GEK-12427B

INSTRUCTIONS

OBSOLETE

STATIC EXCITER-REGULATOR EQUIPMENT

3S7931EA100 SERIES

GENERAL ELECTRIC

CONTENTS

3S7931EA100 SERIES
STATIC EXCITER-REGULATOR EQUIPMENT

INTRODUCTION

The 3S7931EA100 silicon controlled rectifier (SCR) Static Exciter Regulator equipment performs its regulation and excitation function by monitoring generator line voltage and current and producing the proper excitation conditions required by the machine.

The power potential transformers (PPT's) and saturable current transformers (SCT's) are the main source of power for the generator field; at no load all field power is obtained from the PPT's and from the SCT's at full load. The power from these two units is rectified by the three-phase silicon diode rectifiers and then applied to the field of the generator.

The primaries of the SCT being on the neutral side of the machine provides some inherent self regulation. Theorectically, this self regulation should completely compensate for load changes, however, generator saturation, field heating, and other secondary effects make it necessary to add more compensation. This extra compensation is obtained by saturating the SCT with a d-c control winding current. The amount of d-c required is obtained from the automatic regulator whose input continuously monitors line current and voltage when in the automatic mode of operation. Also, a manual control of the d-c control winding current is provided.

The automatic regulator may be equipped with an underexcited reactive - ampere limit circuit, which prevents the excitation of the machine from being reduced to a point below a desired minimum value. The regulator and underexcited reactive - ampere limit components are located on separate panels.

A reactive current compensator is always included to permit proper division of reactive current and to restrict the flow of circulating currents between paralleled machines. In the case of single machines, its connections may be reversed to reduce the effective impedance of the line transformers. An active-and-reactive-current compensator is occasionally provided to facilitate the regulation of voltage at some point remote from the machine terminals. Combinations of the above two compensators can be furnished which will accomplish both functions simultaneously. The excitation equipment also includes a start-up circuit for field flashing, rheostat for manual control, the machine field breaker, and the necessary control transformers, switches, relays, and other components to assure proper operation.

Other components, such as an a-c machine field breaker for a spare exciter, are sometimes furnished. Both the number and the arrangement of auxiliary components vary with the requirements of the particular application. Therefore, it is necessary to refer to the material lists and diagrams provided for each individual application to determine what material is included and what connections should be used. The diagrams shown in this book are for illustrative purposes only; they are not intended to apply to all installations.

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 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 shall 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

COMPONENT ARRANGEMENT

The 3S7931EA--- static-exciter-regulator consists of a main cubicle plus the following separately-mounted equipments:

1. Three power potential transformers, which are floor mounted. They are sometimes mounted in a single case. These step-down transformers supply power for the field and the regulator.

2. Three saturable current transformers, which may be suspended from the bottom of the machine, or be floor-mounted.

3. Regulator control switch, field breaker control switch, transfer volt meter, manual regulator control switch, and exciter voltmeter which are mounted on the control board.

The main cubicle is a floor-mounted enclosure that can be opened at both the front and the back. It usually includes the following units:

1. A 3S7930NA............ Comparison and Trigger Circuit Panel

2. A 3S7932KA............ Underexcited reactive ampere limit panel and limit amplifier panel.

3. A 3S7932CD .... DC Control Panel which contains transfer contactors, protective relays, fuses, and other control devices.

4. A 3S7930ND............... Manual Regulator Panel which may also contain start-up resistors and "dummy load" resistors.

5. Two air-cooled three-phase full-wave bridge rectifiers with high temperature switches.

6. Three linear reactors.

7. One linear field-discharge resistor.

8. Main exciter field breaker.

9. *Thyrite resistors for rectifier protection.

10. Miscellaneous shunts and fuses.

All of the above panels have steel bases except for specially constructed bases for the disconnect switches and field breakers.

STATIC MAGNETIC POWER COMPONENTS AND POWER RECTIFIERS

The power potential transformers (PPT's) have their primary windings wye-connected to the generator terminals. The secondaries of the power potential transformers are connected to the power rectifier section through linear reactors as illustrated in Figure 1. Each saturable current transformer (SCT) primary is located in a line of the generator on the neutral side. The secondary of each saturable current transformer is connected from line to line of the bridge rectifier. When the generator is operating at no-load, the power potential transformers supply voltage to the three-phase full-wave bridge rectifiers so that a uni-directional voltage, VSE, is applied to the field of the generator. Field voltage is controlled by means of the saturable current transformers. The exciting current of the saturable current transformers is virtually proportional to the d-c current, I_c, flowing in their control windings. This exciting current flows from the PPT secondaries through the linear reactors into the SCT secondaries. When I_c is increased, the increased exciting current causes increased voltage drop across the linear reactors so that the input voltage to the bridge rectifier and, consequently, the field voltage is decreased. Thus, no-load terminal voltage of the generator is controlled by the value of I_c.

The control windings of the SCT's are connected in series. A resistor is connected across each control winding to reduce the magnitude of the a-c voltage appearing across the control winding.

When the machine is supplying current to a load, the SCT primaries carry the load current. This primary current helps the secondary current excite the iron core. Therefore, an increase in primary current causes a decrease in secondary exciting current for a given value of I_c. A decrease in secondary exciting current decreases the voltage drop across the linear reactors with the result that bridge rectifier input voltage and field voltage are increased. The turns ratios of the SCT's and the PPT's and the reactance of the linear reactors are selected so that this increase in field voltage which accompanies an increase in load current is approximately the increase necessary to hold terminal voltage constant.

It is an object of the design to maintain required terminal voltage on the machine without requiring a change in control current I_c.

Operation of the static magnetic power components can be better understood by referring to the equivalent circuit illustrated in Figure 2 where:

V - generator terminal voltage (referred to PPT secondary).

X_L - reactance of the linear reactor.

I - Load current (referred to SCT secondary).

R - resistance of the generator field (referred to the a-c side of the rectifier).

I_f - field current (on the a-c side of the rectifier).

I_m - is the magnetizing current of the saturable current transformer (referred to SCT secondary).

X_m - magnetizing reactance of the SCT (referred to the secondary). This reactance decreases with an increase in direct current from the regulator.

From this equivalent circuit the field current at no load is obtained from the generator terminal voltage through X_L. X_m shunts current away from the generator field, R, thus providing control. Under load, the load current, I adds additional current, part of which goes through the generator field R. This equivalent circuit can be simplified by replacing the circuit to the left of point 1 - 2 with an equivalent voltage source and series impedance using Thevenin's

*Registered Trademark of General Electric Company theorem. The simplified equivalent circuit is shown in Figure 3.

Notice that the linear reactors shifts the phase of load current so that the total voltage applied to X_L, X_m, and R is V + j X_L I. This voltage is called the exciter input voltage. The amount of field current required by an a-c generator for various steady state loads can be approximated by using the simplified generator equivalent circuit shown in Figure 4. In this Figure, E represents an imaginary voltage generated by field flux and is always proportional to field current. Xd is the synchronous reactance, which produces the same effect as armature reaction and armature leakage reactance, neglecting magnetic saturation effects. The equation for the circuit in Figure 4 is $-$ E = et + j X_d I.

Since E is proportional to field current, this equation shows the relative amount of field current which the exciter must supply to the generator for various load conditions. Notice that this equation has the same form as the exciter input voltage equation shown in Figure 3. If the value of the linear reactor X_L and the transformer ratios are selected so that V + j X_L I will be proportional to et + j Xd I, then the exciter will supply the proper amount of field current at steady state, regardless of the load or power factor, without a change in regulator output.

Due to various factors, such as a-c generator field heating and field saturation, and other minor effects, it is necessary to trim this action of the PPT's and SCT's to provide the exact compensation for load changes. This is accomplished by the automatic

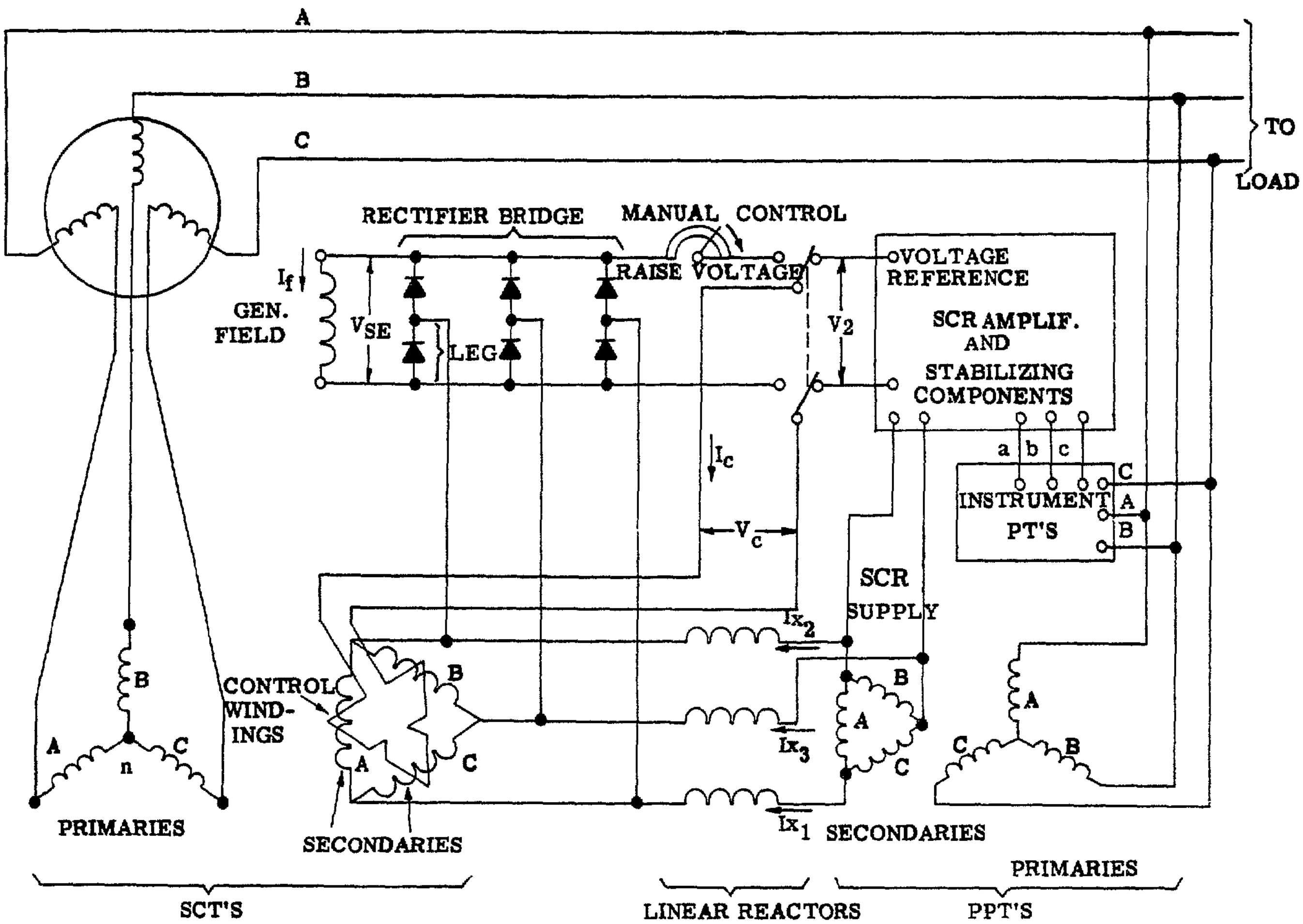


Figure 1. Simplified Static Exciter-Regulator System

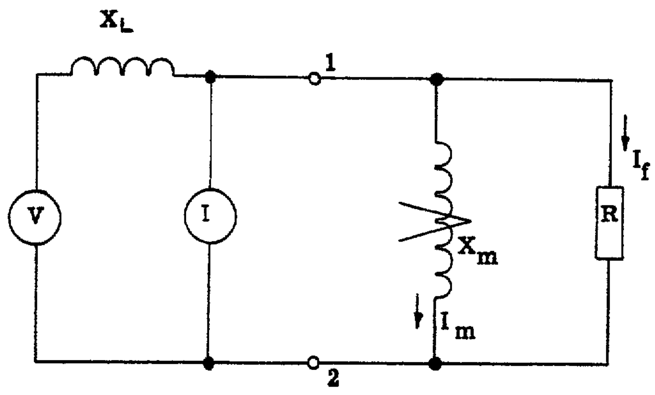


Figure 2. Equivalent Circuit Of Saturable C. T. Type Static Exciter

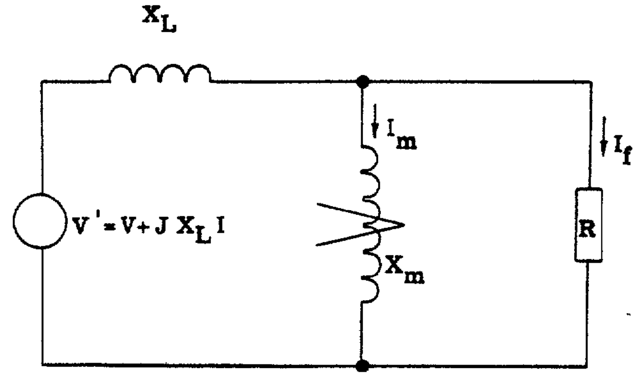


Figure 3. Thevenin's Equivalent of Figure 2

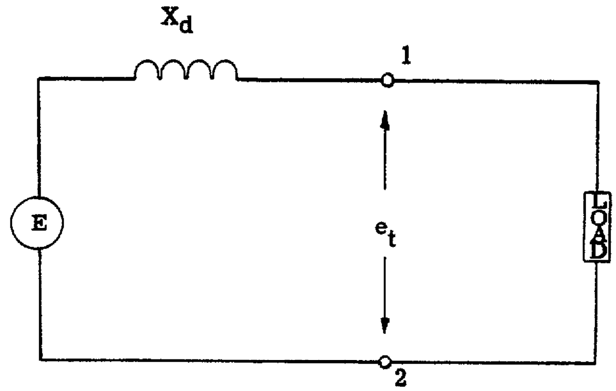


Figure 4. Simplified Generator Equivalent Circuit

regulator or by manually controlling the current in the saturating windings by means of the manual regulator voltage adjuster.

The rectifier complement consists of at least two three-phase bridge rectifiers connected in parallel as shown in Figure 13. Each rectifier bridge is arranged so that it can be completely isolated by opening disconnect switches. These switches are interlocked so that one rectifier bridge only may be removed. A single captive handle provides this feature.

Each three-phase bridge consists of three assemblies, each of which contains six silicon diodes. Two of these diodes are mounted on an aluminum heat sink. These heatsinks are arranged for maximum utilization of convection air. Unless unusually contaminated air, necessitating filters, is used fans are not required.

The electrical connections of the rectifiers are shown in Figure 5. Each rectifier leg consists of three diodes in series to provide sufficient margin for the peak inverse voltages which may appear. Resistor R is connected across each diode to cause equal division of the peak inverse voltage. Capacitor C is connected across each diode to filter high frequency peak inverse voltages which may occur due to power line transients.

The Thyrite resistor, shown in Figure 13, connected across the rectifier bridge protects the diodes from high peak inverse voltages which may occur as a result of abnormal generator operation.

SILICON DIODE FUNDAMENTALS

Figure 6 is a sketch of the waveform across one diode when it is operating properly. During the time interval $t_1 - t_2$, the diode is passing current and the voltage across it is a small amount of forward drop, approximately 1 to 1.5 volts. This forward drop varies only slightly as the current changes and does not change with age.

During the time interval $t_2 - t_3$, the diode is blocking the current and the wave shape is as shown in Figure 6. The peak of this voltage is equal to 1/4 of the peak of the line-to-line voltage applied, if the four diodes in that leg are dividing the reverse voltage equally. The time interval $t_1 - t_2$ is one-half as long as time interval $t_2 - t_3$. Figure 7 shows the waveform across one diode when it is open and there is no parallel rectifier leg to short it out. (This would occur if one rectifier bridge is operating by itself.) During the time interval $t_2 - t_3$, when it normally blocks current, the wave shape is the same as it is on a good diode. During the time interval $t_1 - t_2$, a forward drop occurs. The maximum value of this forward drop is .866 times the peak reverse voltage.

Certain precautions must be taken when dealing with circuits containing silicon rectifiers. Brazing or welding should not be attempted. If soldering is necessary, something must be done to prevent the head from being conducted to the junction. Hipotting should not be done without first shorting out the diodes. Diodes being replaced must be screwed in with the proper amount of torque. (See special data sheet for a particular equipment.)

AUTOMATIC VOLTAGE REGULATOR

See GEK-12428.

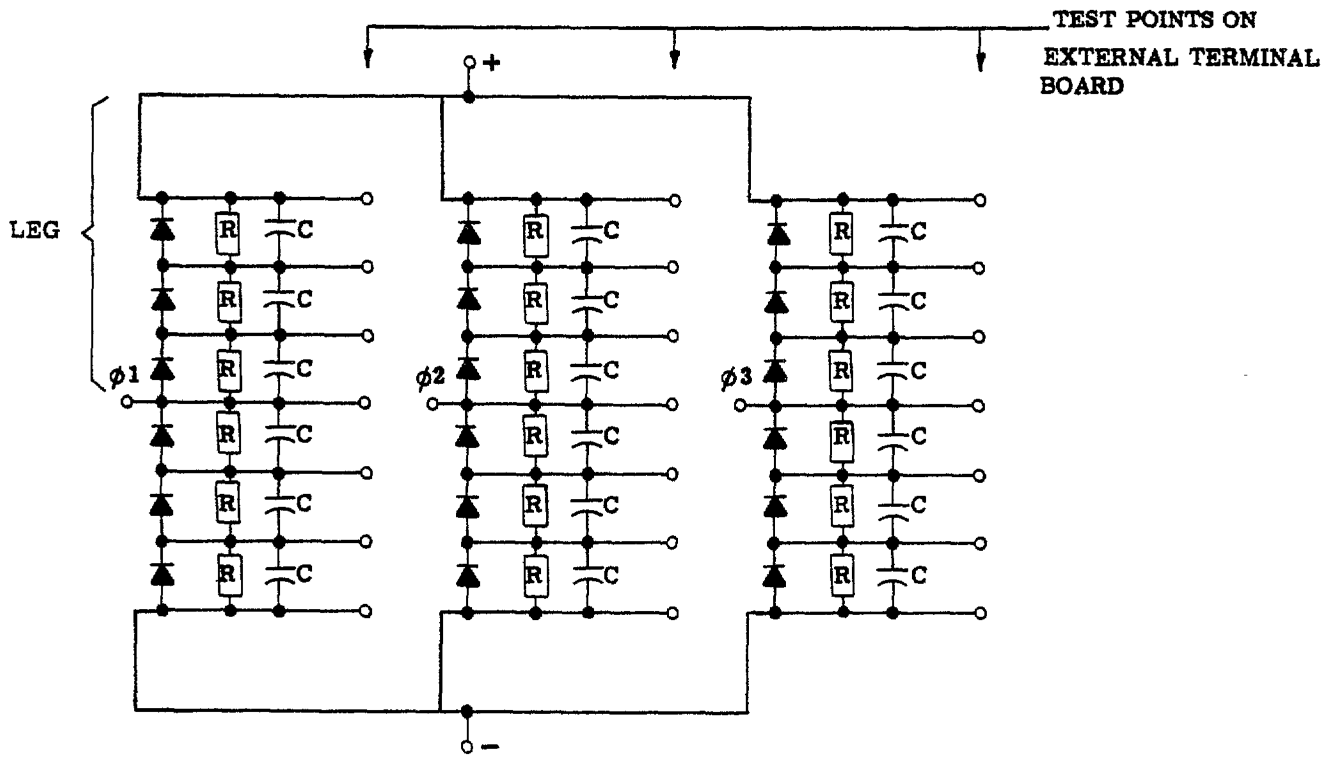


Figure 5. Rectifier Electrical Connections

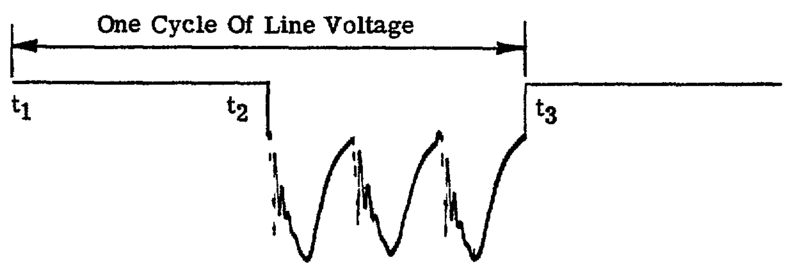


Figure 6. Voltage Across Normal Diode

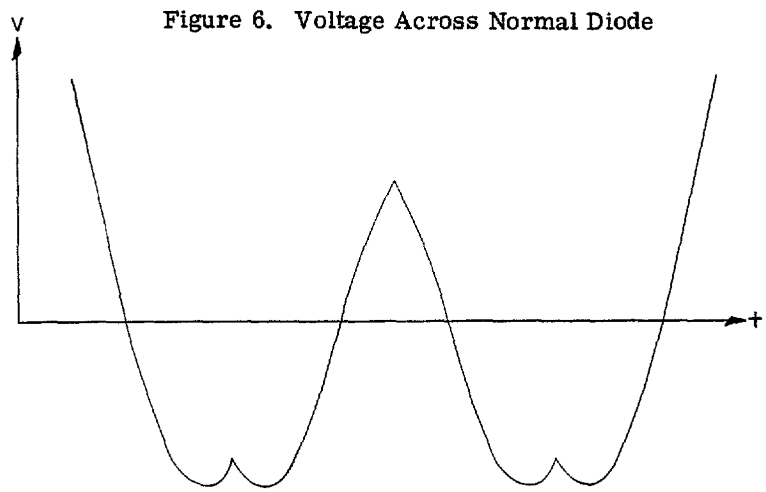


Figure 7. Voltage Across Open Diod

Reactive Current Compensator (RCC)

The RCC is used to apportion reactive kva and to prevent circulating reactive current between a-c machines when two or more machines with individual regulators are operating in parallel. As shown in Figure 8, the adjustable reactor winding is connected to the secondary of a current transformer located in one of the a-c machine lines, while the insulating winding is connected on one phase of the three-phase regulator signal voltage. IT IS ESSENTIAL THAT BOTH WINDINGS OF THE COMPENSATOR BE CONNECTED IN THE SAME PHASE.

The compensator will vary the regulator signal voltage in this phase mainly as a function of the machine reactive current. As the machine overexcited reactive current increases, the voltage will be increased. As a result, the average three-phase signal voltage supplied to the regulator will rise. Due to this higher voltage signal, the regulator will act to reduce excitation, thereby reducing the overexcited reactive current.

If the a-c machine is operating in the underexcited region, the compensator will decrease the average three-phase voltage signal presented to the regulator so that the regulator will act to increase the excitation and decrease the underexcited reactive current. The effect of the compensator can be increased by increasing the active reactance of the unit appearing in the current-transformer secondary circuit. This may be done readily with the tap switches connected to the reactor.

If two a-c machines are connected through transformers, the compensator is not always used as described above. Instead, one winding may be reversed to obtain the opposite effect as that described above. This makes it possible to adjust the transformer impedance to an optimum value of 6 or 7 percent on a reactive basis, improving system voltage regulation.

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

The compensator is built with two independent windings, as shown in Figure 8, so that the current and potential transformer secondaries are electrically separate and both may be grounded.

MANUAL REGULATOR

The manual-regulator voltage adjuster consists of a rheostat (D1P), which is in series with the SCT control winding when operating under manual control. This series combination is supplied from exciter voltage. If the d-c exciter voltage rises above normal, the SCT control current will increase. This acts to return the d-c exciter voltage to normal. If the d-c exciter voltage decreases below normal, the SCT control current will decrease, thereby, raising the exciter voltage toward normal. The exciter voltage can be set for any value necessary for normal operation of the a-c machine by adjusting the manual-regulator voltage adjuster, D1P. It is usually motor-operated, and controlled by a control switch (90S). A "dummy load" resistor, (U6R, Fig. 13), equal to the SCT control winding circuit resistance, is provided to permit smooth transfer from the automatic regulator to the manual regulator.

To accomplish this transfer, the manual-regulator voltage adjuster should be positioned so that the current from the exciter voltage through the adjuster and through the "dummy load" resistor is equal to the current flowing through the SCT control winding circuit from the automatic regulator. The transfer voltmeter (2VM) is used to accomplish this.

AUXILIARY EQUIPMENT

Underexcited Reactive-Ampere Limit (U. R. A. L)

See GEI-98155

Active-and-Reactive-Current Compensator

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

In case line-drop compensation is required on machines that operate in parallel, provision may be made to prevent interference between the compensators. This is accomplished by special connections of the current transformer and compensators.

The reactance of the compensator is divided into a number of equal sections. Taps are brought out from these sections and connected to independently adjustable tap switches, one having coarse adjustments and the other fine. The reactance is variable in one-volt steps based on five amperes in the current transformer. It has a total of 24 steps, and will introduce a maximum of 24 volts total drop in

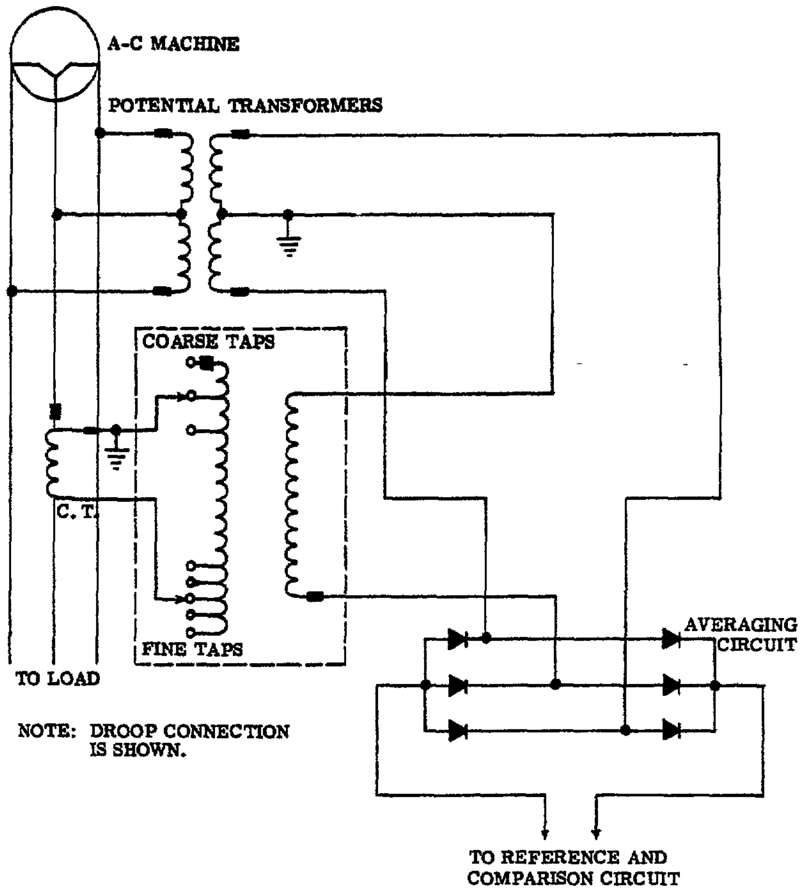


Figure 8. Reactive Current Compensator Connections

the regulator signal voltage circuit with five amperes in the current-transformer secondary. This voltage drop is proportional to the current flowing in the compensator. The resistance portion of the compensator is a 5-ohm rheostat which produces 25 volts drop in the regulator signal with five amperes in the C.T. secondary.

Figure 9 shows the connections for this device when used with a single machine. Isolating windings are provided for both the reactor and resistor to permit grounding the current and potential-transformer secondaries separately. It is essential that the current transformer be in the same phase as the signal-voltage line in which the compensator is connected.

One compensator, connected in one phase of a three-phase circuit, gives an average of approximately 12-percent resistance compensation and 12-percent reactance compensation on a three-phase basis. Two or three compensators may be used if more compensation is required.

CONTROL EQUIPMENT

The regulator equipment usually includes the components required for the control of the regulator. Multi-contact, dead-front, switchboard-type, cam-operated control switches are used for control of the regulator circuits. These switches are used for transfer and control functions, and may be supplied with fixed handles, or with removable handles where protective interlocking is required.

A transfer contactor (TRC, Fig. 13), is provided to apply the automatic regulator output into the saturating windings of the saturable current transformers. Four pairs of contacts are used in the transferring circuit. These are necessary to connect the automatic regulator to the saturating windings and disconnect the automatic regulator from its "dummy load" resistor while disconnecting the manual regulator from the saturating windings and connecting the manual regulator to its "dummy load" resistor. Two contacts in series are used to insure interruption of the arc. A normally-closed contact on the transfer contactor is used to signal the operator if the transfer contactor drops out while the regulator control switch (43, Fig. 13), is in the AUTO position. The "dummy load" resistors are used so that transferring from one regulator to the other can be accomplished without changing the current in the saturating windings, preventing any disturbance of machine voltage or current during transfer.

An overvoltage relay (OVR, Fig. 13), is provided in conjunction with a timing relay (OVX, Fig. 13), to automatically transfer the exciter from automatic

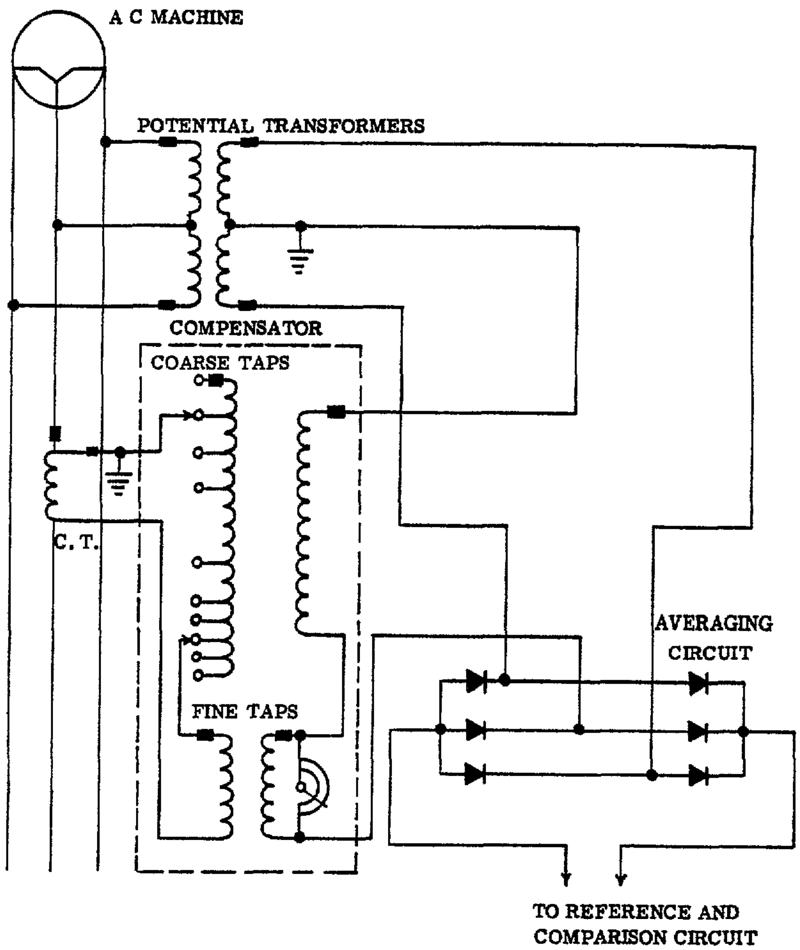


Figure 9. Active-and-Reactive Current Compensator Connections

regulator to manual regulator when the excitation increases above a safe value. The operator is made aware of this transfer by an alarm, actuated by the normally-closed contact on the transfer contactor, which was mentioned above. The start-up contactors (SC1, Figure 13), are energized by the control switch when it is turned to the START UP position. This control switch is spring-loaded to return to MAN when the handle is released.

If the manual-regulator voltage adjuster is motor-operated, it is controlled by relays (D1PR and D1PL, Fig. 13). The former turns the rheostat in the direction to increase resistance which increases the a-c machine terminal voltage. In the same manner, D1PL decreases the resistance, increasing the saturating current and lowering the a-c machine line voltage. These relays are controlled by a switch on the control panel (90S, Fig. 13). The switch is referred to as the "manual-regulator voltage adjuster control switch". Lights or signals indicating the position of the manual-regulator voltage adjuster can be furnished.

P. T. AND C. T. BURDENS

The regulator and underexcited reactive-ampere limit circuits impose a burden on the machine potential transformers which is approximately balanced at 2.5 amperes in each phase at 120V.

The underexcited reactive-ampere limit circuit imposes a burden of about 250 volt-amperes on the current transformer with 5 amperes flowing in the secondary. The reactive-current compensator imposes a burden of 120 volt-amperes on the current transformer at 5 amperes secondary current and with all the reactance in. Approximately 25 volt-amperes is the burden encountered in actual practice since it is usually necessary to turn in only a few steps of the equalizing reactor for a successful parallel operation. The active-and-reactive-current compensator imposes a maximum burden of 225 volt-amperes with 5 amperes in the current transformer secondary and with the total reactance and resistance in the circuit.

INSTALLATION

LOCATION AND MOUNTING

The regulator components are usually supplied in an enclosing case designed for floor mounting. This enclosure should be installed in a well-ventilated, clean, dry location where the normal ambient temperature is not greater than 50°C (122°F).

CONNECTIONS

Connections must be made in accordance with the diagrams supplied with the equipment for each particular installation. Care must be exercised to determine that the connections are correct to avoid damaging the equipment.

The size of the interconnecting wires and cables will vary with the rating of the equipment. Minimum wire sizes are shown on the Elementary diagram.

Care should be taken that the d-c supply is connected with the polarity shown. Reverse polarity will cause the motor on the manual-regulator voltage adjuster to rotate in the wrong direction for a given position of the control switch. In addition, the start-up circuit blocking-rectifiers will prevent start-up current from flowing in the field circuit.

It is extremely important that the PPT's and the SCT's are connected with the polarity-marked ends as shown on the diagram. Failure to do so can cause damage to the equipment or improper operation of the circuit.

Instrument transformers, both current and potential, should be connected as shown in the diagram. The current transformers should be brought to the regulators through a shorting device.

POLARITY AND PHASE ROTATION

When making connections from the exciter to the regulator, polarity should be carefully checked to make certain that the connections are the same as those shown on the applicable diagram. Reactive and active-reactive current compensator polarities must be carefully observed when connections are made. THE CURRENT TRANSFORMERS USED WITH THESE UNITS MUST BE LOCATED IN THE SAME PHASE AS THE SIGNAL-VOLTAGE WINDINGS.

INITIAL OPERATION, TEST, AND ADJUSTMENT

CONTROL CIRCUITS

Control circuits should be tested under such conditions that the excitation system will not affect the operation of the a-c machine. This can be done by leaving the field circuit breakers open.

The start-up circuit contactors can be checked by turning the 43 switch to the START-UP position. SC1 should pickup.

To test the manual regulator control circuit, turn the manual-regulator voltage adjuster control switch (90S, Fig. 13) to the RAISE position. The manual-regulator voltage adjuster should turn in the direction to increase resistance. Turning 90S to the LOWER position should cause the manual-regulator voltage adjuster to turn in the direction to decrease resistance.

To test the transferring and over-voltage portions of the regulator control circuit, turn the regulator control switch (43, Fig. 13) to AUTO. The transfer contactor (TRC, Fig. 13), should pick up. Manually picking up the over-voltage relay (OVR, Fig. 13) should cause the over-voltage auxiliary relay (OVX, Fig. 13), to pick up. Since this is a time delay relay nothing else should occur until the time delay period is over. Then, TRC should drop out and the light or alarm should indicate this on the control board.

STATIC EXCITER

Manual Control

The static exciter - regulator should be tested with the a-c machine operating at normal speed, disconnected from the system, with all field breakers open.

The regulator control switch should be in MAN and the manual-regulator voltage adjuster should be at the extreme LOWER end. This corresponds to a minimum resistance position.

The next step is to close the main-exciter-field circuit breaker. If the exciter voltage builds up to over 50 volts, open the field breaker and recheck polarities. It is expected that the exciter voltage will be near zero, and insufficient to build up the a-c machine line voltage.

If this is true, the 43 switch should be turned to START-UP. The exciter voltage and a-c machine voltage should build up to a small percentage of rated voltage. If, after 5 or 6 seconds, the voltage shows no signs of building up, release the 43 switch, turn the manual-regulator voltage adjuster control switch to RAISE to add some of the resistances, and try again. It should be remembered that the field circuit is highly inductive, and the build-up will be slow. Therefore, it is imperative that all adjustment be made in small increments until the operator becomes familiar with the characteristics of the particular machine. Adding too much resistance in the manual regulator may cause the generator to build up to too high a value.

Once the voltage has started to build up, it should be possible to control it by means of the manual-regulator voltage adjuster. With the a-c machine operating at normal voltage and with the regulator control switch at MAN, turn the manual-regulator voltage adjuster control switch to the RAISE position. This should cause the manual-regulator voltage adjuster to increase the resistance in series with the saturating windings and cause an increase in exciter voltage and a-c machine voltage. Turning the manual-regulator voltage adjuster control switch to the LOWER position should have the opposite effect. The change in exciter voltage and a-c machine voltage should be smooth and easy to control. The voltage adjuster switch is spring-loaded and should return to the NORMAL position when the handle is released.

Paralleling With Spare Exciter

If the static exciter is to be used in parallel with a spare rotating exciter, transferring between spare and main exciters should be tried at this time. THIS TRANSFERRING MUST BE DONE WITH THE MAIN EXCITER OPERATING ON THE MANUAL REGULATOR. With the generator field excited by the main exciter, adjust the spare exciter voltage until it is equal to or slightly higher than the main exciter voltage and close the spare exciter field breaker. With the two exciters in parallel, alternately increase the spare exciter voltage and decrease the main exciter voltage. This should cause an increase in the spare exciter current and a decrease in the main exciter current. When the main exciter current is zero, we can open the main exciter field breaker. Transferring from spare exciter to main exciter can be accomplished in the same manner, except that the spare exciter breaker should be opened before the current gets to zero, to prevent motoring the spare exciter. If the transfer is not smooth, do not proceed until the trouble has been corrected.

Automatic Control

The underexcited reactive-ampere limit amplifier should be removed from service by disconnecting the wire from terminal E8, Figure 13.

The reactive-current compensator knobs should be turned to the zero position and also the knobs of the active-and-reactive-current compensator, if furnished.

With the machine at rated voltage and rated speed, the 43 switch may be turned to the TEST position and the automatic regulator checked. By turning the automatic-regulator voltage adjuster, it should be possible to zero the transfer voltmeter (2VM, Fig. 13). The automatic-regulator voltage adjuster should be varied both ways from this position to make certain that the regulator is operating properly. The transfer voltmeter should be deflected from the center position to the right when the automatic-regulator voltage adjuster is turned in a "lower" (CCW) direction. If the operation of the automatic-regulator voltage adjuster must be reversed, it may be changed as follows, after the regulator control switch has been returned to MAN.

The external connections to the two terminals of the voltage regulator panel which connect to the ends of the voltage adjusting unit may be interchanged. (The connection from the voltage regulator panel to the slider on the voltage adjusting unit should not be changed.) The control switch should then be turned to TEST and the operation of the automatic-regulator voltage adjuster unit rechecked to determine that it is satisfactory.

Voltage Level

The automatic-regulator is designed and transformer ratios are selected to give a nominal signal voltage of approximately 115 volts to the three-phase bridge consisting of diodes A7D through A12D. The automatic regulator voltage adjuster should provide adjustment of at least 7.5 percent above and below the nominal signal voltage for turbine generators. It is usually preferable to delay the final voltage-level adjustment until the under-excited reactive-ampere limit has been reconnected, since it may affect the automatic-regulator voltage adjuster setting for a given voltage. In addition, the reactive-current compensator, and the active-and-reactive-current compensator may appreciably alter the signal voltage after they have been adjusted.

Polarity Tests

Before the a-c regulator is first placed in control of the a-c machine excitation, it is recommended that final polarity tests be conducted. To check the stabilizing connections, put the regulator control switch at TEST. With the a-c machine operating at normal speed and voltage, and under the control of the manual regulator, disconnect the lead bringing exciter feedback to the SCR circuit (R47, A11, Figure 13). Discharging capacitor A2C, then putting the lead back on should cause the transfer voltmeter to deflect to the right. If this voltmeter deflects in the wrong direction, locate and correct the trouble before proceeding.

The reactive-current compensator polarity must be checked, before putting the regulator in service, with an a-c machine which is connected to the system. Turn the compensator adjusting knobs to the zero position and operate the machine overexcited at normal voltage.

With the regulator control switch at TEST, adjust the automatic-regulator voltage adjuster until the transfer meter is at 0. Turn the compensator "coarse" knob to the right to insert reactance. The transfer voltmeter should deflect to the right. If it deflects to the left, the current transformer leads to the compensator must be reversed and the test repeated. When the polarity of the compensator is correct, turn the "coarse" knob back to 0, and set the "fine" knob to 4. It is then possible to proceed with the automatic-regulator tests. The transfer meter should deflect to the left if the preceding test is made with an active-and-reactive-current compensator.

INITIAL OPERATION

It is recommended that the following tests be made with the a-c machine disconnected from the load or system; if the a-c machine must be connected to the system, it should be operated at a light load. For complete information on placing the regulator in service and removing it from service, refer to the section titled "Operation".

With the a-c machine operating at normal speed and voltage and with the regulator control switch at TEST, adjust the transferring voltage on the transfer voltmeter (2VM, Fig. 13), to zero. The regulator control switch may then be turned to AUTO. This will then put the automatic-regulator in control of the a-c machine excitation. There should be no change in a-c machine voltage. If the voltage changes appreciably, immediately turn the control switch to MAN and determine the cause of the incorrect operation. It may be necessary to adjust the "dummy load" resistor (U8R, Fig. 13), if the transfer can not be made without changing a-c generator voltage. The same is true when transferring back to the manual regulator. The "dummy load" resistor in this circuit is called U6R in Fig. 13.

If the transfer voltmeter (2VM) or the SCT saturating current ammeter (C1M) exhibits a gradual change resulting in oscillations which grow steadily greater, the stabilizing connections or adjustment of the stabilizing circuit may be incorrect. The polarity of the stabilizing circuit should be rechecked. If these are found to be correct, attempt to obtain stable operation by adjusting the rheostat in series with the capacitor. Reduce the resistance to a value that is about 15 percent less than the original value and again place the regulator in control of the a-c machine excitation. If the stability still has not improved, repeat the preceding adjustment using larger and smaller values of resistance. It should be possible to stabilize the regulator by gradual adjustments of this rheostat. However, if the regulator still is unstable after the full range of resistance has been tried, the exciter-stabilizer-capacitors should be added and disconnected one at a time. (Refer to the connection diagram supplied with the equipment.) After each change the resistance should be adjusted in the same manner as previously described.

WARNING

All adjustments must be made with the control switch at "man".

With the regulator-control switch at AUTO, turn the automatic-regulator voltage adjuster in the clockwise direction. The transfer voltmeter should change slightly to the left and the exciter voltage and a-c terminal voltage should rise. Next, turn the automatic-regulator voltage adjuster in counter-clockwise direction. The transferring voltmeter should deflect to the right and the exciter voltage and the a-c machine terminal voltage should fall. If the a-c machine is a generator which is not connected to a load or a system, the voltage-adjusting rheostat may be operated to obtain a total change in machine voltage of at least 15% of rated voltage.

Refer to the section titled "Operation" for instructions on removing the regulator from control of a-c machine excitation.

When proper regulator operation has been secured, optimum stability should be checked and the necessary adjustments made.

Optimum Regulator Stability

The following test should enable a quick determination of optimum stability. Place the regulator in control of a-c machine excitation. After suddenly turning the automatic-regulator voltage adjuster a few degrees in the lower direction, the transfer voltmeter will indicate only two or three oscillations and the a-c machine voltmeter will overshoot only slightly before returning to a new steady value.

CAUTION

Before making any adjustments in the stabilizer circuit, it is necessary to turn the regulator control switch to "Man", and follow the procedure outlined under "Initial Operation."

Regulator Sensitivity and Voltage Regulation

Determination of a-c machine voltage regulation with the regulator in service is a difficult procedure under usual operating conditions and one which will produce only qualitative results. Since the regulator is adjusted at the factory to provide adequate sensitivity for close regulation, this measurement is usually unnecessary at the time of installation, and for this reason no special test procedure is given. After the equipment has been placed in service, it is possible to obtain data which will provide a measure of voltage regulation, but results must be carefully interpreted to gain a reliable estimate of performance.

If the machine is connected to a system, the regulation will depend to a great extent upon the characteristics of this system. Regulation will also be considerably affected by the use and adjustment of compensators. Furthermore, the sensitivity of the regulator itself will be a major factor affecting voltage regulation. A method is given in a later section for measuring regulator sensitivity.

START-UP CHECK LIST

1. Wire check.

2. Correct any discrepancies.

3. If prints from the various departments disagree, follow Waynesboro prints unless someone can be consulted in Waynesboro.

4. Pay particular attention to SCT and PPT phasing.

5. Check to see that the signal C. T. is in the proper phase and connected properly.

6. Check forward and reverse resistances of diodes with an ohmmeter.

7. Set dummy loads to approximately the resistance of the SCT windings.

8. Make sure all disconnects and circuit breakers are closed.

9. Turn on DC power and check relay operation, motor operation, and limits.

10. Turn manual control to full lower (minimum resistance).

11. After the unit is up to 95% speed or greater, close field breaker and turn 43 switch to start-up and hold for 5 - 10 seconds.

12. Generator terminal voltage should build up to some value less than rated and hold.

13. If it does not build up, then increase the manual control slightly.

14. If it still does not build up, decrease resistance in the start-up circuit and try again.

15. If the unit still does not build up, check the connections and the main power rectifiers.

16. If the unit builds up and goes to rated or greater, check for a resistor in series with the manual regulator. This resistor (U5R) should be shorted in the factory.

17. If it is found that all the resistance is shorted out and the voltage still goes too high, check the saturating current at rated voltage. If it is not excessively large then check SCT, PPT, and XL connections. If nothing is found to be wrong, then taps on the XL must be changed. Increasing XL decreases the amount of control current needed to hold a particular voltage and thus should enable the exciter to hold a lower voltage. Remember that changing XL changes compounding.

18. After generator voltage builds up and holds some reasonable value of voltage, see that the manual regulator controls the voltage. Raise terminal voltage to rated.

19. Check power diodes for opens with a clamp on ammeter. Could check reactor currents to see if balanced and of the correct magnitude. Remember that reactor current will be about nameplate rating at no load.

20. Place regulator control switch in test position.

21. Zero the transfer voltmeter by means of the automatic voltage adjuster. (Dummy loads already preset.)

22. If the voltage adjuster must be moved very far from the center position, use a A3P and A4P to balance the transfer voltmeter leaving VAP in the center. (Remember increasing A3P and A4P decreases the range that the VAP will adjust over.)

23. Turn VAP to raise voltage; regulator output should decrease and 2VM deflect left. If the regulator output increases then VAP is in backwards; if the regulator output decreases but 2VM goes to the right, then reverse 2VM.

24. Remove exciter stabilizing leads and short the capacitor. Putting the lead back on should cause regulator output to increase and 2VM to deflect right. If not, then reverse stability leads.

25. Transfer to automatic regulator and observe field voltage and 2VM for any violent swings. If field voltage and 2VM swing violently, go back to manual. Change A2P in about 15% steps both above and below factory setting, each time going back to auto to observe stability. If this does not correct the problem, try connecting and disconnecting A2C one at a time, each time moving A2P as before. If the unit still appears to be unstable after all this, then reduce the gain using A1P and repeat the above steps. As a measure optimum stability, offset the manual or automatic 5-10% and transfer from manual to automatic. There should be only 2-3 swings on the field voltmeter and transfer voltmeter.

26. Try a transfer from automatic to manual and vice versa. If this is not smooth, then the dummy load resistors may need to be readjusted.

27. Go on line in manual regulator and pickup some overexcited current.

28. Go to test and zero 2VM. With RCC at zero and overexcited current out of the generator, changing the coarse to tap 5 should cause the regulator output to increase and 2VM will deflect right. If this does not happen, then the current feed to RCC is backwards.

29. If there is a URAL panel, it should now be checked. Try to go underexcited if possible and check to see that as the limit start goes toward zero, limit detector goes from left towards zero and then right. If not, then check PT and CT leads to limit. Remember also that phase rotation affects the limit. Check to see that there is a limit output when the detector operates. Check to see that the regulator output is decreased and 2VM swings left when the limit operates. If not, then the leads from the limit are reversed.

30. Remove the exciter stabilizing input and short at the terminals. 2VM should deflect more to the left. Put the lead back on and it should deflect to the right.

31. Set URAL limit start and power recalibration per I. B. graphs.

32. Load the machine up and check the saturation current from no-load to some heavy load.

33. Check transferring at heavy loads to see if it remains smooth. You may have to readjust the transfer circuit because of heating of the control winding.

UNDEREXCITED REACTIVE AMPERE LIMIT (If Furnished)

Limit Polarity

After satisfactory operation of the regulator has been obtained, the reactive-ampere limit should be tested. Reconnect the limit amplifier to the regulator, set the REACTIVE AMPERE LIMIT POWER RECALIBRATION switch at zero and the REACTIVE AMPERE LIMIT START dial at its highest numbered position.

With the machine carrying power load, and some safe value of underexcited reactive current move the regulator control switch to TEST. Adjust the automatic-regulator voltage adjuster until the transfer voltmeter reads 0. Slowly turn the REACTIVE AMPERE LIMIT START dial toward 0. At some setting of the dial, the limit-detector meter reading will go to 0 and increase in the opposite direction. Limit signal-current will increase from 0 and the transfer voltmeter will deflect to the left. If the limit-detector current does not reverse before the dial has been turned to zero, return the dial to the highest numbered position. Decrease the a-c machine excitation to further increase the underexcited current, being careful not to exceed the safe operating limit for the machine. It may be desirable to reconnect the limit to operate on overexcited reactive current as described in "Reactive Ampere Sensitive Circuit" in a previous section.

Again turn the REACTIVE AMPERE LIMIT START dial towards zero until the limit detector current is 10 MA. If the signal cannot be increased from zero by turning the REACTIVE AMPERE LIMIT START dial to zero, the limit polarity may be reversed. Turn the regulator control switch to MAN and reverse the primary connections of transformer E3T (Fig. 13). Repeat the test previously described to determine if reverse limit-detector current can be obtained by turning the REACTIVE AMPERE LIMIT START dial towards zero. THIS TEST MUST GIVE PROPER RESULTS BEFORE FURTHER TESTS ARE CONDUCTED. If the limit signal-current had an initial value that went to zero as the REACTIVE AMPERE LIMIT START dial setting was reduced, the input to the limit amplifier must be reversed. If the transfer voltmeter deflected to the right, the limit d-c output is reversed. Reverse the connections between the limit amplifier and the first stage amplifier of the automatic-regulator. (See connection diagrams furnished with the equipment.) Repeat the previously described tests to secure proper results.

With the REACTIVE AMPERE LIMIT START dial so set that the transfer voltmeter did deflect slightly to the left of 0, turn the POWER RECALIBRATION switch from point 0 toward point 9. If the a-c machine is delivering power, the transfer voltmeter should deflect more to the left as the POWER RECALIBRATION switch is turned toward point 9.

Turn the POWER RECALIBRATION switch to 0. Readjust the transfer voltmeter to approximately 10 volts to the left with the REACTIVE AMPERE LIMIT START dial. Before proceeding further with the tests on the underexcited reactive limit circuit, it is necessary to check the polarity of the LIMIT stabilizing circuit. Carefully disconnect one of the exciter voltage stabilizing leads from the LIMIT amplifier and short the stabilizing input terminals on the LIMIT amplifier (refer to the connection diagrams supplied with each equipment). This should cause the transfer voltmeter to deflect more to the left. Replacing the primary lead should cause the transfer voltmeter to deflect to the right. Do not proceed with the underexcited reactive-ampere limit tests until the polarity of the limit stabilizer is correct.

Turn the REACTIVE AMPERE LIMIT START dial to its highest reading. Readjust the transfer voltmeter reading to zero with the automatic-regulator voltage adjuster. Operate the a-c machine at normal voltage and with underexcited reactive current. Turn the regulator control switch to AUTO as discussed under "Initial Operation". Slowly turn the REACTIVE AMPERE LIMIT START dial toward zero. The transfer voltmeter should deflect slightly to the left and the exciter voltage should increase, causing the underexcited reactive current to decrease. The dial setting at which the underexcited reactive current starts to decrease is the limit-start point. If the operation is not as described, immediately remove the regulator from control of the a-c machine excitation by turning the regulator-control switch to MAN. Repeat the limit polarity tests. Do not proceed further until satisfactory operation is obtained.

With the regulator control switch at AUTO and the REACTIVE AMPERE LIMIT START dial at the limit-start point, observe the transfer voltmeter, the exciter voltmeter, and the a-c machine ammeter for signs of oscillation. If oscillations of the reactive current or transfer voltmeter voltage appear, remove the automatic-regulator from control of the machine excitation by turning the regulator control switch to MAN. Adjust the resistance in series with the exciter LIMIT stabilizing capacitors in 15 percent steps, first in the direction to decrease resistance and then in the direction to increase resistance. After each of these adjustments repeat the procedure for putting the LIMIT in service as previously described, being very careful to observe the transfer meter voltage and exciter voltage oscillations and reactive-current oscillations. However, if the LIMIT still is unstable after the full range of resistance has been tried, the exciter stabilizer capacitors on the LIMIT amplifier should be added and disconnected one at a time. After each change the resistance should be adjusted in the same manner as previously described.

After stable operation of the LIMIT has been obtained, check the LIMIT operation as follows with the regulator in control of a-c machine excitation. Move the REACTIVE AMPERE LIMIT START dial to the limit-start point. Record the reactive current. Decrease the underexcited reactive-ampere load on the a-c machine by operating the automatic-regulator voltage adjuster to raise the voltage. The underexcited reactive current should decrease. It should be possible to adjust the underexcited reactive current to any value lower than it was at the limit-start point. Now increase the underexcited reactive current by turning the automatic-regulator voltage adjuster to lower the voltage. As the limit-start point is passed, the exciter voltage should increase and it should be impossible to raise the underexcited reactive current appreciably above the previously recorded value no matter how far the automatic-regulator voltage adjuster is turned in the direction to lower voltage.

As a final check of optimum LIMIT stability, move the REACTIVE AMPERE LIMIT START dial until the transfer voltmeter reads approximately 10 volts to the left. Abruptly, move the automatic-regulator voltage adjuster a few degrees in the lower direction and observe carefully the transfer voltmeter and the reactive-current ammeter for signs of oscillations. If oscillations appear, adjust for optimum stability as previously outlined. When the transfer voltmeter and the reactive-current ammeter show only a few oscillations after an abrupt change of the automatic-regulator voltage adjuster, the LIMIT stability is satisfactory. Move the REACTIVE AMPERE LIMIT SENSITIVITY dial slowly toward its highest scale reading. Again check the LIMIT stability.

This completes the preliminary adjustment of the LIMIT. Final adjustment can be made at any time.

Final Adjustment of The Underexcited Reactive-Ampere Limit

The final adjustment of the LIMIT may be made by use of Figure 10 and 11, unless special calibration data are supplied with the equipment.

The limit-start adjustment is determined from Figure 10. This graph shows the value of the machine current-transformer secondary underexcited reactive current which will cause the LIMIT to operate as a function of dial setting and normal a-c machine potential-transformer secondary voltage. Values of voltages differing from those shown on the graph may be easily interpolated. The Power-Recalibrating Reactor adjustment is shown in Figure 11. This curve shows the amount by which the limit-start point will be reduced below the limit-start adjustment as a function of machine current-transformer secondary active current for various values of the tap-switch (EISW) setting.

The two following examples are given to illustrate the method of setting the LIMIT.

EXAMPLE 1. It is required that the LIMIT should start to function when the underexcited reactive-current input to the LIMIT reaches four amperes and that the LIMIT action be independent of the power component of current. The normal voltage on the secondary of the a-c machine potential transformers is 110 volts.

Figure 10 indicates that for an underexcited reactive current of four amperes, the REACTIVE AMPERE LIMIT START dial should be set at approximately 47. As can be seen from Figure 11, the tap switch on the power-recalibrating reactor must be set on tap 0, since the LIMIT action is to be independent of the power component of current.

EXAMPLE 2. It is desired to have the LIMIT start

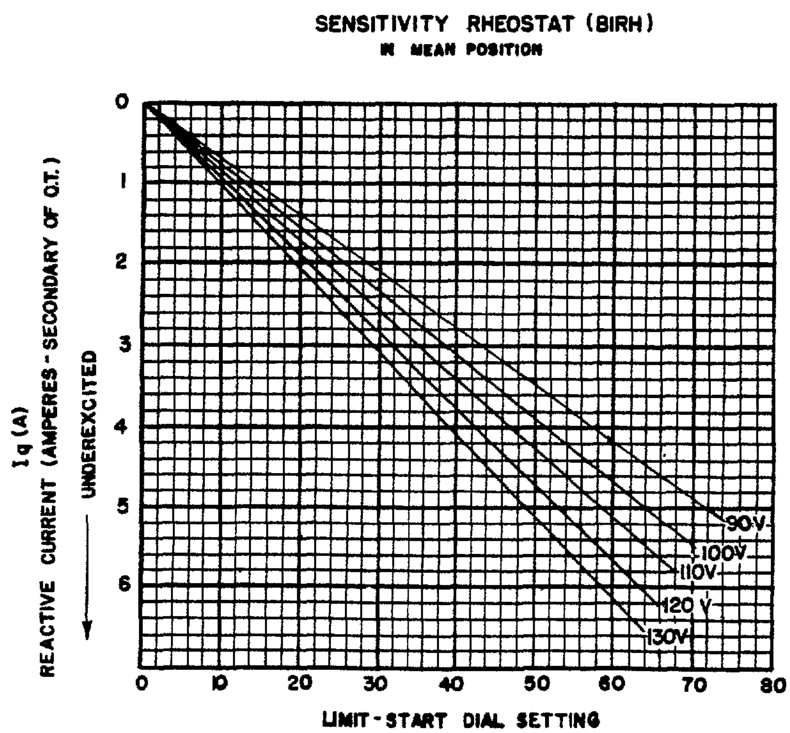


Figure 10. Calibration Curves For Reactive Ampere Limit Start Dial

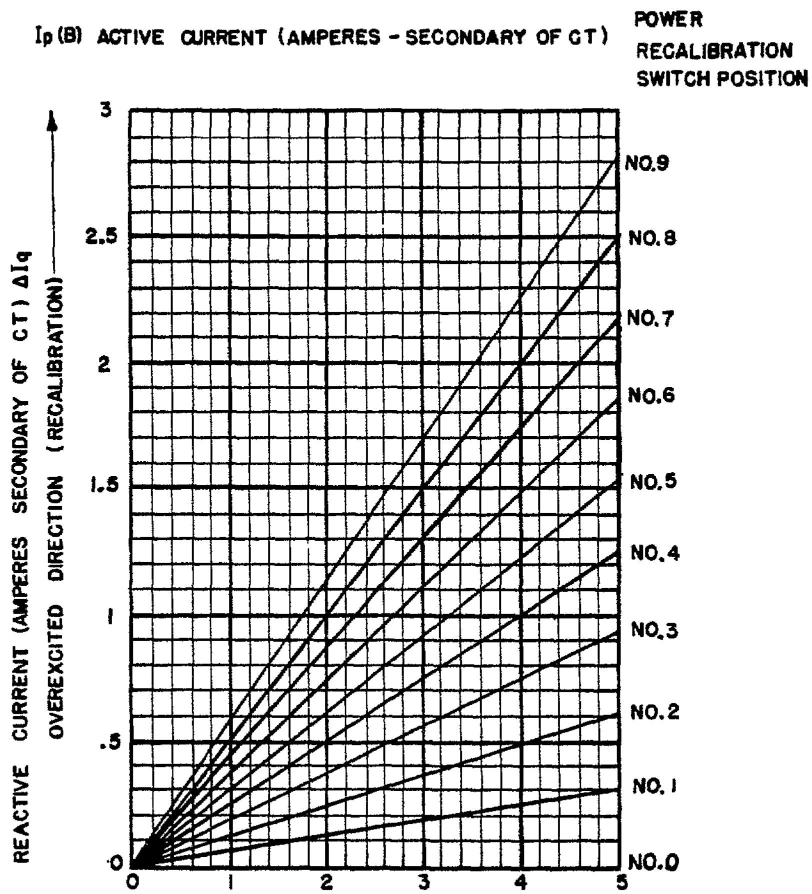


Figure 11. Calibration of Reactive-Ampere Power Recalibration Limit Circuit

to function when the underexcited reactive-current input to the LIMIT reaches four amperes with zero active amperes, and when the underexcited reactive-current input reaches three amperes with four active amperes.

Figure 10 indicates, that for an underexcited reactive current of four amperes, the REACTIVE AMPERE LIMIT START dial should be set at approximately 47. This satisfies the requirement at zero active amperes. Now, the number of reactive amperes necessary to start the limit at four active amperes must be reduced by one reactive ampere to obtain the desired power recalibration. Therefore, in Figure 11, a value of one reactive-ampere recalibration of the LIMIT and four active amperes to the LIMIT, indicates that tap switch EISW should set at tap 4.

If desired, before making the final adjustment of the LIMIT, the calibration curves (Figure 10 and 11) may be checked in the following manner.

Place Power - Recalibrating Reactor tap switch EISW on tap 8. Place the REACTIVE AMPERE LIMIT START dial at its highest scale position. Put the automatic regulator in control of the a-c machine excitation. With the a-c machine carrying some convenient power load at about unity power factor, move the REACTIVE AMPERE LIMIT START dial slowly toward zero. At some position of the dial, the LIMIT will start to operate. This position will be that which will just start to decrease the machine under-excited reactive-current, or increase the overexcited reactive current.

Determine the active and reactive amperes delivered by the machine current transformer to the LIMIT. Draw a vertical line from the active-ampere scale point in Figure 11 to the curve for tap 8. Read the corresponding reactive amperes recalibration of the LIMIT, and the setting of the REACTIVE AMPERE LIMIT START dial.

In Figure 10, use the dial setting and the proper a-c voltage curve to determine the value of underexcited reactive current for which the LIMIT is set. From this value, subtract the reactive amperes recalibration. The result should be essentially equal to the reactive amperes delivered to the limit if the test has been carefully conducted.

Set the LIMIT adjustments to the points which are desired for final operation. If it is desired to check the adjustments, the following procedure may be followed.

Place the automatic regulator in control of the a-c machine excitation. Operate the machine at the desired power load and at a reactive load which should not cause LIMIT operation. Turn the automatic regulator voltage adjuster in the direction to lower voltage until the LIMIT prevents further reduction in machine overexcited reactive current, or increase in underexcited reactive current. Determine the value of reactive current and active current supplied by the machine current transformer to the LIMIT.

Knowing the a-c machine voltage and the setting of the REACTIVE AMPERE LIMIT START dial, determine the underexcited reactive current setting from Figure 10. Determine the underexcited reactive ampere recalibration from Figure 11. The result of subtracting the value of underexcited reactive amperes read in Figure 11 from the value of underexcited reactive amperes read in Figure 10 will be essentially equal to the value of underexcited reactive current to the LIMIT at the limit-start point.

REACTIVE-CURRENT COMPENSATOR

The polarity of the reactive-current compensator is checked as described under "Initial Operation". Final adjustment of the compensator can only be made after considerable experience with the machine operating under control of the automatic regulator. It is desirable to keep the amount of reactance used to the minimum required for proper division of reactive kva between machines to avoid excessive voltage regulation. As an initial adjustment, it is frequently desirable to turn the "fine" knob to position 4 with the "coarse" knob at zero. Adjustments may be made with the compensator current transformer energized. When making adjustments, the a-c machine power factor should swing toward unity as the reactance of the compensator is increased.

ACTIVE-AND-REACTIVE CURRENT COMPENSATOR

Turn both adjusting knobs to 0 and operate the a-c machine overexcited (lagging power factor). With the regulator control switch at TEST and the transfer voltmeter reading 0, turn the "coarse" reactance-adjustment knob to the right to insert reactance; the transfer voltmeter should be deflected to the left. Return the "coarse" reactance-adjustment knob to 0 and turn the "coarse" resistance-adjustment knob to the right to increase resistance; this should also cause the transfer voltmeter to deflect to the left. If the transfer voltmeter deflects in the wrong direction, the compensator current leads must be interchanged and the tests repeated.

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

GAIN MEASUREMENTS

The automatic regulator gain should be checked only when it is thought that the system is not operating properly. If the gain is to be checked it will be necessary to use a laboratory type meter to measure the change in voltage on the secondary of the PT's; the ratio of the change in voltage across points C20 and U5 (See Fig. 13) to the voltage change at the PT secondaries is the gain of the SCR circuit. The voltage across C20 and U5 is the output of the SCR circuit.

SYSTEM SELF-COMPENSATION

It is necessary to determine the degree of self-compensation of this system to be certain that the linear reactors are set at the best taps. This can be done by measuring the value of current through the SCT control winding at no-load and at full load, rated power factor. The degree-of-correction (DOC) is the change in control current divided by the no-load value of control current. If the control current decreases from no-load to full load, the system is under-componded. If the current increases, the system is over-compounded. It should be possible, with the taps available, to limit DOC between 5% under-compounded to 20% over-compounded.

Changing the linear reactors to a higher reactance tap causes increased compensation, i.e., it tends to over-compound the system. CHANGE TAPS ON ALL THREE PHASES OF THE DEVICE BEING ADJUSTED.

OPERATION

NORMAL OPERATION

General

The complete voltage-regulator equipment should be placed in normal service with the a-c machine only after the control circuits, regulator, underexcited reactive-ampere limit, reactive-current compensator, and active-and-reactive current compensator have been properly tested in general conformance with the previously described instructions. Final adjustment of these units may, of course, be delayed until operating experience has been obtained, but circuits which have not been thoroughly tested must not be employed with the automatic-regulator in service if the possibilities of damage to the equipment and disturbance of the system are to be avoided.

Operation With Attended Equipment

In attended stations, the a-c machine must be brought up to normal speed and voltage under control of the manual-regulator before the automatic-regulator is placed in service. Generators are frequently connected to the load or system before the automatic regulator is used, but this is not essential, since this regulator may be placed in service with the machine under any load condition and with the machine connected to or disconnected from the system.

The following procedure should be used to place the automatic regulator in control of machine excitation:

1. With the regulator control switch at MAN and with the a-c machine operating at normal speed, adjust the machine terminal voltage to approximately normal with the manual-regulator voltage adjuster. If the machine is operating under loaded conditions or connected to the system, this step should not be necessary.

2. Turn the regulator control switch to TEST.

3. Adjust the transfer meter to zero with the automatic-regulator voltage adjuster. If this cannot be done, do not proceed further until the trouble has been determined and eliminated.

4. Turn the regulator control switch to AUTO. This will place the automatic-regulator in control of the a-c machine excitation.

5. The terminal voltage or excitation level of the a-c machine may now be adjusted with the automatic-regulator voltage adjuster as required for the normal operating schedule.

With the automatic-regulator in control of the a-c machine excitation, the manual-regulator voltage adjuster becomes ineffective. However, additional excitation system reliability may be secured by proper adjustment of this voltage adjuster when the automatic regulator is in control of machine excitation.

For this purpose, it is recommended that immediately after the automatic-regulator has been placed in service, the manual-regulator voltage adjuster be adjusted to and maintained at a predetermined position. This position should be such that the machine excitation will be sufficient under all normal a-c machine loads, give stable operation and avoid serious operating disturbances if the excitation system should be suddenly returned to manual control through an emergency resulting in loss of the automatic regulator. It is suggested that this voltage adjuster position be selected so that when the excitation system is under manual control, it will produce from three-quarters rated to rated a-c machine field current with preference given to the latter value. Where the a-c machine is closely paralleled with other machines equipped with automatic regulators, without underexcited reactive-ampere or minimum-excitation limits, a position corresponding to the lower value may be found more desirable. The manual-regulator voltage adjuster can be supplied with limit switches which can be adjusted to indicate by means of remote indicating lights, when it is in this predetermined position. It is essential that under any sustained load condition, a manual-regulator voltage adjuster position be maintained which will give sufficient excitation, in the event of sudden return to manual control, to permit stable operation of the generator.

The automatic-regulator may be removed from service and the a-c machine excitation returned to manual control under any load conditions. The following procedure should be used for this purpose:

1. Adjust the transfer meter voltage to zero by use of the manual-regulator voltage adjuster.

2. Turn the regulator control switch to MAN.

WARNING

The transfer voltmeter must be zeroed with the regulator control switch at "on", since turning the regulator control switch to "test" removes the automatic regulator from service.

With the automatic regulator in control, the manual regulator voltage adjuster may be adjusted as follows to bring the transfer voltmeter to 0. If the transfer voltmeter is reading to the left of center, the manual-regulator voltage adjuster control switch should be turned to the RAISE position. If the transfer voltmeter is reading to the right of 0, this control switch should be turned to the LOWER position.

MAINTENANCE

PPT's and SCT's

These devices normally require little or no maintenance. It is suggested, however, that the air passages be cleaned during shut down periods. Exposed connections should be inspected for corrosion and tightness.

STATIC EQUIPMENT

The equipment should be kept relatively clean and dry. If vibration is present, all screw-type connections should be checked regularly to determine that they are properly tightened. Normally, the static components should require no further attention.

OTHER EQUIPMENT

Magnetically-operated contact-making devices should be regularly inspected and maintained in accordance with applicable instructions for these devices. The ground-detecting relay should be maintained in accordance with the instruction for this particular device.

The manual regulator voltage adjuster brushes should be inspected at six month intervals under normal operating conditions. Where unusually dusty or other abnormal atmospheric conditions exist they should be inspected oftener. If arcing occurs or if the brushes are badly worn, they should be replaced. In addition, where discoloration is present the commutator surface should be cleaned with crocus cloth. Because the brushes are of a special material, they should not be replaced with ordinary brushes but with correct brushes purchased from the manufacturer. To properly seat new brushes a piece of crocus cloth or fine sandpaper should be placed between the commutator surface and the brushes so that the smooth side is on the commutator surface and the abrasive side is against the brushes. While holding the cloth or sandpaper tightly in place rotate the brush holder and brushes through a short arc. Blow out the carbon particles which have been removed. Remove the cloth or sandpaper and rotate the brush holder through its range of travel several times to check for smooth travel of the brushes over the commutator surface. The brushes should fit flat over the entire commutator range. No space should be visible between the brushes and the commutator surface. This same procedure should be followed with the automatic regulator voltage adjuster rheostat.

Silicon diodes are used in the power circuit of the static exciter. These diodes are not at this time known to age; therefore, they are either good or should be removed. Individual diodes can be checked as shown in Figure 12. With switch in position 1, the ammeter should read approximately 12 amperes. With switch in position 2, the ammeter should read zero. The DC source should be a battery, rather than a rotating exciter, since the latter may have voltage spikes that may damage the diode.

If the diode is open, the ammeter will read zero in both switch positions. If the diode is shorted, it will read approximately 12 amps in both switch positions.

Some equipments are furnished with a detector for detecting faulty diodes. See separate instruction book for operating instructions.

Bad diodes can be found with the equipment in service with a voltmeter and a clamp-on ammeter.

The shorted diode can be found by measuring the inverse voltage across the diodes, since the shorted diode will have no inverse voltage drop, and the other three diodes in the leg will divide it all between them.

The leg containing an open diode can be found by clamping a clamp-on ammeter around one diode pigtail in each leg. Upon ascertaining that an open diode exists in a leg, the faulty diode can be found by shorting out each of the diodes in that leg one at a time. When current flows, the open diode has been shorted.

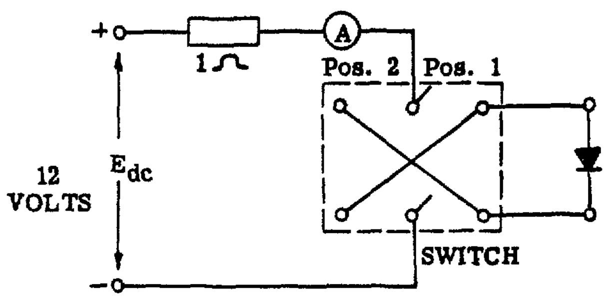


Figure 12. Rectifier Test Circuit

An oscilloscope can be used. It must be remembered, however, that the open diode will not produce an abnormal scope picture if there is a parallel leg which is not open.

If it becomes necessary to replace a faulty diode, the following procedure should be followed:

1. Ascertain if the other rectifier has any open diodes. If it does, replace it first.

2. Isolate the rectifier with the faulty diode by opening the proper disconnect switches (see diagram furnished with the equipment).

3. Remove diode.

*4. Screw in new diode after first covering threaded portion with Wakefield type 120 joint compound. The torque required varies with the type of diode used. For the A90 diode, a torque of 25 ft. lbs. should be used.

WARNING

WHEN REPLACING GENERATOR SLIP RING BRUSHES, REMOVE CONNECTION PLUG ON PJG-GROUND DETECTING RELAY AND DISCONNECT GROUND FROM SHAFT VOLTAGE SUPPRESSION CIRCUIT.

RENEWAL PARTS

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

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

2. Complete nameplate data appearing on the assembly of which the part is component.

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

Renewal parts for the motor drive for the Manual voltage adjuster and for the motor drive for the automatic voltage adjuster, if motor driven type is supplied for the automatic voltage adjuster, should be ordered directly from the manufacturer.

*Both reverse and forward polarity diodes are used in this equipment (forward polarity indicates that the stud is the cathode and reverse polarity indicates that the stud is the anode). In order to insure proper operation, it is imperative that a diode be replaced with one having the proper polarity and grade.

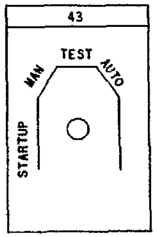
TROUBLESHOOTING

SYMPTOM	POSSIBLE CAUSE	POSSIBLE CURE
Voltage fails to build up after flashing (Regulator on Manual.)	Insufficient Flashing Current	Decrease U4R
	Shorted Power Diode	Replace Diode
	Insufficient Resistance in Manual Regulator	Increase D1P
	Loose Connections	Tighten ALL Power Circuit Connections
Generator Armature Voltage goes to ceiling after flashing (Regulator on Manual.)	Excessive resistance in D1P, SCT circuit.	Decrease D1P
	Incorrect PPT Secondary voltage	Check to see that PPT Ratio is correct
	SCT control windings not in the circuit	Look for wiring error involving SCT control windings. Check contacts of TRC
	Insufficient Reactance in $X'_L S$	Change Taps
Generator Armature Voltage goes to zero after transfer to auto.	Incorrect Sensing Voltage	Adjust A3P and A4P
	Incorrect Zener Voltage	Check Zener and replace if necessary (50 volts).
	Open Potentiometer A5P	Check and replace if faulty.
	Open diode A13D	Check and replace if faulty.
Generator Armature Voltage goes to ceiling (or higher than desired) after transfer to Auto.	Incorrect sensing voltage	Adjust A3P and A4P
	Incorrect Operation of TRC	Check and adjust or replace
	Incorrect Zener Voltage	Check and replace if necessary
	Insufficient supply Voltage to SCR's	Check A1T
	Faulty SCR	Check output of regulator with Oscilloscope and replace the SCR if faulty.
Generator unstable at No-Load	Incorrect Stabilization	Adjust A2P, A5R and/or A2C
	Feedback circuit connected with wrong polarity	Swap leads to A11 and A12
	Excessive Gain	Increase A1P and/or A4R
Generator unstable at Load but stable at No-Load	Change in Gain caused by Excessive Ambient	Decrease Gain or Ambient Temperature
	Change in Gain caused by Phasing Error between SCT and PPT	Check control current as load is changed. If approaches zero or maximum, then check phasing of PPT and SCT.

SB SWITCH ARRANGEMENTS

△
AUTOMATIC REGULATOR TRANSFER SWITCH
43 SWITCH
SPRING RETURN FROM "START-UP" TO "MAN"

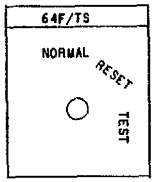
CONTACTS HANDLE END	NO	AUTO	TEST	MAN	START-UP
1-1C 2C-2	1	X	X		
	2	X	X		
3-3C 4C-4	3	X	X		
	4	X	X		
5-5C 6C-6	5	X	X		
	6	X	X		
7-7C 8C-8	7	X	X		
	8	X	X		
9-9C 10C-10	9	X	X		
	10	X	X		
11-11C 12C-12	11	X			
	12	X			
13-13C 14-14C	13				X
	14				X
15-15C 16-16C	15			X	
	16		X		



THIS IS A STANDARD SWITCH.
ALL CONTACTS ARE NOT USED
IN EVERY SYSTEM.
SEE DIAGRAM WITH EACH
SYSTEM.

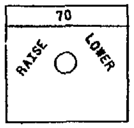
⊖
GROUND DETECTING RELAY TEST SWITCH
64F-TS SWITCH

CONTACTS HANDLE END	NO	TEST	RESET	NORMAL
1-1C 2C-2	1			X
	2	X		
3-3C 4C-4	3		X	
	4		X	
5-5C 6C-6	5			X
	6	X	X	



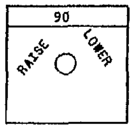
△ ⊖
MAIN EXCITER MANUAL VOLTAGE ADJUSTER
70 SWITCH

CONTACTS HANDLE END	NO	LOWER	NORMAL	RAISE
1-1C 2C-2	1			X
	2	X		



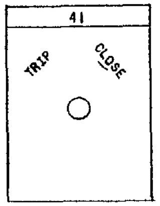
△ ⊖
MAIN EXCITER AUTO VOLTAGE ADJUSTER
90 SWITCH

CONTACTS HANDLE END	NO	LOWER	NORMAL	RAISE
1-1C 2C-2	1			X
	2	X		



△ ⊖
FIELD BREAKER CONTROL SWITCH
41CSM SWITCH

CONTACTS HANDLE END	NO	CLOSE	NORMAL	TRIP
1-1C 2C-2	1			X
	2	X		



CUSTOMER NOTES

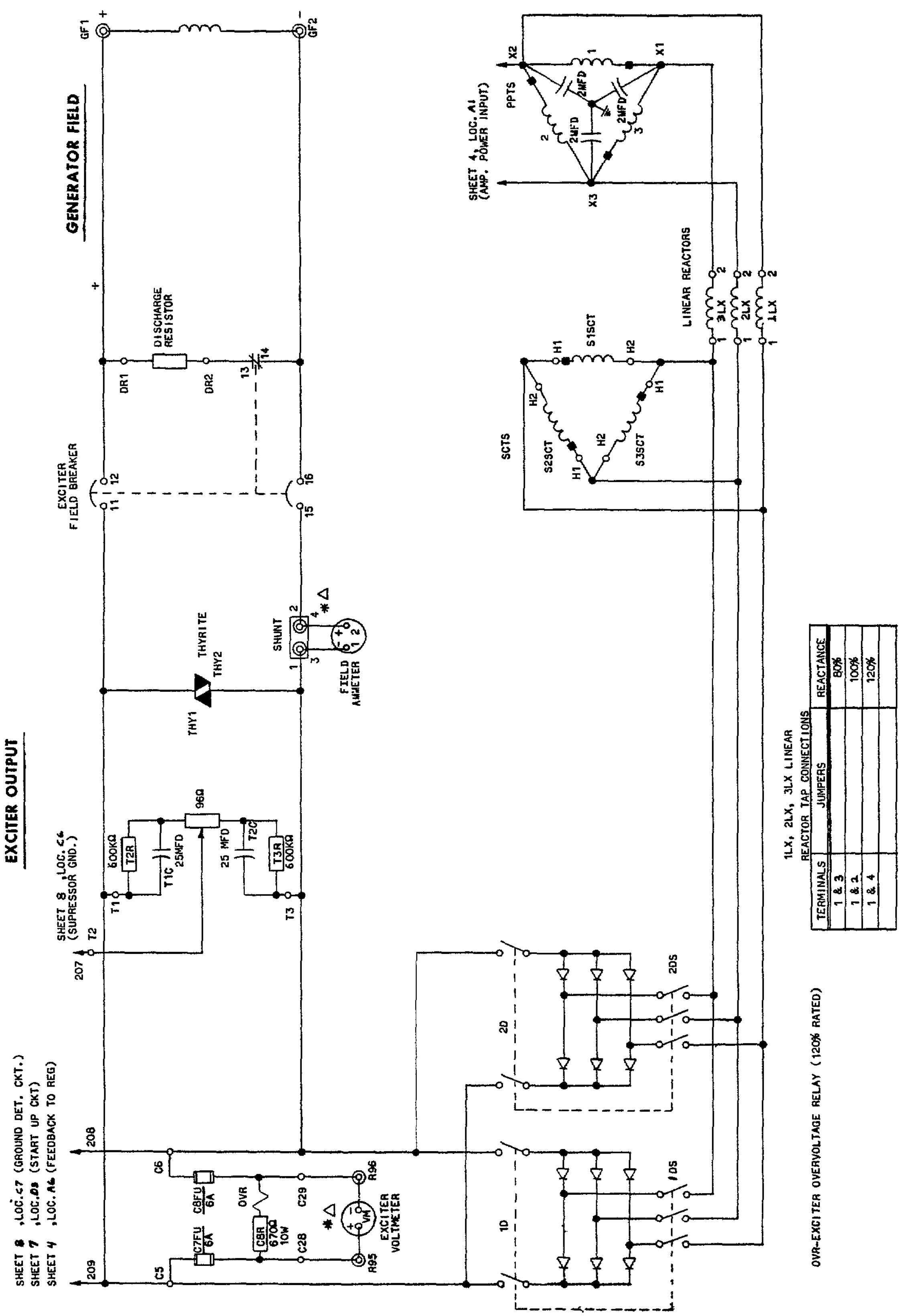
1. SYMBOLS USED:
   - ✳ – NOT FURNISHED BY WAYNESBORO G.E.
   - △ – MOUNTED ON CUSTOMERS' EQUIPMENT
   - ⊖ – SPRING RETURN TO NORMAL
   - -o- – INTERNAL FACTORY CONNECTION
   - ◎ – CUSTOMER TERMINAL BOARD CONNECTION
2. CONNECTION DIAGRAM IS

CUSTOMERS INTERCONNECTING CABLES TO BE SIZED TO CARRY THE FOLLOWING CURRENT:

1. FROM GENERATOR FIELD ________AMPS.
2. FROM S.C.T. SECONDARY ________AMPS.
3. FROM P.P.T. SECONDARY ________AMPS.
4. FOR START UP CIRCUIT ________AMPS.
5. S.C.T. DELTA CONNECTIONS ________AMPS.
6. P.P.T. DELTA CONNECTIONS ________AMPS.
7. ALL OTHER LOW VOLTAGE WIRES TO BE #14 .

(CW) OR (CCW) INDICATES KNOB ROTATION TO INCREASE RESISTANCE.

Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 1 of 9)



1LX, 2LX, 3LX LINEAR REACTOR TAP CONNECTIONS

TERMINALS	JUMPERS	REACTANCE
1 & 3		80%
1 & 2		100%
1 & 4		120%

Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 3 of 9)

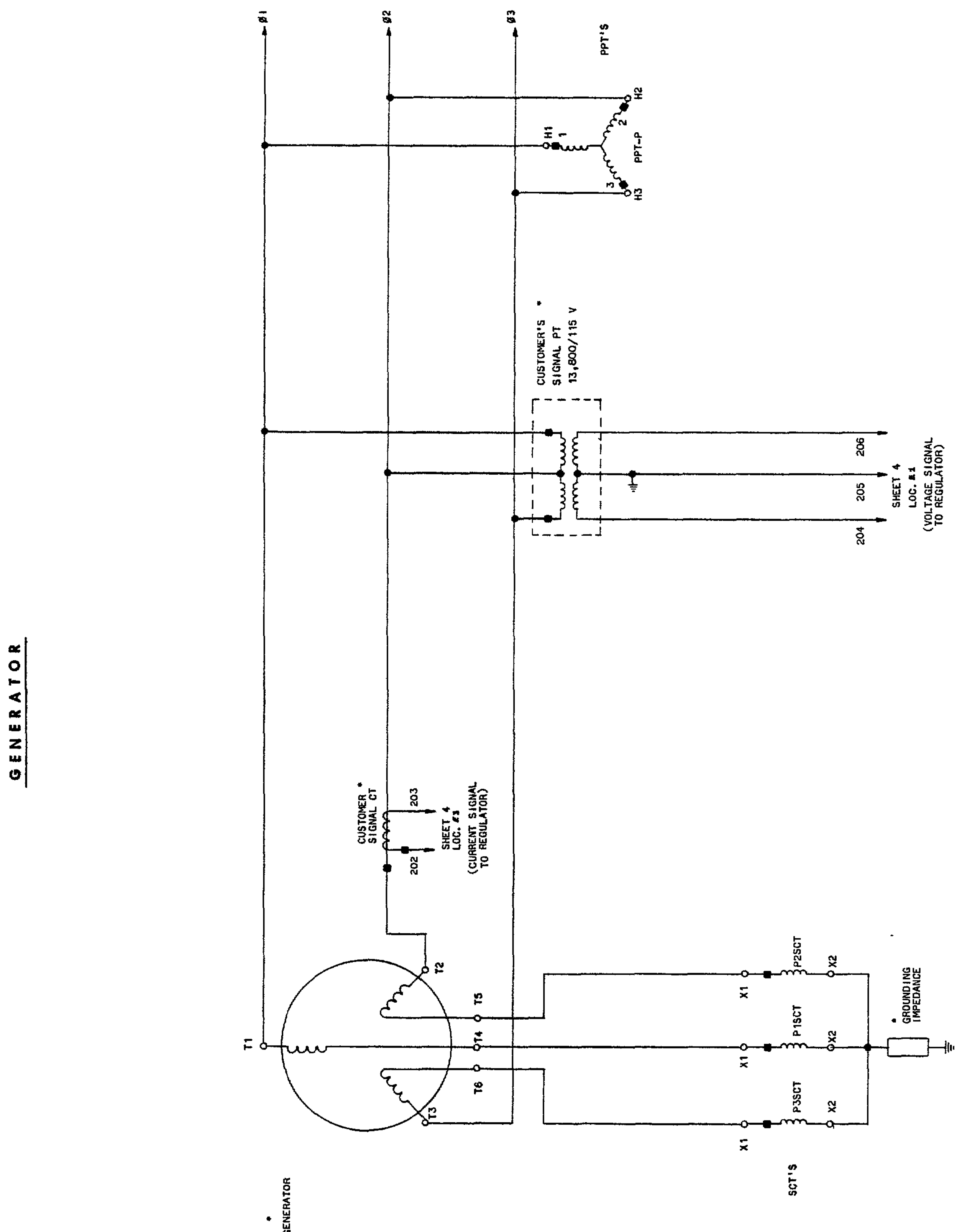


Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 2 of 9)

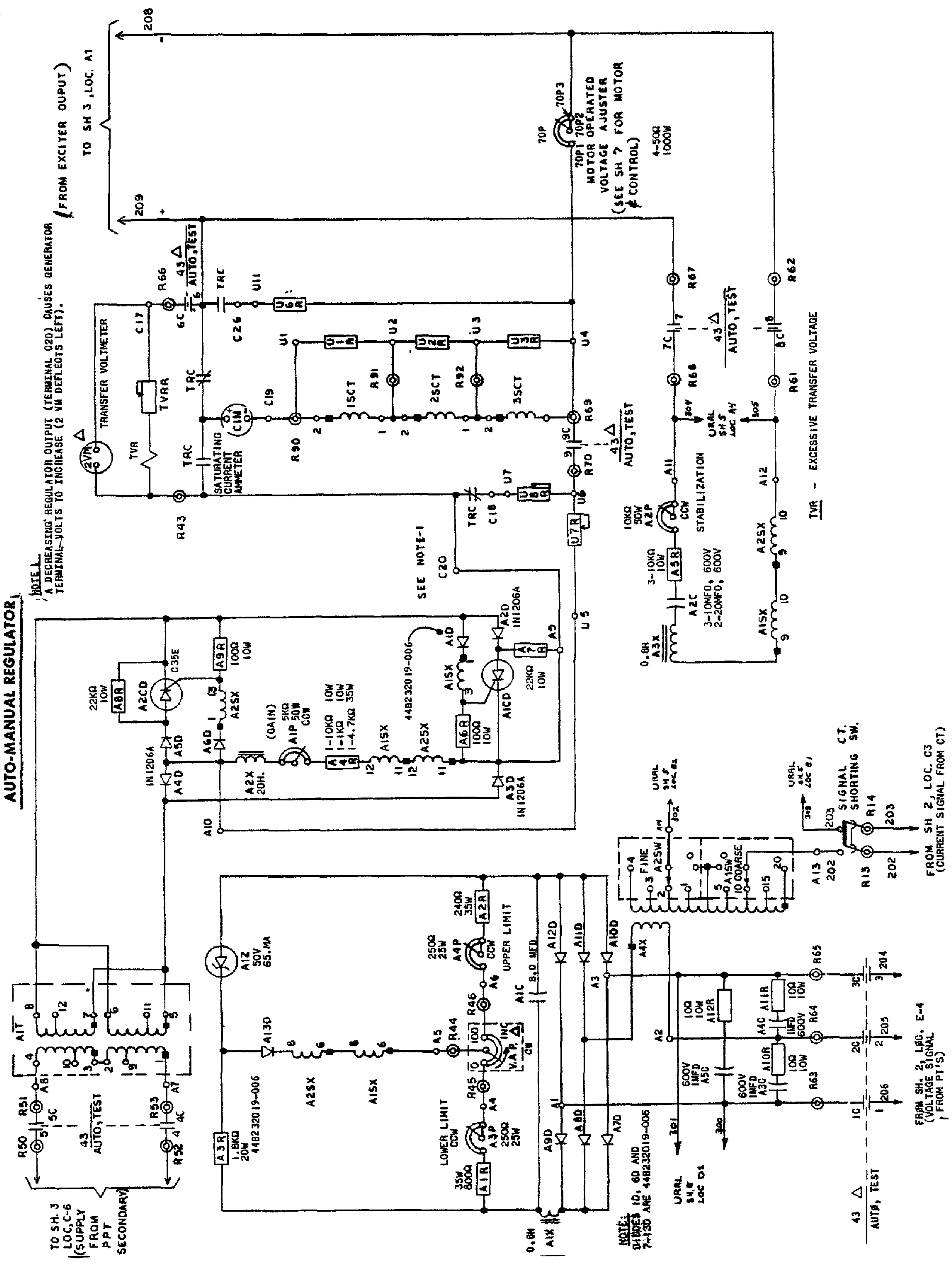


Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 4 of 9)

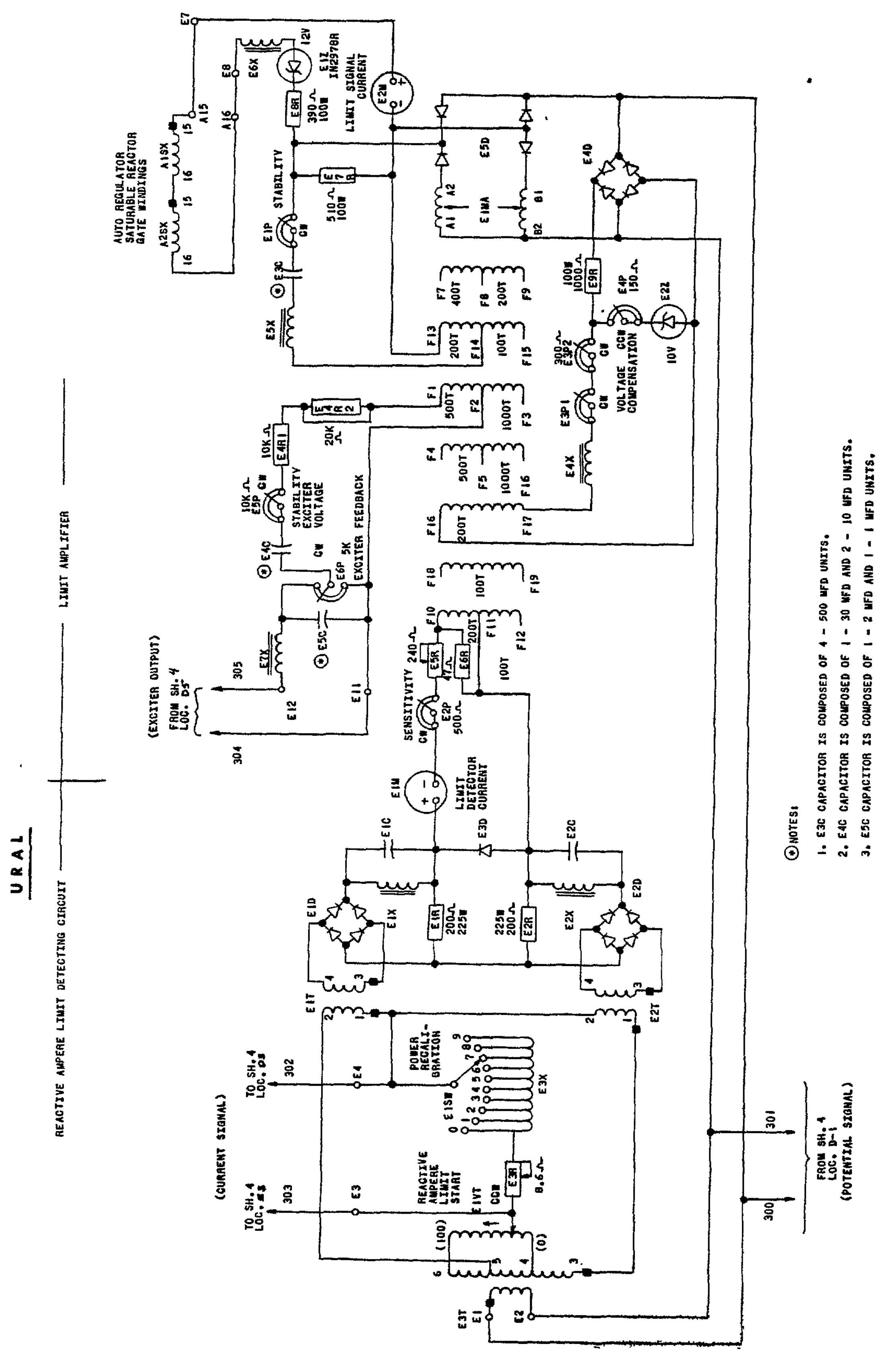


Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 5 of 9)

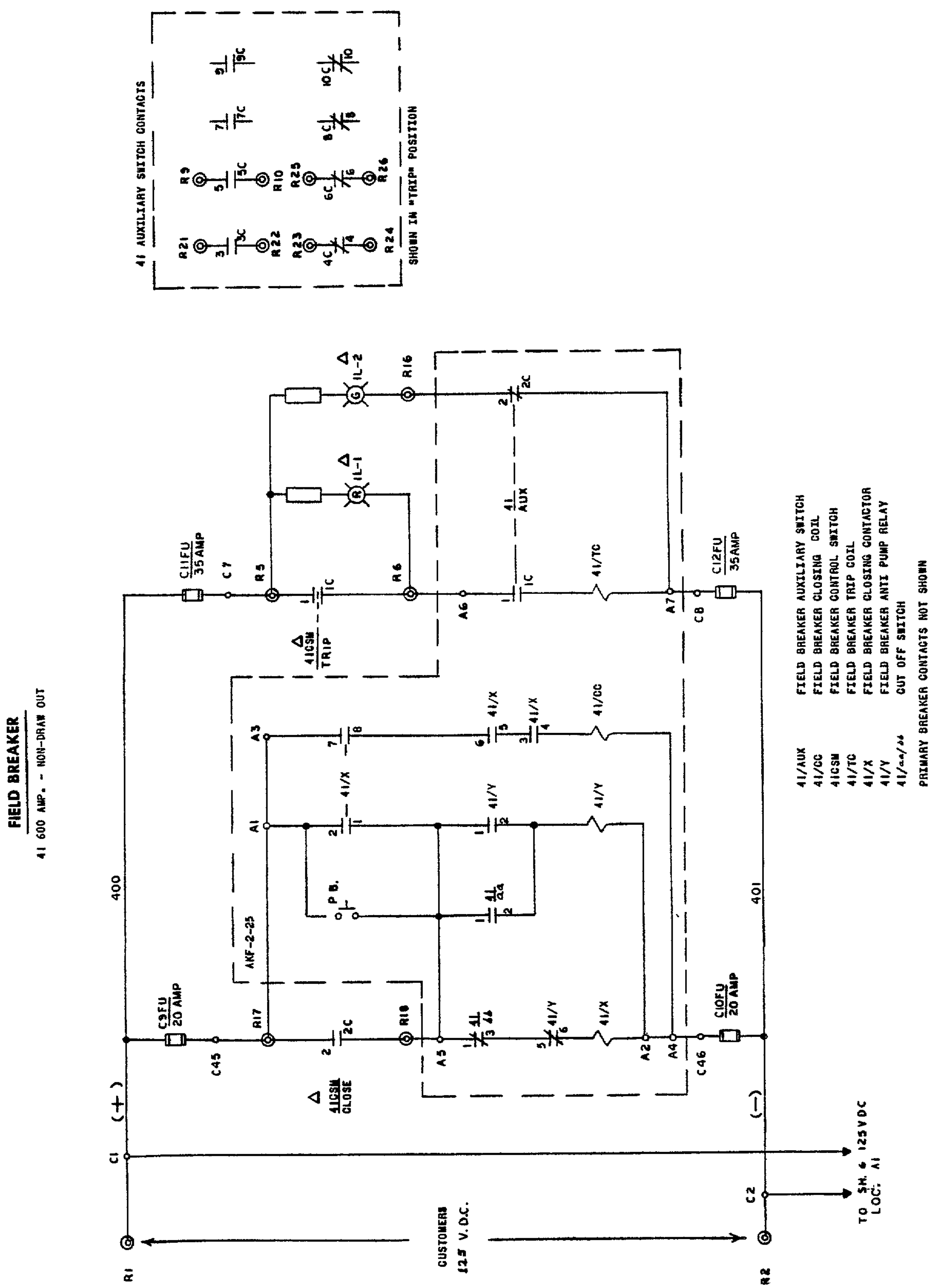


Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 6 of 9)

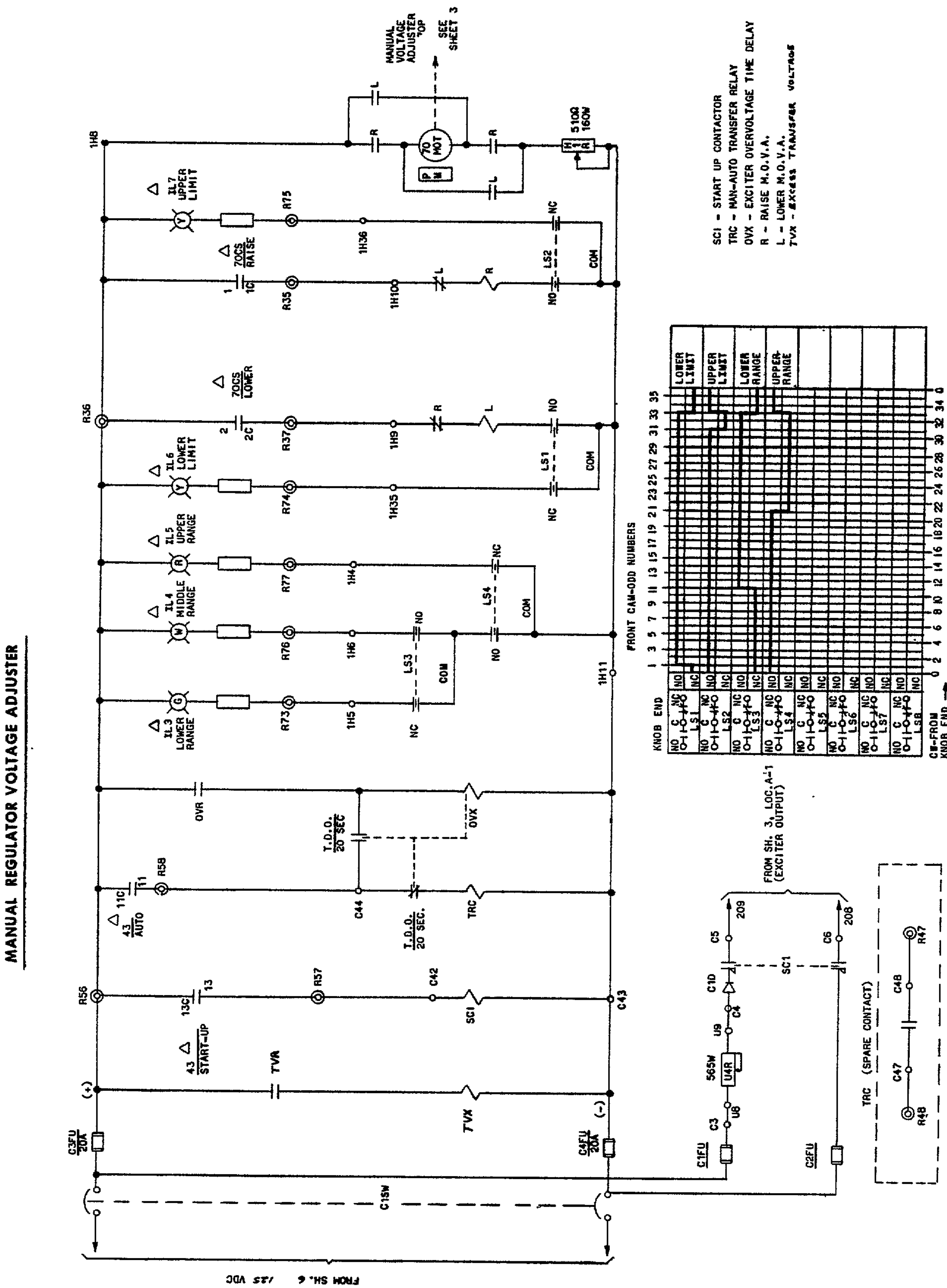


Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 7 of 9)

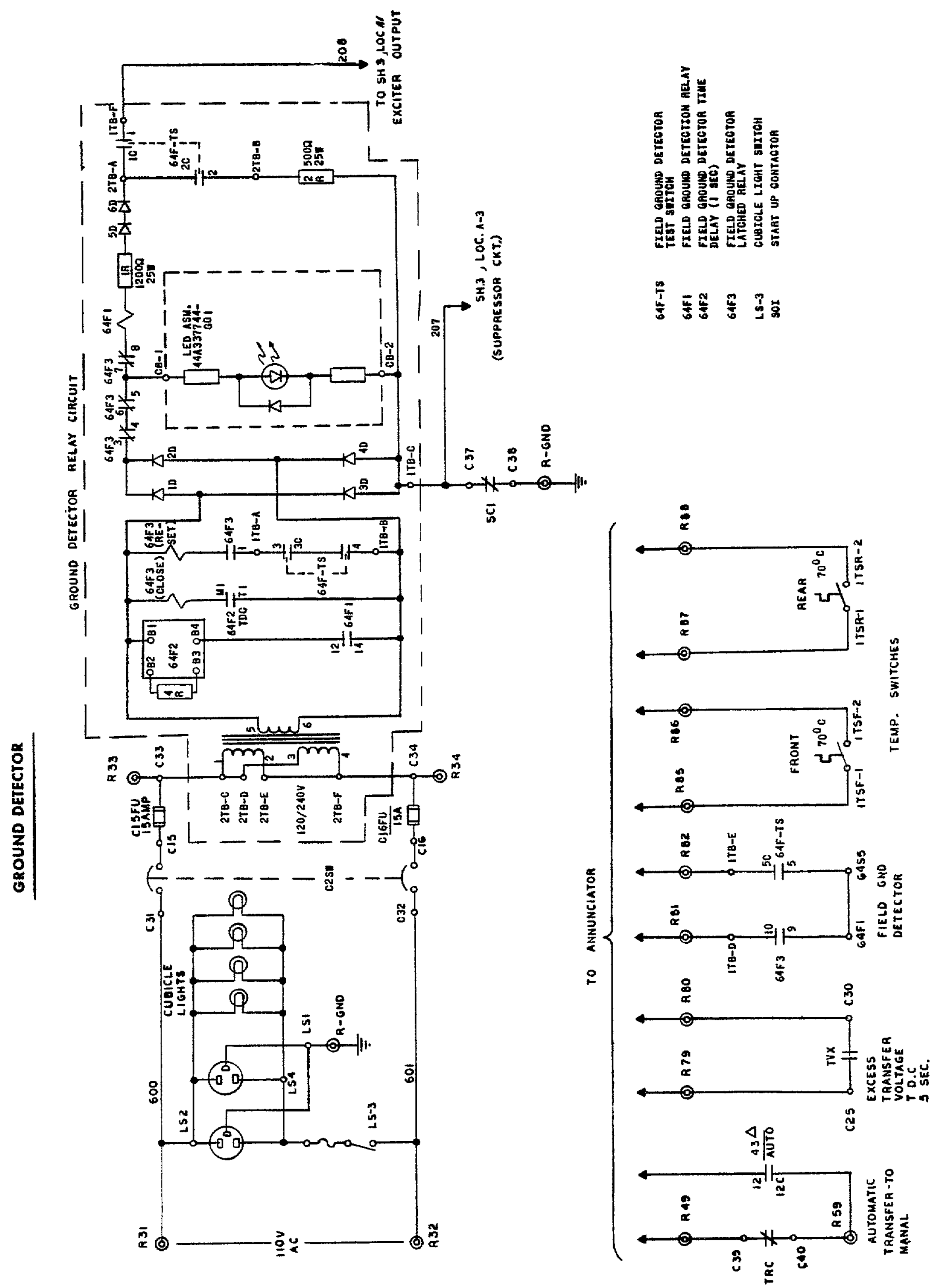


Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 8 of 9)

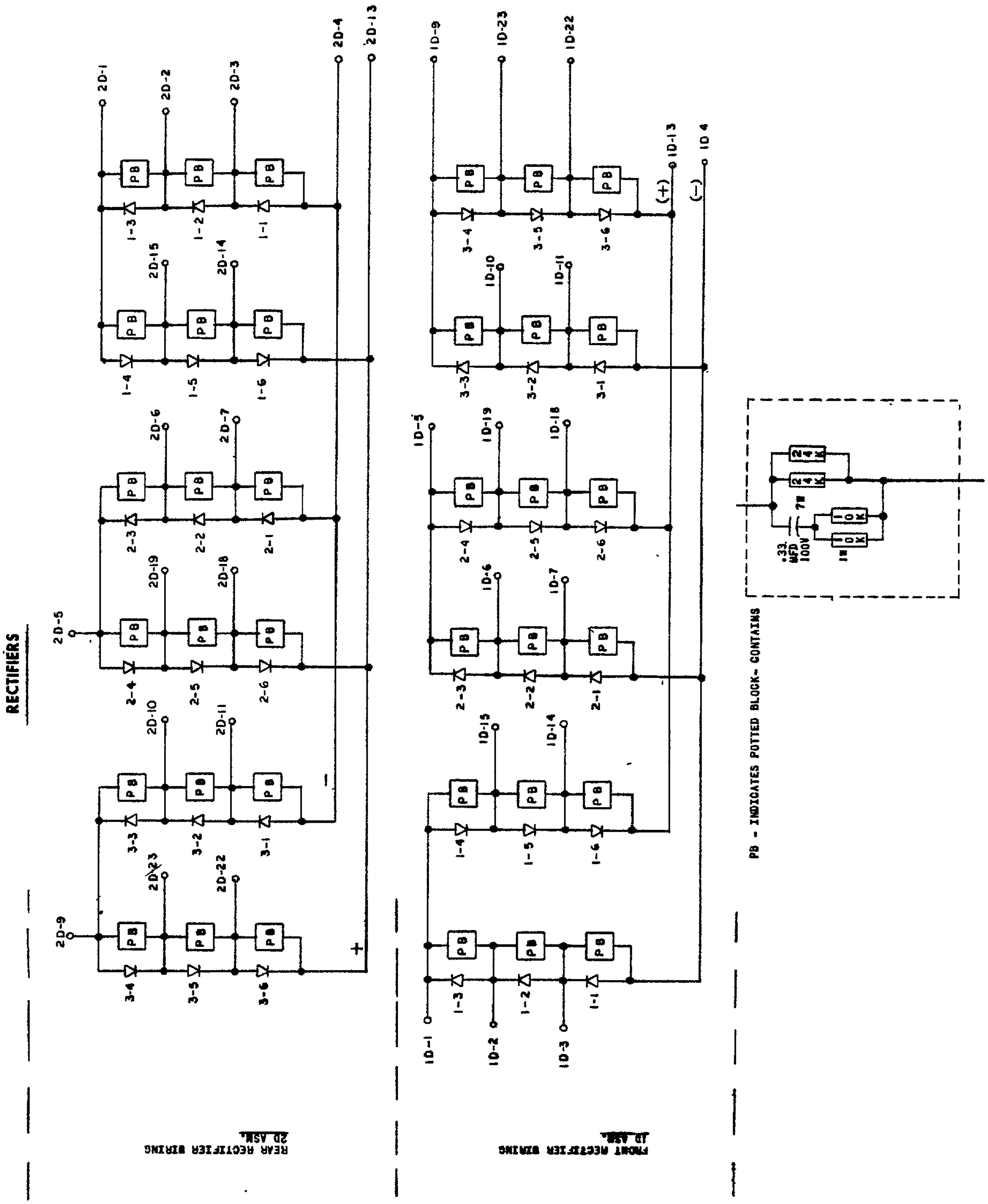


Figure 13. Elementary Diagram Static Exciter-Regulator (Sh. 9 of 9)