjust (3P) and the connections on 2TB. The "Stabilizing" adjust (3P) acts as a fine adjustment; while the connection on 2TB acts as a coarse or range adjustment. Diagrams furnished with regulator give connections on 2TB for increasing or decreasing stabilizing. Figure 1 shows typical response when applying and rejecting load.

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

PRINCIPLES OF OPERATION

GENERAL

The 3S7930SA216 voltage regulator operates by taking power from the generator output; rectifying and controlling the power to furnish DC excitation for the exciter field. Refer to Figure 9, a typical elementary diagram. An exact diagram is furnished with regulator.

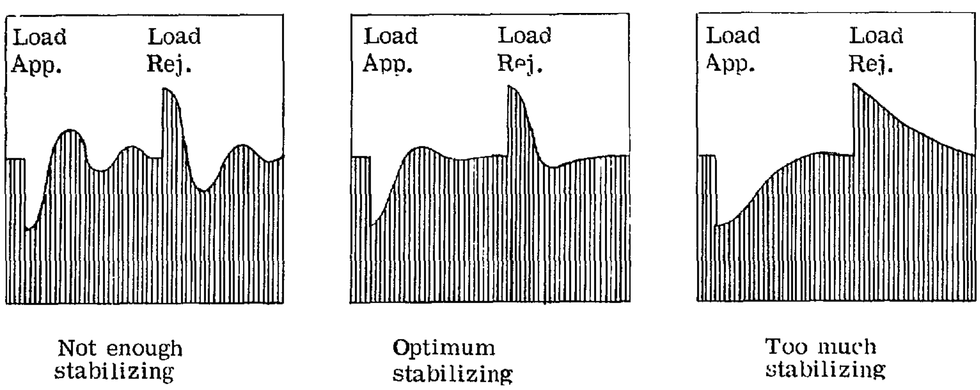
SILICON CONTROLLED RECTIFIERS

The DC excitation power for the exciter (or generator) field is furnished by a single-phase, full-wave bridge using silicon controlled rectifiers (SCR's) in two legs of the bridge. The SCR's (1CD and 2CD) are phase controlled to control the power delivered to the machine field.

An SCR is a simi-conductor device 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 the pulse is applied, the SCR will conduct and remain conducting until the anode voltage goes negative and the current goes to zero.

The voltage regulator controls the exciter field voltage by controlling the firing of 1CD and 2CD on respective positive half cycles. See Figure 2.

If SCR's fire early in respective positive half cycles (Figure 2b), the regulator delivers a larger average voltage to the exciter field. If the SCR's fire late in respective positive half cycles (Figure 2a) the regulator delivers a smaller average voltage to the exciter field. Although the voltage applied to the



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

Figure 1. Stabilizing Adjustment

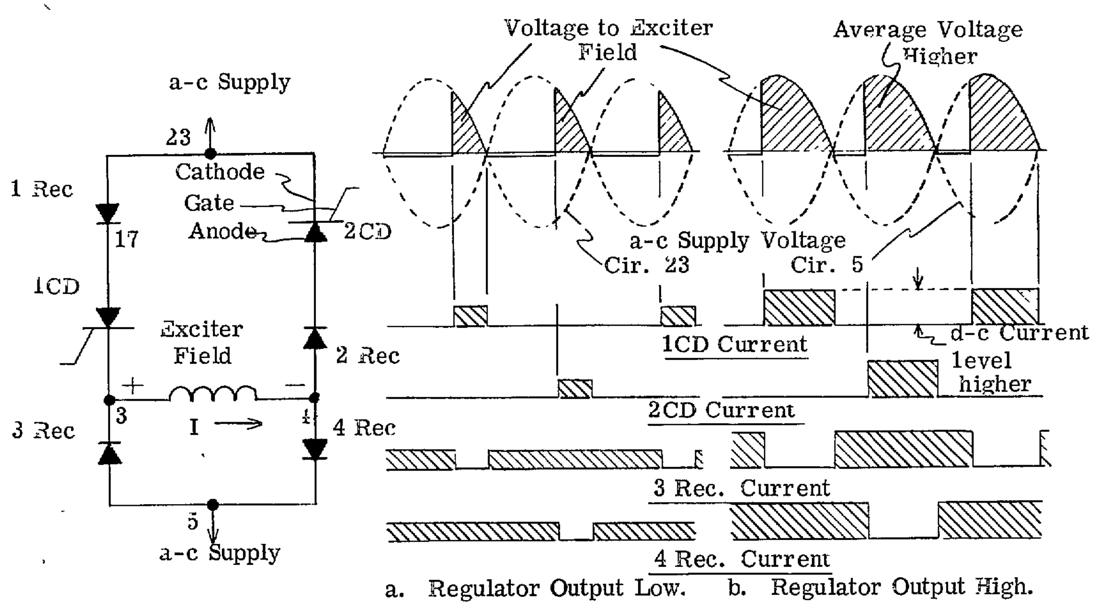


Figure 2. Phase Controlled Output of SCR's (1CD and 2CD).

exciter field is portions of a sine wave, the current through the field is continuous because of the inductance of the field winding. The field current "free-wheels" through 3REC and 4REC during the time that neither 1CD or 2CD is conducting.

SERIES RECTIFIERS - 1REC and 2REC

Rectifiers 1REC and 2REC are series diodes that take most of the inverse voltage during the negative half cycles; thus, protect the SCR's from permanent damage due to excess transient inverse voltage. Resistors 7R and 8R provide leakage paths around 1CD and 2CD; thus, cause most of the inverse voltage to appear across 1REC and 2REC.

Rectifiers 1REC and 2REC also furnish the initial DC voltage to the exciter field when the build-up relay is used on machines with low residual voltage.

FIRING CIRCUIT

The pulses for firing 1CD and 2CD come from saturable reactors 1SX and 2SX respectively. Rectifiers 5REC and 6REC allow voltage to appear across 1SX and 2SX (1 to 5) on the respective half cycles when 1CD and 2CD anodes are positive. See Figure 3, which illustrates firing on 1CD. When circuit 23 is positive, rectifier 5REC allows current to flow through 1SX (1 to 5) and 9R. During the early part of the half cycle (before 1SX saturates) the impedance of 1SX is high compared to 9R; thus, most of the supply voltage is across 1SX. When 1SX has accumulated enough volt-seconds to saturate, its impedance will drop sharply; therefore, current will increase and transfer most of the supply voltage to 9R.

The increasing voltage across 9R forces current through the gate-to-cathode of 1CD; therefore, 1CD will fire at the point on the supply voltage cycle where 1SX saturates. The firing of 2CD is identical to the firing of 1CD, except on alternate half cycles.

Phase control of the firing of 1CD and 2CD is provided by controlling the saturation point of 1SX and 2SX on each positive half cycle. Control of the saturation point is provided by limiting the amount that flux in 1SX and 2SX during the negative or off cycle. The amount of reset flux is controlled by the level of DC error current through the control windings (8 to 6) of 1SX and 2SX. See Figure 4.

SENSING CIRCUIT AND REFERENCE

The sensing circuit consists of rectifiers 7, 8, 9 and 10REC; resistor 1R; and capacitor 1C. This circuit produces a DC voltage that is proportional to AC line voltage. If generator wave shape is distorted, the DC sensing circuit voltage will more nearly follow the average (or RMS) line voltage instead of peak line voltage.

The output DC voltage from the sensing circuit produces both the reference and feedback voltages. See Figure 4.

The 62 volt reference voltage across zener diode 1ZD does not vary with changes in line voltage.

The feedback voltage is a portion of the sensing circuit voltage and varies with AC line voltage. The error voltage is the difference between the reference voltage and feedback voltage. The error voltage causes current to flow from 1P to 1ZD; thus, controls the reset flux in 1SX and 2SX. There is always a slight error voltage, as required to regulate AC line voltage under a particular condition.

Should line voltage drop, the error current through 1SX and 2SX (8 to 6) will decrease. The smaller

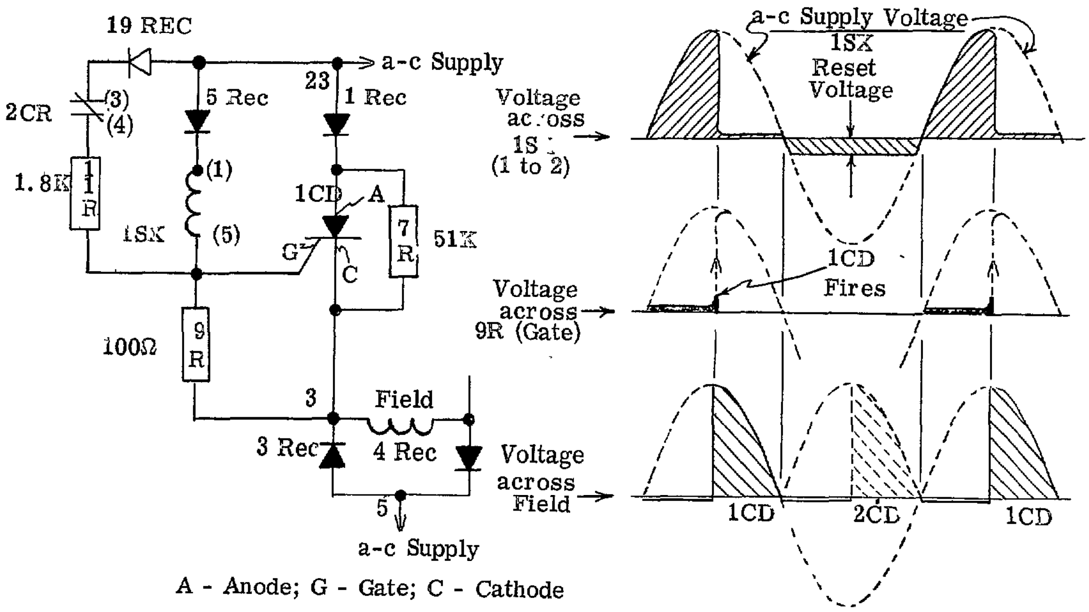


Figure 3. Operation of Firing Circuit

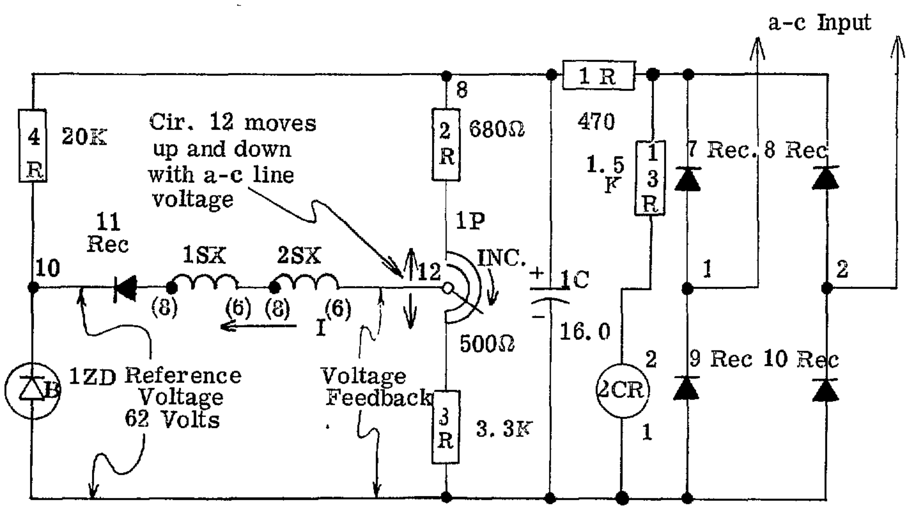


Figure 4. Sensing and Comparison Circuit

current will reset the flux in 1SX and 2SX cores a smaller amount; therefore, 1SX and 2SX will saturate earlier on positive half cycles to fire 1CD and 2CD earlier and increase voltage to exciter field. The increased excitation will increase AC line voltage to correct the original error. The opposite of the above action will take place if line voltage should rise.

STABILIZING AND POSITIVE FEEDBACK CIRCUIT

Control windings of 1SX and 2SX are also provided for positive feedback to increase system gain, and transient negative feedback to stabilize the system.

Both positive and negative feedback circuits take the regulator output, or exciter field voltage, and feed back signals to 1SX and 2SX windings for "Gain" and "Stabilizing". Reactor 2X is a filter to provide a reasonably smooth DC feedback voltage.

The positive feedback signal (through 2P, 6R, 1SX and 2SX windings 9 to 10) adds to the original error signal through windings 8 to 6 to increase system gain; thus, provide close control of AC line voltage.

The transient negative feedback signal (through 3P, 3C or 4C, 1SX and 2SX windings 12 to 11) transiently opposes the original error signal through windings 8 to 6, thus, retards action of system as required for stabilizing. Changing jumper connections on 2TB provides a range of stabilizing capacity.

HARMONIC SUPPRESSION FILTER

Reactor 1X, capacitor 2C, and resistor 5R are provided to reduce the distortion of generator wave shape caused by the SCR full-wave bridge circuit.

Because of the fast "turn-on" characteristics of an SCR, the current from the generator line supplying the SCR must increase by the amount of exciter field current in several microseconds. This high rate of change of current will usually cause a spike or knotch in the generator wave; thus, may create some unwanted harmonics. This knotching or distortion is usually negligible on applications using rotating exciters.

The input to the SCR's is filtered by 1X, 2C, and 5R, so that the rate of change of current is smaller and wave-shape distortion is reduced.

FLASHING OR BUILD-UP CIRCUIT

To assure generator voltage build-up, a build-up or flashing relay is provided. See diagram furnished with regulator.

The build-up relay is furnished as an aid to generator voltage build-up on generators with rotating exciters but low residual voltage output. In this case, relay contacts short 1SX and 2SX firing reactor gates 1-5 and apply firing voltage to the gates of 1CD and 2CD through resistor 11R to turn 1CD and 2CD full on and apply full available voltage to the exciter field; thus assuring automatic system voltage build-up. On many applications, such as small and (or) high speed machines where generator residual voltage is high, the system voltage will build-up automatically without a build-up relay.

MANUAL CONTROL

Manual Control is provided by controlling the DC voltage supplied from separate rectifiers to the exciter field.

To facilitate "Off-Man-Test-Auto" Control a separate DC source supplied by transformer 1T and rectifiers 21, 22, 23, 24 Rec and is controlled by Manual field rheostat 10P. Transfer switch 43 is used to switch to the desired operating positions.

Test

To test regulator turn transfer switch 43 to "test" position. The generator is controlled by rheostat 10P the same as in the "Manual" control position.

In "test" position 15R, a 150 ohm resistor is connected across terminals F+ and F- to load the regulator. Connect 0-150 volt DC meter across regulator terminals F+ and F-. Rotate voltage adjust rheostat 1P and observe voltage on DC meter; voltage should increase and decrease as 1P is rotated back and forth across the point where regulator setting agrees to the generator output after setting 1P to a nominal regulator output voltage decrease.

Now decrease generator voltage with rheostat NOP. This should cause an increase in regulator output voltage. Conversely, an increase in generator voltage will cause a decrease in regulator output voltage.

If regulator checks out as stated above, it is ready for "automatic" operation.

"DROOP" CIRCUIT FOR PARALLELING GENERATORS

A "Droop" circuit (or line drop compensator) is connected in series with the incoming line and the regulator sensing circuit. The droop circuit consists of a loading rheostat (used with a standard 5 amp CT) that 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 upon the phase relationship. See Figure 5. Where 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 5A). Should reactive current tend to increase in the lagging direction (Figure 5B), the regulator sensing circuit will see a higher-than-normal voltage, indicating over excitation; 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 5C), the regulator sensing circuit will see a lower-than-normal voltage, indicating under excitation; thus, the regulator will increase excitation to raise line voltage, thereby decreasing the leading reactive current.

When connections from the loading rheostat are reversed, the reverse of the above described action takes place so that the generator terminal voltage is raised as lagging reactive current increases, the amount of compensation depending upon the setting of the CT loading rheostat. The circuit will, therefore, compensate for line drop due to reactive current. A line drop compensation accessory may also be furnished with a loading rheostat and loading reactor in the CT circuit. In this case, the loading resistor would be adjusted to compensate for reactive current line drop and the loading reactor adjusted to compensate for resistive current line drop.

OVERVOLTAGE PROTECTION

Overvoltage protection is provided in the "Automatic" operating position by overvoltage relay OVR. This feature does not function in the "Manual"or "Test" position.

Relay OVR is set to trip at a predetermined voltage and when the generator voltage reaches this value OVR will close normally open contact to pick up TCR.

Relay TCR has time delay which is adjustable from 1/5 to 180 seconds. This should be set so that it will ride through normal overvoltages. When TCR times out; it closes normally open contact which picks MCR.

Relay MCR closes contacts at M3, M4 and M5 and opens contact at F+ thus returning the regulator to manual control. Normally closed MCR contact at F+ is overlapped with MCR contact at M3 to prevent opening the exciter field when changing from "Automatic" to"Manual" or vice-versa.

Transfer switch 43 must be turned to the "off" position after tripping on overvoltage before going to "Test" or "Automatic" positions.

CURRENT FORCING

Current transformer forcing is provided to supply excitation to the exciter field; to sustain generator short circuit current as required for selective relay tripping; when associated regulator power source fails, due to short circuit fault on generator output.

Since the voltage regulator output and the current transformer forcing unit are in series, either can supply machine excitation.

When the voltage regulator is operating normally, relay 1CR is picked up and shorts out bridge rectifier 15-16-17-18 Rec and current transformer A7CT and B7CT. This prevents the forcing circuit from supplying field excitation. The voltage regulator therefore furnishes voltage to the exciter field normally and the current transformer current circulates through the shorted rectifier bridge.

When the voltage regulator power source fails or falls below 1/3 nominal voltage, 1CR will drop out and open contact across bridge rectifiers 15, 16, 17, 18 Rec and current transformers. The current transformers will then supply DC excitation to the exciter field through bridge rectifiers 15, 16, 17, 18 Rec to sustain generator short circuit current. See Figure 6.

Since there is no control during the current forcing condition and if the current transformer output is too small, the system will collapse and will not sustain short circuit excitation. If the current transformer output current is larger than a critical

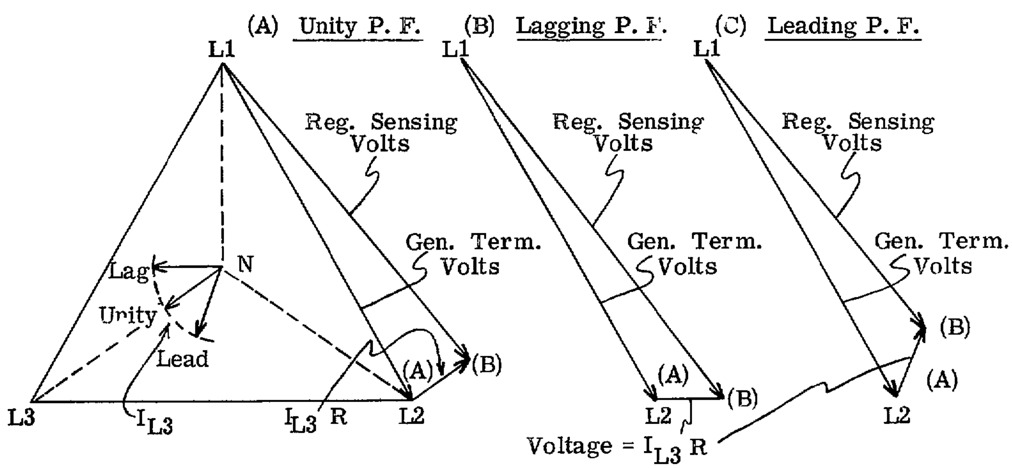


Figure 5. Operation of Paralleling (DROOP) Circuit

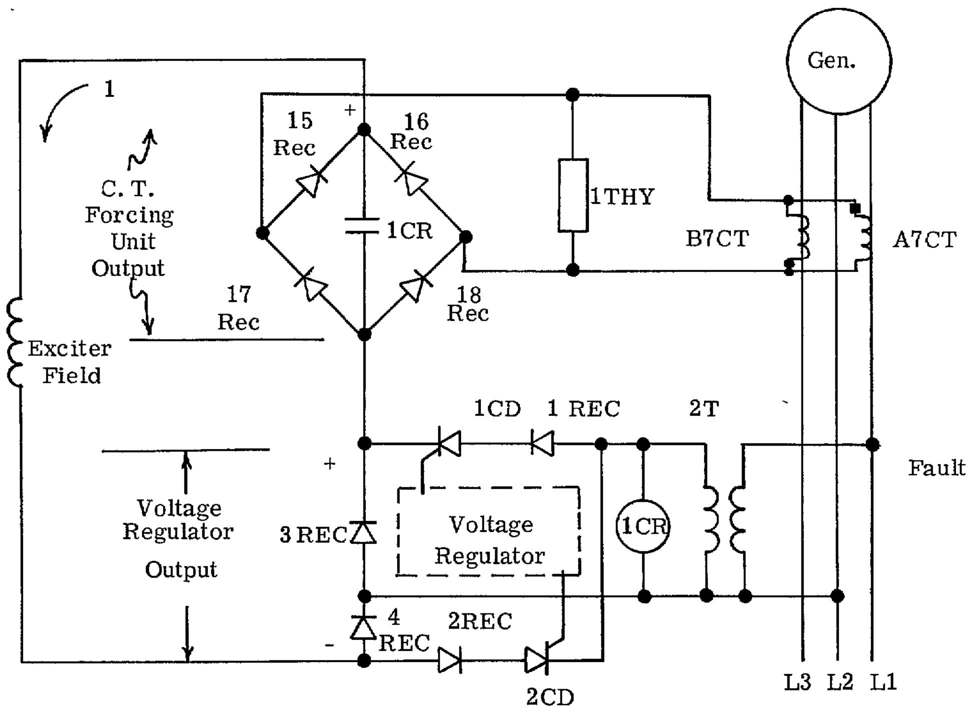


Figure 6. C. T. Forcing Unit Operation

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 increasing the C. T. secondary 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 7.

The setting of the C. T. secondary turns can be established analytically, as shown in Figure 7. 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 7).

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 7 by picking the C. T. turns curve that crosses the critical excitation line nearest the required excitation point X.

UNDERFREQUENCY LIMIT

Transformer 8SX is frequency sensitive below approximately 50 cycles. As generator frequency is decreased, voltage across 9 and 10 increases causing transistor 8Q to turn on. Current will now flow through windings 1SX and 2SX (8 to 6) through 8Q as well as through zener diode 1ZD. This increase in current through 1SX and 2SX will cause a decrease in regulator output. See Figure 8.

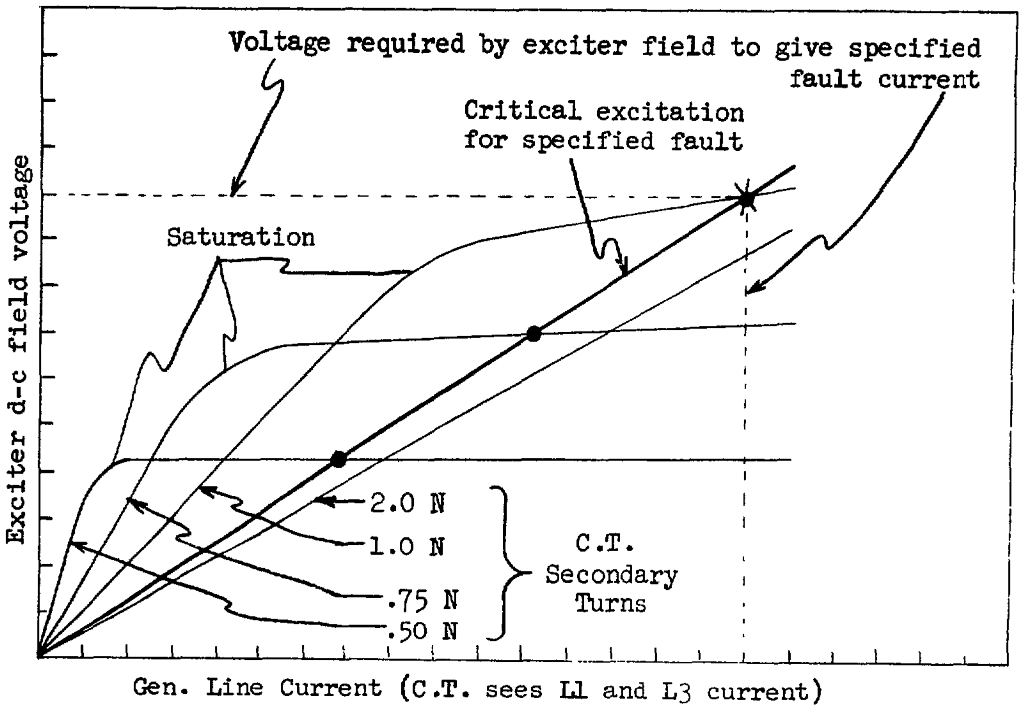


Figure 7. Action of Saturating C. T. On Faults

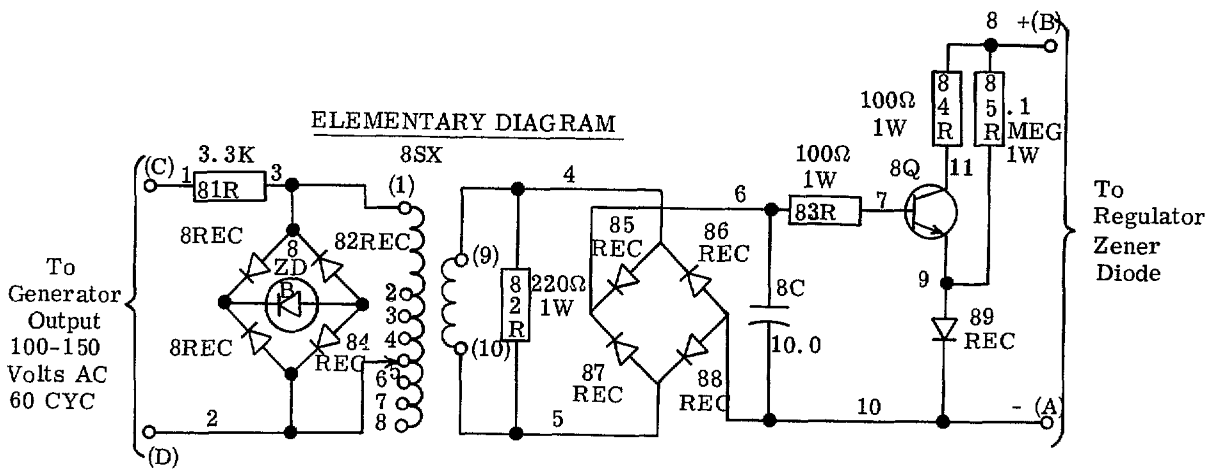


Figure 8. Elementary Diagram of Underfrequency Limiter

MAINTENANCE

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

TROUBLESHOOTING

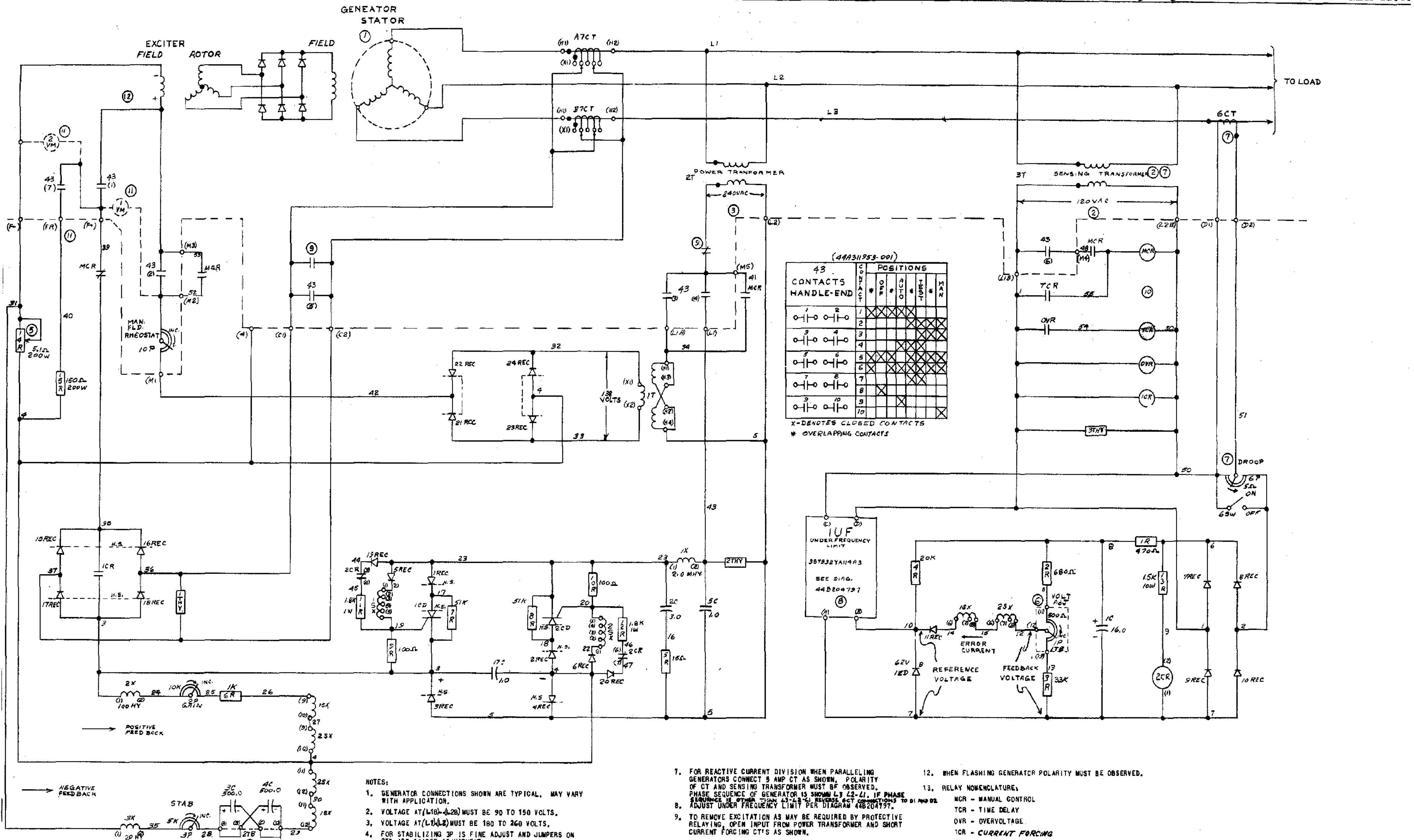
The following chart may be helpful for troubleshooting and locating faulty components; however, a thorough study of the Principles of Operation will be the greatest aid in troubleshooting.

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. 1, 2, 3, and 4REC d. 2CR
	2. No residual voltage out of generator	a. Reverse exciter field connections b. Flash field with external DC power source. Observe polarity.
II. Generator voltage goes to ceiling	1. No feedback voltage	a. "Droop" circuit connections b. 1P connections c. 1ZD d. 7, 8, 9. and 10REC
	2. No control of SCR's	a. 1CD and 2CD b. 2CR c. 1SX and 2SX
III. Poor voltage regulation	1. Loss is system gain	a. "Gain" adjust per OPERATION b. Exciter output to generator field c. Regulator output for unbalanced firing of 1CD and 2CD
	2. Distorted input to sensing circuit	a. For unbalanced 3-phase loads b. Generator wave shape
IV. System Unstable	1. Excess system transient gain	a. "Gain" adjust per OPERATION b. "Stabilizing" adjust per OPERATION c. Add extra capacity on 2TB (A and D)

TROUBLE	PROBABLE CAUSE	CHECK
V. Slow system response	1. Low system transient gain	a. "Stabilizing" adjust per OPERATION b. Loss in system gain; check step III
VI. Paralleled generators will not divide reactive KVA	1. "Droop" circuit	a. Reverse connections from loading rheostat b. Increase "Droop" adjust c. Check generator line phase sequence. Must be L1-L2-L3.

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.



NOTES:

1. GENERATOR CONNECTIONS SHOWN ARE TYPICAL. MAY VARY WITH APPLICATION.
2. VOLTAGE AT (L1B)-(L2B) MUST BE 90 TO 150 VOLTS.
3. VOLTAGE AT (L1)(L2) MUST BE 180 TO 260 VOLTS.
4. FOR STABILIZING 3P IS FINE ADJUST AND JUMPERS ON 2TB ARE COARSE ADJUSTMENT.
   FOR MAX. STABILIZING JUMPER A TO B AND C TO D
   FOR MED. STABILIZING JUMPER A TO B.
   FOR MIN. STABILIZING JUMPER B TO C.
5. SET 14R RESISTANCE EQUAL 1/4TH EXCITER FIELD RESISTANCE--COLD.
6. VOLTAGE ADJUSTOR MAY BE REMOVED FOR REMOTE MOUNTING IF REQUIRED. MOTOR OPERATED RHEOSTAT IS SOMETIMES FURNISHED, SEE SUMMARY SHEET FOR MATERIAL FURNISHED
7. FOR REACTIVE CURRENT DIVISION WHEN PARALLELING GENERATORS CONNECT 5 AMP CT AS SHOWN. POLARITY OF CT AND SENSING TRANSFORMER MUST BE OBSERVED. PHASE SEQUENCE OF GENERATOR IS SHOWN L3 L2-L1. IF PHASE SEQURNCE IS OTHER THAN L3-L2-L1 REVERSE 6CT CONNECTIONS TO D1 AND D2
8. ADJUST UNDER FREQUENCY LIMIT PER DIAGRAM 44B204797.
9. TO REMOVE EXCITATION AS MAY BE REQUIRED BY PROTECTIVE RELAYING, OPEN INPUT FROM POWER TRANSFORMER AND SHORT CURRENT FORCING CT'S AS SHOWN.
10. RELAYING OVR, TCR, AND MCR PROVIDE FOR TRANSFER TO MANUAL CONTROL IF A SUSTAINED OVERVOLTAGE OCCURS. 1SS MUST BE RETURNED TO "OFF" TO RESET THIS CIRCUIT.
11. RESISTOR 15R PROVIDES FOR A DUMMY LOAD ON VOLTAGE REGULATOR WHEN IN "TEST" POSITION. IN THIS POSITION 2VM (0-200 VTS) COULD MONITOR REGULATOR OUTPUT FOR TROUBLE SHOOTING. 1VM (+200-0-200 VTS) COULD BE USED FOR BALANCING VOLTAGE REGULATOR IN "TEST" POSITION TO PREVENT BUMP WHEN TRANSFERING TO "MANUAL" OR "AUTOMATIC".
12. WHEN FLASHING GENERATOR POLARITY MUST BE OBSERVED.
13. RELAY NOMENCLATURE:
    MCR - MANUAL CONTROL
    TCR - TIME DELAY
    OVR - OVERVOLTAGE
    1CR - CURRENT FORCING
    2CR - AUTOMATIC BUILDUP
14. ALL RELAY CONTACTS SHOWN, WITH RELAYS DE-ENERGIZED.

Figure 9. Typical Elementary Diagram

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