INSTRUCTIONS

CR7931-NA108

VOLTAGE REGULATOR EQUIPMENT

GENERAL ELECTRIC

CONTENTS

CR7931-NA108
VOLTAGE REGULATOR EQUIPMENT

INTRODUCTION

The CR7931-NA108 voltage-regulator equipment is designed to regulate automatically the terminal voltage of alternating-current generators and synchronous condensers. The regulator supplies excitation to an amplidyne generator which controls the voltage of the a-c machine.

The regulator is normally equipped with an underexcited reactive-ampere-limit unit. This unit prevents the underexcited reactive current of the a-c machine from being automatically increased materially above a desired minimum value which can be either dependent on, or independent of, the load on the a-c machine.

A maximum excitation limit unit may be provided to reduce the excitation of the a-c machine in the event of excessive a-c machine field or armature currents, or field or stator temperatures. An equalizing reactor is usually included to permit proper division of reactive current and to restrict the flow of cross currents between paralleled machines. A line-drop compensator is occasionally provided to facilitate the regulation of voltage at some point remote from the machine terminals. A motor starter for the amplidyne-driving motor, a magnetic switch for placing the amplidyne in the exciter-field circuit, an amplidyne voltmeter, and the necessary control switches, relays, and control transformers are generally included with the regulating equipment.

Both the number and the arrangement of the 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 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

COMPONENT ARRANGEMENT

The CR7931-NA108 central station regulator is generally housed in a separate floor-mounted enclosure that can be opened at both the front and the back. It usually includes the following units:

1. A CR7932-CA control panel, which may contain a transfer contactor, a motor starter, and other relaying devices.

2. A CR7932-MA stabilizing panel, which contains the adjustable resistors used for adjusting the

gain of the regulator-stabilizing circuits and a terminal board for the customer's control connections.

3. A stabilizing channel, which contains four stabilizing transformers.

4. A CR7930-NA regulator panel, which contains the components of the comparison circuit and the magnetic amplifiers.

5. A CR7932-KA underexcited reactive-ampere-limit panel.

When the equipment is supplied in a separate enclosure, a hinged framework at the front of the case is used to carry the CR7930-NA regulator panel, the CR7932-KA underexcited reactive-ampere-limit panel and any auxiliary panels which may be used. The CR7932-CA control panel and the CR7932-MA stabilizing panel are supported on a stationary framework at the rear of the case. The stabilizing channel is mounted between the front and rear frameworks at the bottom of the case.

All panels have steel bases, except the control panel which has a base made of a compound material. All panels are provided with mounting holes so that they may be bolted to supporting framework.

The adjustments of the regulator panel and the underexcited reactive-ampere-limit panel, together with the adjustments which may be incorporated in the auxiliary panels, are made accessible by opening the front doors of the enclosing case. If it is necessary to adjust any of the components mounted on the rear of these panels, the framework mounting the regulator and the limit panel may be swung open.

The stabilizing-circuit adjustments, the outgoing connections, the transfer contactor, the undervoltage relay, the motor starter and overload relays, a-c and d-c control-power switches, and fuses are accessible after the back doors of the enclosing case have been opened.

VOLTAGE REGULATOR

GENERAL

As shown in Fig. 16, the regulator can be placed in or removed from service by operating the voltage-regulator control switch. With this switch at OFF, the excitation and terminal voltage of the a-c machine can be manually controlled by adjusting the exciter-field rheostat; under this condition, the regulator is completely out of service and the amplidyne is removed from the exciter-field circuit. With the control switch at ON, the amplidyne is connected in series with the exciter field, and the regulator will control automatically the excitation and terminal voltage of the a-c machine.

When the machine voltage is higher than normal, the regulator will supply control-field current to the amplidyne, so that the amplidyne voltage will oppose, or "buck," the exciter voltage impressed across the exciter-field circuit. This will tend to reduce the exciter-field current, lower the exciter voltage, and decrease the field current and terminal voltage of the a-c machine toward normal.

When the machine terminal voltage is below normal, the regulator will supply control-field current to the amplidyne which will produce an amplidyne voltage in the opposite direction to raise, or "boost," the exciter voltage impressed across the exciter-field circuit. This will increase the exciter-field current and the exciter voltage to raise the terminal voltage of the a-c machine toward normal.

The regulator and amplidyne can control automatically the excitation and terminal voltage over the complete load range of the machine, at any load from no load to rated load.

The regulator-control switch is provided with a position to be used for test and adjustment of the regulator preparatory to placing it in service. With the control switch at TEST, the regulator is connected to the generator potential transformers and while the amplidyne is operated, it is disconnected from the exciter-field circuit so that it cannot affect the excitation of the a-c machine. This permits all the regulator equipment to be operated for test purposes.

REGULATOR SIGNAL VOLTAGE

When the control switch is at ON, the regulator is connected to the secondaries of potential transformers, whose primaries are connected to the a-c machine terminals or bus. If an equalizing reactor is not used, the potential transformers supply the regulator with a three-phase signal voltage which is directly proportional to the machine terminal voltage.

In instances where the a-c machine will operate in parallel with other machines, an equalizing reactor is connected in one of the transformer secondary lines to the regulator. The effect of the equalizing reactor upon the signal voltage is described in the section on "Auxiliary Equipment."

REGULATOR CIRCUIT

The three-phase signal voltage from the secondaries of the a-c machine potential transformers is impressed upon the major components of the regulator. These components may be divided into three groups: the comparison circuit, the magnetic amplifier, and the amplidyne. The comparison circuit may be further subdivided into the averaging and the reference circuits.

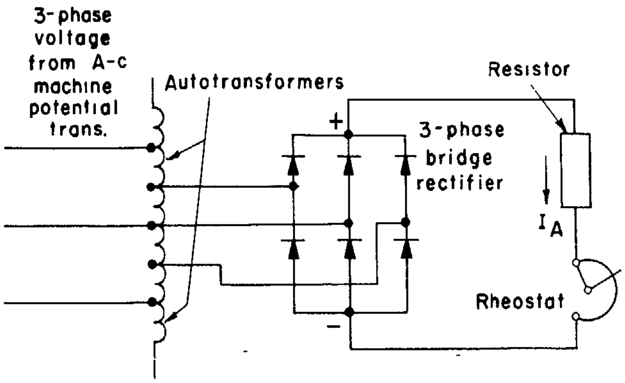

Fig. 1. Elementary diagram of the averaging circuit

The averaging circuit, shown in Fig. 1, consists of two autotransformers connected in open delta across the a-c machine potential transformers, a three-phase bridge rectifier, and a series resistor-rheostat combination. The d-c output voltage of the rectifier is proportional to the average of the three-phase machine voltage. This circuit delivers a current I_A (always in the direction of the arrow) which for any given setting of the rheostat is directly proportional to the average of the three-phase voltages. This characteristic is shown in Fig. 2.

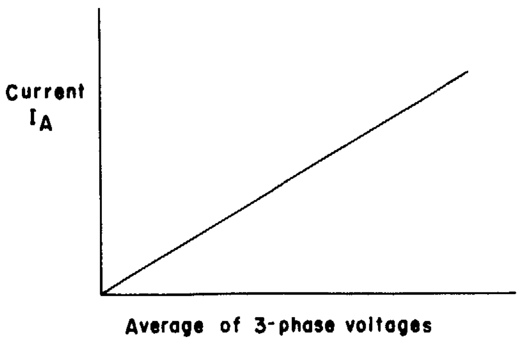

Fig. 2. Curve of averaging-circuit output current vs. average three-phase potential-transformer voltage

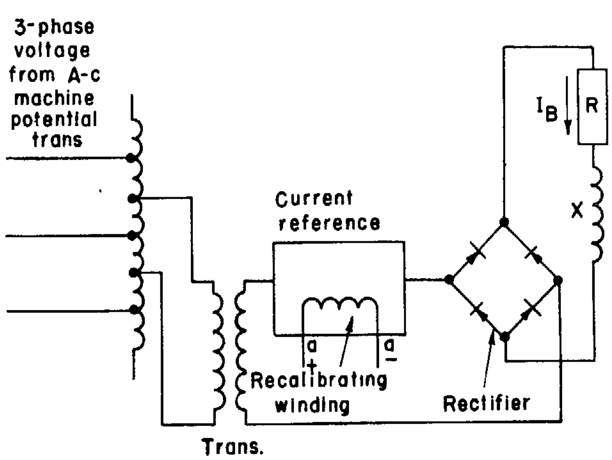

Fig. 3. Elementary diagram of the reference circuit

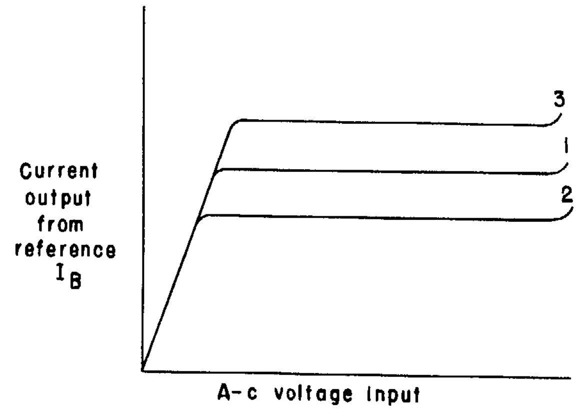

Fig. 4. Curves of reference-circuit output current vs. three-phase potential-transformer voltage showing effect of recalibrating winding a-a

The reference circuit, shown in Fig. 3, consists of a magnetic square-wave current reference supplied with single-phase current from the comparison-circuit autotransformers, a rectifier, a resistor and a filter reactor. The output of the current reference is rectified and appears as an essentially constant current I_B through resistor R. The direct-current output of the reference is shown as a function of a-c voltage input in curve 1, Fig. 4. The output current of the reference is essentially constant with very large variations in a-c machine output voltage. In addition, the output of the reference is very nearly independent of frequency from 45 to 90 cycles.

As shown in Fig. 3, the reference contains an additional winding a-a, called the recalibrating winding. If a d-c voltage of the polarity shown is applied to winding a-a, curve 3 in Fig. 4 will result; if the opposite polarity is applied, curve 2 will result. Thus, an external direct current applied to the recalibrating

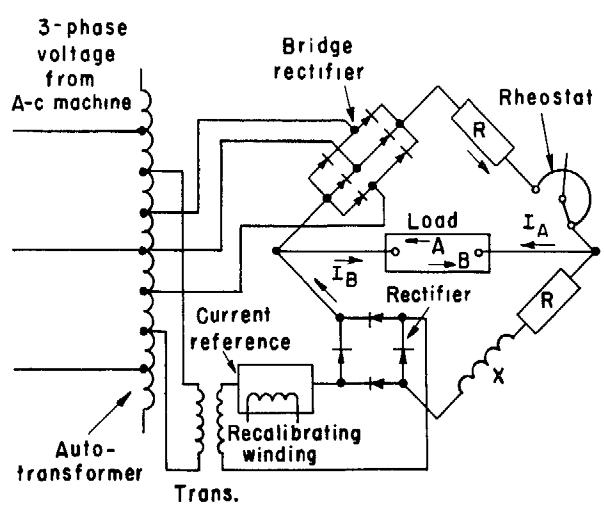

Fig. 5. Elementary diagram of the comparison circuit which is composed of the averaging circuit (Fig. 1) and the reference circuit (Fig. 3)

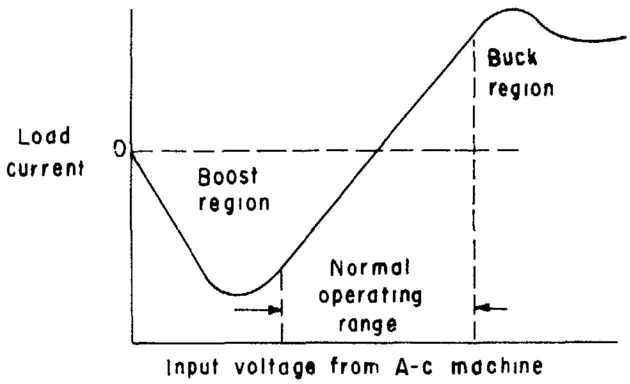

Fig. 6. Curve of comparison circuit output current vs. input voltage from the a-c machine

winding on the reference will result in a change in its current output.

The averaging and the reference circuits are connected as shown in Fig. 5. The current through the load is the difference between the current outputs of the averaging and the reference circuits. If the outputs of the two circuits are equal, the current through the load will be zero. If, however, the output of the averaging circuit is greater than the output of the reference circuit, current will flow through the load in direction A. This corresponds to a "buck" current, as shown in Fig. 6. When the reference-circuit output is greater than the averaging-circuit output, current will flow in direction B, or the "boost" direction (Fig. 6), through the load. The load in Fig. 5 represents the control windings of a magnetic amplifier.

The circuit of a single magnetic amplifier is shown in Fig. 7, and its characteristic curve is shown in Fig. 8. As can be seen from this latter illustration, zero current in the control winding results in a direct-current output that is approximately half of the maximum linear output of the amplifier. An increase of current in control winding F3-F4 (Fig. 7), in the direction indicated by the arrow beside this winding, increases the direct current flowing through the amplifier load in the direction indicated by the arrow beside the load.

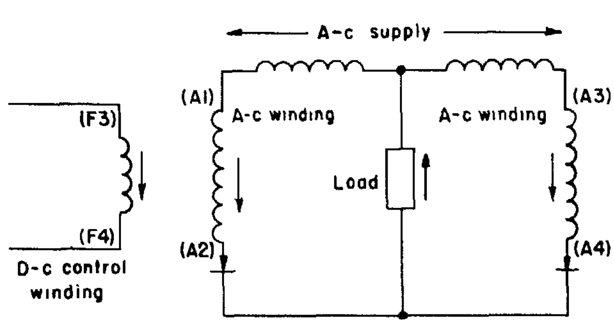

Fig. 7. Elementary diagram showing windings of a magnetic amplifier

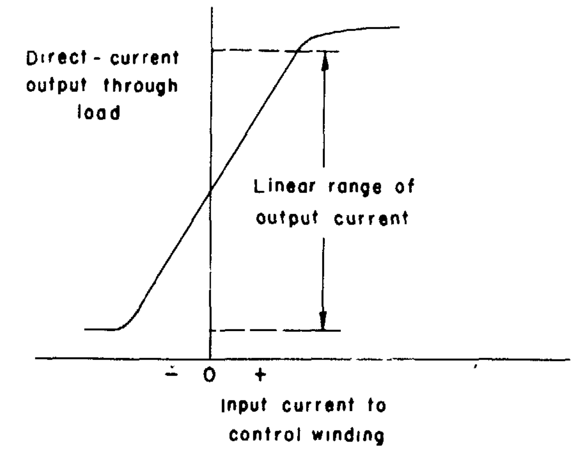

Fig. 8. Characteristic curve of a magnetic amplifier

The first-stage magnetic amplifier, shown in Fig. 9, is a balanced amplifier, consisting of magnetic amplifiers 1SX and 2SX connected to the second-stage control windings of 3SX and 4SX. With zero current in control windings 1SX (F5-F7) and 2SX (F5-F7), the output currents of the two magnetic amplifiers will be equal and will have the values indicated as point 1 in Fig. 10. If a current flows through the control windings in the direction of the dotted arrow, the output of 1SX increases and the output of 2SX decreases. As a result, the operating points are moved from point 1 on the curve in Fig. 10 to points $1'$ and $1''$, and the two amplifiers are no longer in balance.

The second-stage amplifier differs from the first stage in size of components and in the use of bias windings. Fig. 10 shows that for zero-control current in the first stage, the output currents of the first stage have equal values. Since the second stage has the characteristics shown in Fig. 11 under this condition, the output currents of 3SX and 4SX will have the values indicated by points $1'$ and $1''$, and

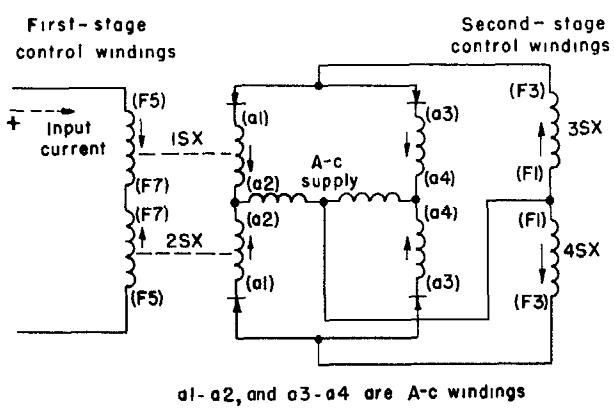

Fig. 9. Elementary diagram of the first stage of the balanced magnetic amplifier

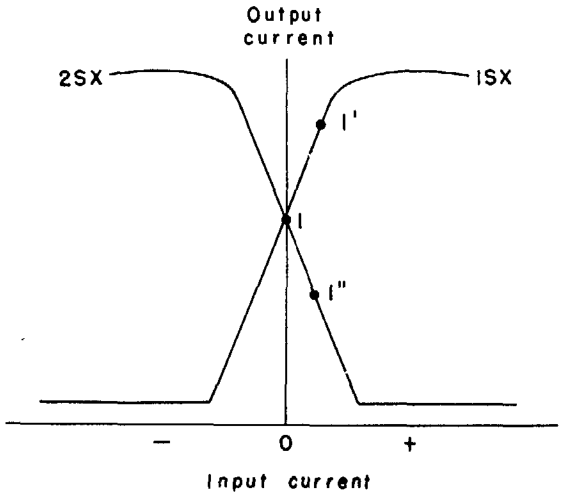

Fig. 10. Characteristic curves of first-stage balanced magnetic amplifier

the individual amplifiers will not respond linearly to changes of input current. By using the bias windings shown in Fig. 17, the values of the second-stage output currents may be changed to point 1 in Fig. 11 when the output currents from the first stage are equal. This will locate the balanced output point at the middle of the linear range of the amplifiers.

Referring to Fig. 17, if the outputs of the two second-stage magnetic amplifiers are equal, then equal currents will flow through the amplidyne-control fields from F2 to F1 and from F3 to F4 and the output voltage of the amplidyne will be zero. If the current flowing from F2 to F1 is greater than the current flowing from F3 to F4, the amplidyne will have a positive voltage at terminal A1 and will buck the exciter voltage to reduce the exciter field current, thereby reducing the a-c machine terminal voltage. Conversely, if the current flowing from F3 to F4 is greater than the current flowing from F2 to F1, the amplidyne voltage at terminal A1 will be negative, and will boost the exciter voltage to increase the exciter-field current, thereby increasing the a-c machine terminal voltage.

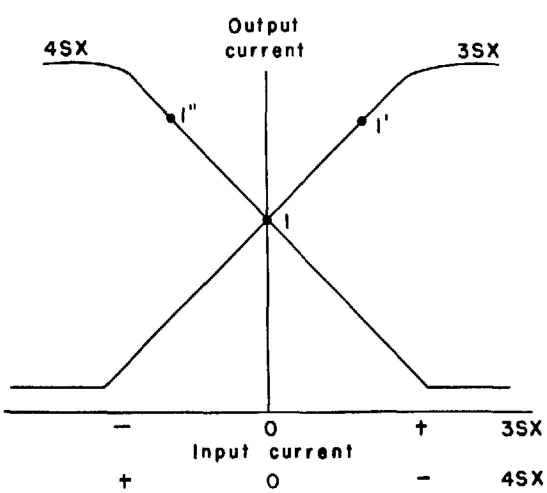

Fig. 11. Characteristic curves of second-stage magnetic amplifier

REGULATOR AND UNDEREXCITED REACTIVE-AMPERE-LIMIT BURDEN

The regulator alone imposes an unbalanced three-phase burden at about 115 volts a-c on the a-c machine potential transformers. The regulator will require a current of approximately 0.30 ampere in line 105, 2.3 amperes in line 107 and, 2.2 amperes in line 109. (Refer to Fig. 16). The regulator and the underexcited reactive-ampere-limit, when both are used, will require a current of 0.4 ampere in line 105 and 2.3 amperes in lines 107 and 109.

The underexcited reactive-ampere-limit circuit imposes a burden of 250 volt-amperes on the current transformer with five amperes flowing in the secondary.

REGULATOR OPERATION

When the terminal voltage of the a-c machine is equal to the value which the regulator is adjusted to maintain, the averaging circuit will deliver a current equal to that supplied by the current reference and no current will flow through the control windings of the first-stage amplifiers. This results in equal currents through the control windings of the second stage, equal currents through the two control fields of the amplidyne, and zero output voltage from the amplidyne.

An increase in a-c machine voltage above the value for which the regulator is adjusted results in a bucking current flowing through the control windings of the first stage from 20 to 14 (Fig. 17). As a result, the current outputs of A1SX and A3SX increase, and those of A2SX and A4SX decrease. The current through amplidyne field F2-F1 will be greater than through field F3-F4. This causes a bucking amplidyne voltage, a reduction in the a-c machine excitation, and a decrease in the a-c machine terminal voltage.

Similarly, a decrease in a-c machine terminal voltage below the value for which the regulator is adjusted will result in a boosting current from the comparison circuit from 14 to 20 and a boosting voltage from the amplidyne. This will produce an increase in a-c machine excitation and terminal voltage.

If the a-c machine voltage increases from zero, the output of the comparison circuit will be a boost current which will cause the amplidyne to raise the exciter voltage until the a-c machine voltage reaches the value for which the regulator is adjusted.

REGULATOR ADJUSTMENTS

The nominal a-c machine terminal-voltage level for which the regulator is adjusted is determined by the connections of the autotransformer taps. Normal adjustment of voltage is obtained by setting the voltage-adjusting rheostat.

Regulator sensitivity may be varied by means of the rheostat in series with the output of the comparison circuits. This rheostat is called the SENSITIVITY rheostat. Increasing the resistance decreases sensitivity, while decreasing the resistance increases the sensitivity.

The BALANCE adjustment provides a means of compensating for slight differences in output of the second-stage magnetic amplifiers with zero input control current to the first-stage magnetic amplifiers

Second-stage bias and amplidyne negative feedback if used are adjusted at the factory and do not usually require further adjustment. Voltage level, sensitivity, and balance are also adjusted at the factory, but further adjustment may be required at the time of installation.

STABILIZING TRANSFORMERS

To prevent excessive overshooting of the a-c machine voltage and to obtain voltage stability, stabilizing transformers are generally used, as shown in Fig. 16 and 17. The primary of the exciter stabilizing transformer is connected to the exciter armature (Fig. 16). The secondary of this stabilizer is connected in series with a reactor and with the two stabilizing windings of the first-stage magnetic amplifier (Fig. 17). The stabilizers will supply current to the amplifier stabilizing windings only when the exciter voltage is changing and, therefore, are effective only during transient conditions. They are ineffective when the exciter voltage is not changing, and stabilizer action is not required.

Neglecting voltage drops due to winding resistance, with the exciter voltage increasing, point 31 on 1ST-S, Fig. 17, will become positive. This will tend to increase the output of A1SX and therefore A3SX and to decrease the output of A2SX and A4SX. This effect will tend to change the amplidyne voltage in the buck direction, and will oppose an increase in exciter voltage to prevent overshooting and instability. With the exciter voltage falling, the opposite action will take place to oppose the decrease in exciter voltage.

A similar stabilizing transformer is connected across the amplidyne. The secondary is connected in series with the magnetic amplifier stabilizing windings of the second stage. If the amplidyne voltage increases in the buck direction, the output of A3SX will tend to decrease and the output of A4SX will tend to increase. This will result in a tendency to reduce the buck voltage or increase the boost voltage from the amplidyne.

A resistor-rheostat combination is usually connected in series with the stabilizer primaries to permit adjustment of the primary-circuit resistance (Fig. 16). Stabilizer adjustments are made in the factory although in individual applications special adjustments may be made to obtain optimum performance.

UNDEREXCITED REACTIVE-AMPERE LIMIT

The function of the underexcited reactive-ampere-limit circuit, shown in Fig. 18, is to prevent the regulator from reducing the a-c machine excitation to such a low value that the machine would fall out of synchronism. It operates by limiting the machine underexcited reactive current.

Under normal operating conditions, with the regulator and the limit in service, the underexcited reactive current of the a-c machine is less than the value at which the limit functions, and the limit is inoperative. However, if the regulator reduces the machine excitation to a sufficiently low value, the limit immediately becomes operative and prevents the underexcited reactive current from rising materially above the value for which the limit is adjusted. The direct-current output from the limit circuit is amplified and applied to the recalibrating winding of the current reference to increase the current output of the reference. As a result, the voltage regulator is recalibrated to hold a higher machine voltage. Consequently, the limit will prevent appreciable increases in machine underexcited reactive current beyond a predetermined value by increasing the voltage for which the regulator is adjusted, and usually will increase the machine terminal voltage held by the regulator.

Since in many cases the magnitude of the underexcited reactive current at which the a-c machine would fall out of synchronism is a function of machine active current, the limit can be adjusted so that the value of underexcited reactive current at which the limit will become operative (the limit-start point) will decrease as the machine active current increases. Therefore, it is possible to arrange the limit so that its starting point is automatically changed as machine active current varies. Active current is the in-phase or watt component of the machine armature current.

A single-phase line to line voltage of the a-c machine is applied through a potential transformer to the primary of transformer B3T (Fig. 18). A current signal, obtained from the secondary of a current transformer connected in the third phase of the machine, is applied across the resistor-reactor combination (B3X-B3R). Reactor B3X is called the power recalibrating reactor. In addition, a variable autotransformer called the limit-start transformer is connected across terminals 4 and 6 on the secondary of transformer B3T.

With both the power recalibrating reactor (B3X) and the limit-start autotransformer (B1VT) set at zero (Fig. 18), and with no reactive current carried by the a-c machine, the voltage across the primary of transformer B2T is equal to the voltage across the primary of transformer B1T. Therefore the output voltage of rectifier B2 equals the output voltage of rectifier B1, and current will not flow from point 8 through the control winding of A5SX (Fig. 17). If, however, the a-c machine carries underexcited reactive current, a component of voltage will be produced by this current across resistor B3R. This voltage will be in phase with the secondary voltage of B3T. It will decrease the voltage of B2T and will increase the voltage of B1T. As a result, the limit will deliver a direct current from terminal 8 to the control winding of A5SX.

The value of the underexcited reactive current which will cause the voltage of B1T to exceed the voltage of B2T is determined by the setting of the limit-start autotransformer and is called the limit-start point. When the reactive amperes increase to the value determined by the limit-start adjustment, the limit will deliver a direct current to the control winding of magnetic amplifier A5SX, which, in turn, will recalibrate the regulator by increasing the current output of the current reference and will therefore raise the voltage for which the regulator is adjusted (Fig. 12).

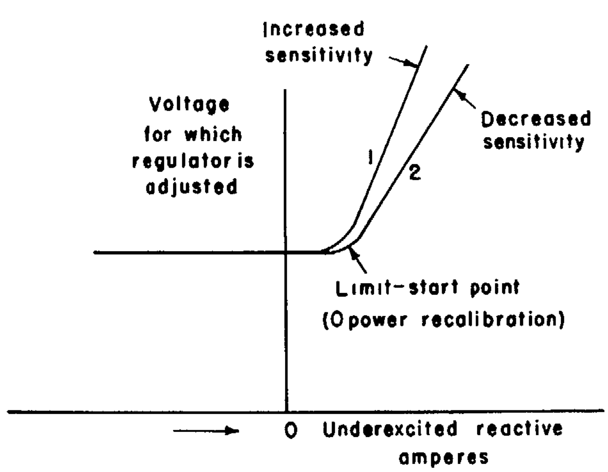

Fig. 12. Curves of underexcited reactive amperes vs. regulator voltage, showing effect of limit-sensitivity adjustment

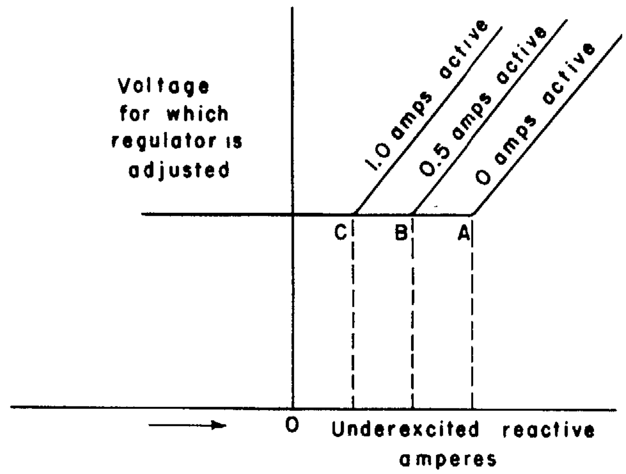

Fig. 13. Curves of underexcited reactive amperes vs. regulator voltage showing how limit-start point is changed as a function of active current

The purpose of the power recalibrating reactor (B3X) adjustment is to change the limit-start point as a function of the active current delivered by the machine. Fig. 13 shows that the limit will become operative at a value of underexcited reactive current less than that set by the limit-start adjustment when the machine is delivering active current if the power recalibrating reactor is in the circuit. With zero active amperes, the limit will start to recalibrate with "A" underexcited amperes. As the active amperes increase, less underexcited reactive amperes are required to recalibrate the regulator.

A rheostat (B1RH) is provided to vary the sensitivity of the limit. Normally this rheostat is set at zero resistance to provide maximum sensitivity. If, however, a less sensitive limit is desired, resistance may be inserted to permit the underexcited reactive current to increase further above the limit-start point as the limit becomes increasingly effective. The rheostat used for this adjustment is usually referred to as the limit-sensitivity adjusting rheostat. Curve 2 in Fig. 12 shows how the voltage for which the regulator is effected by decreasing the sensitivity.

In some cases stabilizing transformers are connected in the limit circuit, and function in a similar manner to the stabilizers used in the regulator circuit. The secondary windings of the stabilizers are connected in series in the limit output circuit while the primary windings are usually connected across the exciter armature, as shown in the elementary diagram provided with the equipment. In some cases the secondaries may be connected in parallel to provide optimum stability, or the primaries may be connected at other points.

EXCITER POLARIZING

An exciter polarizing circuit is sometimes provided. If the polarity of the exciter is wrong, it may be reversed by means of the circuit consisting of rectifiers 1REC, 2REC2, and 2REC1, resistor 2R, and amplidyne field F9-F10 (Fig. 16). With the control switch at POLARIZE, rectifiers 1REC, 2REC1, and 2REC2 will allow current to flow from the exciter, through the rectifiers, through resistor 2R, and through the amplidyne field from F9 to F10, if the exciter has the opposite polarity from that shown in Fig. 16. This current flow is aided by the voltage from transformer secondary 3TS1, rectified by 1REC. As a result amplidyne terminal C2 will become positive, and current will flow in the exciter field in a direction to cause the exciter voltage to be reduced to zero. Transformer 3T will maintain the voltage on the amplidyne in the same direction until the exciter voltage has been reversed and increased in the correct direction. When the exciter voltage balances the voltage from 1REC, the current through field F9-F10 becomes zero. This will occur at a low value of exciter voltage. The exciter will then be correctly polarized.

This circuit may also be used when the exciter residual-field flux is not sufficient to permit the exciter armature voltage to build up when starting the exciter as a self-excited machine. In special cases, other circuits may be used for exciter polarizing.

AUXILIARY EQUIPMENT

EQUALIZING REACTOR

The equalizing reactor is used where means must be provided to equalize division of reactive kva and to prevent circulating reactive current between a-c machines when two or more machines with individual regulators are operating in parallel. The equalizing reactor is essentially an insulating transformer which functions as an adjustable reactor. It is connected to the secondary of a current transformer located in one of the a-c machine lines, and in series with one phase of the three-phase regulator signal voltage inputs to the averaging circuit. Connections for this device are shown in Fig. 14. IT IS ESSENTIAL THAT THE CURRENT WINDING AND THE SIGNAL-VOLTAGE WINDING BE CONNECTED IN THE SAME PHASE.

The equalizing reactor will vary the regulator signal voltage in this phase mainly as a function of the machine reactive current. As the machine reactive current increases with the machine operating in the overexcited region, the regulator signal 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 machine is operating in parallel with another machine.

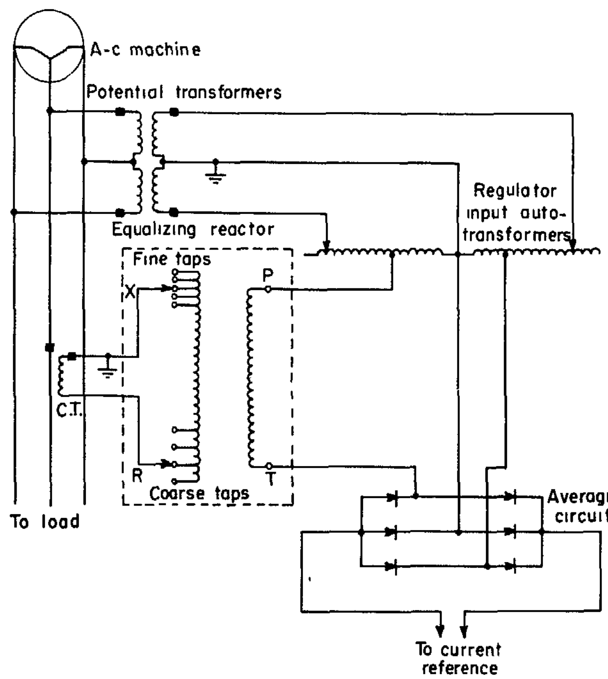

Fig. 14. Equalizing-reactor connections

If the a-c machine is operating in the underexcited region, the equalizing reactor 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 equalizing reactor can be increased by increasing the active turns of the current winding. This increases the effective reactance and may be done readily with the tap switches located on the reactor.

The reactor is adjustable in one-volt steps, on the basis of five amperes flowing through the current winding, by means of two manually operated tap switches. One of the switches provides coarse adjustments and the other fine. The voltage across the signal voltage winding is proportional to the current flowing through the current winding. With five amperes flowing through the reactor current winding and with all the winding in the circuit, the total voltage is 24 volts. This is equivalent to about a 90 percent voltage in one phase of the regulator signal voltage, or an average effect of approximately 30 percent of the three-phase signal voltage.

The equalizing reactor imposes a burden of 120 volt-amperes on the current transformer with a five-ampere secondary current, and with all the reactance in the circuit.

The equalizing reactors are built with two independent windings, as shown in Fig. 14, so that the current and potential-transformer secondaries are electrically separate and both may be grounded. The unit is enclosed in a perforated steel case with a dead-front control panel. It is arranged for surface or bracket mounting.

LINE-DROP COMPENSATOR

In certain special applications, the line-drop compensator is used to simulate, at the regulator, the resistance and reactance between the a-c machine and a predetermined point in the system. The function of the compensator is to lower the signal voltage to the regulator as the machine load increases, in an effort to cause the regulator to maintain normal voltage at some predetermined point on the system, regardless of changes in voltage drop over the system due to the impedance between the machine and this point.

In case line-drop compensation is required where regulators are equipped with equalizing reactors and control machines operating in parallel, provision may be made to prevent interference between the reactor and the line-drop compensator. This is accomplished by special connections of the current transformers supplying the equalizing reactors, or by special line-drop compensator connections.

This device is similar to the equalizing reactor. In addition to a variable reactance winding and insulating current winding, it has a variable resistor connected in series with the reactance winding.

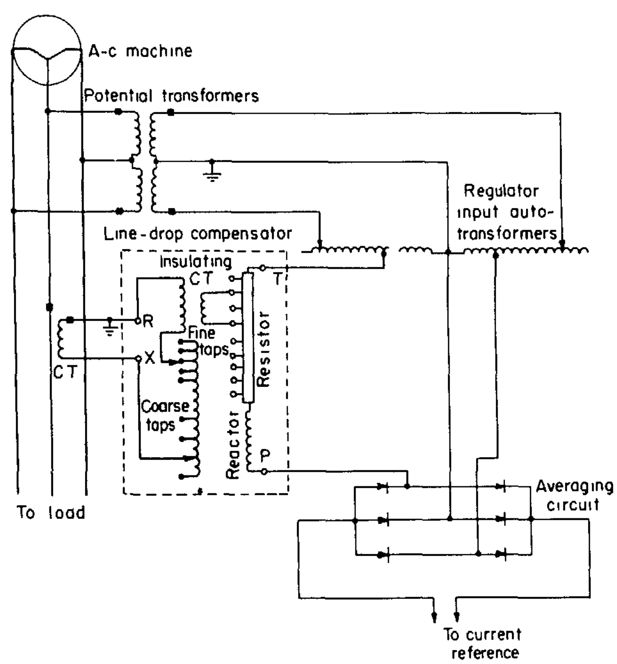

Fig. 15. Line-drop compensator connections

The resistance and reactance elements of the compensator are each divided into a number of equal sections. Taps are brought out from each of these sections and connected to two independently adjustable tap switches, one for coarse adjustments and the other for fine. Both the reactance and resistance elements are variable in one-volt steps, based on five amperes flowing in the current winding. A maximum of 24 volts can be obtained across each element with five amperes in the current winding. This voltage is proportional to the current flowing in the compensator.

Fig. 15 shows the connections for this device when used with a single machine. Insulating windings are provided for both the reactance and resistance elements to permit grounding the current and potential-transformer secondaries.

One compensator connected in one phase of a three-phase circuit gives approximately 30 percent resistance compensation and 30 percent reactance compensation.

This device imposes a maximum burden of 225 volt-amperes on the current transformer with a secondary current of five amperes, and with all of the reactance and resistance elements in the circuit.

AMPLIDYNE GENERATOR

The amplidyne generator is normally individually driven by an induction motor, although other arrangements are sometimes used. Separate instructions are supplied for the amplidyne.

The amplidyne is usually provided with five control fields. The field and armature leads are marked with metal identification tags which should not be removed even after installation is complete. The field leads are connected to a small terminal board mounted on the machine frame, the terminals being marked with the field-lead identification numbers.

Two fields are excited by the regulator, and are so connected that the difference between their respective currents will determine the amplidyne voltage.

A single field is sometimes used as a negative-feedback winding to increase amplidyne linearity and speed of response. The output voltage of the amplidyne causes a current to flow through resistors A20R and A20AR and the negative feedback field in a direction to decrease the amplidyne voltage (Fig. 17).

A fourth field is an amortisseur winding which is connected to resistor 8R. It provides a path for dissipating the energy produced by the ripple currents

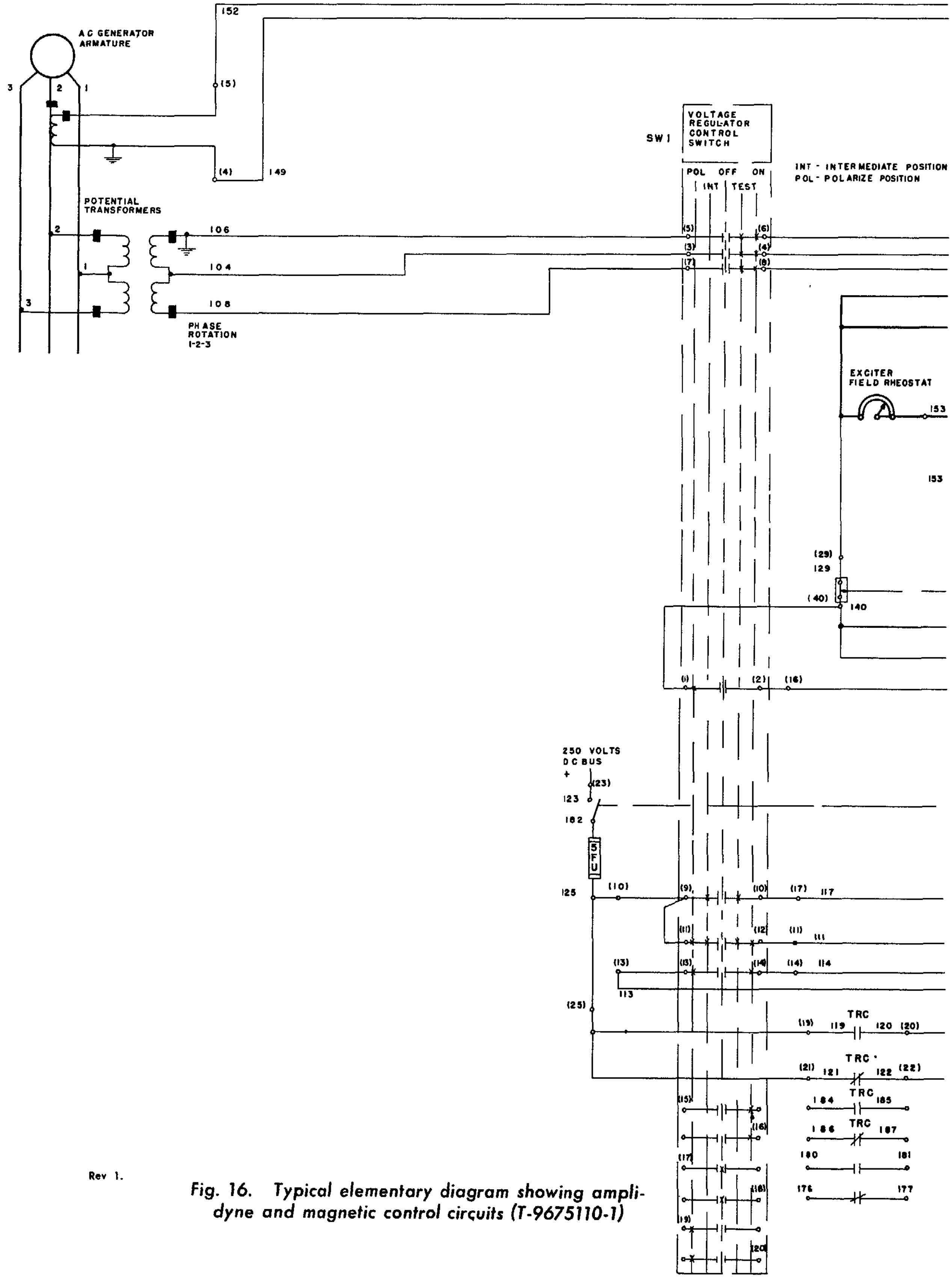

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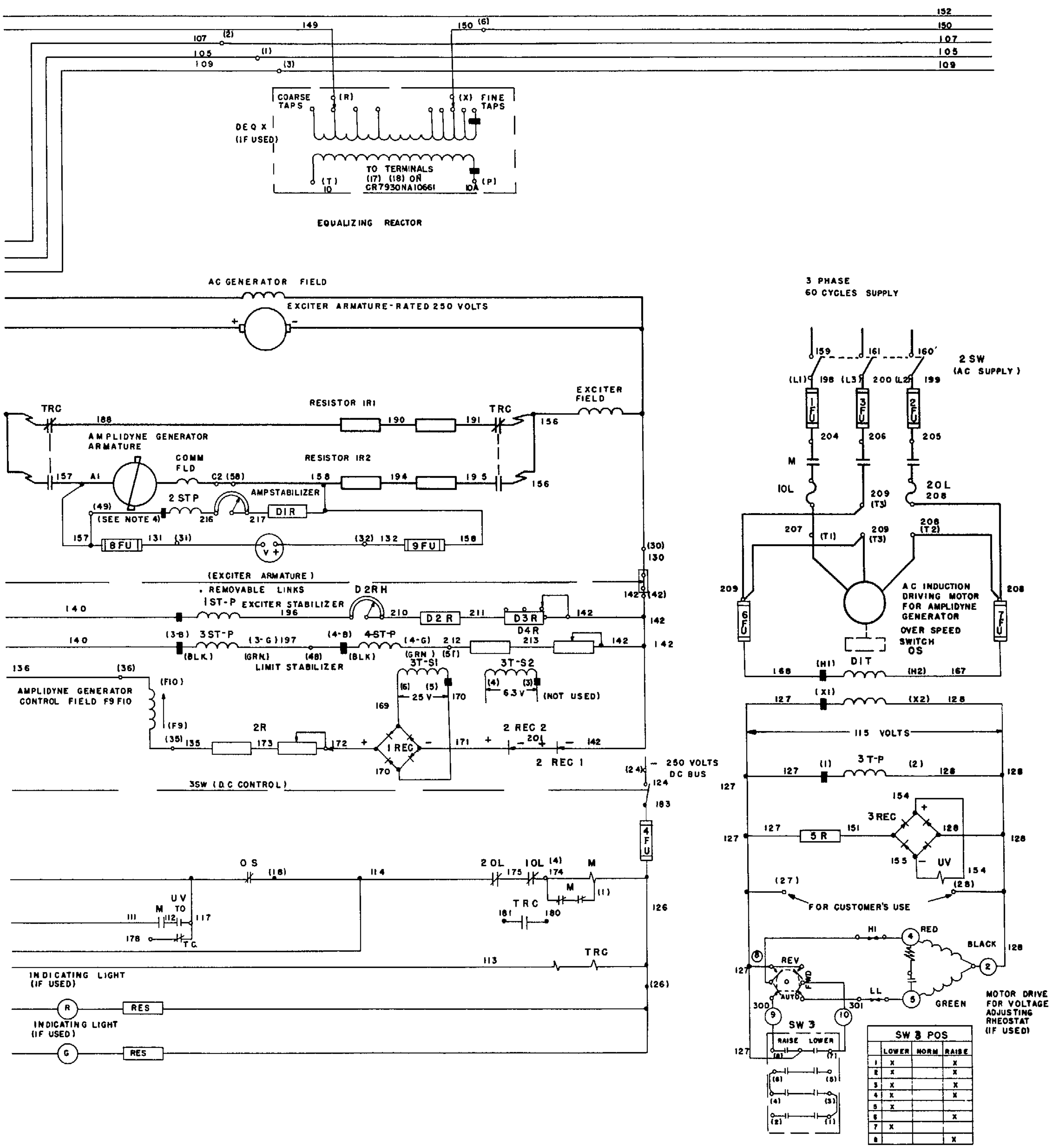
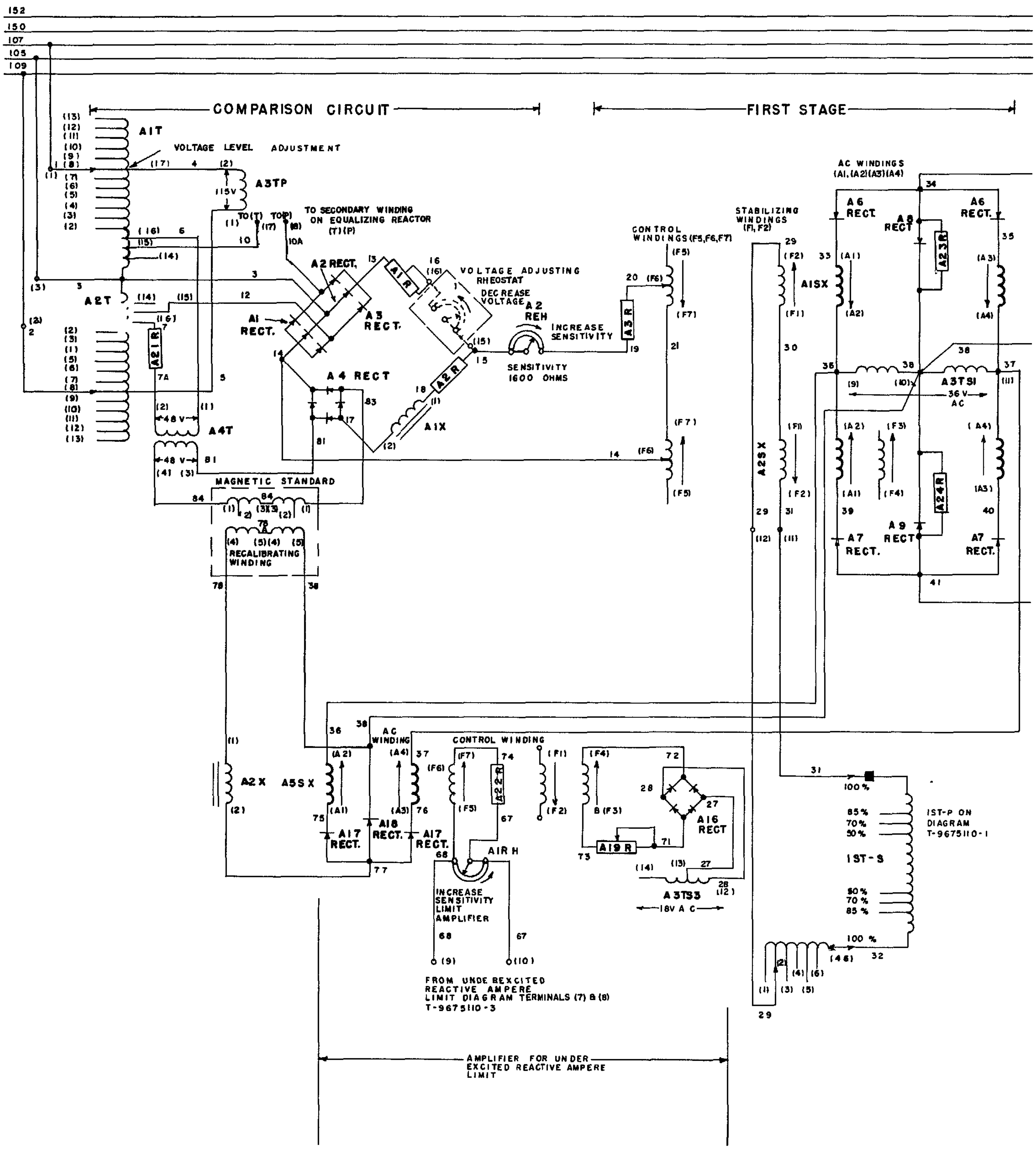
Fig. 16. Typical elementary diagram showing amplidyne and magnetic control circuits (T-9675110-1)


COARSE TAPS
FINE TAPS
DEQ X (IF USED)
TO TERMINALS (17) (18) ON CR7930NA10661
EQUALIZING REACTOR
AC GENERATOR FIELD
EXCITER ARMATURE-RATED 250 VOLTS
3 PHASE 60 CYCLES SUPPLY
2 SW (AC SUPPLY)
EXCITER FIELD
RESISTOR IR1
RESISTOR IR2
TRC
AMPLIDYNE GENERATOR ARMATURE
COMM FLD
AMPSTABILIZER
(SEE NOTE 4)
(EXCITER ARMATURE)
• REMOVABLE LINKS
EXCITER STABILIZER
LIMIT STABILIZER
AMPLIDYNE GENERATOR CONTROL FIELD F9 F10
(NOT USED)
250 VOLTS DC BUS
3SW (D.C CONTROL)
AC INDUCTION DRIVING MOTOR FOR AMPLIDYNE GENERATOR
OVER SPEED SWITCH OS
115 VOLTS
FOR CUSTOMER'S USE
INDICATING LIGHT (IF USED)
MOTOR DRIVE FOR VOLTAGE ADJUSTING RHEOSTAT (IF USED)
RED
BLACK
GREEN
SW 3
RAISE LOWER
SW 3 POS
LOWER NORM RAISE



152
150
107
105
109
COMPARISON CIRCUIT
FIRST STAGE
A1T
VOLTAGE LEVEL ADJUSTMENT
A3TP
115V
TO (T) TO (P)
TO SECONDARY WINDING ON EQUALIZING REACTOR (T) (P)
A2T
A21R
A2 RECT.
A1 RECT.
A3 RECT.
A1R
VOLTAGE ADJUSTING RHEOSTAT
DECREASE VOLTAGE
A2 REH
INCREASE SENSITIVITY
SENSITIVITY 1600 OHMS
A4 RECT
A2R
A1X
A3R
CONTROL WINDINGS (F5,F6,F7)
48 V
A4T
MAGNETIC STANDARD
RECALIBRATING WINDING
STABILIZING WINDINGS (F1, F2)
A1SX
A2SX
AC WINDINGS (A1, (A2) (A3) (A4)
A6 RECT.
A8 RECT
A23R
A3TS1
36 V AC
A24R
A9 RECT
A7 RECT.
A2X
A5SX
AC WINDING
CONTROL WINDING
A22R
A17 RECT.
A18 RECT.
A1RH
INCREASE SENSITIVITY LIMIT AMPLIFIER
A16 RECT
A19R
A3TS3
18V A C
100 %
85 %
70 %
50 %
1ST-S
1ST-P ON DIAGRAM T-9675110-1
FROM UNDEREXCITED REACTIVE AMPERE LIMIT DIAGRAM TERMINALS (7) & (8) T-9675110-3
AMPLIFIER FOR UNDER EXCITED REACTIVE AMPERE LIMIT

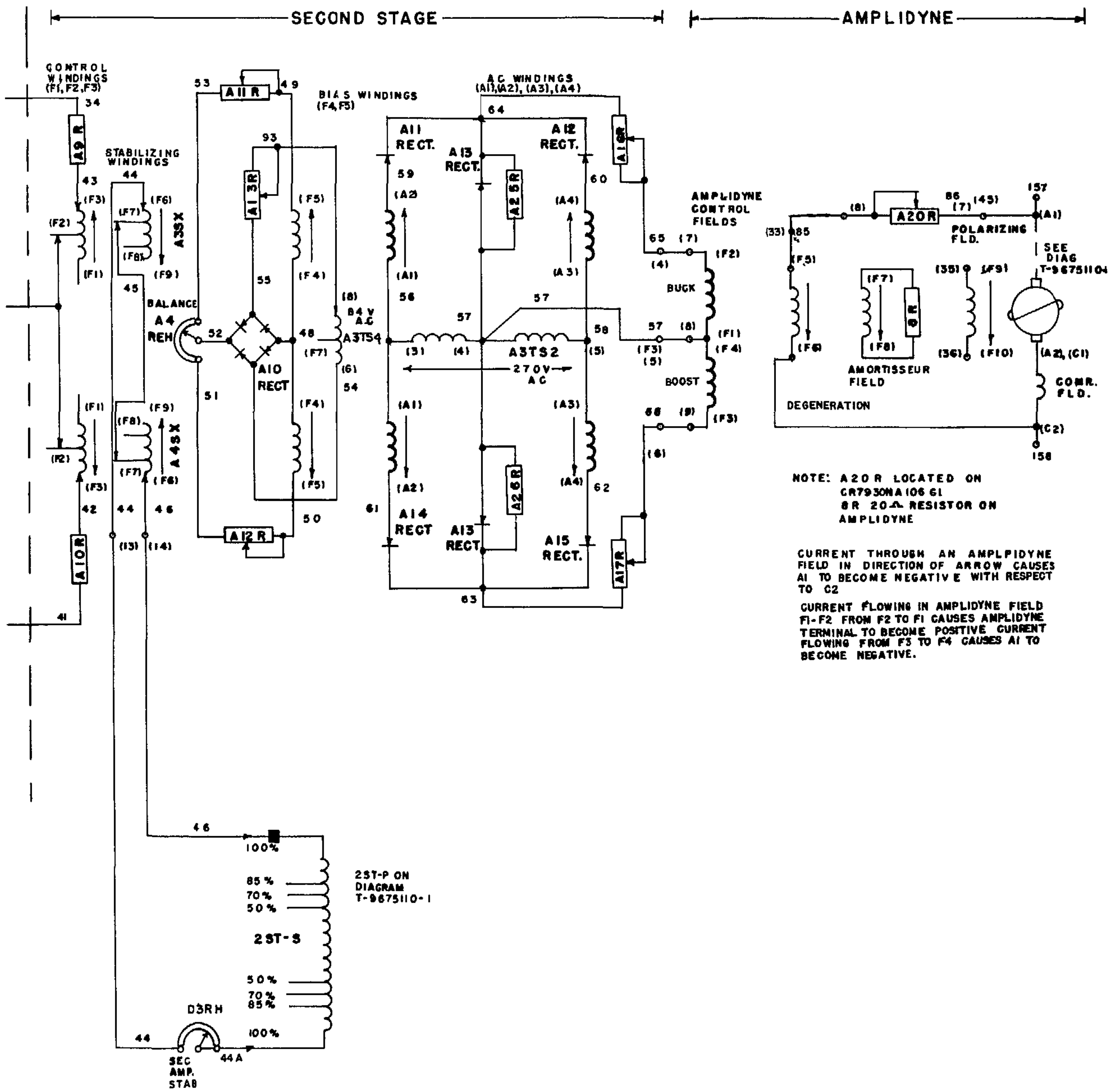


Fig. 17 Typical elementary diagram of the voltage-regulator circuit (T-9675110-2)

in the control fields which might result in improper operation.

A fifth field is sometimes used as a polarizing winding used in conjunction with the control circuit for polarizing the exciter.

The current rating and number of turns of each field is indicated on the amplidyne nameplate.

The armature leads are marked A1 and C2 and the polarity of the leads will depend upon the magnitude and direction of current flow through the amplidyne fields. Current flow through any field in the direction of the arrow (except field F1-F2, Fig. 17) will cause armature terminal C2 to become positive.

The amplidyne motor-generator set is usually equipped with an overspeed switch having a normally closed contact which is usually set to open at 150 percent of rated speed. Overspeeding might occur if the driving motor were disconnected from the line, and the amplidyne left connected in the exciter field circuit so that it operates as a d-c motor. The switch contact is rated at 110 volts, 10 amperes, a-c; 110 volts, 0.3 ampere, d-c; or 220 volts, 0.15 ampere, d-c.

CONTROL EQUIPMENT

The regulator equipment usually includes the components required for the control of the regulator and the amplidyne generator. Multi-contact, dead-front, switchboard-type, cam-operated control switches are generally 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 motor starter is provided in cases where the amplidyne is supplied with an individual driving motor. This starter is generally equipped with a fusible disconnect switch. The starter magnetic switch is a three-pole d-c operated device with overload relays.

A transfer contactor is usually provided for switching the amplidyne in and out of the exciter-field circuit. It has both normally open and normally closed main contacts.

To protect against the possibility of establishing a serious amplidyne short circuit through the normally open and normally closed contacts of the transfer contactor, a current-limiting resistor is supplied. This resistor is usually composed of several resistance units assembled with mounting brackets. The resistance used depends upon the installation.

A zero-center d-c voltmeter is usually supplied for connection across the amplidyne terminals.

The various control devices are covered by individual instructions.

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).

All of the equipment should be readily accessible for adjustment and testing. The amplidyne should be located to permit easy inspection and maintenance.

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. Interconnecting wires will conduct a maximum current of approximately five amperes in all regulator circuits. Maximum current in the amplidyne driving motor lines and amplidyne armature connections will be appreciably greater and will vary depending upon the ratings of these units.

Amplidyne driving motors may in some cases be connected for either of two voltages and the proper connections for the appropriate voltage must be made to avoid damaging the motor. Rotation of the amplidyne should be investigated to determine that it is in the proper direction.

POLARITY AND PHASE ROTATION

When making connections from the exciter armature leads to the regulator, polarity should be carefully checked to make certain that the connections are the same as those shown in the applicable diagram. The amplidyne armature lead marked A1 must be connected to the positive side of the exciter armature circuit and terminal marked C2 to the positive side of the exciter field circuit.

Amplidyne field polarity should be checked at the regulator terminals. For this check it is possible to use a small dry cell or other source which will deliver a voltage not in excess of two volts.

Amplidyne armature polarity should be determined with a portable voltmeter directly at the amplidyne terminals.

The amplidyne must be operated disconnected from the exciter field circuit to make this test, and care should be taken to avoid exceeding the ratings of the amplidyne fields and the amplidyne armature voltage ratings. Polarities should be as previously described; if discrepancies exist, the amplidyne field leads must be interchanged to obtain the correct polarity at the armature terminals.

Equalizing-reactor and line-drop 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, TESTING AND ADJUSTMENT

CONTROL CIRCUITS

Control circuits should be tested under such conditions that the regulator will not affect the operation of the a-c machine. First, turn the regulator control switch to OFF and energize the control-power supply. Under this condition the amplidyne-driving motor-starter magnetic switch, and the transfer contactor should remain de-energized. The regulator-control switch then may be turned to TEST. The motor-starter magnetic switch should be energized and the switch should close but the transfer contactor should remain in the de-energized position. The switch may then be turned to ON, the transfer contactor should be energized and should operate to place the amplidyne in series with the exciter field circuit. The switch may be returned to TEST to determine that the transfer contactor will be properly de-energized and the motor-starter magnetic switch will remain closed. Turning the switch to OFF should de-energize the magnetic switch.

The overspeed-switch circuit should be checked after placing the control switch at ON to energize the motor-starter magnetic switch and transfer contactor. Disconnect one overspeed-switch lead terminal on the motor amplidyne set. This should de-energize the motor starter and transfer contactor. The control switch should be left at ON and the lead reconnected; the devices should not be re-energized.

Some installations involve two or more regulator equipments consisting of normal equipments and spare equipments for a single or several a-c machines. In such instances, transfer switches are frequently provided for selection of the proper regulator. If these switches are equipped with removable handles for protective interlocking, all handles but one of each type must be immediately removed and stored in a remote location to prevent incorrect and dangerous operation of the regulator equipment. The previously described tests must then be conducted on each equipment by turning the transfer switches to the proper positions to place the regulators successively under control of the respective control switches.

Occasionally regulator control circuits are interlocked with the exciter circuit breaker opening and closing the control circuits, either with or without the use of relays. These circuits must be carefully tested by operating the circuit-breaker control switches and the circuit breakers themselves to ascertain that all details of operation are correct.

In general, control circuits are arranged to prevent placing two regulators in service with one a-c machine and exciter, and to prevent placing a single regulator in service with an exciter operating in parallel with a second exciter on the same a-c machine field. The regulator diagrams must be carefully studied to determine what control functions are provided, and no further tests should be made until the control circuits have been completely tested.

REGULATOR

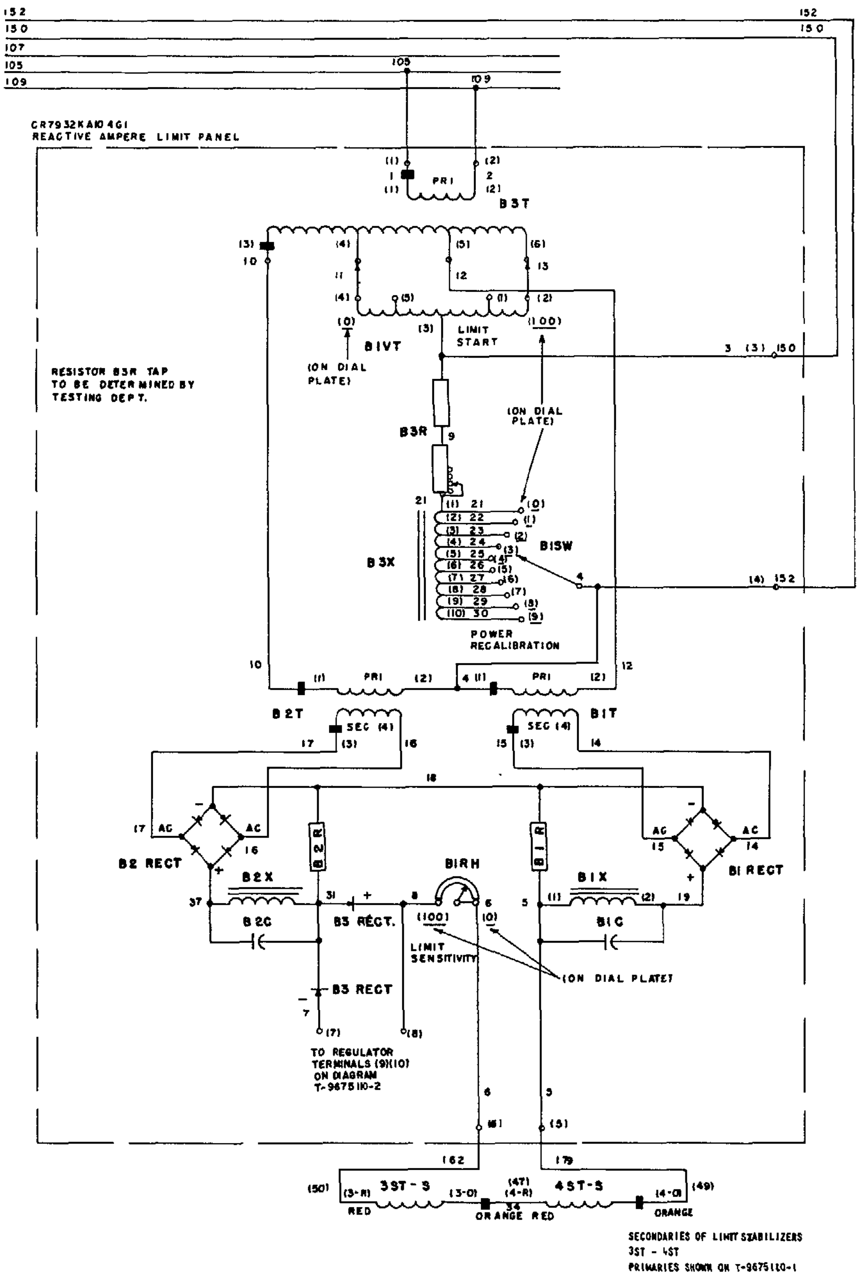
PRELIMINARY

The regulator should be tested with the a-c machine operating at normal speed and voltage, and in the case of a generator, at no load and disconnected from the system. The underexcited reactive-ampere limit should be removed from service by disconnecting its d-c output circuit at terminal 7 (Fig. 18).

If an equalizing reactor and line-drop compensator are used, their adjusting knobs should be turned to the zero position.

VOLTAGE-ADJUSTING UNIT

The regulator control switch should be kept at OFF until the a-c machine has been started and



NOTES

1 THE VOLTAGE REGULATOR CONTROL SWITCH (SW) IS PROVIDED WITH FIVE POSITIONS.

A. WITH THE SWITCH AT "OFF," THE REGULATOR IS OUT OF SERVICE.

B. WITH THE SWITCH AT "TEST," THE REGULATOR IS ENERGIZED FOR ADJUSTMENT ONLY, AND IS NOT ACTUALLY IN SERVICE.

C. WITH THE SWITCH AT "ON," THE REGULATOR IS IN SERVICE. IF POLARITY OF EXCITER ARMATURE IS REVERSED FROM THAT SHOWN IT CAN BE CORRECTED THUS·

D. WITH THE SWITCH AT "INTER," THE A-C MOTOR-AMPLIDYNE GENERATOR SET IS STARTED.

E. WITH THE SWITCH AT "POLARIZE," THE POLARITY OF EXCITER VOLTAGE IS CORRECTED.

2. TRANSFORMER PRIMARIES AND SECONDARIES ARE NOT NECESSARILY SHOWN ADJACENT BUT ARE MARKED P OR S AFTER THE TRANSFORMER DESIGNATION.

3. THE COMPENSATING AND MAIN CONTROL FIELD WINDINGS OF THE AMPLIDYNE HAVE THE SAME MAGNETIC AXIS AS THE LOAD CURRENT IN THE ARMATURE.

4 THE AMPLIDYNE GENERATOR ARMATURE LEADS ARE MARKED A1 AND C2 AND WHEN THE GENERATOR IS RUNNING THE POLARITY OF THE LEADS WILL DEPEND UPON THE MAGNITUDE AND DIRECTION OF CURRENT FLOW THROUGH THE AMPLIDYNE CONTROL FIELDS. CURRENT FLOW THROUGH ANY FIELD IN THE DIRECTION OF THE ARROW WILL CAUSE AMPLIDYNE TERMINAL A1 TO BECOME NEGATIVE AND C2 TO BECOME POSITIVE.

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Fig. 18. Typical elementary diagram of the under-excited reactive-ampere-limit circuit (T-9675110-3)

brought up to normal speed and voltage. Exciter polarity should be checked to be certain that it is correct. After the control power supply has been energized, the switch may be turned to TEST to energize the regulator circuit. When this is done, the amplidyne armature voltage may suddenly increase in either direction. Do not allow the amplidyne to operate continuously at more than rated voltage. It should be possible to reduce the amplidyne voltage to zero by turning the voltage-adjusting rheostat. This condition will be met if the normal voltage at the machine potential transformers is about 115 volts. If the normal voltage is not approximately 115 volts, it will be necessary to change the regulator autotransformer connections located on the rear of the CR7930-NA regulator panel to correspond to the normal operating voltage. (Refer to the connection diagram supplied with each equipment.) Turning the voltage-adjusting rheostat knob or voltage-adjusting control switch clockwise should cause the amplidyne voltage to increase in the boost direction so that the amplidyne voltmeter needle will move to the right (boost direction) and amplidyne terminal C2 will become negative with respect to A1. Turning the voltage-adjusting rheostat knob or voltage-adjusting control switch counterclockwise should cause the amplidyne voltage to increase in the buck direction

If the operation of the voltage-adjusting unit must be reversed because the operation is not as described or because reverse operation is desired, turn the control switch to OFF, and transpose the end connection of the jumper connecting the center arm to the end of the resistance element.

VOLTAGE LEVEL

It is possible that operation of the voltage-adjusting rheostat or switch will have no noticeable effect on the amplidyne voltage when the regulator is first tested.

Inability to control the amplidyne voltage may be due to the signal voltage falling outside of the regulator range: if the amplidyne voltage is too high in the buck direction, the signal voltage may be too high; if the amplidyne voltage is too high in the boost direction, the signal voltage may be too low. The regulator is normally connected for a nominal signal voltage of approximately 115 volts but usually can be adjusted for nominal signal voltages from 85 to 140 volts by use of the taps on the autotransformers. The voltage-adjusting rheostat will usually provide adjustment of 10 percent above to 10 percent below the nominal signal voltage. The signal-voltage supply should be connected to autotransformer taps corresponding to the appropriate voltage as given in the table shown on the connection diagram provided with the equipment. A higher signal voltage requires the use of higher numbered taps. Taps of the same number should be used on each transformer.

CHANGE TAPS ON AUTOTRANSFORMER ONLY WHEN THE REGULATOR CONTROL SWITCH IS SET AT "OFF."

Final connections should be made which will permit adjustment of a-c machine terminal voltage over the desired range by use of the voltage-adjusting rheostat. If nominal voltage is not obtained when the voltage-adjusting rheostat is in its midposition, resistor A1R (Fig. 17) may be increased or decreased so that the voltage-adjusting rheostat is in the midposition with a-c machine nominal voltage.

It is usually preferable to delay the final voltage-level adjustment until the underexcited reactive-ampere limit has been reconnected, since it may affect the voltage-adjusting rheostat setting for a given voltage. In addition, the equalizing reactor and line-drop compensator may appreciably alter the signal voltage after they have been adjusted. Readjustment may also be required following the addition or removal of equalizing reactors or line-drop compensators.

ADDITIONAL CONTROL-SWITCH CIRCUITS

Where additional control, transfer, or exciter-polarity reversing switches are used, the previous tests should be repeated, with these switches adjusted for all operating conditions, to determine that the amplidyne voltage may be properly controlled with the voltage-adjusting unit when each of the regulator control switches is at TEST. This will indicate that all switch connections are correct.

POLARITY TESTS

Before the regulator is first placed in control of machine excitation, it is recommended that final polarity tests be conducted.

Amplidyne polarity should be checked as follows: with the regulator control switch at OFF, short circuit the normally open contact on the transfer contactor which is connected between amplidyne-armature terminal A1 and the exciter-field rheostat, or occasionally between A1 and the positive side of the exciter armature. This can be done with a small wire, since the shorting connection will not be required to carry current. Connect a d-c voltmeter between the amplidyne-armature terminal C2 and the negative side of the exciter armature, with the positive voltmeter lead on C2. These connections may be made with the a-c machine and exciter in operation if the necessary precautions are taken.

With the a-c machine operating at normal speed and voltage, turn the regulator control switch to TEST and adjust the amplidyne-armature voltage to zero with the voltage-adjusting knob or switch. The voltage indicated by the previously connected test voltmeter should be equal to that portion of the exciter voltage which is impressed across the exciter field. Turn the voltage-adjusting knob or switch in the raise direction to increase the amplidyne voltage in the boost direction. The test voltmeter should indicate the total of the exciter-field and amplidyne-armature voltages. Then turn the voltage-adjusting knob or switch in the lower direction to increase the amplidyne voltage in the buck direction. The test voltmeter should indicate the difference between the exciter-field voltage and the amplidyne-armature voltage.

If the above tests are not satisfactory, connections must be carefully checked and proper operation obtained before any further tests are made.

Before proceeding it is necessary to check the polarity of the stabilizing transformers in the following manner. With the control switch at TEST and the a-c machine operating at normal speed and voltage, adjust the voltage-adjusting rheostat until the amplidyne is delivering about 150 volts in the boost direction. Carefully disconnect one primary lead of the amplidyne stabilizer (refer to the connection diagram supplied with the equipment). Removing this lead should cause the amplidyne voltmeter to momentarily increase in the boost direction; replacing the primary lead should momentarily decrease the amplidyne boost voltage.

If conditions are as outlined above the amplidyne stabilizer has the correct polarity.

To check the polarity of the exciter stabilizer proceed as follows. With the exciter operating at not less than 25 percent of rated voltage, disconnect one of the primary leads of the exciter stabilizing transformer. This should momentarily increase the amplidyne boost voltage; replacing the exciter stabilizer primary lead should momentarily decrease the amplidyne boost voltage.

Equalizing reactor polarity must be checked before putting the regulator in service with a machine which is connected to the system. Turn the equalizing reactor-adjusting knobs to the zero position and operate the machine overexcited at normal voltage. With the regulator-control switch at TEST, adjust the amplidyne voltage to zero with the voltage-adjusting rheostat. Turn the equalizing reactor coarse-adjusting knob to the right to insert reactance. The amplidyne voltage should increase in the buck direction. If the voltage increases in the boost direction, the potential circuit leads to the equalizing reactor must be reversed and the tests repeated. When the polarity of the equalizing reactor is correct turn both knobs to zero and set the fine-adjusting knob at 5. It is then possible to proceed with the regulator tests.

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 amplidyne voltage to zero. The control switch may then be turned to ON. This will place the amplidyne in the exciter-field circuit and the regulator in control of the a-c machine excitation. The amplidyne voltage should not change more than about 20 volts and should immediately return to nearly zero. If the amplidyne voltage changes appreciably, immediately turn the control switch to OFF and determine the cause of incorrect operation.

A sudden and large change in amplidyne voltage may mean incorrect amplidyne polarity or equalizing reactor polarity. The amplidyne and equalizing reactor polarity checks should be repeated before again placing the regulator in control of the a-c machine excitation.

If the amplidyne exhibits a gradual change in voltage resulting in oscillations which grow steadily greater, the stabilizing connections or adjustment of the stabilizing circuits may be incorrect. The polarity of the stabilizing transformers should be rechecked. If after all polarity connections have been rechecked, the amplidyne voltage oscillates when the control switch is placed at ON, remove the regulator from service. Now attempt to obtain stable operation by adjusting the resistor-rheostat combination in series with the exciter stabilizing transformer primary. First, increase the resistance in series with the exciter stabilizer primary approximately 15 percent. Again place the regulator in control of the a-c machine excitation. If the stability has not improved, reduce the resistance in series with the exciter stabilizer primary 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 resistor-rheostat combination. However, if the regulator still is unstable after the full range of resistance has been tried, the taps on the exciter stabilizer transformer secondary should be changed in 15 percent steps. (Refer to the connection diagram supplied with the equipment.) After each tap change the resistance in series with the exciter stabilizer should be adjusted in the same manner as previously described.

NOTE: ALL ADJUSTMENTS MUST BE MADE WITH THE CONTROL SWITCH AT 'OFF'.

In general, stability difficulties are more likely to appear at reduced excitation than at normal a-c machine excitation. Therefore it is usually possible to obtain satisfactory stability under loaded conditions, if satisfactory stability is obtained at no load.

NOTE: SATISFACTORY STABILITY MUST BE SECURED BEFORE FURTHER TESTS ARE CONDUCTED.

With the regulator-control switch at ON, turn the voltage-adjusting knob or switch in the raise direction; the amplidyne voltage should change slightly in the boost direction and the exciter armature voltage and a-c machine terminal voltage should rise. Now turn the voltage-adjusting knob or switch in the lower direction; the amplidyne voltage should change in the buck direction and the exciter and 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 about 20 percent of rated voltage.

Operation of the voltage regulator may also be tested by changing the resistance of the exciter-field rheostat. As the rheostat resistance is decreased, the amplidyne voltage should change in the buck direction; as resistance is increased, the voltage should change in the boost direction. No appreciable change in exciter voltage should occur.

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

Where additional control, transfer, or exciter-polarity reversing switches are used, the previous tests should be repeated with these switches adjusted for all operating conditions to determine that the a-c machine excitation may be properly controlled with the regulator. This will assure the correctness of all switch connections.

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. With the regulator in control of a-c machine excitation:

1. The amplidyne voltmeter will indicate only two or three oscillations after suddenly turning the voltage-adjusting rheostat a few degrees in the lower direction.

2. After suddenly turning the voltage-adjusting rheostat a few degrees in the lower direction, the a-c machine voltmeter will overshoot only slightly before returning to a new steady value.

Optimum regulator stability can usually be obtained by following the procedure outlined in "Initial Operation." However, in some instances, it may be desirable to follow a similar procedure with the amplidyne-stability primary resistance, and secondary taps, to improve the regulator stability. In addition, changing the taps on the reactor in series with the exciter stabilizer secondary may improve stability in certain cases.

Before making any adjustments in the stabilizer circuit, it is necessary to TURN THE CONTROL SWITCH TO "OFF," 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 equalizing reactors and line-drop compensators. Furthermore, the sensitivity of the regulator itself will be a major factor affecting voltage regulation.

If it is desired to improve regulation and the response of the regulator to transient disturbances by increasing the regulator sensitivity, the sensitivity-adjusting rheostat may be used for this purpose. This should be done cautiously in steps of no more than 100 ohms at a time, with the regulator out of service. Decreasing resistance will not only increase sensitivity, but may produce stability difficulties which will only appear at low values of a-c machine excitation current, such as are encountered under no load or underexcited conditions. Changes should, therefore, be made carefully, and the stability should be checked with the a-c machine at no load or light load after each change. If necessary, sensitivity may be reduced to increase regulation or improve stability by increasing the resistance of the sensitivity-adjusting resistor as previously described.

UNDEREXCITED REACTIVE-AMPERE LIMIT

LIMIT POLARITY

After satisfactory operation of the regulator has been obtained, the reactive-ampere limit should be tested. Set the REACTIVE-AMPERE-LIMIT SENSITIVITY dial at zero. Set the REACTIVE-AMPERE-LIMIT POWER RECALIBRATION switch at zero. Set the REACTIVE-AMPERE-LIMIT START dial at its highest numbered position. Reconnect the limit d-c output circuit at terminal 7 (Fig. 18).

With the machine carrying power load and some safe value of underexcited reactive current, move the regulator control switch to TEST. Adjust the voltage-adjusting rheostat for zero amplidyne volts. Slowly turn the REACTIVE-AMPERE-LIMIT START dial toward zero. At some setting of the dial, the amplidyne voltage will increase in the boost direction. If the amplidyne voltage does not increase appreciably 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.

Again turn the REACTIVE - AMPERE - LIMIT START dial toward zero. The point at which the amplidyne voltage starts to move from zero is considered the limit-start point. Continue turning the dial until the amplidyne voltage is 20 volts boost. If the amplidyne voltage cannot be increased from zero by turning the limit-start dial to zero, the limit polarity may be reversed. Turn the regulator control switch to OFF and reverse the primary connections of transformer B3T (Fig. 18). Repeat the tests previously described to determine if a boost amplidyne voltage can be obtained by turning the limit-start dial toward zero. THIS TEST MUST GIVE PROPER RESULTS BEFORE FURTHER TESTS ARE CONDUCTED.

If the amplidyne voltage increases from zero in the buck direction, the limit d-c output may be reversed. Reverse the connections to limit terminals 7 and 8 (Fig. 18). Repeat the previously described tests to secure proper results.

With the REACTIVE - AMPERE - LIMIT START dial so set that the amplidyne voltage is 20 volts in the boost direction, turn the POWER RECALIBRATION tap switch from zero toward point 9. If the a-c machine is delivering power, the amplidyne voltage should increase in the boost direction as the POWER RECALIBRATION switch is turned toward point 9.

Turn the POWER RECALIBRATING REACTOR switch to zero. Readjust the amplidyne voltage to 20 volts boost 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 reactive-ampere-limit stabilizing transformers. Carefully disconnect one of the primary leads of a limit stabilizing transformer (refer to the connection diagrams supplied with each equipment). This should cause the amplidyne voltage to increase in the boost direction. Replacing the primary lead should cause the amplidyne voltage to change in the buck direction. Do not proceed with the underexcited reactive-ampere-limit tests until the polarity of the limit stabilizer is correct.

INITIAL OPERATION

Turn the REACTIVE - AMPERE - LIMIT START dial to its highest reading. Readjust the amplidyne voltage to zero with the voltage-adjusting rheostat, if necessary. Operate the a-c machine at normal voltage and with underexcited reactive current. Turn the regulator control switch to ON as discussed under "Initial Operation." Slowly turn the REACTIVE-AMPERE - LIMIT START dial toward zero. The amplidyne voltage should increase slightly in the boost direction 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 OFF. Repeat the limit polarity tests. Do not proceed further until satisfactory operation is obtained.

With the regulator-control switch at ON, and the REACTIVE - AMPERE - LIMIT START dial at the limit-start point, observe the amplidyne voltmeter, the exciter voltmeter, and the a-c machine ammeter for signs of oscillation. If oscillations of the reactive current or amplidyne voltage appear, remove the regulator from control of the a-c machine excitation by turning the regulator control switch to OFF. Adjust the resistance in series with the primary of the limit stabilizing transformers 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 amplidyne and exciter voltage oscillations and reactive current oscillations.

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 voltage-adjusting rheostat 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 voltage-adjusting rheostat to lower the voltage. As the limit-start point is passed, the amplidyne voltage should increase in the boost direction and it should be impossible to raise the reactive current appreciably above the previously recorded value no matter how far the voltage-adjusting rheostat is turned in the direction to lower voltage.

As a final check of optimum limit stability, move the REACTIVE-AMPERE-LIMIT START dial until

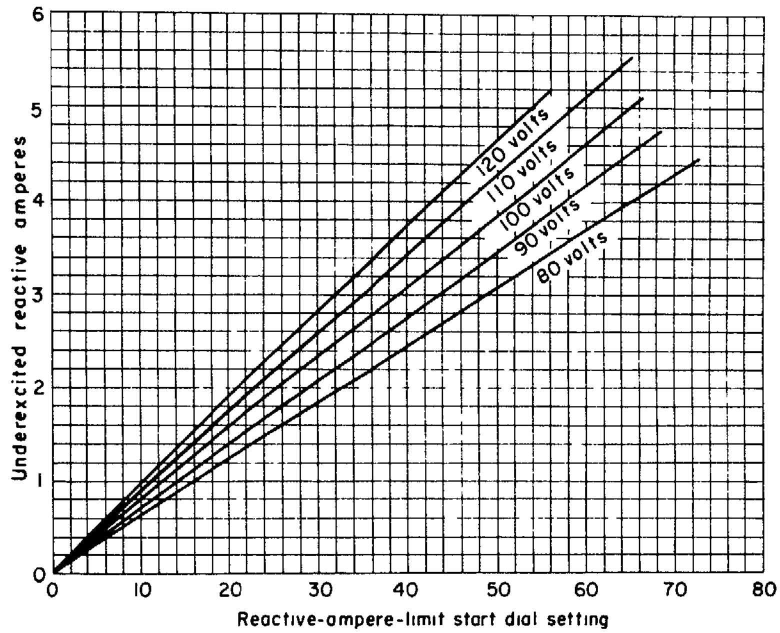

Fig. 19. *Curves of underexcited reactive current vs. reactive-ampere-limit start dial settings (sensitivity rheostat at mean position)*

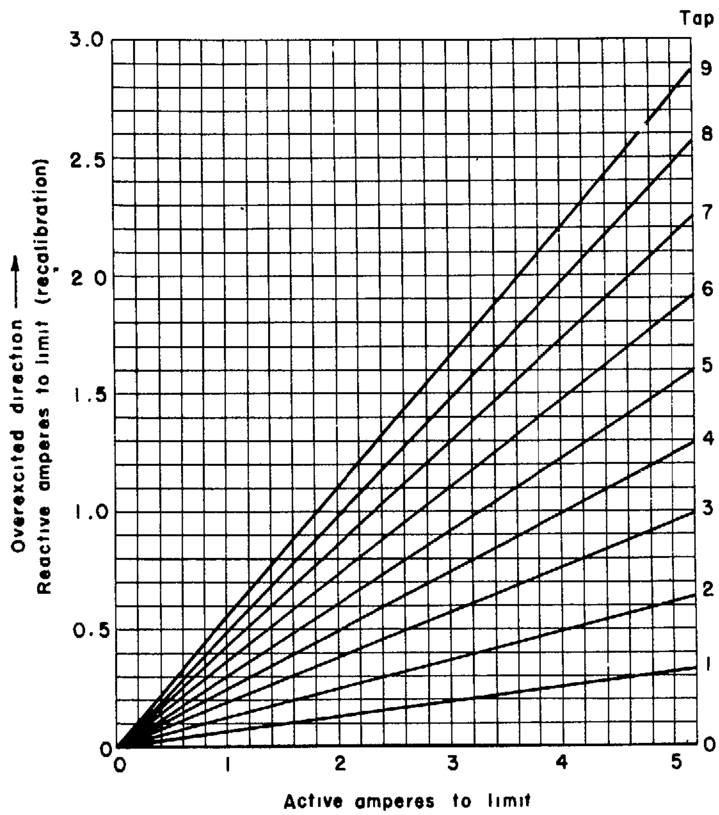

Fig. 20. *Curves of active amperes to limit vs. reactive amperes to limit (recalibration) with power recalibrating reactor tap switch adjustment as the parameter*

the amplidyne voltage is about 20 volts in the boost direction. Abruptly move the voltage-adjusting rheostat a few degrees in the lower direction and observe carefully the amplidyne voltmeter and the reactive-current ammeter for signs of oscillations. If oscillations appear, adjust for optimum stability as previously outlined. When the amplidyne voltmeter and the reactive-current ammeter show only a few oscillations after an abrupt change of the voltage-adjusting rheostat, 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 LIMIT

The final adjustment of the limit may be made by use of Fig. 19 and 20, unless special calibration data are supplied with the equipment.

The limit-start adjustment is determined from Fig. 19. 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 Fig. 20. 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 (B1SW) 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.

Fig. 19 indicates that for an underexcited reactive current of four amperes, the REACTIVE-AMPERE-START dial should be set at approximately 47. As can be seen from Fig. 20, 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 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.

Fig. 19 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 Fig. 20, a value of one reactive ampere recalibration of the limit and four active amperes to the limit, indicates that tap switch B1SW should be set at tap 4.

If desired, before making the final adjustment of the limit, the calibration curves (Fig. 19 and 20) may be checked in the following manner.

Place POWER RECALIBRATING REACTOR tap switch B1SW on tap 8. Place the REACTIVE-AMPERE-LIMIT START dial at its highest scale position. Put the 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 underexcited 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 Fig. 20 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 Fig. 19, 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 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 voltage-adjusting rheostat 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 Fig. 19. Determine the underexcited reactive amperes recalibration from Fig. 20. The result of subtracting the value of underexcited reactive amperes read in Fig. 20 from the value of underexcited reactive amperes read in Fig. 19 will be essentially equal to the value of underexcited reactive current to the limit at the limit-start point.

EQUALIZING REACTOR AND LINE-DROP COMPENSATOR

EQUALIZING REACTOR

The polarity of the equalizing reactor is checked as described under "Initial Operation." Final adjustment of the equalizing reactor can only be made after considerable experience with the machine operating under control of the 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-adjustment knob to position 5 with the coarse knob at zero. Adjustments may be made with the equalizing-reactor current transformer energized. When making adjustments, the a-c machine power factor should swing toward unity as the reactance of the equalizing reactor is increased.

LINE-DROP COMPENSATOR

Turn both adjusting knobs to zero, and operate the a-c machine at lagging power factor. With the regulator control switch at TEST and the amplidyne voltage adjusted to zero, turn the coarse reactance-adjustment knob to the right to insert reactance; the amplidyne voltage should increase in the boost direction. Return the reactance-adjusting knob to zero, and turn the coarse resistance-adjusting knob to the right to increase resistance; this should also increase the amplidyne voltage in the boost direction. If the amplidyne voltage increases in the buck direction during these tests, the compensator potential 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 regulator in service.

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, equalizing reactor, line-drop compensator, and maximum-excitation limit 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 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 is generally brought up to normal speed and voltage under manual control before the regulator is placed in service. Generators are frequently connected to the load or system before the regulator is used, but this is not essential since the 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 regulator in control of machine excitation:

1. With the regulator-control switch at OFF, and with the a-c machine operating at normal speed, adjust the machine terminal voltage to approximately normal with the exciter-field rheostat. 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 amplidyne voltage to zero with the voltage-adjusting rheostat or switch. If this cannot be done, do not proceed further until the trouble has been determined and eliminated.

4. Turn the regulator-control switch to ON. This will place the 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 voltage-adjusting rheostat or switch as required for the normal operating schedule.

The regulator will successfully control the a-c machine excitation over the complete load range of the machine with the exciter-field rheostat at a position which will give rated machine voltage at no load without the regulator in service, or at a position which will give rated machine voltage at rated load without the regulator in service, or at any intermediate position. However, additional excitation system realiability may be secured by the proper adjustment of the exciter-field rheostat when the regulator is in control of machine excitation.

For this purpose, it is recommended that immediately after the regulator has been placed in service, the field rheostat 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 to 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 control by the regulator. It is suggested that this rheostat position be selected so that with the excitation system under manual control, it will produce from 3/4 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 voltage regulators, without underexcited reactive ampere or minimum excitation limits, a position corresponding to the lower value may be found more desirable. Rheostats are normally supplied with a position switch which may be used in conjunction with remote indicating lights to facilitate obtaining the predetermined setting as a normal operating procedure. Operation with the rheostat at such a predetermined position should result in buck amplidyne voltage at most a-c machine loads, and as a result, under most load conditions, sudden return to manual control will actually cause an increase in excitation.

Regardless of the operating procedure employed when the regulator is in control of the a-c machine excitation, it is essential that under any sustained load condition a field-rheostat position be maintained which will give sufficient excitation in the event of sudden return to manual control, to permit stable operation in the case of a generator, and to avoid other serious disturbances for all types of a-c machines.

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

1. Adjust the amplidyne voltage to zero by use of the exciter-field rheostat.

2. Turn the regulator control switch to OFF.

With the regulator in control, the exciter-field rheostat may be adjusted as follows to bring the amplidyne voltage to zero:

1. If the amplidyne voltage is in the boost direction, slowly reduce the rheostat resistance until the amplidyne voltage is zero. No appreciable change in exciter voltage or a-c machine voltage should occur.

2. If the amplidyne voltage is in the buck direction, slowly increase the rheostat resistance. No appreciable exciter or a-c machine voltage change should appear.

OPERATION WITH UNATTENDED EQUIPMENT

In unattended generating stations, the regulator is generally in control of a-c machine excitation and terminal voltage during the entire machine starting cycle. The regulator control switch is normally at ON, and the exciter-field rheostat is adjusted in accordance with the procedure given under "Operation with Attended Equipment."

EXCITER POLARITY REVERSAL

INCORRECT POLARITY

If, when the a-c machine exciter is started at any time, it is found that the exciter polarity is reversed, the polarizing circuit may be used to correct this condition. The exciter should be operated at reduced voltage and, whenever possible, with the a-c machine disconnected from the load or system. Turn the regulator control switch through INTERMEDIATE to POLARIZE. The amplidyne voltage should increase in the boost direction but the exciter voltage should reduce to zero and then immediately increase with the proper polarity to a value of about 10 to 25 volts.

After the exciter polarity is correct, the control switch must be returned to OFF and the normal starting cycle completed.

MAINTENANCE

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

Motor starter, amplidyne contactor, control relays, and other magnetically-operated contact-making devices should be regularly inspected and maintained in accordance with applicable instructions for these devices. Normally, the amplidyne will be the only unit requiring frequent inspection, and this machine should be maintained as described in the amplidyne instructions.

Variable transformer contact brushes should be inspected annually and the brushes should be reset by working them back and forth across the total winding surface many times. If arcing is present or if the brush becomes worn, a complete, new brush assembly should be installed. Since it is made of special material it should be obtained from the transformer manufacturer. In addition where discoloration is present, clean the contact surfaces with crocus cloth. The same procedure should be followed with the voltage-adjusting rheostat, and the sensitivity rheostats.

TROUBLE SHOOTING

GENERAL

In the event of abnormal operation of any part of the regulator equipment, the complete equipment should be immediately removed from service and carefully tested to determine the cause of the difficulty. When incorrect operation is noticed, it is often possible to reduce greatly the over-all servicing time by studying all of the symptoms. The trouble can usually be isolated by the process of elimination, if the circuit functions are clearly understood.

If any connections are changed, the affected circuits should be fully tested and adjusted before being returned to service.

TROUBLE-SHOOTING CHART

TROUBLE	POSSIBLE CAUSE
Regulator operation apparently normal, except that regulator will not reduce excitation to the desired value.	Underexcited reactive-ampere-limit adjustment in correct.
Sudden change in excitation and reduction of amplidyne voltage to zero (no control of amplidyne voltage possible with voltage-adjusting rheostat).	Opening of amplidyne driving-motor starter switch due to loss of control power, operation of overload relays, operation of amplidyne overspeed switch, or failure of control switch.
Sudden increase in excitation and amplidyne boost voltage (no control of amplidyne voltage possible with voltage-adjusting rheostat).	Open connection in signal circuit due to loose connection, failure by open circuit of voltage-adjusting rheostat or other circuit component.
Sudden decrease in excitation and increase in amplidyne buck voltage (no control of amplidyne voltage possible with voltage-adjusting rheostat).	Open connection in current reference circuit or failure of any circuit component.
Sudden change in excitation (with control of amplidyne voltage possible by use of voltage-adjusting rheostat, but no control of excitation possible with control switch at ON).	Amplidyne contactor open due to coil failure, open control circuit, loss of control power, or control-switch contact failure.

TROUBLE-SHOOTING CHART (CONT'D)

TROUBLE	POSSIBLE CAUSE
Failure of underexcited reactive-ampere limit to function at the proper values.	High resistance at brush contact surface in limit-start variable transformer.
Variation of machine power factor. (With system or load power factor essentially constant.)	Incorrect adjustment or failure of equalizing reactor or line-drop compensator.
Erratic fluctuations of amplidyne voltage and exciter voltage during operation of voltage-adjusting rheostat or limit.	Poor contact between brush and wire on voltage-adjusting rheostat.
Regulator stable with some amplidyne voltages, but unstable with other amplidyne voltages.	Improper operation of amplidyne.

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 a component.

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

Renewal parts for the variable-transformer and motor drive for the voltage-adjusting potentiometer should be ordered directly from the manufacturer.

SPECIALTY CONTROL DEPARTMENT

GENERAL ELECTRIC

WAYNESBORO, VA.

Supersedes GEI-31208

6-53 (500)

5-55 (500)

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