Aug. 8, 1950 R. G. ROWE ET AL 2,518,380

RELAY CIRCUIT

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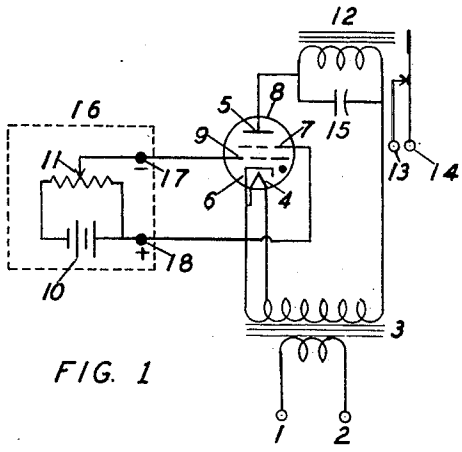

FIG. 1

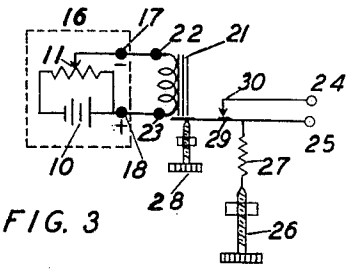

FIG. 3

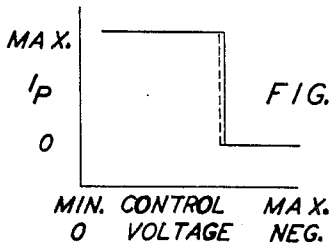

FIG. 2

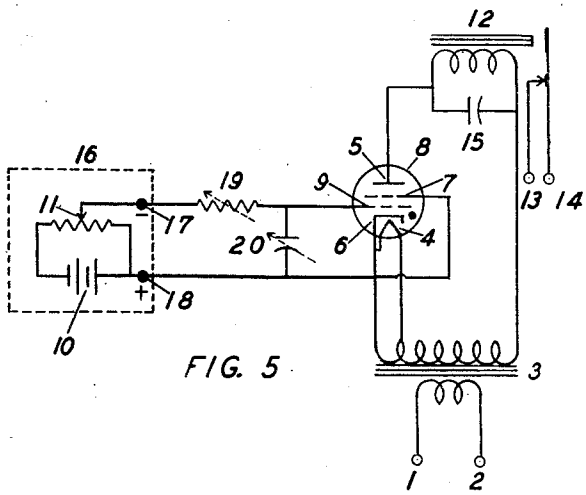

FIG. 5

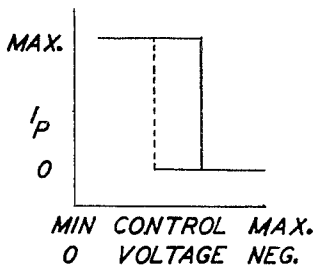

FIG. 6

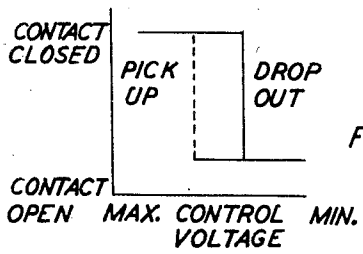

FIG. 4

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RELAY CIRCUIT

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10 Claims. (Cl. 250—27)

1

Our invention relates to relay circuits and, more particularly, to such circuits using gaseous conductor or thyratron tubes for controlling the energization of a load device or circuit.

As is well known to those versed in the art, gaseous conductor or thyratron tubes contain essential cathode, grid and anode elements usually in a low pressure atmosphere of mercury vapor, neon, argon and similar gases or combinations thereof. By proper manipulation of electrode potentials and circuit parameters the gas in a given thyratron can be ionized. When the contained gas is ionized the anode-cathode circuit is substantially conducting and the tube is said to be "fired." When the contained gas is not ionized the anode-cathode circuit is substantially non-conducting and the tube is said to be "extinguished." For convenience, the process or state of being fired can be termed "ignition"; the process or state of being extinguished can be termed "extinction."

For a thyratron of given characteristics, ignition and extinction may be controlled by the direct current grid voltage for certain combinations of cathode and anode potentials.

However, if direct current is used for the anode supply, the grid loses control after the tube has once fired and it becomes necessary to break the anode supply circuit to extinguish the tube. In order to permit the grid to retain control over the anode current and extinguish the tube it is common practice to employ alternating current for the anode supply, which effectively reduces the anode voltage to zero once during each supply voltage cycle. Being conductive on only alternate halves of the supply voltage cycle, the tube fires and extinguishes at a rate equal to the supply frequency, and the grid can regain control during periods of extinction.

With circuit parameters adjusted for normal operating conditions with the tube in the extinguished state, the grid-cathode potential which will just fire the tube may be called the "critical ignition potential." With the tube in the fired state, the grid-cathode potential which will just extinguish the tube may be called the "critical extinction potential."

Many relay circuits employing thyratrons, both of the gas-triode and gas-tetrode types have been proposed for the switching of heavy-duty, high powered electrical load circuits by exceedingly small control voltage changes. Some thyratron tubes, in particular those of the hot-cathode gas-tetrode type in typical circuit connections, can be fired and extinguished by as little

2

as 0.05 volt change in control grid bias at exceedingly minute currents. Thus, a power relay or other current responsive electrical load device coupled in the thyratron anode-cathode circuit can be controlled by very small grid bias voltage changes at very low power requirements.

We have found, in fact, that such circuits are often too sensitive to small changes in control grid voltage. In systems in which the control grid bias voltage slowly approaches the "critical" ignition or extinction potential, operation of the circuit becomes erratic, unstable and unreliable.

A further fault in prior art thyratron tube relay circuits is that while they have eliminated some of the disadvantages they have not retained the advantages of the easily controlled sensitivity and the adjustable "pick-up" and "drop-out" features of the magneto-mechanical electric relay.

One object of our invention is to provide a thyratron tube relay circuit with improved stability, reliability, and resistance to chatter and misfire.

Another object of our invention is to provide a thyratron tube relay circuit with easily variable sensitivity.

A further object of our invention is to provide a simple thyratron tube relay circuit wherein the applied control potential required to fire the tube may be substantially different from that required to extinguish the tube and wherein the difference in these two potentials is easily, cheaply and readily controllable.

The novel features which we believe to be characteristic of our invention are engendered with particularity in the appended claims; the invention itself, however, will be best understood by reference to the accompanying description and drawings, in which:

Figure 1 shows a typical thyratron tube relay circuit.

Figure 2 shows the approximate grid voltage-plate current characteristic curve of a typical thyratron tube relay circuit.

Figure 3 shows a magnetic-mechanical electric relay circuit.

Figure 4 shows the approximate "pick-up" and "drop out" characteristics of a magneto-mechanical electric relay.

Figure 5 shows a thyratron tube relay circuit employing the principles of our invention.

Figure 6 shows the approximate grid voltage-plate current characteristic curve of a thyratron tube relay circuit employing the principles of our invention.

With reference to Figure 1, alternating current power supply lines 1 and 2 supply, through transformer 3, the filament voltage to filament 4 and the anode voltage through the field coil of relay 12 to anode 5 and cathode 6 of thyratron tube 8. Potentiometer 11 and battery 10, connected as shown to cathode 6 and grid 9, cooperate to represent any source of variable control voltage desired to activate the relay circuit. Such a source, represented by box 16 and terminals 17 and 18, might be, for example, the voltage drop subtended across an impedance carrying current or the like. Shield grid 7 of thyratron tube 8 is connected to cathode 6 and is not further essential to a simple description of circuit operation. Filter condenser 15 is usually essential to prevent "chatter" in relay 12 caused by the interrupted unidirectional current flow through tube 8 on only alternate halves of the supply voltage cycle. Power relay contacts 13 and 14 are open when tube 8 is extinguished and closed when tube 8 is fired. For a given combination of filament and anode potentials along with other circuit parameters, the ignition and extinction of tube 8 and thereby by the condition of relay contacts 13 and 14 is determined by the applied control potential across cathode 6 and grid 9.

For example, using a thyratron tube type number 2050 or a tube having similar characteristics, with 6.3 volts applied to the filament and 115 volts 60 cycle alternating current for the anode supply, circuit parameters can be adjusted so that the tube will fire with approximately 2.05 volts and extinguish with approximately 2.10 volts negative grid bias, a difference of 0.05 volt.

Figure 2 illustrates the operation of this circuit graphically in a rough approximation. The "control voltage" is that supplied from control source 16 across terminals 17 and 18. With reference to both Figures 1 and 2, this control voltage is equal to the grid voltage of tube 8 applied from grid 9 to cathode 6 regardless of the condition of ignition or extinction of tube 8 because of the low impedance in the circuit.

In Figure 2 the solid vertical line represents the critical extinction potential and the dotted vertical line the critical ignition potential. In practice these two potentials do not exactly coincide, but, as shown roughly in the graph, differ by only 0.05 volt. As the applied control voltage is slowly varied from negative 3 volts toward zero volts, for example, the tube will fire at 2.05 volts. As the applied control voltage is slowly varied from zero toward negative 3 volts, the tube will extinguish at 2.10 volts. However, using slowly varying applied control voltage as is often desirable and as may be produced at terminals 17 and 18 in Figure 1, the tube becomes unstable when either the critical firing or extinguishing potentials are approached. Unreliable and erratic operation of the circuit occurs, particularly in the case of slow-varying control voltage.

Figure 3 illustrates a typical magneto-mechanical electric relay 21, with field coil terminals 22 and 23 coupled directly to output terminals 17 and 18 of control voltage source 16 and with secondary power contacts 24 and 25 provided for coupling in the power circuit to be controlled.

Figure 4 illustrates graphically the operation of relay 21 and is prepared such that for practical purposes of interpretation the actions of relays and relay circuits in all of the figures shown can be compared. For example, in Figure 2 the solid vertical line represents the circuit control voltage at which thyratron tube 8 will extinguish, whereas in Figure 4 the solid vertical line represents the circuit control voltage at which the armature of magneto-mechanical relay 21 will drop out. In Figure 2 the dotted vertical line represents the circuit control voltage at which thyratron tube 8 will fire, whereas in Figure 4 the dotted vertical line represents the circuit control voltage at which the armature of magneto-mechanical relay 21 will pick up. Thus, the "pick-up" and "drop-out" of the magneto-mechanical relay can be likened to the "ignition" and "extinction" of thyratron tube 8, relaying being accomplished in each case by the ability of each device to control high-power secondary loads from control voltages having low power and/or magnitude.

Comparison of Figures 2 and 4 shows that a larger difference in applied control voltage exists between "pick-up" and "drop-out" of magneto-mechanical electric relay 21 than exists between ignition and extinction of the thyratron tube relay. Further, with reference to Figure 3, the difference between pick-up and drop-out control voltage requirements for relay 21 may be easily controlled within wide limits by simple adjustment of thumb-screw 26 in cooperation with tension spring 27, along with thumb-screw 28 for controlling the initial spacing between armature contact 29 and fixed contact 30. For example, if the initial spacing between armature contact 29 and fixed contact 30 is increased, the difference in control voltage between pick-up and drop-out increases; if the initial contact spacing is decreased, the difference in control voltage decreases. However, in prior art thyratron tube relay circuits no such simple expedient exists for controlling the difference between ignition and extinction control voltages.

With reference now to Figure 5, an illustration of one embodiment of our invention, the circuit and components are identical with those in Figure 1 with the exception that we prefer to employ in addition resistor 19 in series connection with grid 9 and control voltage source terminal 17, as well as condenser 20 in shunt with grid 9 and cathode 6 of tube 8. By varying the resistance of resistor 19, which may be a low-priced radio potentiometer or the like, we have found that we can obtain a continuously adjustable difference between the applied control voltage required for ignition and that required for extinction and results closely comparable to those obtained with the magneto-mechanical relay.

Using the constants and voltages as described in connection with Figure 1, but with the addition of resistor 19 and condenser 20 as described in connection with Figure 5, the following differences between ignition and extinction control potentials as supplied from source 16 through terminals 17 and 18 are noted:

Resistor 19, in ohms	Condenser 20, in mfds	Ignition voltage	Extinction voltage
None	None	−2.05	−2.10
10,000	1.0	−2.25	−2.60
15,000	1.0	−2.25	−3.40
20,000	1.0	−2.25	−3.80
25,000	1.0	−2.25	−4.60
51,000	1.0	−2.25	−7.40

Further, by following the practice of our present invention, the stability and reliability of prior art thyratron relays can be greatly improved. The circuit containing the disclosed modifica-

tions exhibits a "locking-in" characteristic, which in many applications is extremely desirable, such that once the tube fires or extinguishes small control voltage changes will not disturb the present condition of the circuit. It will be appreciated that by modifications in the values of resistor 19 and condenser 20, smaller differences between the values of ignition voltage and extinction voltage can be obtained, except as limited by the values with neither resistor 19 nor condenser 20 in the circuit.

At the instant of ignition, a voltage is developed across resistor 19, the magnitude of which is determined in part by the RC combination of resistor 19 and condenser 20, for effecting this difference between ignition and extinction control voltage, as measured across terminals 17 and 18, may be accomplished by holding resistor 19 constant while varying the capacity of condenser 20, as shown below:

Resistor 19, in ohms	Condenser 20, in mfds.	Ignition voltage	Extinction voltage
10,000	1.0	−2.25	−2.60
10,000	1.1	−2.25	−2.70
10,000	1.2	−2.25	−2.80
10,000	1.3	−2.25	−2.90
20,000	1.0	−2.25	−3.80
20,000	1.1	−2.25	−4.10
20,000	1.2	−2.25	−4.40
20,000	1.3	−2.25	−4.70

The polarity of the voltage developed across resistor 19 due to current flow is of a sense such that the negative potential existing from cathode 6 to grid 9 of tube 8 is effectively reduced; that is, approaches zero potential when tube 8 fires. This potential drop which appears across resistor 19 when tube 8 fires adds algebraically to the applied control potential across terminals 17 and 18 and thereby produces the locking-in features characteristic of the present invention resulting in vastly improved stability, reliability and resistance to chatter and misfire. In order for extinction of the tube, the applied control voltage at terminals 17 and 18 must increase in a negative direction until the algebraic sum of the control voltage and the voltage drop across resistor 19 is equal to the actual critical extinction potential. After extinction of thyratron tube 8, the additional voltage appearing across resistor 19 is reduced to substantially zero and the system is automatically and instantaneously recycled for a subsequent operation. In the present circuit the grid voltage of tube 8 as measured from cathode 6 to grid 9 is no longer always equal to the applied control voltage. The introduction of resistor 19, by effectively increasing the impedance of the control source, and the application of condenser 20 to effectively store the periodic charging voltage during extinction cycles, permits a new voltage component to be automatically produced when tube 8 fires and permits the thyratron relay to function in a novel and desirable manner.

Figure 6 illustrates graphically the nature of the relay characteristics obtainable by practicing the art of the present invention. Comparison with Figure 4 shows how the characteristics of the magneto-mechanical electric relay are simulated. By simple adjustment of variable resistor 19, the difference between the control voltage across terminals 17 and 18 required for ignition and that required for extinction can be controlled from nearly zero to as large a practical value as is desirable.

While we have shown and described in detail a preferred embodiment of our invention, we are aware that it is adaptable to rearrangement and modification without departing from the true spirit and scope thereof. Therefore, we wish it understood that we are not necessarily limiting this invention to the precise embodiment herein disclosed, except in so far as we are limited by the appended claims.

We claim as our invention:

1. A method for controlling a thyratron gas discharge device having at least two control electrodes, comprising producing a variable control potential by means external to said thyratron, internally producing a potential across said control electrodes by positive ion flow during iterative ignition periods of said thyratron, storing said last-named potential during intervening extinction periods of said thyratron and simultaneously applying said externally-produced control potential and said internally-produced stored potential to said control electrodes.

2. A method for controlling a thyratron gas discharge device having at least two control electrodes, comprising producing a variable control potential by means external to said thyratron, internally producing a potential across said control electrodes by positive ion flow during iterative ignition periods of said thyratron, storing said last-named potential during intervening extinction periods of said thyratron and applying the algebraic sum of said externally-produced control potential and said internally-produced stored potential to said control electrodes.

3. A method for controlling a thyratron gas discharge device having at least two control electrodes, comprising producing a variable control potential by means external to said thyratron, internally producing a potential across said control electrodes by positive ion flow during iterative ignition periods of said thyratron, storing said last-named potential during intervening extinction periods of said thyratron and applying said externally-produced control potential and said internally-produced stored potential simultaneously to said control electrodes, whereby a substantial difference between the control potential required for ignition and that required for extinction of said thyratron obtains.

4. A method for controlling a thyratron gas discharge device having at least two control electrodes, comprising producing a variable control potential by means external to said thyratron, internally producing a predetermined potential by positive-ion grid-current flow between said control electrodes during iterative ignition periods of said thyratron, storing a predetermined portion of said last-named potential during intervening extinction periods of said thyratron and simultaneously applying said externally-produced control potential and said internally-produced stored potential to said control electrodes, whereby a predetermined difference between the control potential required for ignition and that required for extinction of said thyratron obtains.

5. In a relay circuit comprising a pulsating supply potential, a control potential variable by external means, a load and a gas discharge tube having at least an anode, a cathode and a grid electrode, said last two elements comprising a pair of control electrodes and said supply potential being connected through said anode and cathode to said load; means to produce a substantial difference between the control potential required for ignition and that required for ex-

tinction of said gas tube circuit, comprising a first connection between one side of said control potential and one of said control electrodes, a second connection including resistance between the other side of said control potential and the other control electrode and a capacitance connected in shunt with said control electrodes; said resistance means being limited to sufficient resistance to produce substantial potential pulses thereacross by positive-ion grid-current therethrough during each conducting cycle of said gas tube, and said capacitance means being limited to sufficient capacitance to store a substantial portion of said ion-current-produced potential for a time corresponding to at least one half cycle of said pulsating supply potential frequency.

6. A method for controlling a thyratron gas discharge tube having at least two control electrodes, comprising producing a variable control potential by means external to said thyratron, internally producing a potential of adjustable range by positive-ion grid-current flow between said control electrodes during iterative ignition periods of said thyratron, storing a substantial portion of said last-named potential during intervening extinction periods of said thyratron and simultaneously applying said externally-produced control potential and said internally-produced stored potential to said control electrodes, whereby an adjustable difference between the control potential required for ignition and that required for extinction of said thyratron obtains.

7. A method for controlling a thyratron gas discharge tube having at least two control electrodes, comprising producing a variable control potential by means external to said thyratron, internally producing a potential by positive-ion grid-current flow between said control electrodes during iterative ignition periods of said thyratron, storing an adjustable portion of said last-named potential during intervening extinction periods of said thyratron and simultaneously applying said externally-produced control potential and said internally-produced stored potential to said control electrodes, whereby an adjustable difference between the control potential required for ignition and that required for extinction of said thyratron obtains.

8. In a relay circuit comprising a pulsating supply potential, a control potential variable by external means, a load and a gas discharge device having at least an anode, a cathode and a grid electrode, said last two elements comprising a pair of control electrodes and said supply potential being connected through said anode and cathode to said load; means to produce a substantial difference between the control potential required for ignition and that required for extinction of said circuit, comprising resistor means of sufficient resistance to produce substantial potential pulses thereacross by positive ion grid current therethrough during each ignition cycle of said gas discharge device, capacitor means of sufficient capacitance to store a substantial portion of said ion-current-produced potential for a time corresponding to at least one half cycle of said pulsating supply potential frequency and circuit means arranged to connect said resistor between the control potential and the control electrodes to establish said ion-current potential and to connect said capacitor in shunt with said control electrodes to store said ion-current potential.

9. In a relay circuit comprising a pulsating supply potential, a control potential variable by external means, a load and a gas discharge tube having at least an anode, a cathode and a grid electrode, said last two elements comprising a pair of control electrodes and said supply potential being connected through said anode and cathode to said load; a modifying network arranged to connect said control potential and said control electrodes, including resistance means having sufficient resistance to produce substantial potential pulses thereacross by positive ion grid current therethrough, a capacitance means having sufficient capacitance to store a substantial portion of said ion-current-produced potential for a time corresponding to at least one half cycle of said pulsating supply potential frequency and circuit means arranged to connect said resistance between the control potential and the control electrodes to establish said ion-current potential and to connect said capacitance in shunt with said control electrodes to store said ion-current potential.

10. In a relay circuit comprising a pulsating supply potential, a control potential variable by external means, a load and a gas discharge tube having at least an anode, a cathode and a grid electrode, said last two elements comprising a pair of control electrodes, and said supply potential being connected through said anode and cathode to said load; a modifying network arranged to connect said control potential and said control electrodes, including resistance means having sufficient resistance to produce substantial potential pulses thereacross by positive ion grid current therethrough, capacitance means having sufficient capacitance to store a substantial portion of said ion-current-produced potential for a time corresponding to at least one half cycle of said pulsating supply potential frequency and circuit means arranged to connect said resistance between the control potential and the control electrodes to produce the ion-current potential, to connect said capacitance across the control electrodes to store the ion-current-produced potential and to apply the algebraic sum of said ion-current-produced potential and said control potential to said control electrodes.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,938,742	Demarest	Dec. 12, 1933
2,100,460	Specht	Nov. 30, 1937
2,114,828	Bedford	Apr. 9, 1938
2,132,264	King	Oct. 4, 1938
2,190,552	Swart	Feb. 13, 1940
2,198,541	Krebs	Apr. 23, 1940
2,403,609	Perkins	July 9, 1946
2,404,001	Smith	July 16, 1946
2,420,188	Olving	May 6, 1947

FOREIGN PATENTS

Number	Country	Date
443,880	Great Britain	May 30, 1934
420,100	Great Britain	Nov. 26, 1934

OTHER REFERENCES

Gleason: "Pulse Response," Proc. of the I. R. E., Feb. 1946.