April 28, 1953 S. A. STEVENS ET AL 2,636,930

RELAY FOR CONTROLLING THE SUPPLY OF OPERATING CURRENT TO ELECTROMAGNETICALLY ACTUATED DEVICES

Filed July 29, 1949 3 Sheets-Sheet 1

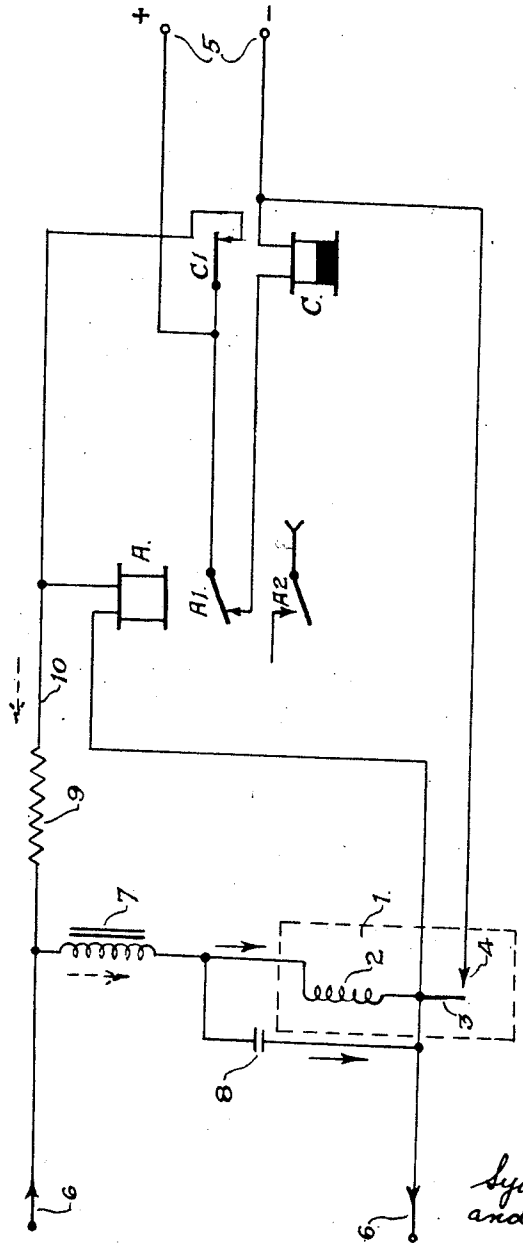

FIG. 1.

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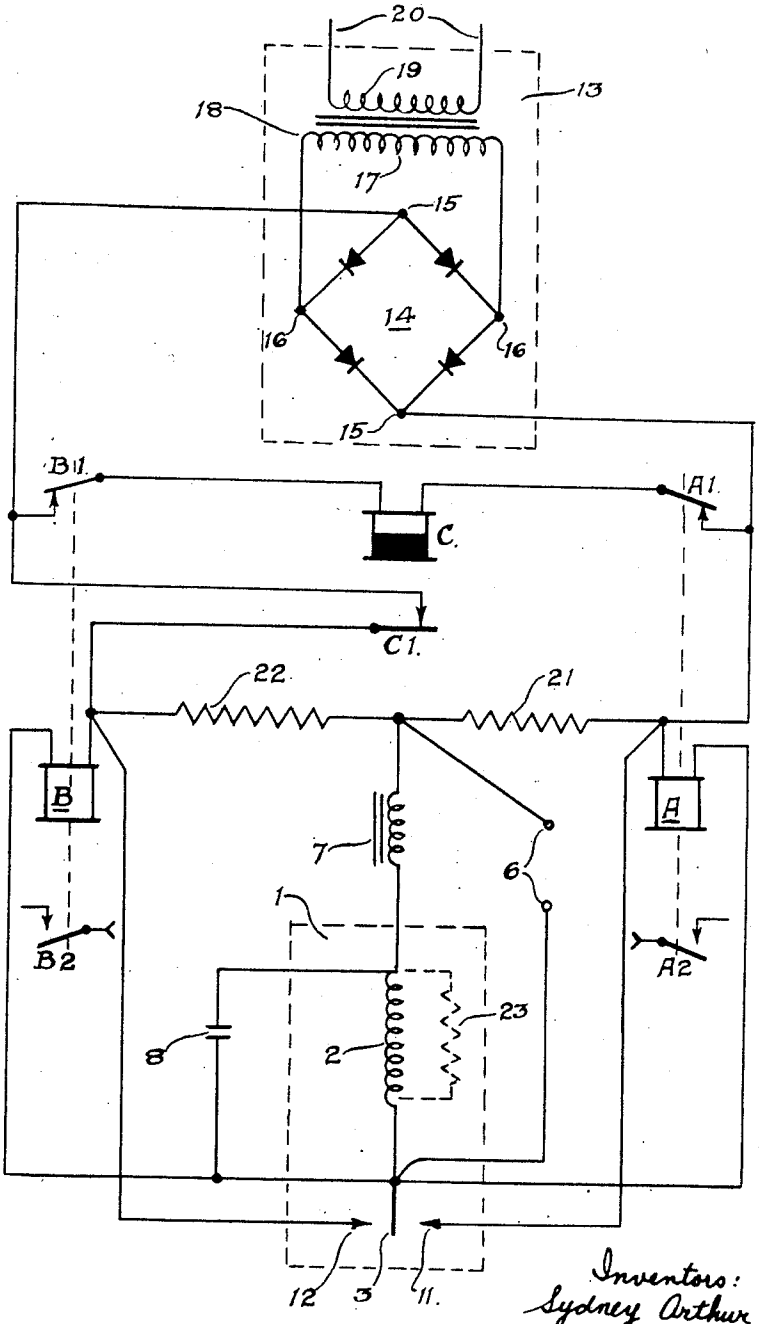

FIG. 2.

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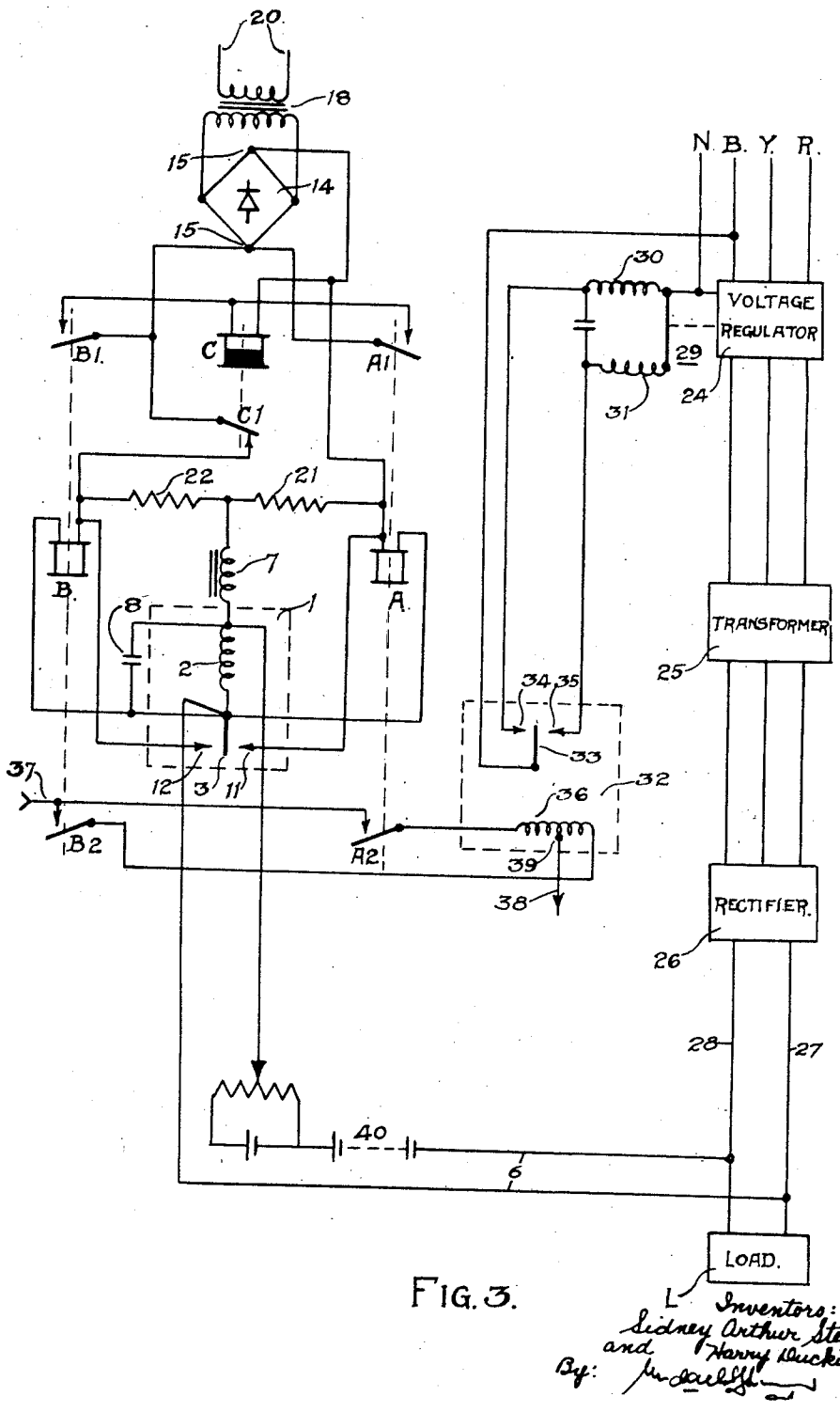

FIG. 3.

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UNITED STATES PATENT OFFICE

2,636,930

RELAY FOR CONTROLLING THE SUPPLY OF OPERATING CURRENT TO ELECTROMAGNETICALLY ACTUATED DEVICES

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In Great Britain August 13, 1948

5 Claims. (Cl. 175—320)

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This invention relates to relays for controlling the supply of operating current to electro-magnetically operated devices of the kind in which the supply of operating current effected when the circuit for this current, closed when the control relay is energised, is arranged to be interrupted at a point other than the control relay contacts after a predetermined time interval.

According to the invention, the electro-magnetic energy stored in the device while the latter is supplied with operating current is arranged to be utilised, when the circuit of the device is interrupted, to effect a positive and rapid opening movement of the control relay contacts which are subsequently reclosed provided that the control relay continues to be energised.

The invention is illustrated by way of example in the accompanying drawings of which Figures 1, 2 and 3 are diagrammatic circuit diagrams of control relay apparatus embodying various forms of the invention.

Referring now first to Figure 1, the control apparatus therein shown comprises a sensitive control relay 1 having an energising winding 2, a movable element 3 and a single fixed contact 4, the element 3 being normally out of engagement with the contact 4 and making contact therewith when the winding 2 is energised from a control circuit.

The control relay 1 is arranged to control the supply of operating current to a power relay A from the terminals 5 of a power supply circuit through a front contact C^1, of a normally energised slow release relay C when the control relay 1 is energised, the relay C being normally energised from the terminals 5 through a circuit including a back contact A^1 of the power relay A, this contact A^1 being closed so long as the relay A is deenergised.

The control relay winding 2 is connected to the conductors 6 of a control circuit in series with an inductance 7, a suitable condenser 8 being connected in parallel with the relay winding 2. A relatively high resistance 9 is included in a conductor 10 extending as shown from one end of the inductance 7 to one of the terminals of the power relay A which is provided with a front contact A^2 controlling the energising circuit of an electro-magnetically operated device (not shown) to be controlled.

The operation of the apparatus of Figure 1 is as follows:

Under normal conditions the relay C is maintained energised from the supply terminals 5 through a circuit including the back contact A^1 of the power relay A, the front contact C^1 of the relay C being thus closed.

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When energising current is supplied from the conductors 6 to the winding 2 of the control relay 1 through a circuit including the inductance 7, the control relay 1 is energised and the element 3 of this relay is caused to engage with the fixed contact 4.

A circuit for the operating winding of the power relay A is thus completed from the supply circuit terminals 5 through the closed contact C^1 of the relay C and an additional or reinforcing current is at the same time supplied to the control relay winding 2 in parallel with the winding of the power relay A from the terminals 5 through conductor 10, the resistance 9 and the inductance 7 this additional current causing the element 3 of the control relay to be firmly maintained in its closed position against the contact 4.

The energisation of the control relay 1 effects the interruption of the energising circuit of the slow release relay C which after the expiration of an interval of time releases its contact C^1 and thereby breaks the energising circuit of the power relay A at this contact.

As soon as this occurs, the discharge of the electro-magnetic energy stored in the magnetic circuit of the power relay A due to the decay of the magnetic flux tends to cause a transient current to flow in the circuit of the energizing winding 2 of the control relay in a direction opposed to that of the control current from the conductors 6. The actual current traversing the control relay winding 2 during this short period of time will evidently be the difference between the value of the transient current above referred to and the control current and its direction of flow will be such as to cause the control relay element 3 to be positively and promptly moved away from the fixed contact 4 to an extent dependent on this actual current temporarily traversing the control relay winding 2.

As soon as the transient current ceases the control current will return the element 3 of the control relay 1 into engagement with the contact 4 and this action will evidently occur after a short interval of time dependent upon the extent of the opening movement of the control relay element 3. If, therefore, the control current is relatively high, the extent of the opening movement above referred to will be relatively small and the return movement of the control relay element 3 will be completed after a relatively short time interval. If, on the other hand, the

control current is relatively low the extent of the return movement of the relay element 3 will be correspondingly great and the re-engagement of the control relay element with the contact 4 will be delayed.

It will be evident that in the apparatus above described the operating circuit of the power relay A is opened and closed, the opening of this circuit being effected at the contact C^1 of the slow release relay C while the duration of the closed period is constant and determined by the characteristic of the slow release relay C. The duration of the deenergised periods of the power relay A is, on the other hand, dependent upon the magnitude of the control current relative to the magnetic characteristics of the power relay.

This action is particularly advantageous where the power relay A is arranged to control (through a circuit including a contact A^2 of the relay A) a voltage or current regulator for a circuit in which it is desired to maintain substantially constant voltage or current conditions, the current energising the control relay 1 being arranged to be dependent upon the extent of the deviation in one direction of the voltage or current conditions in the circuit controlled by the regulator from a given standard value.

Since, as above explained the time interval between the de-energisation of the power relay A and its subsequent re-energisation is dependent upon the magnitude of the control current the duration of this time interval will be shorter when the voltage or current deviation from the standard value is greater so that the power relay will be re-energised more rapidly and the regulator will repeat its regulating action more promptly than if the deviation is smaller.

Referring now to Figure 2, in the apparatus therein shown the control relay 1 is of the double contact type having a contact element 3 arranged to be moved into engagement with one or other of two fixed contacts 11, 12 when the control relay 1 is energised by current in one direction or the other.

Two power relays A, B are provided the energising circuits of which each include a contact C^1 of the slow release relay C, the windings of the two power relays being connected in series with one another to a source 13 of uni-directional current. The source 13 comprises a full-wave rectifier 14 the out-put terminals 15 of which are connected to the operating windings of the power relays A, B in series with one another, the input terminals 16 of the rectifier 14 being supplied with current from the secondary winding 17 of a transformer 18 the primary winding 19 of which is connected to an alternating current circuit 20. The energising coil 2 of the control relay 1 is connected through suitable resistances 21, 22 with the energising windings of both power relays A, B as clearly shown in the drawing.

In operation, the slow release relay C is normally maintained energised by uni-directional current from the output terminals 15 of the rectifier 14 through a circuit including the normally closed contacts A^1 and B^1 of the power relays A and B. So long as the movable element 3 of the control relay 1 is not in engagement with either of the fixed contacts 11, 12 the operating windings of the power relays A and B are connected in series with one another to the output terminals 15 of the rectifier through the normally closed contact C^1 of relay C but the current traversing this circuit is under these conditions insufficient to operate either of the power relays A and B. As a result the relay contacts A^2 and B^2 controlling the operation of a voltage or current of the circuit to be controlled, remain open and the regulator is accordingly inoperative.

When the control circuit conductors 6 are supplied with current in one direction or the other, the winding 2 of the control relay 1 is correspondingly energised to cause the relay element 3 to engage with the contact 11 or the contact 12 of the control relay in accordance with the direction of the current in the winding 2.

Assuming that the element 3 is moved into engagement with the fixed contact 12, the operating winding of the relay B is short-circuited through the element 3 and contact 12 with the result that the current supplied to the operating winding of the relay A from the output terminals 15 is considerably increased and the relay A is operated to open its contact A^1 and to close its contact A^2. Current is also supplied from the output terminals 15 to the winding 2 of the control relay 1 through a parallel circuit to the winding of relay A including the inductance 7 and the resistance 21 this current augmenting the current supplied to the winding 2 from the control conductors 6 and thus causing the element 3 to be firmly held in engagement with the contact 12.

The closure of the relay contact A^2 by the full energisation of the power relay A as above described causes the regulator to effect the desired voltage or current adjustment in the circuit to be controlled and the opening of the relay contact A^1 breaks the energising circuit of the relay C which accordingly releases after a time interval and opens the energising circuit of the relay A at the relay contact C^1. The electro-magnetic energy stored in the power relay A is then utilised as in the apparatus of Figure 1 to cause a transient current to traverse the winding 2 of the control relay 1 and thus to effect the prompt movement of the element 3 of the control relay away from its contact 12 as already described with reference to Figure 1. The inductance 7 and the condenser 8 in the apparatus of Figures 1 and 2 serve as a smoothing device to prevent vibration of the movable element 3 of the control relay 1 this element being preferably arranged to have a relatively long natural time period of oscillation. A suitable damping resistance may also if desired be connected in parallel with the energising coil 2 of the control relay 1 as indicated for example at 23 in Figure 2.

In the apparatus embodying the invention described with reference to Figures 1 and 2 the operating circuit of the electro-magnetically operated device e. g. the energising circuit of the power relay A or B is arranged to be automatically interrupted after the expiration of a time interval (determined by the action of the slow release relay C) from the closure of this circuit under the action of the control relay 1.

In a modification or development of the invention the actual operation of the electro-magnetically operated device when its operating circuit is interrupted is arranged to be delayed for a predetermined interval of time so that in the event of a return movement of the control relay being completed within this period, the device will be re-supplied with operating current before its previous operation has ceased. The device will not, under these conditions undergo any cessation in operation while if the duration of the time interval between the de-energisation of the device or of the power relay and its re-energisation is greater than the predetermined interval of time above referred to, the

operation of the device or of the power relay will be intermittently interrupted. This operation will under all conditions be aperiodic, the intervals separating each period of operation varying between zero and an indefinitely long duration in accordance with the magnitude of the current supplied to the control relay.

Figure 3 illustrates control apparatus similar to that of Figure 2 but embodying the modification or development above referred to as applied to the control of current supply to a load L from a three-phase supply circuit the phase conductors of which are indicated at R, Y, B and the neutral conductor at N. These conductors are connected through a voltage regulator **24** of any suitable type to the primary windings of a main transformer **25** the secondary windings of which are connected to the input terminals of a rectifier **26** the output terminals of which are connected to the load L through conductors **27, 28**. The voltage regulator **24** is operated by an electric motor device **29** comprising motor windings **30, 31** to one or other of which current is supplied to effect the operation of the motor device **29** in one direction or the other to raise or to lower the voltage applied to the primary windings of the main transformer **25** through the regulator **24**.

The current supplied to the motor winding **30** or **31** is derived from the phase conductor B and the neutral conductor N of the alternating current supply circuit and this current supply is controlled by an intermediate polarised relay **32** having slow release characteristics.

The relay 32 comprises a movable element **33** arranged to engage with one or other of two fixed contacts **34, 35** connected to the field windings **30, 31** respectively and an energising winding **36**. The terminals of the winding **36** are connected through the contacts A^2 or B^2 of the power relays A and B to one terminal **37** of a suitable source of uni-directional current the other terminal **38** of which is connected to the mid-point **39** of the winding **36**.

The control circuit conductors **6** are connected to the load conductors **27, 28**, this control circuit including a substantially constant adjustable source of uni-directional current constituted as indicated by a set of primary cells **40**.

The relay C is, in this form of apparatus, normally deenergised and is arranged to be supplied with energising current from the output terminals **15**, of the rectifier **14** through the contact A^1 or B^1 of the power relays A or B when this relay is energised.

The operation of the apparatus of Figure 3 is similar to that of the apparatus of Figure 2 above described as regards the action of the control relay **1** and the power relays A and B. The current traversing the winding **2** of the control relay **1** is, however, in the apparatus of Figure 3 dependent upon the difference between the voltage across the load conductors **27, 28** and the voltage of the source **40** which constitutes an adjustable standard of reference. In the event therefore of the voltage across the conductors **27, 28** rising above or falling below the voltage of the source **40**, current will traverse the control conductors **6** and the winding **2** of the control relay **1** in one direction or the other respectively, the magnitude of this current being dependent upon the magnitude of the difference between the voltage across the load conductors **27, 28** and that of the source **40**.

The operation of the voltage regulator **29** instead of being directly controlled by the power relays A, B as in the apparatus of Figure 2, is controlled by the intermediate relay **32**, current in one direction or the other being supplied to the winding **36** of the relay **32** from the terminals **37, 38** through the contact A^2 or B^2 respectively of the power relays A or B when this relay is energised.

If for instance the power relay A is energised, current will be supplied to the left half of the winding **36** of the relay **32** from the terminals **37, 38**. The movable element **33** will accordingly be moved into engagement with the relay contact **35** and current will be supplied to the motor winding **31** of the device **29** from the conductors B and N of the polyphase supply circuit.

The intermediate relay **32** has slow release characteristics so that when this relay is deenergised by the action of the power relay A or B, the intermediate relay **32** is not operated to cause the regulator **24** to cease operation until the release period of the intermediate relay **32** has expired.

In the event of the extent of the opening movement of the control relay **1** being relatively small due to the control current in the conductors **6** being relatively high as above described with reference to Figure 1 or 2, the interval of time between the opening and reclosure of the control relay **1** may be less than the release period of the intermediate relay **32** so that the latter, under these conditions, will not release before it is re-energised and there will consequently be no cessation in the operation of the regulator **24**.

For smaller values of the control current in the sensitive relay **1**, the duration of the time intervals during which the regulator **24** is rendered inoperative will evidently depend upon the difference between the duration of the interval between the opening and reclosure of the sensitive control relay **1** and the release period of the intermediate relay **32** so that the duration of the periods during which the regulator **24** is inoperative will vary from zero to an indefinitely large value.

Although, therefore, the power relay A or B is intermittently energised and deenergised, the operation of the regulator **24** is only intermittent for control currents in the sensitive relay **1** of below a predetermined value the durations of the inoperative periods of the regulator **24** increasing as the control current decreases until eventually the regulator is continuously inoperative.

It will be obvious that an intermediate relay controlled by the power relay may be provided in the apparatus of Figure 1 if desired with a similar effect upon the action of the apparatus.

The invention is evidently not limited to the particular forms of apparatus above described and illustrated by way of example.

Having thus described our invention, what we claim is:

1. A circuit arrangement for controlling the operation of a relay in accordance with the value of a variable, comprising in combination, a variable voltage direct current power supply; a substantially constant voltage direct current power supply; a direct current control relay having an operating winding; a first contact closed by said control relay when and only when said operating winding is energized with direct current of one polarity; a first energizing circuit connecting said operating winding of said control relay to said variable voltage power supply, whereby

said operating winding is energized with direct current of said one polarity; a direct current power relay having an operating winding; circuit means connecting said power relay operating winding in parallel with said first energizing circuit across said variable voltage power supply, said circuit having sufficient resistance to prevent current from said variable voltage power supply operating said power relay; a second contact; a second energizing circuit including, in series, said energizing winding of said power relay, said first contact, said second contact and said constant voltage power supply such that the polarity of each of said power supplies is the same in relation to said energizing winding of said power relay; and a time delay device automatically opening said second contact a predetermined time after the completion of said second energising circuit and automatically re-closing said second contact a predetermined time after said opening thereof.

2. A circuit arrangement for controlling the operation of a relay in accordance with the value of a variable, comprising in combination, a variable voltage direct current power supply; a substantially constant voltage direct current power supply; a direct current control relay having an operating winding; a first contact closed by said control relay when and only when said operating winding is energized with direct current of one polarity; a first energizing circuit connecting said operating winding of said control relay to said variable voltage power supply, whereby said operating winding is energized with direct current of said one polarity; a direct current power relay having an operating winding; circuit means connecting said power relay operating winding in parallel with said first energizing circuit across said variable voltage power supply; a second contact, operated by said power relay and closed when said operating winding of said power relay is de-energized; a slow acting relay having an operating winding; a second energizing circuit including said second contact and connecting said slow acting relay to said constant voltage power supply; a third contact operated by said slow acting relay and closed when said operating winding of said slow acting relay is energized; and a third energizing circuit including, in series, said energizing winding of said power relay, said first contact, said third contact and said constant voltage power supply such that the polarity of each of said power supplies is the same in relation to said energizing winding of said power relay.

3. A circuit arrangement for controlling the selective operation of two relays in accordance with the value of a variable, comprising in combination, a first direct current power supply the voltage and polarity of which depend upon the variable; a second direct current power supply having a substantially constant voltage; a direct current control relay having an operating winding; a first energizing circuit connecting said operating winding of said control relay to said first direct current power supply; a first control contact closed when and only when said control relay operating winding is energized by current of normal polarity; a second control contact closed when and only when said control relay operating winding is energized by current of reverse polarity; a first power relay having an operating winding; a second power relay having an operating winding; a second energizing circuit including said first control contact connecting said first power relay operating winding to said second direct current power supply; a third energizing circuit including said second control contact connecting said second power relay operating winding to said second direct current power supply; contact means included in said second and third energizing circuits closed when both said power relays are de-energized and adapted to be opened a predetermined time after the energization of either of said power relays; and means operative when said second and third energizing circuits are opened for discharging energy stored in one of said power relays through said control relay operating winding as current of a polarity opposite to that of the current flowing in said first energizing circuit.

4. A circuit arrangement comprising in combination, a first direct current power supply of substantially constant voltage; a first power relay and a second power relay, each having an operating winding respectively; a series circuit including said operating windings and connected across said first direct current power supply, the resistance of said series circuit limiting the current therethrough to a value insufficient to operate either one of said power relays; a second direct current power supply the voltage and polarity of which depend upon a variable; a direct current control relay having an operating winding; an energizing circuit connecting said control relay operating winding across said second direct current power supply; circuit means connecting said control relay operating winding in parallel with both said power relay operating windings, said circuit means having sufficient resistance to prevent current from said second power supply operating either of said power relays; a first control contact closed when and only when said control relay winding is energized with current of normal polarity and connected across the operating winding of said first power relay; a second control contact closed when and only when said control relay winding is energized with current of reverse polarity and connected across the operating winding of said second power relay; contact means included in said series circuit, closed when both said power relays are de-energized and adapted to be opened a predetermined time after the energization of either of said power relays; and means for discharging the energy stored in the operated one of said first and second power relays through said control relay operating winding as a current of a polarity opposite to that of said second power supply.

5. A circuit arrangement comprising in combination, a first direct current power supply of substantially constant voltage; a first power relay and a second power relay, each having an operating winding respectively; a series circuit including said operating windings and connected across said first direct current power supply, the resistance of said series circuit limiting the current therethrough to a value insufficient to operate either one of said power relays; a second direct current power supply the voltage and polarity of which depend upon a variable; a direct current control relay having an operating winding; an energizing circuit connecting said control relay operating winding across said second direct current power supply; circuit means connecting said control relay operating winding in parallel with both said power relay operating windings, said circuit means having sufficient resistance to prevent current from said second

power supply operating either of said power relays; a first control contact closed when and only when said control relay winding is energized with current of normal polarity and connected across the operating winding of said first power relay; a second control contact closed when and only when said control relay winding is energized with current of reverse polarity and connected across the operating winding of said second power relay; a slow acting direct current relay having an operating winding; a first normally closed contact operated by said first power relay and opened when said first power relay is energized; a second normally closed contact operated by said second power relay and opened when said second power relay is energized; and energizing circuit for said slow acting relay connected to said first power supply and including, in series, said first and second normally closed contacts and said operating winding of said slow acting relay; a normally open contact operated by said slow acting

relay, closed when said slow acting relay is energized, said contact being included in said series circuit; and means for discharging the energy stored in the operated one of said first and second power relays through said control relay operating winding as a current of a polarity opposite to that of said second power supply.

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