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ELECTRONIC RELAY

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Fig. 1.

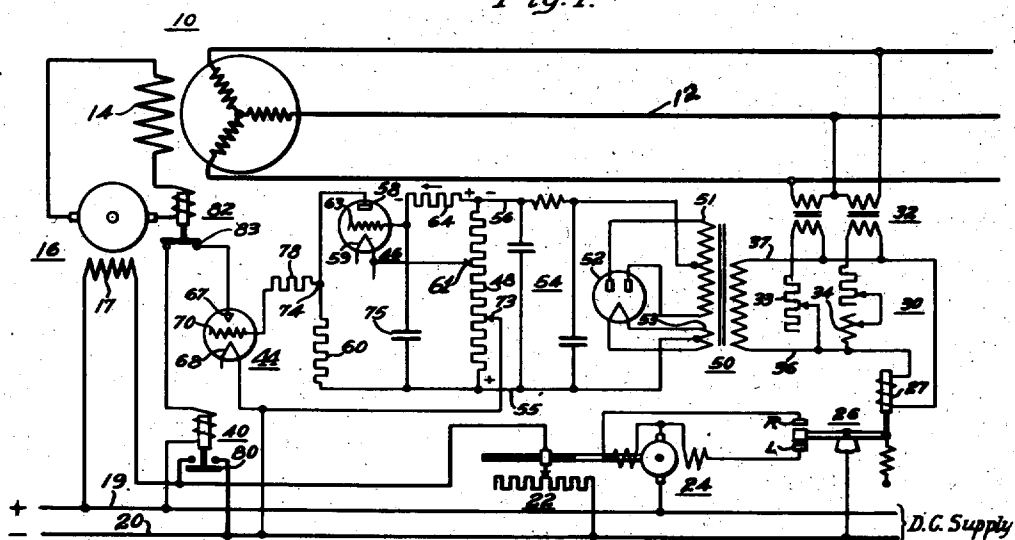
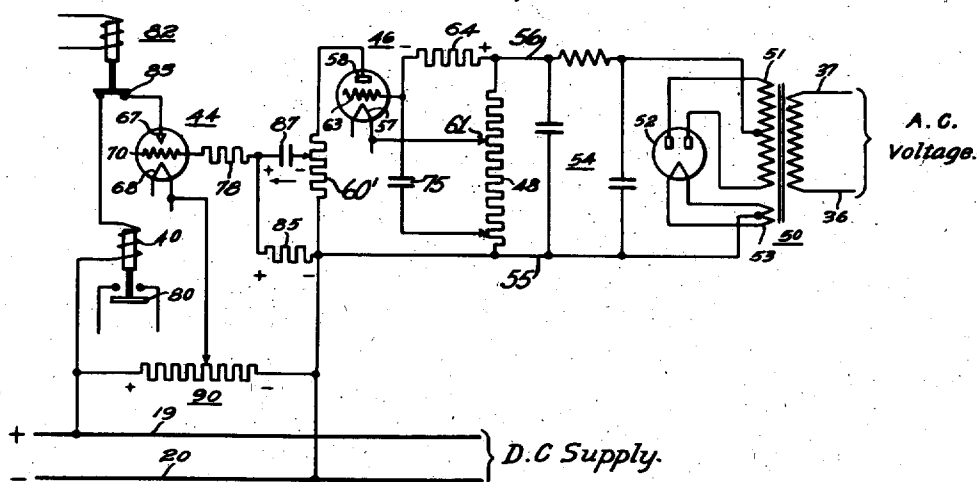


Fig. 2.



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ELECTRONIC RELAY

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My invention relates to electrical relays and has particular relation to relay systems which may be made responsive to sudden changes or impulses in the voltage of an electrical circuit without being affected by the absolute magnitude of that voltage.

A relay system possessing impulse-responsive characteristics is useful in a number of applications, particularly, for example, in connection with quick-response excitation systems for dynamo-electric machines, especially those of the synchronous type which may form a part of an alternating-current power system, in that it permits sudden changes in machine voltage to directly correct the machine excitation without appreciable delay, the ordinary or more gradual voltage fluctuations being taken care of by regulating apparatus of a conventional type to which the impulse relay equipment is supplementary. My invention is directed to the provision of an impulse relay system which possesses the desirable features and advantages particularized hereinafter.

One object of my invention is the provision of a relay system which is responsive only to those changes in the voltage of an electrical circuit which take place with a predetermined suddenness or rapidity.

Another object of my invention is the provision of an impulse-responsive relay system which is unaffected by and independent of the absolute magnitude of the voltage of the influencing circuit.

A further object of my invention is the provision of a relay system of the type described which is applicable to either alternating-current or direct-current circuits.

An additional object of my invention is to provide in a regulating system relay apparatus of the type described which is responsive to sudden changes in the voltage of the regulated circuit.

A still further object of my invention is the provision of an impulse relay system which is particularly suited for application in quick-response excitation systems for dynamo-electric machines.

In practicing my invention I dispose intermediate the electrical circuit and the relay device which is to be actuated upon the occurrence of sudden changes in the circuit voltage, an electronic tube, in the grid-controlling circuit of which is disposed a resistor through which a capacitor is acted upon by a direct-current potential determined by the circuit voltage. The electronic tube is so energized that the output thereof, to which the relay device is responsive, is independent of the absolute magnitude of the circuit voltage and is unaffected by gradual changes therein. A rapid change in the circuit

voltage results in the capacitor drawing an appreciable current through the grid circuit resistor, thereby setting up therein a voltage drop which acts to materially change the electronic tube output to cause the desired relay actuation. When it is desired that the relay device remain actuated after the voltage impulse has subsided, a second electronic tube, of the gas-filled or discontinuous control type, may be disposed intermediate the first tube and the relay.

My invention will best be understood from the following description of specific embodiments thereof when taken in conjunction with the accompanying drawing in which:

Figure 1 is a diagrammatic view of apparatus and circuits arranged in accordance with a preferred form of my invention illustrated as forming a part of a quick-response excitation system for a dynamo-electric machine, and,

Fig. 2 is a diagrammatic illustration of the impulse-relay equipment of Fig. 1, showing certain modifications therein.

Referring to the drawing, and more particularly to Fig. 1 thereof, the impulse-responsive relay system of my invention is shown as a part of a quick-response excitation system for an alternating-current dynamo-electric machine 10 which has armature windings directly connected to the conductors of a three-phase circuit 12 and a field winding 14 which is supplied with exciting current by means of a direct-current exciter generator 16. The field winding 17 of the exciter 16 is shown as being energized from a direct-current circuit comprising conductors 18 and 20, the potential difference between which is maintained substantially constant.

The machine 10 may be a generator driven at substantially constant speed by suitable mechanical means (not shown) from which it is desired to supply a substantially constant voltage to the circuit 12. To adjust the magnitude of this voltage a rheostat 22 is connected in the energizing circuit of the exciter field winding 17. An increase in the field winding current is effected by an adjustment of the rheostat 22 in the resistance decreasing direction and raises the voltage of exciter 16, which by increasing the current supplied to machine field winding 14, raises the voltage of machine 10. In a similar manner, a rheostat adjustment in the resistance-increasing direction serves to lower the voltage supplied to the circuit 12.

To effect an automatic adjustment of the rheostat 22 in response to changes in the voltage of the circuit 12, a rheostat-operating motor 24 of suitable reversible type is shown as being controlled by a contact making device 26 having an actuating winding 27 which is influenced, through a positive phase sequence network equipment 30, by the voltage of polyphase circuit 12.

Network 30, which is the same as that shown and described in U. S. Patent No. 1,571,224, granted February 2, 1926 to C. T. Allcutt, is for the purpose of supplying a single-phase voltage which is dependent upon all of the phase voltages of circuit 12 rather than upon any individual one to insure that the regulator response at all times be representative of the effective or average circuit conditions.

The network 30 is energized through voltage transformers 32 connected in open delta to the conductors of three-phase circuit 12. The secondary windings of these transformers are connected through properly proportioned impedance devices 33 and 34 to a conductor 35 which has a voltage with respect to the neutral conductor 37 of the secondary windings which is proportional only to the positive-phase-sequence voltage of circuit 12.

In operation of the regulating equipment thus far described, which is shown in a highly simplified form, when the voltage of machine 10 is of the desired value, contact making device 26 occupies the neutral position shown, and no operation of rheostat motor 24 takes place. A decrease below the desired value of this voltage causes device 26 to complete through contact member R an energizing circuit for motor 24 which then operates rheostat 22 in the voltage-raising direction to appropriately correct the machine voltage. Similarly, an increase above the desired value of the machine voltage causes the completion through contact member L of a motor energizing circuit which adjusts the rheostat 22 in the voltage-lowering direction.

The rate of excitation change which a conventional regulator, of the type described, is capable of effecting is relatively slow, and when the regulated machine forms a part of an alternating-current power system sudden load demands or other abnormal conditions may result in instability unless supplementary quick-response means be provided. In the past the expedients resorted to for the purpose of obtaining such quick-response excitation have been subject to the disadvantage of having a certain amount of delay in their operation, a typical arrangement (not shown in the drawing) being to provide field-circuit resistance shunting relays which are controlled by the circuit-influenced contact-making device (26) in such manner that an excitation change is effected in advance of the necessary adjustment of the motor-operated rheostat (22). Assuming that when the "lower" contacts of the device are engaged, a sudden drop in circuit voltage occurs, before any excitation correction can be effected it is necessary that the contact-carrying arm of the device move to the other limiting or "raise" position. The time required for such movement to be effected represents a substantial delay, which delay the improved relay system of my invention is capable of overcoming.

The need for a rapid excitation adjustment is more pronounced upon a sudden decrease in the machine voltage than upon a sudden increase in the voltage, the requirement then being to very rapidly raise the machine excitation, and the impulse-responsive relay system of my invention is illustrated as being disposed to fulfill this requirement. In the modification of my invention shown in Fig. 1, the impulse-responsive equipment is illustrated as being disposed to effect the actuation of an excitation-raising relay 40, upon

the occurrence of a sudden decrease in the voltage of circuit 12.

The relay 40 comprises an actuating winding which is supplied with energizing current through a grid-controlled gas-filled electronic tube 44. The tube 44 in turn is influenced by a second electronic tube 46 which is preferably of the triode vacuum or amplifying type. The tube 46 is acted upon by a unidirectional voltage derived from a resistor 48 across which is impressed a unidirectional voltage which, at all times, is proportional to the alternating-current voltage appearing between conductors 36 and 37, and is a measure of the average phase voltage of circuit 12.

This unidirectional potential is supplied from the conductors named through a transformer 50, having secondary windings 51 and 53 which feed into a full-wave rectifying tube 52 of well-known type, which, together with filtering equipment 54, causes the desired unidirectional voltage to appear between conductors 55 and 56, which, in the system shown, is substantially proportional to the voltage of the polyphase circuit 12.

A potential is impressed upon the anode element 58 of the amplifying tube 46 of such value as to make it positive with respect to the cathode element 59. This potential is supplied from the portion of direct-current energized resistor 48 below tap connection 61 through a circuit which includes a resistor 60. The grid element 63 of the tube is energized by a negative potential, from the portion of the direct-current energized resistor 48 above the tap connection 61, through a circuit which includes a resistor 64. The magnitudes of these two potentials are so chosen that, as the voltage between conductors 55 and 56 changes, the potential caused to appear between points 73 and 74, which potential controls the tube 44, will remain substantially constant. This is accomplished by the fact that as the anode voltage is, for example, increased the grid voltage becomes proportionally more negative, increases the repulsion by the control-grid element of the electrons liberated by the tube cathode, and thus checks the tendency for the anode current to rise.

The tube 44, which is of the gas-filled type, comprises anode and cathode elements 67 and 68, respectively, connected in a circuit with the actuating winding of relay 40 which is energized from the direct-current control circuit conductors 19 and 20. When the grid element 70 of the tube is maintained at a negative potential, with respect to the cathode, and exceeds a given critical value, which in practice is of the order of several volts, the tube is maintained non-conductive and no current flows between the anode and cathode elements. However, when the grid bias is reduced below this critical value, conduction between the anode and cathode starts and continues until the anode circuit is interrupted. Thus, in the system of Fig. 1, as long as the grid 70 of tube 44 is maintained sufficiently negative, the actuating winding of relay 40 will remain unenergized.

In the system of Fig. 1, this negative bias applied to tube 44 is determined by the excess of the voltage drop through resistor 60 over that through the portion of direct-current energized resistor 48 below tap connection 73. The purpose of the inclusion in the circuit of a portion of resistor 48 is to compensate for deviations from a constant value of the anode current of tube 46 as the voltage across resistor 48 changes in a

gradual manner. These resistors are so proportioned that normally this excess will be sufficiently above the critical value for tube 44 to maintain the tube non-conductive. Thus, a gradual change through a wide range in the voltage of circuit 12 will be prevented from effecting the actuation of excitation-raising relay 40.

In order that sudden drops in the voltage of circuit 12 may be instrumental in actuating relay 40, I provide, in association with the grid circuit of amplifying tube 46, a capacitor 75 which is acted upon through the resistor 64 by the voltage which energizes the resistor 48. Gradual changes in the magnitude of the potential between conductors 55 and 56 cause only a small capacitor current to flow through the resistor 64 setting up therein a voltage drop insufficient to materially unbalance the proportional change relation between the tube grid and anode potentials. More rapid changes, however, produce larger values of capacitor current which are sufficient to effect appreciable changes in the anode current of tube 46.

Thus, in operation of the complete impulse-responsive relay equipment shown in Fig. 1, a rapid fall in the voltage of circuit 12, by directly lowering the direct-current potential impressed upon resistor 48, causes capacitor 75 to circulate through resistor 64 a discharge current which has a direction indicated by the arrow, which discharge current sets up in the resistor a voltage drop in such direction that the value of negative bias applied to the grid element 63 of tube 46 is abnormally increased. This abnormal increase effects a corresponding reduction in the magnitude of tube anode current which flows through resistor 60, with the result that the voltage drop through the resistor is decreased to a point where the potential impressed upon the grid element 70 of tube 44, through a resistor 78, is allowed to fall below the critical value and the tube 44 immediately becomes conductive.

By virtue of this conduction, the energizing circuit for the actuating winding of relay 40 is completed, causing the relay to bias upwardly to the closed position, a contact member 80 which shunts rheostat 22 from the energizing circuit of exciter field winding 17, and thus raises the excitation of regulated machine 10. The tube 44 remains conductive until the current supplied to field winding 14 of machine 10 rises to a predetermined value, at which time, a current-responsive relay 82 disposed in the field-winding circuit, actuates a contact member 83 thereof upwardly to interrupt the anode circuit of tube 44 and thus effect the deenergization of relay 40. Such deenergization having been effected, the excitation control is returned to the motor-operated rheostat 22.

In Fig. 2, I have illustrated a modified form of impulse responsive relay equipment which fundamentally is the equivalent of that shown and described in connection with Fig. 1, but which possesses certain additional advantages thereover in that the characteristics of the electronic tubes utilized thereby do not have to be so critically taken into account as in the system of Fig. 1. In the schematic diagram of Fig. 2 the direct-current voltage across resistor 48 is, as in the system of Fig. 1, proportional to the voltage of regulated circuit 12.

The amplifier tube 46 is connected to resistor 66 in such manner that the anode current of tube 46 does not change as the regulated voltage changes slowly, this being obtained by selecting

the location of tap 61 so that any change in tube anode voltage is compensated for by a proportional change in grid bias voltage. The resistor 64 and capacitor 75 are connected in a discharge circuit to the grid element 63 of tube 46 so that for decreasing regulated voltage the tube grid will become more negative and consequently the voltage drop across resistor 60 will decrease, due to the decreased plate current of tube 46.

When the voltage drop across resistor 60 decreases a voltage drop will obtain across resistor 85, due to the discharging action of a capacitor 87. The polarity of the voltage drop across the resistor 85 will be as indicated in the diagram, so that the grid voltage of the gas-filled tube 44 becomes more positive and causes the tube to break down and energize the winding of the quick-response shunting relay 40.

The relay 40 remains closed until the direct-current supply voltage for tube 44 is disconnected by means of contact member 83 of the field-current limiting relay 82. The direct-current supply for the tube 44 is supplied from the control circuit conductors 19 and 20, through the voltage divider 90, the negative bias for the tube grid element being derived from the right-hand portion of the divider resistor and the positive anode potential from the left-hand portion.

As above pointed out, the system of Fig. 2, by virtue of the modified scheme of grid control for the tube 44 just described, is more flexible and less responsive to changes in the tube characteristics than is the scheme of Fig. 1. Either of the two schemes are capable of response adjustment by changing the relative values of resistor and capacitor elements 64 and 75, or as in the system of Fig. 2, by adjusting the magnitude of voltage which acts upon capacitor 75 through the use of a tap connection 92.

Although the impulse responsive relay equipment of my invention has been illustrated in quick-response excitation system for a dynamoelectric machine, it will be apparent that it is in no way limited to this one particular application, nor is it limited to relay actuation only in response to sudden changes in the voltage lowering direction of the regulated circuit. For example, in the event that voltage impulses in a direct current circuit are to be detected, circuit conductors 55 and 56 could be joined directly to the circuit instead of being supplied through the intermediate apparatus shown in the drawing. It will be apparent therefore, that the equipment is exceedingly flexible in its application.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the scope of the appended claims.

I claim as my invention:

1. In combination with a variable-voltage electrical circuit and a relay influenced thereby, means for causing the relay to respond to voltage-change impulses, comprising an electronic tube having an anode, a cathode, and a grid element, a circuit including said anode and cathode elements for controlling the actuation of said relay, a circuit including said grid and cathode elements for controlling the current in said anode circuit, means for energizing said anode and grid circuits in accordance with potentials derived from said electrical circuit in such manner that the anode-circuit current remains substantially constant and of an appreciable magnitude during

gradual changes in the electrical circuit voltage, a resistor connected in said grid circuit, and a capacitor connected through said resistor to said electrical circuit for energization in accordance with the voltage thereof, the effect of said connection being to modify the tube grid potential in such manner that when the said electrical-circuit voltage changes at a rapid rate in the voltage-decreasing direction an actuation of the above-mentioned relay will result.

2. In combination, an electrical circuit, an electronic tube, means for so connecting said tube to the circuit that the output current of the tube varies only upon the occurrence of rapid changes in the voltage of the circuit, a second electronic tube, a relay device connected to said second tube for energization in accordance with the output current thereof, means for impressing upon said second tube a control potential which maintains it non-conductive, and means responsive to changes in the output current of said first tube which result from a rapid decrease in said electrical circuit voltage for modifying said control potential in a manner to render the second tube conductive.

3. In combination, an electrical circuit, an electronic tube, means for so connecting said tube to the circuit that the output current of the tube varies only upon the occurrence of rapid changes in the voltage of the circuit, a second electronic tube, a relay device connected to said second tube for energization in accordance with the output current thereof, means for impressing upon said second tube a control potential which maintains it non-conductive, and means responsive to changes in the output current of said first tube which result from a rapid decrease in said electrical circuit voltage for modifying said control potential in a manner to render the second tube conductive, said last-named means comprising a resistor and a capacitor connected in series for energization by a potential determined by the output current of said first tube, said resistor being connected to modify the control potential applied to the second tube.

4. In combination with a relay and a source of potential, means for causing said relay to be responsive to sudden changes in the potential-decreasing direction in the magnitude of said potential and to be unaffected by the absolute value thereof comprising an electronic tube, a circuit connecting the relay to said tube in a manner to effect actuation of the relay when the tube is rendered conductive, a second electronic tube connected to render said first tube conductive when the output of the second tube exceeds a given value, said second tube being of the triode type and having associated therewith anode and grid circuits, means for so connecting said circuits to said source of potential that the tube output remains below the said given value throughout a wide range of steady state values of the potential, a resistor connected in the said tube grid circuit, and a capacitor energized by the potential of said source through a circuit which includes said resistor, the effect of said resistor and capacitor when so connected being to cause the tube output to increase when the potential of said source decreases at a rapid rate.

5. In combination, an electrical circuit, an electronic tube having anode and grid elements connected to be energized in accordance with potentials derived from said circuit, said connection being such that variations in the voltage of the circuit which produce changes in the negative direc-

tion in the potential supplied to the tube grid also produce changes in the positive direction in the potential supplied to the tube anode, and vice versa, to thereby cause the anode current of the tube to be independent of the steady state magnitude of said circuit voltage, a relay, means responsive to changes in said tube anode current for controlling the actuation of said relay, and means responsive to rapid changes in said circuit voltage in the voltage-decreasing direction for so modifying the potential impressed upon the grid element of the tube as to produce a relay-actuating change in the tube anode current.

6. In combination, an electrical circuit, an electronic tube having anode and grid elements connected to be energized in accordance with potentials derived from said circuit, said connection being such that variations in the voltage of the circuit produce changes in opposite directions in said two potentials to thereby cause the anode current of the tube to be independent of the steady state magnitude of said circuit voltage, a relay, means responsive to changes in said tube anode current for controlling the actuation of said relay, and means, comprising a resistor connected intermediate the tube grid element and its source of potential and a capacitor energized through said resistor by a measure of said circuit voltage, for causing rapid changes in said circuit voltage in the voltage-decreasing direction to so modify the tube grid potential as to produce a relay-actuating change in the tube anode current.

7. Means for causing a relay device to be responsive to sudden changes in a decreasing direction in the voltage of a direct-current circuit comprising, in combination, an electronic tube having anode and grid elements connected to be energized in accordance with potentials derived from said circuit, said connection being such that the anode current of the tube will be maintained substantially constant as the voltage of said circuit gradually changes, a relay, means responsive to changes in said anode current for controlling the actuation of said relay, and means, comprising a series-connected capacitor and resistor energized by a measure of said circuit voltage, adapted to vary said tube anode current upon the occurrence of a predetermined rapid change in said decreasing direction in the magnitude of said circuit voltage, said resistor being connected between the tube grid element and its source of potential and acting to modify the voltage impressed upon said grid in accordance with the current which the capacitor allows to pass through the resistor.

8. In combination, an alternating-current circuit, an electronic tube having anode and grid elements, rectifying means for supplying from said alternating-current circuit direct-current potentials to said tube elements, said potentials being so interdependent that the anode current of the tube will be maintained substantially constant and of an appreciable magnitude as the voltage of the alternating-current circuit gradually changes, a relay, means responsive to predetermined changes in said anode current for controlling the actuation of said relay, and means for so predeterminedly varying said anode current in accordance with the rate of change of said circuit voltage in a decreasing direction, said last-named means comprising a resistor connected intermediate the tube grid element and its source of potential and a capacitor energized through said resistor by a direct-current potential supplied from the circuit through said rectifying means.

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