Sept. 16, 1947. S. R. DURAND 2,427,450

ELECTRIC VALVE PROTECTIVE SYSTEM

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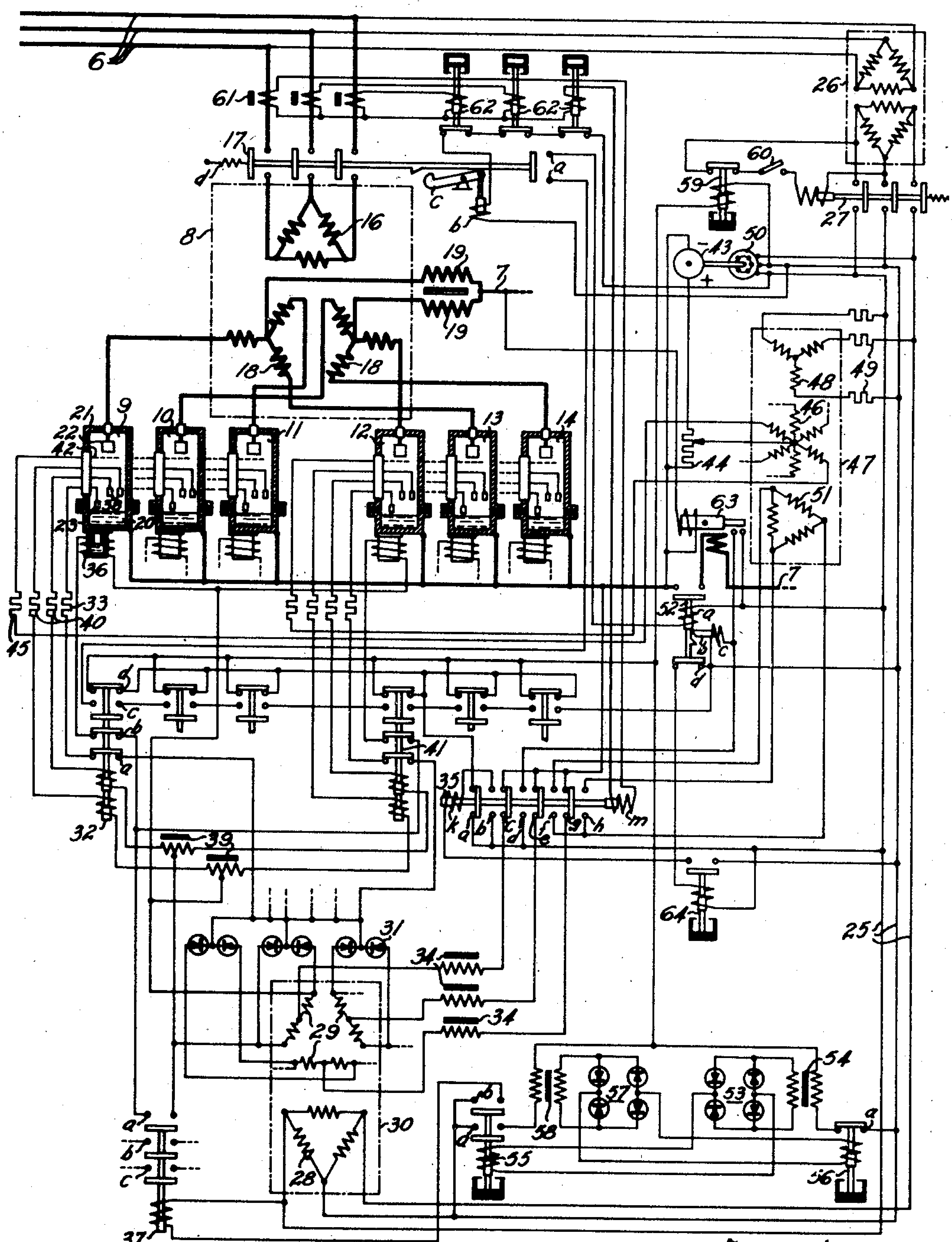

Fig. 1

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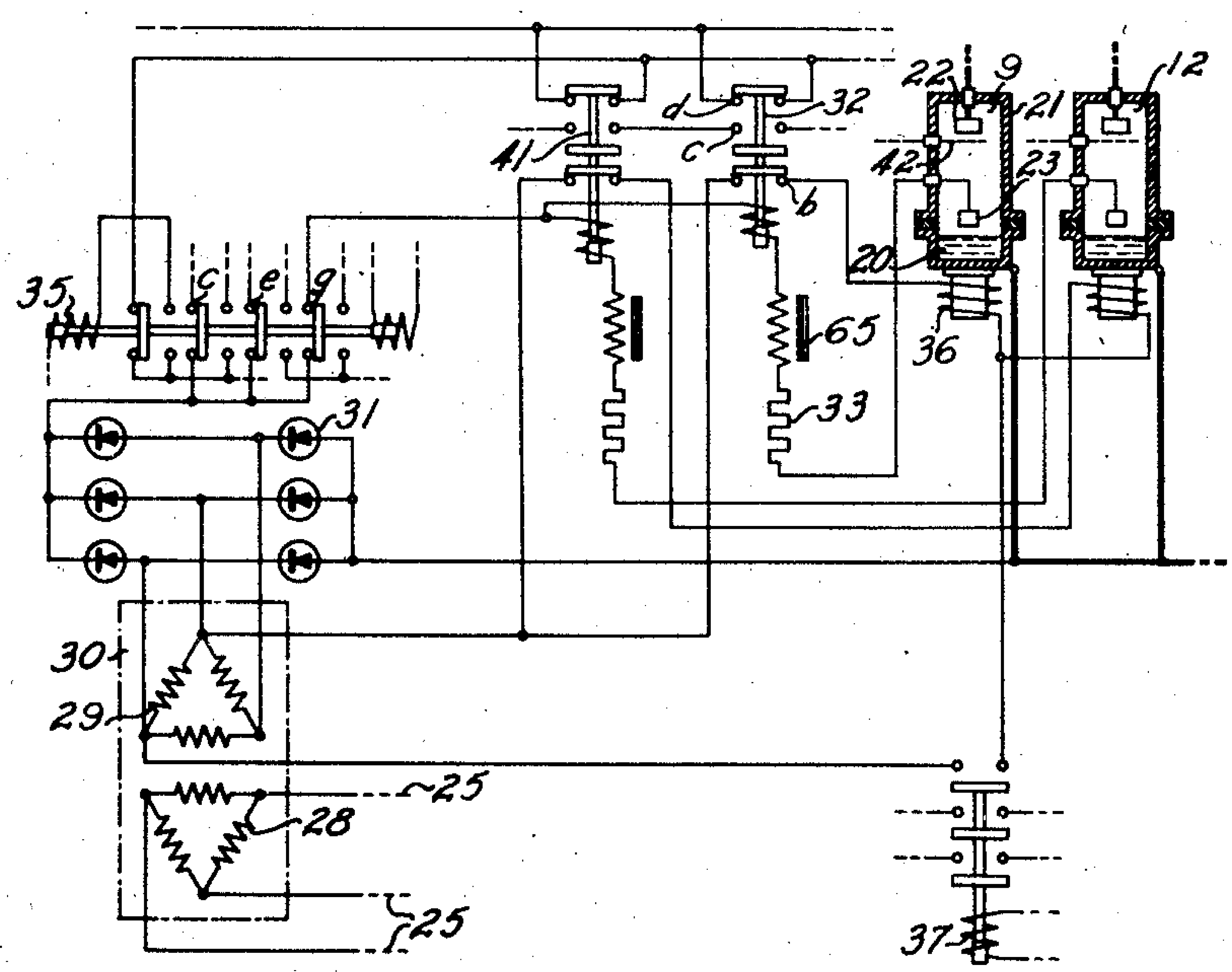

Fig. 2

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ELECTRIC VALVE PROTECTIVE SYSTEM

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10 Claims. (Cl. 175—363)

This invention relates in general to improvements in electric valve control systems, and more particularly to means for controlling the excitation of a group of electric valves having separate cathodes in such manner as to render the valves conductive or nonconductive in accordance with the requirements of a converting system of which the valves are a part.

Electric current converting systems frequently comprise a group of valves each provided with a single main anode and with a separate vaporizable cathode. To maintain such a system in operation it is generally preferable to maintain the different cathodes continuously emissive even when they are required to operate only intermittently. Upon occurrence of a disturbance such as a backfire in one of the valves, the flow of current through the different valves may be interrupted by means of control electrodes of the so-called grid type. The action of the control electrodes, however, is not always absolutely reliable and it is therefore preferable to rely on the interruption of the excitation currents of the cathodes to render the cathodes nonemissive and to utilize the action of the control electrodes at the same time for deionizing the valves and thereby prevent any abnormal reignition thereof.

The excitation currents of all the cathodes should be interrupted simultaneously and as rapidly as possible. In general, continuous excitation current is obtained from a source of alternating current through a transformer and through connections which may include rectifying devices, at least when a single excitation anode is associated with each cathode. The connections between the excitation transformer secondary winding and the valve electrodes are preferably made inductive to render the excitation current more uniform and to render the excitation arc more stable. If excitation is interrupted by switching means controlling the current between the source and the transformer primary winding, opening of the switching means does not result in immediate interruption of the excitation current. The reason therefor is that the transformer secondary circuit remains closed, so that the excitation current is able to continue to flow therethrough for an appreciable length of time to discharge the magnetic energy stored in the inductive means forming part of the secondary circuit. It is therefore preferable to provide for opening the secondary connections to insure interruption of the excitation current immediately upon opening of the switching means.

In converters provided with automatic control

it is generally desirable simultaneously to interrupt the excitation currents and to cause opening of a switch controlling the connection of the valves with the supply circuit or with the load circuit. The excitation currents may then be re-established after a predetermined interval following opening of the switch, and re-establishment of the excitation currents may also be utilized for causing reclosure of the switch.

It is therefore one of the objects of the present invention to provide a control system for a plurality of electric valves of the continuously excited cathode type, by means of which the cathodes may be rendered simultaneously nonemissive in the shortest possible time.

Another object of the present invention is to provide a control system for an electric valve of the continuously excited cathode type utilizing the cooperative action of control electrode energization and of excitation current interruption to effect interruption of the flow of current through the valve.

Another object of the present invention is to provide a control system for a plurality of electric valves of the continuously excited cathode type by means of which the valve excitation currents may all be interrupted within a predetermined time interval regardless of the inductance of the excitation circuits.

Another object of the present invention is to provide a control system for an electric valve of the continuously excited cathode type for coordinately controlling the excitation of the valve and the operation of a switch controlling the connection of the valve with a supply circuit or with a load circuit.

Objects and advantages other than those above set forth will be apparent from the following description when read in connection with the accompanying drawing, in which:

Fig. 1 diagrammatically illustrates one embodiment of the present invention applied to the control of a group of six valves forming part of an alternating current rectifying or direct current inverting system; and

Fig. 2 diagrammatically illustrates a modification of a part of the excitation circuits of the embodiment illustrated in Fig. 1.

Referring more particularly to the drawing by characters of reference, reference numeral 6 designates a polyphase alternating current circuit to be connected with a direct current circuit 7 through a converting system comprising a transformer 8 and a plurality of interconnected electric valves 9 to 14 inclusive. Either circuit 6 or circuit 7 may be chosen as supply circuit for the system, but it will be assumed that circuit 6 is a supply circuit energized from a suitable generator (not shown). Circuit 7 is accordingly a load circuit transmitting current to suitable load devices (not shown).

Transformer 8 comprises a primary winding 16 subdivided into a plurality of phase portions connectable with circuit 6 through a switch 17 serving to control the connection between circuits 6 and 7 through the valves. Winding 16 is inductively related with a secondary winding 18 constituting a network divided into a plurality of pairs of opposite phase portions. The different pairs of phase portions of winding 18 are severally connected with one of the conductors of circuit 7 through pairs of valves such as valves 9, 12. Winding 18 is preferably arranged to define a plurality of neutral points severally connected with the other conductor of circuit 7 through an interphase transformer 19.

Valves 9 to 14 are preferably of a uniform design, each valve comprising a casing which may be made of insulating or conductive material. Valve 9 comprises a cathode 20 consisting of a pool of a suitable liquid conductor such as mercury which may be insulated from the associated casing 21 when the casing is made of conductive material. Valve 9 further comprises a single main anode 22 cooperating with cathode 20 for the flow of current between circuits 6 and 7 connected therewith.

Valve 9 may be rendered conductive by an ignition system comprising an ignition anode 23 supported a short distance above the surface of cathode 20. Current may be supplied to anode 23 from circuit 6 through connections comprising the usual step down transformer 26, a switch 27, an auxiliary circuit 25 and the primary winding 28 of an ignition-excitation transformer 30. The secondary winding 29 of transformer 30 is divided into a plurality of independent phase portions each provided with two terminals and a midtap or neutral point. The terminals of winding 29 are connected with a six-phase rectifying device 31, and ignition current is supplied to anode 23 from the different phase portions of winding 29 operating in sequence through rectifier 31, contacts 32a of an excitation relay 32, and a resistor 33. The ignition current returns to winding 29 through cathode 20, the common connection between the cathodes, contacts 35c, 35e and 35g of a relay 35, and a plurality of reactors 34 severally connected with the phase midtaps of winding 29.

Relay 35 is preferably chosen of a fast operating type provided with such arc extinguishing means that the current flow through the contacts is completely interrupted upon full opening of the relay contacts, even if the circuits controlled by the relay are highly inductive. The relay may be of a type in which the closed contacts open before the open contacts close or may be of the so-called make before break type in which the open contacts close before the closed contacts open. Regardless of the type of relay utilized, the operation of all the contacts should take place within a time interval which is very short relative to the operating period of each valve so that all contacts may be considered to operate simultaneously.

Momentary engagement of anode 23 with cathode 20 to establish a cathode spot rendering the cathode emissive is controlled by means of a solenoid 36 which may be energized from winding 29. Solenoid 36 is preferably connected with only one phase portion of winding 29 through contacts 37a of a control relay 37 and contacts 32b of relay 32. Solenoid 36 may cause engagement of anode 23 with cathode 20 in any known manner. For example, this result may be obtained by the solenoid attracting an armature forming a piston projecting a jet of cathode material against the anode.

Valve 9 is provided with excitation anodes 38 connected with the terminals of one of the phase portions of winding 29 through the left hand portions of a pair of paralleling reactors 39, the coils of relay 32 and a pair of resistors 40. Further connections extend from the right hand portions of reactors 39 through the coils of an excitation relay 41 similar to relay 32 to the excitation anodes of valve 12. Anode 22 and excitation anodes 38 are preferably connected with phase portions of windings 18 and 29 respectively of such phase relation that the flow of current is transferred from one excitation anode 38 to the other once during each conductive period of anode 22 and once toward the end of each idling period of anode 22. In this manner both current transfers are removed from the period of transient conditions immediately following each conductive period of anode 22 and the stability of the excitation arc is thereby improved.

The conductivity of valve 9 for the flow of current between anode 22 and cathode 20 may be controlled by means of a control electrode 42. Valve 9 may be rendered and maintained nonconductive by impression on electrode 42 of a deionizing negative potential from a suitable source of direct current, such as a generator 43, through a voltage divider 44. Generator 43 may be driven by any suitable means such as a motor 50 energized from circuit 25. Control electrode 42 is preferably connected with the movable tap of voltage divider 44 through a resistor 45 and through one of the phase portions of the secondary winding 46 of a transformer 47. The primary winding 48 of transformer 47 may be energized from circuit 25 through current limiting resistors 49 to cause winding 46 to impress on control electrode 42 a variable potential component. The composite potential impressed on control electrode 42 from voltage divider 44 and from winding 46 serves to control the conductivity of valve 9 during normal operation. A tertiary winding 51 of transformer 47 may be short circuited by contacts 35f and 35h to render transformer 47 inoperative.

Valves 10 to 14 inclusive are provided with electrodes similar to those of valve 9 and connected as well as controlled in a similar manner. The cathodes of the different valves are connected with the positive conductor of circuit 7 through a switch 52. The solenoids controlling the ignition of the different valves may be simultaneously connected with winding 29 and may likewise be simultaneously disconnected from winding 29 by means of contacts 37a, 37b, 37c of relay 37 for causing simultaneous initiation of the flow of current through the different valves.

To supply the necessary current impulses to the solenoids, relay 37 is alternately energized and de-energized during predetermined time intervals by suitable timing means. The timing means may comprise a timing relay 55 for connecting the coil of relay 37 with circuit 25. Relay 55 is illustrated conventionally on the drawing as it may be of any suitable known type. In order, however, to permit a convenient adjustment of the times of operation of relay **55**, the relay is preferably chosen of the well known flux decay type in which release of the armature is controlled by the decay of the flow of current through an adjustable short-circuited conductor. The coil of relay **55** must therefore be energized with direct current, which is most conveniently obtained from a transformer **54** and a rectifying device **53**.

The primary winding of transformer **54** is connected with circuit **25** through contacts **35***a* of relay **35**, contacts **32***d* of excitation relay **32** and similar contacts of the other excitation relays, and through the contacts of a second timing relay **56** similar to relay **55**. The coil of relay **56** is preferably energized from a rectifying device **57** and a transformer **58** having its primary winding connected with circuit **25** through contacts **35***a*, contacts **32***d* and other similar excitation relay contacts, and contacts **55***a* of relay **55**. The coils of relays **55**, **56** are preferably designed for operation at relatively low voltage to reduce the cost of rectifying devices **53**, **57**. Contacts **55***a*, **56***a* are then preferably inserted in the primary circuits of transformers **54**, **58**, which generally operate at a higher voltage, to minimize the effect of the contact resistance. Contacts **35***a* with contacts **32***d* and the similar contacts also control the connection between circuit **25** and the coil of a lockout time delay relay **59**. The contacts of relay **59** control a connection between transformer **26** and the coil of switch **27** through a hand operated switch **60**.

The operating coil **35***m* of relay **35** is energized in response to the magnitude of the flow of current through transformer **8** by means of one of a bank of current transformers **61**. The current transformers are connected with overload relays **62** which operate in a slightly longer time than relay **35** and are therefore conventionally shown as time delay relays. Relays **62** control the energization of a holding coil **17***b* of switch **17** serving to maintain the latch **17***c* of the switch in engaged position.

The trip coil **52***c* of switch **52** may be connected with circuit **25** through contacts **35***d* or through the contacts of a reverse current relay **63** responsive to the direction of flow of current in circuit **7**. Switch **52** may be provided with auxiliary contacts **52***d* for controlling a time delay reclosing relay **64**.

The system being connected as shown on the drawing and circuit **6** being energized, operation may be initiated by closing switch **60**. The coil of switch **27** thereupon receives current from transformer **26** through the contacts of relay **59** and through switch **60**, thereby causing switch **27** to connect circuit **25** with transformer **26**. Current is then supplied from circuit **25** to transformer **54** through contacts **35***a*, **32***d* and **56***a*. Transformer **54** and rectifier **53** supply current to the coil of relay **55** which closes its contacts. Contacts **55***a* connect transformer **58** with circuit **25** through contacts **35***a* and **32***d*. Transformer **58** and rectifier **57** energize the coil of relay **56**, which opens contacts **56***a*. The coil of relay **55** is thereby de-energized and, after a predetermined time delay, relay **55** returns to the position shown. Contacts **55***a* are thereby opened to de-energize the coil of relay **56**. After another predetermined time delay, relay **56** also returns to the position shown. The above described sequence of operation of the two relays is continually repeated as long as the relay coils remain supplied with current.

Each operation of relay **55** causes alternate closure and opening of contacts **55***b*, thereby causing intermittent operation of relay **37**. When relay **37** closes its contacts, contacts **37***a* connect one of the phase portions of winding **29** with solenoid **36** through contacts **32***b*, and contacts **37***b*, **37***c* similarly connect the solenoids associated with valves **10** to **14**. The solenoids simultaneously attract the associated pistons to cause jets of cathode material to impinge upon the ignition anodes of the valves.

Ignition circuits are thereby completed from winding **29** through rectifier **31**, through parallel circuits such as the circiut comprising contacts **32***a*, resistor **33**, ignition anode **23** and cathode **20**, through contacts **35***c*, **35***e*, **35***g* and reactors **34** back to winding **29**. When relay **37** opens its contacts the solenoids are simultaneously disconnected from winding **29** to cause simultaneous interruption of the jets of cathode material. Arcs are thereby simultaneously drawn between the ignition anodes and the cathodes, thereby establishing cathode spots rendering the cathodes emissive. If for any reason, however, a cathode spot is not established at one of the cathodes, the associated solenoid continues to receive current impulses through the corresponding set of contacts of relay **37** until the cathode is rendered emissive.

When cathode **20**, for example, has been rendered emissive, alternate half waves of current flow from winding **29** through the two coils of relay **32**, resistors **40**, excitation anodes **38**, cathode **20**, contacts **35***c* and one of reactors **34** back to winding **29**. The excitation current impulses are caused to overlap by the inductance of reactor **34** so as to render the current through cathode **20** continuous and sufficiently uniform and stable to maintain the cathode continuously emissive. The flow of current through the coils of relay **32** causes the relay to operate to open the circuits of solenoid **36** and of ignition anode **23**. During the ignition operation of the valves, current is also supplied from circuit **25** to the coil of relay **59** through contacts **35***a* and through excitation relay contacts such as **32***d*.

If all of the excitation currents have become established before relay **59** has operated, the excitation relays such as **32** all operate to de-energize relays **59**, **55** and **56**. Switch **17** may then be closed and latch **17***c* is held engaged by holding coil **17***b* to maintain switch **17** closed. Closure of switch **17** also results in energization of the closing coil **52***a* of switch **52** through contacts **17***a* and through serially connected contacts such as **32***c* of the excitation relays. Switch **52** is closed by coil **52***a* and is held closed by latch **52***b*. Voltage divider **44** is so adjusted that winding **46** is able to render valves **9** to **14** periodically conductive in sequence, and upon closure of switches **17** and **52** the flow of current is established between circuit **6** and circuit **7** through the valves as is well known.

During normal operation of the system, current impulses are established in sequence through the different valves and combine in conductors **7** to form a flow of substantially uniform direct current supplied to the load. If at any time the flow of excitation current fails in one of the valves, valve **9** for example, relay **32** returns to the position shown. Relays **55**, **56** and **59** are thereby re-energized as above described and the ignition operation is repeated in valve **9** only. If ignition cannot be established initially within a predetermined time interval following closure of switch **27**, or if it cannot be re-established within an equal time interval following de-energization of relay **32**, relay **59** opens its contacts to cause opening of switch **27**. Circuit **25** is thereby de-energized and the flow of current through valves **9** to **14** is interrupted because of lack of excitation current. Coil **17b** is also de-energized and latch **17c** is released, thereby causing switch **17** to be opened by spring **17d**.

Normal operation may also be affected by a disturbance such as a backfire in one of the valves. During a backfire, one of the valves becomes conductive for a reverse flow of current, and the sound valves supply current to the faulty valve to thereby short circuit winding **18**. Circuit **6** then transmits to transformer **8** current of excessive magnitude and the current supplied to coil **35m** from current transformer **61** reaches such value as to cause operation of relay **35**. The relay opens contacts **35c**, **35e**, **35g**. Each set of contacts interrupts simultaneously the excitation currents of a pair of valves, such as **9**, **12**, and the excitation currents of all the valves are interrupted substantially simultaneously. If this interruption were effected by means of switch **27**, reactors **34** would maintain the excitation currents through the valves after opening of switch **27** for a length of time sufficient to dissipate the magnetic energy stored within the reactors. Contacts **35c**, **35e**, **35g**, however, are serially connected with reactors **34**, and the flow of current through the reactors and through the excitation anodes is interrupted immediately upon opening of the contacts regardless of the inductance of the reactors. All the cathodes, except those momentarily carrying load or fault current, are thereby rendered nonemissive substantially simultaneously. The cathodes carrying load or fault current also become nonemissive at the end of their operating periods.

Substantially at the same time as it interrupts the excitation currents, relay **35** short circuits winding **51** through contacts **35f**, **35h**. The voltages appearing in winding **46** are thereby caused to collapse. The deionizing negative potential thereupon remaining impressed alone on the control electrodes from voltage divider **44** is thereby, in effect, substituted for the variable composite potential previously impressed on the control electrodes from voltage divider **44** and winding **46**. When the cathodes have become nonemissive, the normal current impulses through the different valves are no longer established. But the flow of excessive current having taken place through the valves from the inception of the backfire until interruption of the excitation currents causes the conductive vapor contained in the valve casings to be in a highly ionized condition. The result of this abnormal ionization is that, in spite of the lack of excitation current, some of the valves may reignite or even backfire. Impression of a deionizing negative potential on the control electrodes causes rapid deionization of the vapor and thereby substantially precludes accidental reignitions or additional backfires in the valves. The flow of current from transformer **8** through the sound valves to circuit **7** and to the backfiring valve is thus interrupted in the shortest possible time interval.

Upon interruption of the excitation currents, the excitation relays return to the position shown, thereby de-energizing closing coil **52a**. Operation of relay **35** causes energization of trip coil **52c** through contacts **35d**, and latch **52b** is thereby withdrawn to cause opening of switch **52**. The trip coil may also be energized through the contacts of relay **63** in response to a flow of reverse current to the backfiring valve from a load having a back E. M. F. or from other generators or converters connected with circuit **7**. Switch **52** closes auxiliary contacts **52d**, thereby energizing the coil of relay **64**. After a predetermined time delay following opening of switch **52**, relay **64** connects coil **35k** with circuit **25** through contacts **35b**, which are then closed. Coil **35k** resets relay **35** to the position shown on the drawing. The ignition operation of the valves is thereby again initiated in the manner above set forth. When excitation is re-established in all the valves, the circuit of closing coil **52a** is again completed by the excitation relays and switch **52** recloses to restore the system to its normal operating condition.

If, however, the disturbance persists as a result of failure of any element of the system to perform its function, the continued flow of excessive current in circuit **6** and through current transformers **61** causes operation of relays **62**. The relays open the circuit of holding coil **17b** and switch **17** is opened by spring **17d**.

To simplify the design of valves **9** to **14**, it is desirable to omit the excitation anodes and to supply direct current continuously to the ignition anode, which then also functions as excitation anode. This simplification, however, generally requires an increase in excitation current. The above described system may then again be used with only the modifications shown in Fig. 2. Each excitation relay such as **32** is then provided with only one coil, and the contacts such as **32a** are omitted. The phase portions of winding **29** and rectifier **31** may remain as shown in Fig. 1 or may be reconnected as shown in Fig. 2 for the more advantageous full wave operation to supply only direct current to the ignition-excitation anodes.

The individual connections between the ignition-excitation anodes and winding **29** are preferably made inductive by means of reactors such as **65** to render the excitation currents more uniform and stable. The different connections may be controlled by a single set of contacts of relay **35**, but are preferably joined in pairs to contacts **35d**, **35f**, **35h** to permit the use of contacts of relatively small current carrying capacity as in the embodiment illustrated in Fig. 1. Except that ignition current is maintained in each valve to serve as excitation current, the operation of the present embodiment is identical to that of the embodiment illustrated in Fig. 1. By simultaneously opening the connections between rectifier **31** and the ignition-excitation anodes, relay **35** simultaneously interrupts the excitation currents of the different valves regardless of the inductance of the reactors such as **65**.

The cathodes of the idling valves are thereby simultaneously rendered nonemissive and the others become nonemissive at the end of their operating periods as in the embodiment illustrated in Fig. 1.

Although but two embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes or modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. The combination of a supply circuit, a load

circuit, an electric valve comprising a single main anode and a cathode connected with said circuits for the flow of energy therebetween and excitation anode means, a switch for controlling the connection between said circuits through said valve, means for rendering said cathode emissive comprising a source of current connected with said cathode and with said excitation anode means to supply said cathode with excitation current, means for interrupting said excitation current and for causing opening of said switch, and time delay means for causing re-establishment of said excitation current in response to opening of said switch.

2. The combination of a supply circuit, a load circuit, an electric valve comprising a single main anode and a cathode connected with said circuits for the flow of energy therebetween and excitation anode means, means for rendering said cathode emissive comprising a source of current connected with said cathode and with said excitation anode means to supply said cathode with excitation current, switching means responsive to an operating condition of said valve for interrupting said excitation current, and means for causing said switching means to re-establish said excitation current with a predetermined time delay in response to current interrupting operation of said switching means.

3. The combination of a supply circuit, a load circuit, an electric valve comprising a single main anode and a cathode connected with said circuits for the flow of energy therebetween and excitation anode means, a switch for controlling the connection between said circuits through said valve, means for rendering said cathode emissive comprising a source of current connected with said cathode and with said excitation anode means to supply said cathode with excitation current, switching means for interrupting said excitation current and for causing opening of said switch, time delay means for causing said switching means to re-establish said excitation current in response to opening of said switch, and means responsive to re-establishment of said excitation current for causing reclosure of said switch.

4. In a control system for a plurality of electric valves each comprising a single main anode and a cathode for the flow of nonconsecutive load current impulses, means for rendering said cathodes emissive comprising excitation anodes associated with said cathodes and a source of alternating current, the combination of a transformer comprising a primary winding connected with said source and a secondary winding having terminals and a neutral point, connections between said terminals and said excitation anodes, a further connection between said cathodes and said neutral point, and means for simultaneously rendering said cathodes nonemissive to thereby interrupt the flow of said load current impulses comprising means responsive to an operating condition of said valves for opening said further connection.

5. The combination of a plurality of electric valves each comprising an anode and a cathode, means for rendering said cathodes emissive comprising excitation anodes associated with said cathodes, a source of alternating current, a transformer comprising a primary winding connected with said source and a secondary winding having terminals and a neutral point, connections between said terminals and said excitation anodes, a further connection between said cathodes and said neutral point, inductive means in said further connection for rendering the flow of current therethrough more uniform, and means for simultaneously rendering said cathodes nonemissive comprising switch means for opening said further connection, whereby the flow of current through said excitation anodes is interrupted immediately upon interruption of the flow of current through said switch means regardless of the inductance of said inductive means.

6. In a control system for a plurality of electric valves each comprising a single main anode and a cathode for the flow of nonconsecutive load current impulses, means for rendering said cathodes emissive comprising excitation anodes associated with said cathodes and a source of alternating current, the combination of a transformer comprising a primary winding connected with said source and a secondary winding, connections between said secondary winding and said excitation anodes, a further connection between said secondary winding and said cathodes, and means for simultaneously rendering said cathodes nonemissive to thereby interrupt the flow of said load current impulses comprising means responsive to an operating condition of said valves for opening said further connection.

7. In a control system for a plurality of electric valves each comprising a single main anode and a cathode for the flow of nonconsecutive load current impulses, and means for rendering said cathodes emissive comprising excitation anodes associated with said cathodes and a source of alternating current, the combination of a transformer comprising a primary winding connected with said source and a secondary winding, a plurality of inductive circuits connecting said secondary winding with said excitation anodes and said cathodes, and means for simultaneously rendering said cathodes nonemissive to thereby interrupt the flow of said load current impulses comprising means responsive to an operating condition of said valves for simultaneously opening said inductive circuits.

8. In a control system for a plurality of electric valves each comprising a single main anode and a cathode for the flow of nonconsecutive load current impulses, means for rendering said cathodes emissive comprising excitation anodes associated with said cathodes and a source of alternating current, the combination of a transformer comprising a primary winding connected with said source and a secondary winding, connections between said secondary winding and said excitation anodes, a connection between said secondary winding and said cathodes, and means for simultaneously rendering said cathodes nonemissive to thereby interrupt the flow of said load current impulses comprising means responsive to an operating condition of said valves for simultaneously opening the first said connections.

9. The combination of a plurality of interconnected electric valves, each of said valves comprising a single main anode, a cathode, excitation anode means and a control electrode, means for rendering and maintaining the different said cathodes continuously emissive comprising a source of current connected with said cathodes and with the different said excitation anode means to supply the different said cathodes with continuous excitation currents, and means for rendering said valves nonconductive comprising means for simultaneously interrupting the different said excitation currents to render the different

said cathodes non-emissive and for substantially simultaneously therewith impressing a deionizing potential on the different said control electrodes to prevent accidental reestablishment of the flow of current through any of said valves.

10. The combination of a plurality of interconnected electric valves, each of said valves comprising a single main anode, a cathode, excitation anode means and a control electrode, means for rendering and maintaining the different said cathodes continuously emissive comprising a source of current connected with said cathodes and with the different said excitation anode means to supply the different said cathodes with continuous excitation currents, means for impressing variable control potentials on the different said control electrodes to control the conductivity of the different said valves and means for rendering said valves non-conductive comprising means for simultaneously interrupting the different said excitation currents to render the

different said cathodes non-emissive and for substantially simultaneously therewith substituting a deionizing potential for said variable control potentials to prevent accidental reestablishment of the flow of current through any of said valves.

SAMUEL R. DURAND.

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