CIRCUIT DESCRIPTION

CD-80620-01
ISSUE 2AR
APPENDIX 1B
DWG ISSUE 17B

POWER SYSTEMS
RECTIFIER CIRCUIT
REGULATED
PHASE SHIFT CONTROL
190-250V, 50-60 CYCLES AC
ELECTRON TUBE TYPE 132-152V, 8 AMP DC
SEMICONDUCTOR TYPE 132-152V, 9 AMP DC
J86207C

CHANGES

B. Changes in Apparatus

B.1 Superseded	Superseded By
CR1 Diode KS-15987 L7, Fig. 11, "ZT" Option	CR1 Diode KS-15987 L10, Fig. 11, "ZU" Option
V1 and V2 Thyratrons KS-15968 L1, (Mfd by G.E. Only), Fig. 11	V1 and V2 Thyratrons KS-19699 L4, Fig. 11

D. Description of Changes

D.1 Added Note 135

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 5154-OMY-CSK-EDC

POWER SYSTEMS
RECTIFIER CIRCUIT
REGULATED
PHASE SHIFT CONTROL
190-250V, 50-60 CYCLES AC
ELECTRON TUBE TYPE 132-152V, 8 AMP DC
SEMICONDUCTOR TYPE 132-152V, 9 AMP DC
J86207C

CONTENTS PAGE

SECTION I - GENERAL DESCRIPTION

1. PURPOSE OF CIRCUIT

1.01 This circuit is designed to provide dc power for automatically charging storage batteries from an ac supply and to regulate the battery voltage.

SECTION II - DETAILED DESCRIPTION

1. INSULATION OF DC FROM AC

1.01 The secondaries of T1 and T2 transformers supply all of the ac power required. Since they are electrically insulated from their primary windings, extraneous currents are prevented from passing through the ac service ground to the central office ground.

2. RECTIFYING AND FILTERING

2.01 The main rectifying circuit consists of T1 plate transformer and either two 3-element grid controlled tubes (Fig. 10) or two solid state thyratron plug-in units (Fig. 11) arranged for full wave operation. When Fig. 10 is used the filaments of the V1 and V2 electron tubes are supplied from T2 transformer per "ZO" option. "N" and "M" options are provided to supply the correct filament voltages to the 354A and 334A electron tubes respectively of Fig. 10. When Fig. 11 is used, winding (11-13) of T2 transformer is deleted from the circuit since no connection is made to terminals 11 and 13. A 10-ampere A ammeter is furnished to show the rectifier output current. A L1 Inductor is connected to the negative lead for filtering the output. "Z" option, L8 and L9 inductors, and C1 capacitor provide a TIF filter for the ac input at 60 cycles. The L2 and L3 inductors, E and F capacitors, and the electrostatic shields in T1 and T2 transformers serve to eliminate radio interference generated in the V1 and V2 grid controlled tubes or solid state thyratrons. "X" and "Y" wiring is provided to permit the rectifier to be used with either the positive or negative output leads grounded, as described in note 108. It should be noted that when starting with room temperature between 14° and 50 F the tubes of Fig. 10 probably will not deliver output current after TD relay operates until the tubes are warmed by their filaments from 2 to 20 minutes.

2.02 On rectifiers equipped with Fig. 11, CR1 diode provides an easy path for the load current to flow under the influence of the L1 inductor when neither solid state thyratron is conducting. When the voltage across the conducting thyratron is reduced to zero, the load current switches from this thyratron to CR1 diode until the other thyratron is fired. This reduces the current through and the voltage across the plug-in units. The C1 Capacitor and R1 resistor reduce the magnitude of the voltage transients created during the switching interval to a safe value.

3. CATHODE PROTECTING TIME DELAY

3.01 The V1 and V2 power tubes of Fig. 10 have coated cathodes which must be protected from bombardment while they are heating. This heating period is provided by a nominally 45 second delay between the time the ac power is connected and the time the tubes are permitted to pass plate current. When the ac is first applied winding (3-5) of T2 transformer energizes the heater of TD time delay relay. In about 45 seconds the heater warms the elements of this relay sufficiently to cause its contacts to make and operate GR relay, which gets its dc supply from W varistor. The heater winding of the TD relay is disconnected after the GR relay operates by upper contacts(3-4) and the GR relay locks up over its upper contacts (1-2). The GR Relay, being unoperated during the delay interval, opens the resistance leg of the phase shift circuit and keeps the V1 and V2 thyratrons from firing, as described in 5.01. This is done by the GR relay bottom contacts (1-2). When the relay operates at the end of the delay these contacts complete the circuit for operation as described in paragraphs 5, 6, and 7.

3.02 The TD time delay relay is left in the circuit when solid state thyratrons per Fig. 11 are used in place of Fig. 10 in order to provide a warm up period for the auxiliary control tubes and simplify the circuit changes required to convert the early model Fig. 10 rectifiers to Fig. 11 operation.

4. REGULATOR TRANSFER

4.01 In a voltage regulated rectifier, the rectifier output current follows variations in the load current on the battery with the addition of the trickle charge current. If the load current exceeds the full load rating of the rectifier, the regulator might force the rectifier to deliver an output in excess of its safe carrying capacity. To prevent this, the T resistor is connected in series with the negative charge lead of the rectifier, and in conjunction with the A and B rheostats and the OL and TR relays, converts the rectifier from a voltage regulator to a current regulator when a certain predetermined load current is reached.

4.02 The OL relay requires for operation approximately 0.6 volt, which is provided by the T resistance and the A rheostat through the F1 and F2 fuses when "P" option is specified. Sufficient margin is provided to permit the relay to be adjusted by means of the A rheostat to operate for rectifier output currents from approximately 7 to 12 amperes. When the current reaches a predetermined value of output current, the OL relay operates and in turn operates the TR relay which locks up over its bottom contacts (1-2). The TR relay transfers the regulator circuit from the arrangement described in paragraph 6 for voltage regulation to the current regulation. Ground from the external alarm equipment is on terminal C at all times except when it is removed by the connecting circuit to restore voltage regulation.

4.03 The S resistance is for limiting the current in the winding of the TR relay.

4.04 The top contacts 4, 5, and 6 on TR relay and contact 2 on OL relay are provided for control when two or more rectifiers are operating in parallel.

4.05 "S" option provides an RA relay which provides rectifier failure indication to the plant.

5. OUTPUT CONTROL - MANUAL OPERATION

5.01 The output current of the rectifier is controlled by means of the phase relation of the ac control voltage applied to the grids of the tubes or gates of the V1 and V2 thyratrons with respect to their anode voltages. When the ac control voltages are in phase with the anode voltages, the output of the rectifier is maximum, and when 180 degress out of phase, the output is zero. To approach the 180 degree phase angle, it is necessary to open the resistance arm of the phase shift circuit. The phase shifting circuit consists of windings (8-10) of T2 transformer, C capacitor and a variable resistance arm. In the manual mode of operation, the variable resistance arm consists of R rheostat. In the automatic mode of operation, the plate to cathode circuit of V3 is substituted as the variable resistor. Since the V3 tube can not conduct bilaterally, its resistance is not the same in the forward and reverse directions. This unbalance, unless corrected, will distort the control voltage and cause one of the thyratrons to conduct more than the other. In rectifiers equipped with Fig. 10 and "Z" option, the A capacitor is connected across V3 to provide a path for the current to flow in both directions. In rectifiers equipped with Fig. 2, B capacitor is connected across the primary of T3 transformer to improve the symmetry of the firing voltage. In rectifiers equipped with Fig. 11, a CR2 fullwave bridge is used so that either polarity control current flows in the same direction through the V3 tube. Although the CR2 bridge is needed only in the automatic mode of operation it is so connected that it remains active in the manual mode as well. This was done to facilitate the wiring changes required for converting Fig. 10 rectifiers to Fig. 11 operation.

5.02 The R rheostat has a single pole double throw switch mounted on it. The first 15 degrees of rotation snaps the switch from the AUTO position to the MANUAL position which connects the rheostat for manual control. Further rotation decreases the resistance to raise the output current. The resistance varies from approximately 1000 ohms for in-phase operation to approximately 12,000 ohms for out-of-phase operation. The output or charging rate of the rectifier can be varied from minimum to maximum under control of R rheostat with any line voltage or battery voltage within the specified limits. The T3 transformer connects the phase-shifting circuit to the grids of the power tubes or gates of the V1 and V2 thyratrons. The E and F resistors of Fig. 2 serve to limit the control current to a small value.

6. OUTPUT CONTROL - AUTOMATIC VOLTAGE REGULATION

6.01 For automatic constant voltage regulation the plate-cathode circuit of V3 is substituted as the resistance arm of the phase shifting circuit as described in 5.01. This substitution is made by switching R rheostat to the AUTO position. The value of the plate-cathode resistance is changed by its grid voltage. The grid voltage for V3 is the output of V4 amplifier which is connected to the battery to be regulated by means of the L, CR if equipped with Fig. 8, K, FLOAT REG, J, OVERCHG, and H potentiometer resistors. This potentiometer is connected across the battery and the drop over the resistance between "R" and "S" leads provides the screen voltage for V4. With Fig. 8 rectifiers, this voltage can be adjusted to compensate manufacturing tolerances in the 24A tubes. The drop over the total resistance between "R" and "T" leads provides a voltage positive with respect to the cathode of V4 of approximately 88 volts. This voltage is connected to the grid of V4 through the 90-volt grid battery connected with opposing polarity to provide a net negative voltage of approximately -2 volts on the grid of V4. The drop over the total resistance between "R" and "U" leads provides a positive voltage for the plate of V4. The V4 electron tube acts as a dc amplifier to amplify changes in the regulated battery voltage in the order of 0.1 volt to several volts which are applied to the grid of V3 as the voltage drop over the resistance of the RV voltmeter. Thus the grid voltage of V3 is at all times indicated by the RV voltmeter, a relationship which is useful in maintenance.

6.02 When a load is applied to the battery its voltage decreases slightly which decreases the positive voltage drop over the total resistance between "R" and "T" leads; therefore since the grid battery voltage is constant, the negative bias on V4 increases. This increase in grid voltage decreases its plate current and the voltage drop over the RV voltmeter. The decrease in voltage drop over the voltmeter decreases the grid voltage of V3 causing its plate-cathode resistance to decrease which decreases the phase angle of the grid voltage applied to V1 and V2 tubes to increase the output of the rectifier and return the battery voltage to the floating value. With a decrease in load the battery voltage increases slightly and its effect is reflected through the regulating circuit with an opposite effect as described above.

6.03 The D capacitor of Fig. 4, 5 or 9 and N rheostat of Fig. 9 or N resistor of Fig. 4 serve as an electrical fly-wheel on the regulating circuit to control the speed of response of the rectifier to load changes and to filter the voltage applied to the grid of V3 or V4 tubes when Fig. 5 is used. This feature adapts each rectifier for the particular battery conditions it encounters.

6.04 The G capacitor serves to drain off voltage surges on the regulating leads connected to terminals RC+ and G to prevent them from affecting the operation of the regulating circuit.

6.05 The H resistor is provided to allow the rectifier to operate on 132, 142, or 152 volts. The FLOAT REG rheostat provides a fine adjustment of the regulated voltage and compensates for aging of the 90-volt grid battery.

6.06 The OVER CHG rheostat is provided to allow the regulated voltage to be raised for overcharging without disturbing the setting of the REG rheostat. It can raise the regulated voltage as much as 15 volts and is normally at zero resistance for floating.

7. OUTPUT CONTROL - AUTOMATIC CURRENT REGULATION

7.01 When the rectifier transfers from voltage regulation to current regulation, the TR relay transfers the grid-cathode circuit of V4 from the voltage potentiometer and 90-volt grid battery to a current potentiometer consisting of B rheostat and the 3-volt grid battery. The regulator then operates to maintain a constant voltage drop over B rheostat which is accomplished by maintaining a constant current through it. After a power failure, the rectifier starts up with constant voltage operation but immediately overloads to operate the OL relay converting the rectifier to current regulation. The rectifier continues on current regulation until the battery voltage is charged to a value selected for the high voltage alarm. When the alarm operates, ground is removed from lead connected to punching "C" which releases the TR relay and the rectifier goes back to voltage regulation.

SECTION III - REFERENCE DATA

1. WORKING LIMITS

1.01 AC Input

190 to 250 volts 50 to 60 cycles ac.

1.02 DC Output

8 amperes at 132, 142, or 152 volts with Fig. 10. 9 amperes at 132, 142, or 152 volts with Fig. 11. Room Temperatures of 14° to 104 F.

2. FUNCTIONS

2.01 To provide a means of rectifying ac power to a filtered dc supply to charge storage batteries. The charging rate of the rectifier may be adjusted manually by means of a rheostat on the rectifier or automatically controlled to regulate the voltage of the battery at the floating value. The regulator will compensate for changes in line voltage of 10 percent and with a constant load holds the voltage variation to less than ±0.05 percent. With a constant line voltage at variable load from no load to full load, the regulator will hold the voltage variation to ±0.25 percent. Means are provided to prevent the rectifier from overloading by converting the rectifier from voltage regulation to current regulation. The regulated current can be set between 7 and 12 amperes.

3. CONNECTING CIRCUITS

3.01 Power Service Circuit

3.02 Charge and Discharge Circuit

4. ADJUSTMENTS

4.01 Adjustment of the Output Voltage: Start the rectifier with R rheostat snapped to the manual operation and minimum output position. After the rectifier starts, increase the output by R rheostat until the rectifier is charging at the desired rate. When the battery is charged to its floating value and the OVER CHG rheostat in the normal position (max counterclockwise position), adjust the FLOAT REG rheostat until the voltage on the RV voltmeter reads 20 to 30 volts. Snap the R rheostat to the automatic position and then make a final adjustment of the regulated voltage with the FLOAT REG rheostat. The voltage on the RV voltmeter is normally between 5 and 20 volts depending on the load and line voltage. Never snap the R rheostat to the auto position if the RV voltmeter reads less than 10 volts as this indicates that the battery voltage is low and the rectifier might overload if the overload circuit has not been adjusted.

4.02 Adjustment of the Output Current - Fig. 6 or 7: To adjust the load current value at which the transfer from voltage to current regulation is desired, rotate A rheostat for the OL relay to operate at the desired value. The output current of the rectifier may be used for this adjustment by operating the rectifier under manual control. After the OL relay has been adjusted to the proper operate current, then adjust the B rheostat for the desired output current to be regulated. The R rheostat must be in the automatic position for this adjustment. The OL relay must always be adjusted first as a change in the adjustment of the A rheostat will change the current regulated value, but a change of the setting on the B rheostat does not change the operate point of the OL relay.

4.03 Adjustment of the Output Current - Fig. 8: To adjust the regulated current, rotate the slider on the B rheostat to its maximum left position with the CR rheostat in its maximum counterclockwise position, set the regulated voltage as in 4.01. Convert the rectifier to current regulation (TR relay operated) by turning the rectifier off for a few minutes by means of the R rheostat and switch. Adjust the output current by means of the CR rheostat. This will change the screen voltage slightly and make it necessary to readjust the regulated voltage.

4.04 When the voltage and current regulation of the rectifier is in adjustment, it is only necessary to turn on the ac to start the rectifier.

4.05 To overcharge the battery turn the OVER CHG rheostat in a clockwise direction until the output current is near but less than the current required to operate the OL relay. It might require one or two adjustments to get the voltage up to the desired overcharge value. To turn to floating operation it is only necessary to turn the rheostat back to the normal maximum counterclockwise position. The output current will fall to near zero but will increase automatically to the desired value for floating when the voltage decreases to the floating value. If the voltage is raised too rapidly the OL relay will operate and the OVER CHG rheostat will have no further control until the high voltage alarm unlocks the TR relay. If this occurs, care should be taken that the OVER CHG rheostat is not left in a position representing a voltage above the value at which the high contact of the voltage relay in the connecting circuit is made, or else the rectifier will overload when the TR relay releases.

4.06 The FLOAT REG rheostat should not be changed when the rectifier is operating as a current regulator and the B rheostat should not be changed when it is operating as a voltage regulator.

4.07 The resistance of FLOAT REG rheostat is selected to compensate the aging of the 90-volt grid battery. When it is new, the rheostat will be near its maximum counterclockwise position. As the grid battery ages the rheostat is moved clockwise. When it is in its maximum clockwise position and the float voltage cannot be obtained, the grid battery should be renewed.

4.08 With Fig. 6 or 7, the B rheostat also is moved clockwise as the 3-volt grid battery ages but not over its entire range as the rheostat must also cover a range required by the manufacturing variations of the V4 tubes which is about three times as large as the aging range of the grid battery. It is suggested that the 3-volt grid battery be renewed when the 90-volt grid battery is renewed.

4.09 If the V4 amplifier tube or grid batteries are changed, it is necessary to readjust the FLOAT REG and B rheostats as described above. No adjustments are required when V1, V2, and V3 are changed.

4.10 The N rheostat should be adjusted with the rectifier operating as a current regulator (TR relay operated.) Beginning with the N rheostat maximum clockwise, turn it counterclockwise until it begins to affect the RV voltage then turn it clockwise approximately 1/8 turn. Too far counterclockwise will cause the rectifier output to change from the regulated current setting. Too far clockwise with large batteries will cause the rectifier to follow variable loads too slowly.

SECTION IV - REASONS FOR REISSUE

CHANGES

B. Changes in Apparatus

B.1

Removed	Replaced By
V1 and V2 Thyratrons KS-15968 L1, Fig. 11	V1 and V2 Thyratrons, KS-15968 L1 (Mfd by G.E. only), Fig. 11
C1 Capacitor 535AB, Fig. 11	C1 Capacitor, KS-14980 L20, Fig. 11

B.2 Added

CR2 Rectifier Stack, KS-19741 L4, Fig. 11

D. Description of Changes

D.1 Titles of Fig. 10 and Fig. 11 were expanded to show the associated ratings.

D.2 Added Circuit Note 133 to remove only the V1 and V2 thyratrons per KS-15968 L1 which are not manufactured by General Electric Company.

D.3 Added Circuit Note 134 to facilitate the conversion of rectifiers from operation with electron tube thyratrons to solid state thyratrons.

D.4 Added Information Note 301.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 5154-OMY-CSK-EDC