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O. P. McCARTY

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TIME DELAY CIRCUIT

Original Filed July 28, 1936

Fig. 1.

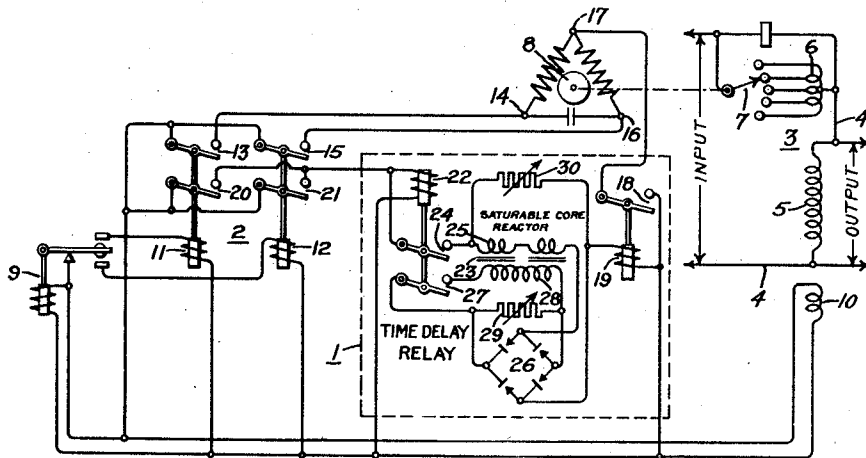


Fig. 2.

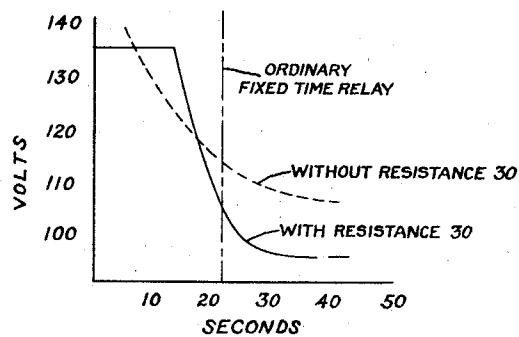
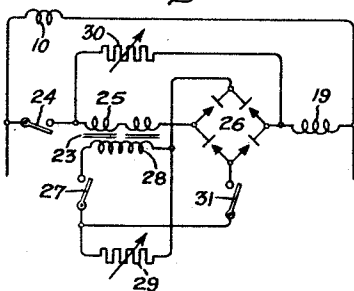


Fig. 3.



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UNITED STATES PATENT OFFICE

2,216,595

TIME DELAY CIRCUIT

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newed March 22, 1940

25 Claims. (Cl. 175—320)

My invention relates to time delay circuits and more particularly to improvements in time delay relays for automatic electrical regulators.

It is often desirable to provide certain automatic regulators with time delay elements so as to prevent unnecessary operation of the regulator when the regulated quantity is subject to relatively rapid and small fluctuations. Heretofore this time delay element has been of the motor operated type involving relatively numerous and expensive moving parts. In some cases it has been energized in accordance with the magnitude of the regulated quantity so as to produce a time delay which varies inversely with the magnitude of this quantity.

In accordance with my invention I provide a novel and simple time delay element which, with the exception of standard magnetic relays or contactors, has no moving parts, is very simple and inexpensive in construction and maintains its setting indefinitely.

An object of my invention is to provide a new and improved time delay element.

Another object of my invention is to provide a new and improved time delay relay for electrical regulators.

A further object is to provide a new combination of electrical regulator and time delay relay. That invention is being claimed in my application Serial No. 161,261, filed August 27, 1937, as a continuation-in-part of an earlier filed divisional application.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a diagrammatic showing of an embodiment of my invention combined with an automatic transformer tap changing step voltage regulator; Fig. 2 shows the operating characteristic of the time delay relay of Fig. 1, and Fig. 3 is a modification of the time delay relay of Fig. 1.

Referring now to the drawing and more particularly to Fig. 1, my time delay relay is shown in the box 1. The time delay relay is inserted in a control circuit 2 for an automatic regulator 3. The regulator 3 is a voltage regulator for an alternating current power circuit 4 and it is shown by way of example as an autotransformer having a common winding 5 and a series winding 6 provided with a tap changing switch 7 shunted by a non-linear current by-pass. The tap changing switch 7 is mechanically coupled to a reversible driving motor 8. Such regulators are

well known in the art. The control circuit 2 comprises a voltage-sensitive main controller in the form of a contact-making voltmeter 9 connected to be energized in response to the regulated voltage of the circuit 4 by means of an auxiliary winding 10 on the regulating autotransformer. Under the control of the voltage-sensitive device 9 are auxiliary "raise" and "lower" relays 11 and 12 which are connected to be energized from the auxiliary winding 10 through the contacts of the device 9. The raise relay 11 has a set of contacts 13, which, when closed by the operation of the relay, connect to a terminal 14 of the motor 8 for causing it to rotate in reverse direction and lower relay 12 has a set of contacts 15 which, when closed by the operation of relay 12, make a connection to a terminal 16 of motor 8 for causing it to rotate in a forward direction. The common, or return terminal 17 of the motor 8 has a circuit through it completed by a set of contacts 18 on a relay 19 forming part of the time delay relay. Auxiliary relays 11 and 12 also have electrically parallel contacts 20 and 21, respectively, which, whenever either relay 11 or relay 12 is energized, complete a circuit for energizing a relay 22 from across the auxiliary winding 10. Relay 22 also forms a part of the time delay relay.

The time delay relay, in addition to the relays 19 and 22, includes a saturable core reactor 23 and a rectifier 26. The main circuit through the time delay relay is a series one which, starting at a pair of contacts 24 on the relay 22, includes the alternating current winding or windings 25 of the reactor, the upper input terminal of the rectifier 26, the left-hand output terminal of rectifier 26, another set of contacts 27 on the relay 22, a direct current saturating winding 28 for the reactor, the right-hand output terminal of the rectifier, the remaining input terminal of the rectifier and the operating winding of the relay 19. As shown, this circuit is arranged to be connected, by means of the contacts 20 or 21 of the auxiliary relays 11 and 12, across the auxiliary winding 10 of the regulating transformer. In addition to the above elements the time delay relay is also provided with an adjustable resistance 29 which is connected across the rectifier output terminals and which is provided for the purpose of adjusting the time delay setting of the relay. There is also provided a second adjustable resistor 30 which is connected to bypass the reactor and rectifier and which serves to improve the operation of the time delay re-

lay in a manner which will be described in connection with the operation of Fig. 1.

The parts are shown in Fig. 1 in the positions they occupy when the output voltage of the regulated power circuit 4 is normal.

The operation of Fig. 1 is as follows: If the regulated output voltage of circuit 4 departs from normal the voltage of the auxiliary winding 10 will change correspondingly thereby causing the contact-making voltmeter 9 to close its "raise" or "lower" contacts depending upon whether the voltage has decreased or increased, respectively. This will cause the proper auxiliary relay to be operated so as to make a connection enabling motor 8 to turn in the proper direction to cause the tap-changing switch 7 to move so as to vary the ratio of the regulating transformer in such a manner to restore the voltage to normal. Motor 8 cannot start, however, until the contacts 18 of the relay 19 close and these contacts will not close for a predetermined time determined by the setting of the time delay relay, provided that the contact-making voltmeter has been making contact throughout this time delay interval. Operation of either one of the auxiliary relays also serves, through the closure of either contacts 20 or contacts 21, to connect the time delay relay across the auxiliary winding 10.

The time delay relay operates in the following manner: As soon as it is connected across the winding 10 the relay 22 closes its contacts 24 and 27. This completes the series circuit through the reactor windings, the rectifier 26 and the winding of relay 19. The alternating current winding 25 of the saturable core reactor initially has a relatively high reactance as its core is unsaturated. Consequently the current through the relay winding 19 will be insufficient to cause operation of the relay. However, the small amount of current which does flow in the circuit, while flowing through the direct current saturating winding 28, begins to saturate the core with the result that the reactance of the alternating current winding is decreased. This action is cumulative because as soon as the reactance of the alternating current winding decreases the direct current in the direct current saturating winding 28 increases thereby further decreasing the reactance of the alternating current winding and allowing the current to build up. In a predetermined time the reactor core becomes sufficiently saturated by direct current in the winding 28 so that enough current can flow through the alternating current winding 25 and relay winding 19 to cause operation of the relay.

The energizing circuit for the motor 8 will now be completed and the motor will cause the regulator to restore the voltage to normal whereupon the contact making voltmeter will again become balanced in its mid-position, the auxiliary relay will drop out thereby causing relay 22 to drop out, thereby deenergizing the time delay relay and causing the relay 19 to drop out and reset the time delay relay.

The rate at which unidirectional flux in the core of the saturable reactor builds up is determined by the adjustment of the resistor 29. The lower this resistance the more direct current through the rectifier is by-passed from the direct current saturating winding 28 and the longer it takes for the time delay relay to operate, while the higher the value of this resistance the shorter the time interval of the time delay relay.

The resistance 30 serves to permit a certain amount of current to flow through the relay winding 19 immediately upon the closure of the contacts 24 because this resistance by-passes the reactor. By properly adjusting this resistance the amount of the current flowing through it can be made insufficient to cause operation of the relay so that the reactor need only control the marginal amount of additional current necessary for causing the relay 19 to operate. In this manner less duty is required of the saturating circuit and greater time delays can be secured with a given size of reactor. Resistance 30 also causes the time delay characteristic of the relay to be such that for voltages above a predetermined value the response of the relay is substantially instantaneous while for voltages below another value the time delay is continuous and the relay 19 never closes its contacts. Both these features are very desirable. The instantaneous response on over-voltage feature is desirable because over-voltage is usually more serious than under-voltage due to the danger of destruction to apparatus, and consequently it is desirable that serious over-voltage be corrected as quickly as possible. The second feature is desirable because it takes the place of the usual low voltage release or cutout provided in such regulating systems. In an ordinary voltage regulator when serious under-voltage occurs for any reason, such for example as a short circuit on the line, the regulating apparatus will of course try to restore the voltage to normal by running the regulator to its highest voltage position. If now the voltage is suddenly restored to normal on the supply circuit and the regulating transformer is in its maximum raise or boost position serious momentary over-voltage may be applied to load devices thereby injuring them. To prevent this most regulators are provided with an auxiliary device known as a low-voltage release or cutout which upon the occurrence of predetermined under-voltage prevents the regulator from being run to its maximum "raise" position. However, because of the second above-mentioned feature of my time delay relay no such auxiliary low-voltage release is necessary because upon the occurrence of this under-voltage the time delay automatically becomes indefinite or continuous so that no regulating action takes place under these conditions. Upon restoration of voltage the regulator will be in the position it was in before the under-voltage occurred and thus the production of serious over-voltage on the circuit by the regulator is prevented.

In Fig. 2 the vertical dot and dash line represents the characteristics of an ordinary fixed time delay relay set for 20 seconds. With such a relay the time delay is the same for all values of voltage. The dashed curve represents the inverse time delay which would be secured by the time delay relay of Fig. 1 if it were not provided with the resistance 30. The full line characteristic is the characteristic of the time delay relay of Fig. 1. It will be apparent with the values chosen by way of illustration in Fig. 2 that for voltages above 135 volts the time delay is zero. Below 135 volts the time delay starts at about 15 seconds and increases rapidly to about 30 seconds at a voltage of about 100. For voltages below 100 the curve flattens out and becomes horizontal so that there is a continuous time delay and the relay does not operate for voltages below 100. By adjusting the value of the resistance 30 the upper and lower voltage

limits of the characteristic may be changed while by adjusting the resistance 29 the steepness of the inverse characteristic portion of the curve and therefore the amount of time delay may be adjusted at will.

In Fig. 3 the time delay circuit is shown provided with an additional set of control contacts 31 interposed between the rectifier on the one hand and the direct current saturating winding 28 and the resistor 29 on the other hand. Control of the time delay circuit by the contacts 24 or 27 or 31 or various combinations of these contacts produce different operating characteristics of the time delay circuit as follows: (1) If the contacts 24 and 31 are maintained closed and the circuit is controlled by closing and opening contacts 27 there will be a definite time delay between the closing of contacts 27 and the energization of the relay winding 19 in the manner previously described. When the contacts 27 are opened the time delay relay will immediately reset and relay winding 19 will immediately be deenergized. There will be complete resetting each time the contacts 27 open so that even for the extreme case where the contacts of the contact making voltmeter 9 chatter the contacts will have to stay closed for the full time delay period before the regulator will operate. (2) If now the control is by contacts 31 and contacts 24 and 27 are kept closed there will be the usual time delay between the closing of contacts 31 and the operating of the relay 19. However, upon opening of the contacts 31 there will be a time delay in the drop out of the relay 19. This is because of the appreciable time constant of the loop circuit containing the direct current winding 28 and the resistance 29, which maintains the flux in the core of the reactor for an appreciable period after the contacts 31 open. This keeps the impedance of the reactor low enough, for an appreciable time, so that the leakage current through the rectifier 26 plus the current through the bridging resistor 30 will hold relay 19 closed. However, because of the presence of this loop circuit the unidirectional flux in the core of the reactor tends to build up if the contacts 31 are intermittently opened and closed so that in the case of chattering of the main control contacts the relay 19 will eventually operate. (3) When the control is by contacts 24 alone and contacts 27 and 31 remain closed there is the usual time delay upon closing of the contacts 24 and there will be instantaneous resetting and drop-out of the relay 19 upon opening of the contacts 24. However, because of the circulating path through the direct current winding 28 and the resistance 29 the flux tends to build up in the core upon intermittent operation of the contacts 24 so that excessive intermittent operation or chattering of the main control contacts will eventually cause operation of the relay 19.

In Fig. 1 it is the contacts 27 of relay 22 which give the time delay relay its time delay closing, instantaneous drop out characteristic with no build-up of flux with chattering contact control and contacts 24 which are operated simultaneously with contacts 27 prevent the losses in the resistance 30 and relay winding 19 which otherwise would take place due to the fact that resistance 30 by-passes the reactor and thereby in effect by-passes the contacts 27.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that changes and modi-

fications can be made in my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a time delay relay, in combination, a rectifier having direct current output terminals and an alternating current side with alternating current input terminals, a saturable core reactor having a direct current winding connected in series with the rectifier's direct current output terminals and having an alternating current winding connected in series with the rectifier's alternating current input terminals, and a circuit maker and breaker connected in series with said alternating current winding on the alternating current side of said rectifier.

2. In a time delay relay, in combination, a rectifier having direct current output terminals and an alternating current side with alternating current input terminals, a saturable core reactor having a direct current winding connected in series with the rectifier's direct current output terminals and having an alternating current winding connected in series with the rectifier's alternating current input terminals, and a pair of circuit makers and breakers connected respectively in circuit with the input and output terminals of said rectifier.

3. In a time delay relay, in combination, a rectifier having direct current output terminals and an alternating current side with alternating current input terminals, a saturable core reactor having a direct current winding connected in series with the rectifier's direct current output terminals and having an alternating current winding connected in series with the rectifier's alternating current input terminals, a load device and a pair of contacts connected in series with said alternating current winding on the input side of said rectifier, an adjustable resistor connected to by-pass said alternating current winding and said rectifier, an adjustable resistor connected in parallel with said direct current winding, and a second pair of contacts for connecting and disconnecting said direct current winding from said rectifier without changing the connections between said rectifier and the last mentioned adjustable resistor.

4. In a time delay relay, in combination, a rectifier having direct current output terminals and an alternating current side with alternating current input terminals, a saturable core reactor having a direct current winding connected in series with the rectifier's direct current output terminals and having an alternating current winding connected in series with the rectifier's alternating current input terminals, and a circuit maker and breaker connected between said output terminals and said direct current winding.

5. In a time delay relay, in combination, a rectifier having direct current output terminals and an alternating current side with alternating current input terminals, a saturable core reactor having a direct current winding connected in series with the rectifier's direct current output terminals and having an alternating current winding connected in series with the rectifier's alternating current input terminals, an adjustable resistor connected in parallel with said direct current winding, and a circuit maker and breaker for opening and closing the circuit through said direct current winding without changing

the connections between said resistor and said rectifier.

6. In a time delay relay, in combination, a rectifier having direct current output terminals and an alternating current side with alternating current input terminals, a saturable core reactor having a direct current winding connected in series with the rectifier's direct current output terminals and having an alternating current winding connected in series with the rectifier's alternating current input terminals, an adjustable resistor connected in parallel with said direct current winding, and a circuit maker and breaker for opening and closing the circuit from said rectifier to said resistor and direct current winding.

7. In a time delay relay of the type having a variable impedance in series with a controlled device, the combination of a constant impedance for conducting current to said controlled device in an amount insufficient to cause operation thereof whereby said variable impedance controls the marginal amount of current necessary for the operation of said device, the current conducted by said constant impedance to said controlled device being in the same direction in said device as the marginal amount of current controlled by said variable impedance whereby the current in each of said impedances is less than the total current in said controlled device.

8. In a time delay relay including a series circuit comprising a source of alternating current, a pair of control contacts, a relay winding, an alternating current winding of a saturable core reactor, a rectifier and the direct current winding of said reactor, a combination of a resistor connected to by-pass said rectifier and the windings of said reactor, said reactor being so proportioned that the current it permits to flow through said relay winding upon closure of said contacts is insufficient to cause operation of said relay.

9. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, and a rectifier having alternating current input terminals and direct current output terminals, said direct current saturating winding being connected in circuit with the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller being connected in circuit with one of said windings, said electroresponsive device being connected in circuit with one of said windings.

10. In combination, an electroresponsive device, a circuit controller controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, and a rectifier having alternating current input terminals and direct current output terminals, said direct current saturating winding being connected in circuit to the direct current output terminals of said rectifier, said alternating current winding connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being

adapted to be energized by any suitable source of alternating current, said circuit controller being connected in circuit with one of said windings, said electro-responsive device being connected in circuit with said alternating current variable reactance winding.

11. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, and a rectifier having alternating current input terminals and direct current output terminals, said direct current saturating windings being connected in circuit with the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller being connected in circuit with said alternating current variable reactance winding, said electroresponsive device being connected in circuit with one of said windings.

12. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, and a rectifier having alternating current input terminals and direct current output terminals, said direct current saturating winding being connected in circuit with the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller being connected in circuit with said direct current saturating winding, said electroresponsive device being connected in circuit with one of said windings.

13. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, and a rectifier having alternating current input terminals and direct current output terminals, said direct current saturating windings being connected in circuit with the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, a series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller and said electroresponsive device being connected in circuit with said alternating current variable reactance winding.

14. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating

connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller being connected in circuit with one of said windings, said electroresponsive device being connected in circuit with one of said windings.

18. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, a rectifier having alternating current input terminals and direct current output terminals, and an adjustable resistor, said direct current saturating winding and said adjustable resistor being connected in parallel across the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller being connected to control the connection and disconnection of said direct current saturating winding across the direct current output terminals of said rectifier independently of the connection of said adjustable resistor across the direct current output terminals of said rectifier, said electroresponsive device being connected in circuit with one of said windings.

19. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, a rectifier having alternating current input terminals and direct current output terminals, and an adjustable resistor, said direct current saturating winding and said adjustable resistor being connected in parallel across the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller being connected between one of said direct current output terminals on the one hand and said direct current saturating winding and adjustable resistor on the other hand, said electroresponsive device being connected in circuit with one of said windings.

20. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, a rectifier having alternating current input terminals and direct current output terminals, and an adjustable resistor, said direct current saturating winding and said adjustable resistor being connected in parallel across the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any

suitable source of alternating current, said circuit controller being connected in circuit with one of said windings, said electroresponsive device being connected in circuit with said alternating current variable reactance windings.

21. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, a rectifier having alternating current input terminals and direct current output terminals, and an adjustable resistor, said direct current saturating winding and said adjustable resistor being connected in parallel across the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized from any suitable source of alternating current, said circuit controller being connected in the direct current saturating winding branch of the parallel circuit connection between said winding and said adjustable resistor, said electroresponsive device being connected in circuit with said alternating current reactance winding.

22. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, a rectifier having alternating current input terminals and direct current output terminals, and an adjustable resistor, said direct current saturating winding and said adjustable resistor being connected in parallel across the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller being connected between one of the direct current output terminals of said rectifier on one hand and said direct current saturating winding and adjustable resistor on the other hand, said electroresponsive device being connected in circuit with said alternating current variable reactance winding.

23. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, and means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, a rectifier having alternating current input terminals and direct current output terminals, and an adjustable resistor, said direct current saturating winding and said adjustable resistor being connected in parallel across the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller and said electroresponsive device being connected in circuit with said alternating current variable reactance winding, and a resistor connected in shunt with said reactor and said rectifier.

nals, and an adjustable resistor, said direct current saturating winding and said adjustable resistor being connected in parallel across said direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller having a first set of contacts connected in circuit with said alternating current variable reactance winding and having a second set of contacts connected in the parallel branch circuit containing said direct current saturating winding, said electroresponsive device being connected in circuit with said alternating current variable reactance winding.

24. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, a rectifier having alternating current input terminals and direct current output terminals, said direct current saturating winding being connected in circuit with the direct current output terminals of said rectifier, said alternating current winding being connected in a series circuit with the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller being connected in circuit with one of said windings, said electroresponsive device being connected in circuit with one of said windings, and means for supplying said electroresponsive device with current which is independent of the current passing through the winding with which said electroresponsive device is connected in circuit.

25. In combination, an electroresponsive device, a circuit controller for controlling the actuation of said device, means for delaying the response of said device to the operation of said controller, said means comprising a saturable core reactor having a direct current saturating winding and an alternating current variable reactance winding, a rectifier having alternating current input terminals and direct current output terminals, said direct current saturating winding being connected in circuit with the direct current output terminals of said rectifier, said alternating current winding being connected in the series circuit of the alternating current input terminals of said rectifier, said series circuit being adapted to be energized by any suitable source of alternating current, said circuit controller and said electroresponsive device being connected in circuit with said alternating current variable reactance winding, and a resistor connected in shunt with said reactor and said rectifier.

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