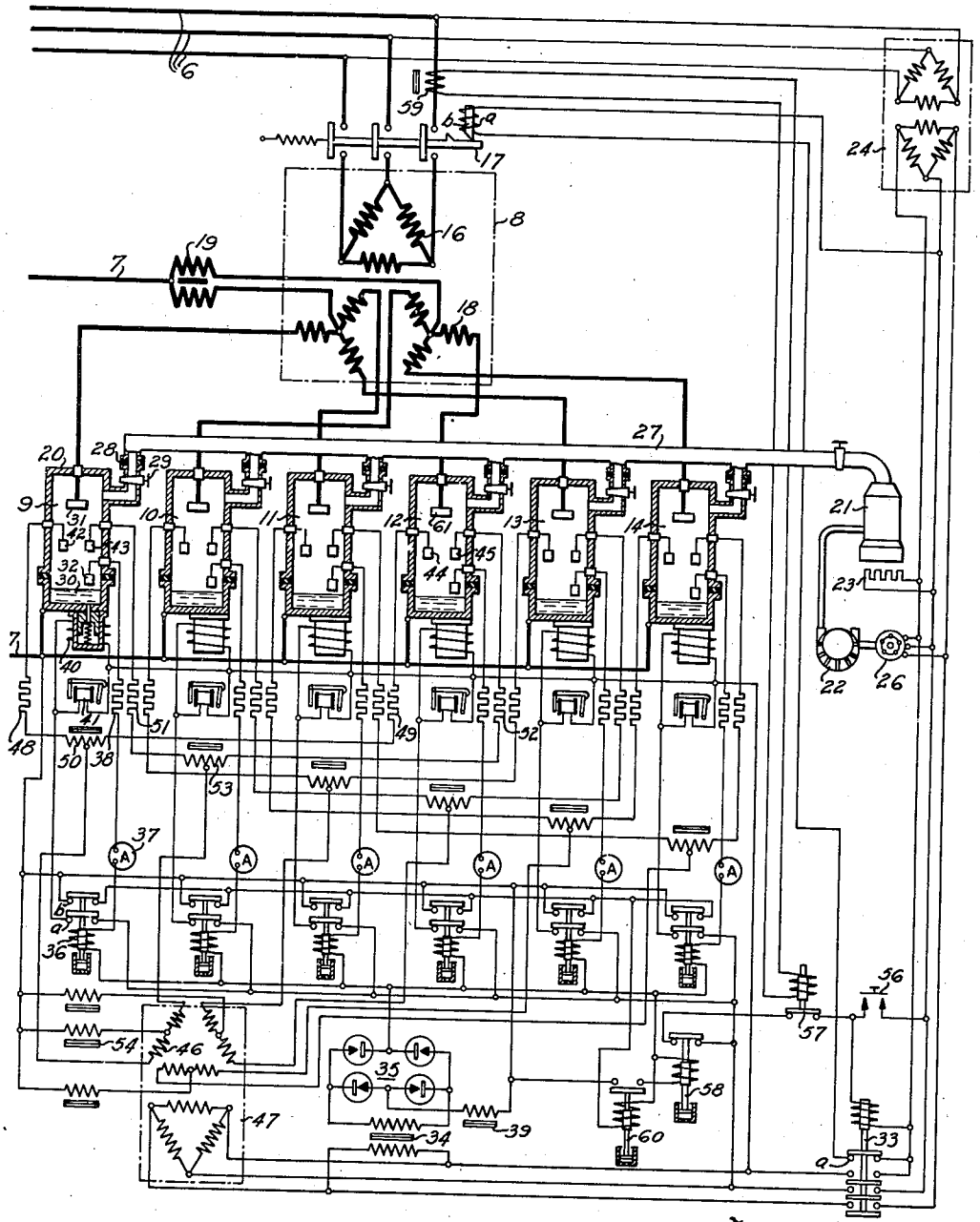
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ELECTRIC VALVE CONTROL SYSTEM

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ELECTRIC VALVE CONTROL SYSTEM

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This invention relates in general to improvements in electric valve control systems and more particularly to means for controlling the operation of a group of electric valves of the liquid cathode type forming part of an electric current converting system and provided with a common evacuating apparatus.

Electric valves of the liquid cathode type utilized in current converting systems are generally provided with excitation anodes to which current is supplied to maintain the cathode in electron emissive condition regardless of the presence or absence of current through the main anode. When the anodes of a plurality of valves are enclosed within a common casing and are associated with a common cathode, the current impulses of the main anodes generally overlap and result in a continuous current which maintains the cathode continuously emissive. It is then unnecessary to maintain a separate stable excitation arc at the cathode while current is flowing through the anodes and such arc is needed only when the anodes do not carry any appreciable current.

Valves in which the cathode current is discontinuous, such as the valves provided with a single main anode, require excitation current under all load conditions to maintain the cathode emissive between periods of current conduction of the main anode. It has been found, however, that it is difficult to maintain, in a valve of this type, either a continuous excitation arc or a succession of overlapping periodic arcs under all contemplated load conditions because of the wide variation of vapor pressure and of wall temperature brought about by the variations in the load current. The excitation arc may generally be maintained stable under all conditions by supplying the excitation anode or anodes with current of relatively high intensity under a relatively high voltage. As, however, the excitation current is entirely wasted by conversion into heat, it is important for reasons of economy to reduce the power consumed in the excitation circuit to a minimum amount.

It has been found that this result may be achieved by maintaining in each valve two independent low power excitation arcs of which one is stable under low load conditions of the cathode and the other is stable under high load conditions of the cathode. One of the excitation arcs is preferably a continuous arc which is sensitive to the gas pressure within the casing. The valves may be connected to a common evacuating system and the relative gas pressure within the different valves or the occurrence of abnormal gas pressures therein may be determined by observing the variations of their excitation currents. These variations may also be utilized for controlling the operation of the system.

It is therefore one object of the present invention to provide a control system for an electric valve by means of which the valve may be maintained conductive with a minimum expenditure of excitation power.

Another object of the present invention is to provide a control system for a plurality of cooperating electric valves by means of which each valve is provided with a plurality of low power excitation arcs which are stable for different ranges of current intensity through the valves.

Another object of the present invention is to provide a control system for a plurality of cooperating electric valves by means of which the flow of current through all the valves may be interrupted upon unsuccessful operation of the ignition apparatus of any valve during a predetermined length of time.

Another object of the present invention is to provide a control system for a plurality of cooperating electric valves by means of which the valves may be rendered non-conductive by disconnecting the excitation anodes of the valves from the source of supply therefor.

Another object of the present invention is to provide a control system for a plurality of cooperating electric valves by means of which the relative values of the gas pressures within the different valves may be determined from the values of the excitation currents of the valves.

Another object of the present invention is to provide a control system for a plurality of cooperating electric valves by means of which the occurrence of a temporary or permanent excessive increase in the gas pressure of any one of the valves may be determined from the failure of the excitation current of the valve.

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

Referring more particularly to the drawing by characters of reference, a polyphase alternating current circuit 6 is 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. Circuit 6 is a supply circuit energized from a suitable generator (not shown) and circuit 7 is an output circuit transmitting current to suitable load devices (not shown). The load devices may be electric motors utilized for a service calling for a flow of current of widely variable intensity such as electric traction.

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 connections between circuits 6 and 7 through the valves. Winding 16 is inductively related to 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 of electrically conductive material. The casing 20 of valve 9 and the casings of valves 10 to 14 are connected to a common evacuating means such as a pump 21 of the diffusion type discharging into another pump 22 of the sliding vane rotary type. Pump 21 comprises a resistance heater 23 connected with circuit 6 through a transformer 24. Pump 22 is actuated by a motor 26 connected with transformer 24. The connection between pump 21 and the different valve casings is preferably effected through a manifold 27 of relatively large diameter connected with each casing through an insulating joint as at 28 and through a stop cock or valve as at 29. Valve 9 comprises a cathode 30 consisting of a pool of suitable electrically conductive material, such as mercury, which is preferably insulated from the associated casing 20. Valve 9 further comprises a single main anode 31 cooperating with cathode 30 for the flow of current between circuits 6 and 7 connected therewith.

Each of the valves 9 to 14 is rendered conductive and is maintained conductive by an ignition-excitation system comprising a plurality of excitation anodes. Valve 9 for example comprises an ignition-excitation anode 32 arranged adjacent the surface of cathode 30 at a distance of approximately one inch therefrom. Direct current may be supplied to anode 32 from circuit 6 through transformer 24, the main contacts of a control switch or contactor 33, a single phase or polyphase transformer 34, a suitable rectifying device 35, the coil of a time delay ignition relay 36, an electro-responsive device such as an ammeter 37, and a resistor 38. The current of anode 32 returns to rectifier 35 through cathode 30 and a current smoothing reactor 39.

Momentary engagement of anode 32 with cathode 30 to establish a cathode spot rendering the cathode emissive is controlled by means of a solenoid 40 which may be energized from circuit 6 through transformer 24, switch 33, and contacts 36*a* of ignition relay 36. Solenoid 40 may cause engagement of anode 32 with cathode 30 in any known manner, for example, by attracting an armature forming a piston projecting a jet of cathode material against anode 32. An annunciator 41 is connected in parallel with solenoid 40 to indicate that the ignition system of valve 9 has operated. Similar means are severally associated with the other valves for initiating and for maintaining therein continuous excitation arcs.

Further excitation means provided for valves 9 to 14 are divided into three groups each associated with a pair of valves. The two valves of a pair, such as valves 9 and 12, are preferably chosen having the main anodes thereof connected with opposite phases of winding 18. Valve 9 is provided with a pair of excitation anodes 42, 43, and valve 12 is similarly provided with a pair of excitation anodes 44, 45. Each of these excitation anodes is preferably arranged at a distance of substantially three inches from the associated cathode and is provided with the usual shielding means for enhancing its stability of operation.

Excitation anodes 42 to 45 receive current from one of the secondary phase portions 46 of a transformer 47 energized from circuit 6 through transformer 24 and switch 33. One terminal of winding 46 is connected with excitation anodes 42, 44 through a pair of connections comprising resistors 48, 49 and these connections are inductively linked by the winding of a paralleling reactor 50 to force simultaneous flow of current therethrough. The other terminal of winding 46 is similarly connected with excitation anodes 43, 45 through another pair of connections comprising resistors 51, 52, and another paralleling reactor 53. The current of excitation anodes 42 to 45 returns to the midtap connection provided in winding 46 through a smoothing reactor 54. Similar means are severally associated with the pairs of valves 10, 13 and 11, 14.

Switch 33 controlling the supply of excitation current to valves 9 to 14 may be closed by means of a push button switch 56 connecting the switch coil with transformer 24. Upon closure of switch 33, a holding circuit therefor is completed through the contacts of an overload relay 57 and the contacts of a time delay lockout relay 58. The coil of relay 57 is connected with a current transformer 59 inserted in one of the conductors of circuit 6. The coil of relay 58 may be energized from rectifier 35 through the contacts of an auxiliary time delay relay 60. The coil of relay 60 may be energized from rectifier 35 through contacts 36*b* of ignition relay 36 or through the similar contacts of any of the other ignition relays, such contacts being connected in parallel. Switch 33 is provided with auxiliary contacts 33*a* for connecting transformer 24 with the trip coil 17*a* of switch 17 upon opening of switch 33.

The system being connected as shown on the drawing and circuit 6 being energized, pumps 21 and 22 are first operated for a sufficient length of time to reduce the gas pressure within the valve casings to the desired value as indicated by the usual vacuum meter (not shown). The system may then be put in operation by momentarily closing push button switch 56. Current then flows from transformer 24 through push button switch 56 and the coil of switch 33. Switch 33 closes and completes its holding circuit through the contacts of relays 57 and 58.

Upon closure of switch 33, current is supplied therethrough simultaneously to the ignition solenoids and to the annunciators associated with all the valves as well as to the coil of relay 60. Solenoid 40 and annunciator 41, for example, receive current through contacts 36*a* of relay 36, and the annunciator releases its shutter. Solenoid 40 attracts the associated piston to cause

a jet of cathode material to impinge on anode 32. An ignition circuit is thereby completed from rectifier 35 through the coil of relay 36, ammeter 37, resistor 38, anode 32, cathode 30, and reactor 39 back to the rectifier. Relay 36 immediately opens contacts 36a, thereby disconnecting solenoid 40 from circuit 6. The jet of cathode material is thereby broken and the flow of current between anode 32 and cathode 30 thereupon takes place through an arc which renders the cathode electron emissive.

Anode 31 does not carry current as switch 17 is still open and the arc between anode 32 and cathode 30 is stable even if only a relatively low amount of energy is dissipated in its circuit. A stable arc may be maintained when the output voltage of rectifier 35 is 25 volts and resistor 38 is adjusted to limit the current through anode 32 to two amperes. The arc is accordingly maintained at anode 32 and maintains valve 9 conductive. Continuous excitation arcs are established substantially simultaneously in all the valves in the same manner. All the excitation relays having operated, relay 60 is deenergized and returns to the position shown after a predetermined time delay. The coil of relay 58 is thereby deenergized before relay 58 has opened its contacts.

When the different cathodes are rendered emissive, the potentials impressed from transformer 47 on the excitation anodes such as 42, 43 initiate additional excitation arcs thereat. More particularly, when winding 46 brings anodes 42, 44 to a sufficient positive potential with respect to the cathode potential, current impulses flow through anodes 42, 44, the flow of current therethrough being forced to occur simultaneously by the action of reactor 50. This action is repeated during every other half cycle of the voltage of circuit 6 to cause the occurrence of periodic arcs at anodes 42, 44.

During the intervening half cycles, periodic arcs are likewise established at anodes 43, 45 and the flow of current therethrough is forced to take place simultaneously by the action of reactor 53. The two sets of periodic arcs are, however, caused to overlap by the action of reactor 54 so that anodes 42, 43 for example supply to cathode 30 a continuous excitation current independently of the current of anode 32. The current of reactor 54 may be of intensity as low as eight amperes when the voltage of winding 46 has a value of thirty volts.

When anode 31 is without current, the arcs of anodes 42, 43 would not be sufficiently stable in the absence of current at anode 32, but the arc of anode 32 is stable under such conditions, and maintains the arcs of anodes 42, 43 in stable operation. The excitation arcs being established in the valves, switch 17 may be closed. Valves 9 to 14 then transmit current from circuit 6 to circuit 7 in the well known usual manner.

The flow of current through each valve takes place in non-consecutive periodic impulses. For example, anode 31 carries a current impulse once during every cycle of the voltage of circuit 6 when the anode is brought by winding 48 to a potential which is higher than the potentials of the other anodes. Anode 61 of valves 12 carries current impulses which occur one-half cycle later than the current impulses of anode 31. The current impulses of the different valves combine into a substantially uniform flow of current delivered to circuit 7. After closure of switch 17 the annunciators are all reset by any preferred known means in order that they may be able to indicate subsequent operations of the ignition system.

When the flow of current through circuit 7 is of relatively low intensity, below one hundred and fifty amperes, the continuous excitation arc attaching at anode 32 is stable and maintains the arcs of anodes 42 and 43 in stable operation. When the flow of current through the circuit exceeds one hundred and fifty amperes, the vaporized cathode material within casing 29 is at relatively high pressure and at a relatively high temperature. The vapor also reaches a high degree of ionization during the periods of current flow through anode 31. Under these conditions the relatively short arc of anode 32 would not be sufficiently stable in the absence of relatively long arcs at anodes 42, 43.

The latter arcs are inherently stable during the portion of the voltage cycle in which the voltages impressed on anodes 42, 43 are relatively high but they are not reliably stable when the voltages impressed on the anodes are relatively low. The phase relation of transformers 8 and 47 is so chosen that during each cycle the voltage of winding 46 reverses once during the current conducting period of anode 31 and once during the current conducting period of anode 61.

Let it be considered that at a particular moment anode 31 is carrying current, while anodes 42, 44 also carry current under a decreasing voltage. When the potential of anodes 42, 44 becomes lower than the potential of anodes 43, 45, the flow of current through anodes 42, 44 is transferred to anodes 43, 45 by initiation of arcs thereat. The high degree of ionization of the vapor in valve 9 resulting from the flow of a high current through anode 31 causes the establishment of the arc at anode 43 to take place instantly without difficulty. The conditions are less favorable in valve 12 in which ionization is then produced only by the arc at the ignition excitation anode. If the arc is not immediately established at anode 45, the flow of current through anode 43 and through reactor 53 causes impression on anode 45 of an inductive voltage impulse which is sufficient to cause formation of an arc at anode 45 to take over the current of anode 44.

One-half cycle later current is to be transferred back from anodes 43, 45 to anodes 42, 44. Anode 61 is then carrying current and the transfer of current from anode 45 back to anode 44 takes place without difficulty. If the transfer of current from anode 43 back to anode 42 fails to take place immediately, the flow of current to anode 44 through reactor 50 causes impression on anode 42 of an inductive voltage impulse which causes anode 42 to take over the current of anode 43. The arc at anode 42 or anode 43 is thus maintained stable at every instant, thereby insuring the stability of the arc at anode 32. Stable excitation arcs are likewise maintained in the other valves by the combination of excitation anodes and of paralleling reactors above described.

The ignition resistors are preferably adjusted so that the readings of the ammeters are all equal. While the arc at anode 32 is stabilized as above set forth under all conditions of vapor pressure and temperature resulting from variation of the current of anode 31, this stability is affected by the presence of foreign gases within casing 29. These gases may be air leaking through a defective seal of the casing or other

gases released from the material utilized in the valve as a result of the operation thereof.

If gases appear in casing 20 for example, at a faster rate than they can be removed by pumps 21, 22, the gas pressure within the casing exceeds the value normally maintained therein by operation of the pumps and the current indicated by ammeter 37 decreases to an extent commensurate with the increase in gas pressure. The gases, however, do not generally diffuse from casing 20 into the casings of the other valves because the connection between the casings is effected through manifold 27, which is constantly being evacuated by pumps 21, 22. Inspection of the ammeters will therefore show that the excitation current of anode 32 is lower than the currents of the corresponding anodes of the other valves, thereby indicating that the gas pressure in valve 9 is relatively greater than the gas pressure within the other valves.

If the gas pressure within casing 20 becomes excessive, the arc at anode 32 becomes unstable and subject to extinction even though the arcs at anodes 42, 43 and 31 may not be so affected. Upon failure of the flow of current through valve 9 by way of anode 32, the ignition system associated with valve 9 is caused to operate. More particularly, relay 36 returns to the position shown to reconnect solenoid 40 with transformer 24. The solenoid again attracts the armature thereof to reestablish the arc at anode 32. If the increase in gas pressure in casing 20 was only momentary, the arc may be reestablished after a single operation of the ignition system or after a small number of such operations.

If the gas pressure remains excessive during a period of several seconds, relay 36 continues to operate to attempt to reestablish the arc. After each operation relay 36 returns to the position shown, thereby connecting the coil of relay 60 with rectifier 35. Upon the first return of relay 36 to the position shown, relay 60 instantaneously attracts its armature. Relay 60 is provided with suitable time delay means which maintain the armature attracted through each operation of relay 36. The contacts of relay 60 are thus continuously maintained closed during the series of operations of relay 36 to maintain the coil of relay 58 energized.

If the operation of relay 36 continues for a predetermined length of time depending on the adjustment of relay 58, the latter relay opens its contacts to deenergize the coil of switch 33. Switch 33 opens, thereby rendering the ignition means of all the valves ineffective and simultaneously disconnecting the excitation anodes of all the valves from circuit 6. The flow of current through the valves is thereby interrupted, the valves being rendered non-conductive for lack of excitation current at the cathodes thereof. When switch 3 has returned to the position shown, contacts 33a connect trip coil 17a of switch 17 with transformer 24. The trip coil withdraws latch 17b, thereby causing switch 17 to open under the action of spring 17c.

The operation of relay 36 also causes operation of annunciator 41 which releases its shutter to indicate that relay 36 has operated in response to failure of the flow of current through anode 32. The other annunciators, however, have not operated, so that an indication is obtained that the gas pressure was excessive only in valve 9. Valves 10 to 14 and pumps 21, 22 may then be disconnected from manifold 27 and the rate of increase of the gas pressure in casing 20 and manifold 27 may be determined by means of the common vacuum meter (not shown) usually associated with the evacuating system. If valve 9 has become permanently defective, stop cock 29 is closed and valve 9 may be removed after disassembling its different electrical connections and joint 28. The valve may then be repaired and reinstalled or a spare valve may be substituted therefor.

If the flow of current through valve 9 becomes excessive because of overloading of circuit 7 or because of a backfire in any one of the valves, current transformer 59 supplies to the coil of relay 57 a current of sufficient magnitude to cause the relay to operate. Relay 57 opens the circuit of the coil of switch 33, which causes interruption of the flow of current through the valves and opening of switch 17 in the manner above described. This operation, however, does not cause any of the ignition relays to function and none of the annunciators operates, thereby indicating that the disconnection of the system was not due to excessive gas pressure within one of the valves.

Although but one embodiment of the invention has been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims. Some of the features of the invention disclosed and claimed herein are also disclosed in Patent No. 2,251,484, issued August 5, 1941, to Samuel R. Durand, upon an application Serial No. 297,210, filed September 30, 1939.

It is claimed and desired to secure by Letters Patent:

1. The combination of a supply circuit, an output circuit, a plurality of electric valves each comprising an anode and a cathode connected with said circuits for the flow of energy therebetween, means for controlling said flow of energy comprising a plurality of means each including an element of one of said valves for rendering said valves conductive, and means for interrupting the flow of current between said circuits by way of said valves comprising means responsive to continual operation of the first said means during a predetermined length of time.

2. The combination of a supply circuit, an output circuit, a plurality of electric valves each comprising an anode and a cathode connected with said circuits for the flow of energy therebetween, ignition means severally associated with the different said valves for rendering said valves conductive, means responsive to failure of the flow of current through any one of said valves for causing operation of the said ignition means associated with the said one of said valves, and means for interrupting the flow of current between said circuits by way of said valves comprising means responsive to continual operation of any one of said ignition means during a predetermined length of time.

3. The combination of a supply circuit, an output circuit, a plurality of electric valves each comprising an anode and a cathode connected with said circuits for the flow of energy therebetween, a switch for controlling the connection between said circuits through said valves, means for controlling said flow of energy comprising a plurality of means each including an element of one of said valves for rendering said cathodes emissive, and means responsive to an operating

condition of said valves for rendering the first said means ineffective and for causing opening of said switch.

4. The combination of a supply circuit, an output circuit, a plurality of electric valves each comprising an anode and a cathode connected with said circuits for the flow of energy therebetween, a switch for controlling the connection between said circuits through said valves, ignition means severally associated with the different said valves for rendering said cathodes emissive, means responsive to failure of the flow of current through any one of said valves for causing operation of the said ignition means associated with the said one of said valves, and means responsive to continual operation of any of said ignition means during a predetermined length of time for rendering said ignition means ineffective and for causing opening of said switch.

5. The combination of an electric valve comprising a cathode and excitation anode means, means for rendering said valve conductive, means comprising a source of current connected with said excitation anode means for supplying a continuous excitation current to said cathode to maintain said valve continuously conductive, and means for rendering said valve non-conductive comprising means responsive to an operating condition of said valve for disconnecting said source from said excitation anode means.

6. The combination of a supply circuit, an output circuit, a plurality of electric valves each comprising an anode and a cathode connected with said circuits for the flow of energy therebetween and excitation anode means, means for rendering said valves conductive, means comprising a source of current connected with said excitation anode means for supplying continuous excitation current to each of said cathodes to maintain said valves continuously conductive, and means for rendering said valves non-conductive comprising means responsive to an operating condition of said valves for simultaneously disconnecting all said excitation anode means from said source.

7. In a control circuit for an electric valve comprising a main anode and a cathode for the flow of current of variable intensity, a plurality of excitation anodes arranged within said valve, means comprising a source of alternating current connected with said cathode and with said excitation anodes for producing a plurality of overlapping periodic excitation arcs therebetween which are stable during flow of current of relatively high intensity between said main anode and said cathode, and means comprising a source of direct current connected with said cathode and with one of said excitation anodes for maintaining a continuous excitation arc therebetween which is stable during flow of current of relatively low intensity between said main anode and said cathode.

8. In a control circuit for an electric valve comprising a main anode and a cathode for the flow of current of variable intensity, a plurality of excitation anodes arranged within said valve, means comprising a source of direct current connected with said cathode and with one of said excitation anodes and means for causing momentary engagement of said cathode with said one of said excitation anodes to initiate and maintain therebetween a continuous excitation arc which is stable during flow of current of relatively low intensity between said main anode and said cathode, and means comprising a source of alternating current connected with said excitation anodes and with said cathode for producing a plurality of overlapping periodic excitation arcs therebetween which are stable during flow of current of relatively high intensity between said main anode and said cathode.

9. The combination of an electric valve comprising a single main anode, a cathode, and a plurality of excitation anodes, a source of periodic current connected with said main anode and with said cathode for the flow of non-consecutive periodic current impulses of variable intensity therebetween, means comprising a source of direct current connected with said cathode and with one of said excitation anodes for producing a continuous excitation arc which is stable during the intervals between said current impulses and during the flow of said current impulses of relatively low intensity, and means comprising a source of alternating current connected with said cathode and with others of said excitation anodes for producing a plurality of overlapping periodic excitation arcs therbetween which are stable during flow of said current impulses of relatively high intensity.

10. The combination of a plurality of interconnected electric valves each comprising a single main anode, a cathode, and a plurality of excitation anodes, means comprising a source of periodic current connected with said main anodes and with said cathodes to cause the flow of periodic current impulses alternately between the different said main anodes and said cathodes, and means for maintaining excitation arcs in said valves comprising a source of alternating current connected with said cathodes, a plurality of connections between said source of alternating current and a group of said excitation anodes associated with different ones of said cathodes for the supply of current impulses from said source of alternating current to said group of excitation anodes, and means inductively linking said connections for causing the periods of occurrence of said current impulses to coincide.

11. The combination of a pair of interconnected electric valves each comprising a single main anode, a cathode, and excitation means comprising a pair of excitation anodes, means comprising a source of periodic current connected with said main anodes and with said cathodes to cause the flow of periodic current impulses alternately between the said main anodes and the said cathodes, and means for maintaining excitation arcs in said valves comprising a source of alternating current connected with said cathodes, a pair of connections between said source of alternating current and one excitation anode of each of said valves to cause simultaneous impression thereon of arc initiating potentials during flow of current through one of said main anodes, means inductively linking said connections to force simultaneous flow of current therethrough, a second pair of connections between said source of alternating current and the remaining said excitation anodes to cause simultaneous impression thereon of arc initiating potentials during flow of current through the other one of said main anodes, and means inductively linking the second said connections to force simultaneous flow of current therethrough.

12. The combination of a pair of interconnected electric valves each comprising a single main anode, a cathode, and a plurality of excitation anodes, means comprising a source of periodic current connected with said main anodes

and with said cathodes to cause the flow of periodic current impulses alternately between the said main anodes and the said cathodes, and means for maintaining excitation arcs in said valves under all conditions of current flow therethrough comprising a source of alternating current connected with said cathodes, a pair of connections between said source of alternating current and one excitation anode of each of said valves to cause simultaneous impression thereon of arc initiating potential during flow of current through one of said main anodes, means inductively linking said connections to force simultaneous flow of current therethrough, a second pair of connections between said source of alternating current and another excitation anode of each of said valves to cause simultaneous impression thereon of arc initiating potential during flow of current through the other one of said main anodes, means inductively linking the second said connections to force simultaneous flow of current therethrough, and a source of direct current connected with said cathodes and with a third excitation anode of each of said valves to maintain continuous excitation arcs therebetween.

13. The combintaion of a plurality of interconnected electric valves each comprising a casing, main anode means and a cathode, means for maintaining said cathodes continuously emissive comprising an excitation anode in each of said casings and a source of direct current connected with said excitation anodes and with said cathodes, evacuating means connected with each of said casings, and means for indicating the relative values of the gas pressures within the different said casings comprising a plurality of electroresponsive devices severally connected between said source and the different said excitation anodes.

14. The combination of a plurality of interconnected electric valves each comprising a casing, main anode means and a cathode, means for maintaining said cathodes continuously emissive comprising an excitation anode in each of said casings and a source of direct current connected with said excitation anodes and with said cathodes to maintain excitation arcs therebetween, each said excitation arc being subject to extinction upon excessive increase of the gas pressure within the corresponding casing, ignition means severally associated with the different said valves for establishing said excitation arcs, relay means responsive to failure of the said excitation arc of any one of said valves for causing operation of the said ignition means associated with the said one of said valves, evacuating means connected with each of said casings, and means for indicating in which of said casings an excessive gas pressure occurs comprising indicating means responsive to operation of said relay means.

15. The combination of a supply circuit, an output circuit, a plurality of electric valves each comprising a casing containing main anode means and a cathode connected with said circuits for the flow of energy therebetween, a switch for controlling the connection between said circuits through said valves, means for maintaining said cathodes continuously emissive comprising an excitation anode in each of said casings and a source of direct current connected with said excitation anodes and with said cathodes to maintain excitation arcs therebetween, each said excitation arc being subject to extinction upon excessive increase of the gas pressure within the corresponding casing, ignition means severally associated with the different said valves for establishing said excitation arcs, relay means responsive to failure of the said excitation arc of any one of said valves for causing operation of the said ignition means associated with the said one of said valves, means responsive to operation of said relay means during a predetermined length of time for rendering said relay means ineffective and for causing opening of said switch, evacuating means connected with each of said casings, and means for indicating in which of said casings an excessive gas pressure resulted in the operation of said switch comprising indicating means responsive to operation of said relay means.

16. The combination with a supply circuit, an output circuit, a plurality of electric valves each having an anode and a cathode connected with said circuits for the flow of current therebetween and each having excitation anode means, ignition means distinct from said excitation anode means severally associated with the different said cathodes for rendering said valves conductive, and means comprising a source of current connected with said excitation anode means for supplying continuous excitation current to each of said cathodes to maintain said valves continuously conductive independently of said ignition means, of means for rendering said valves simultaneously non-conductive for the flow of current between said circuits comprising timing means responsive to initiation of the operation of said ignition means for rendering said excitation current supply means inoperative after a predetermined time interval.

17. The combination with a supply circuit, an output circuit, a plurality of electric valves each having an anode and a cathode connected with said circuits for the flow of current therebetween and each having excitation anode means, a switch for controlling the connection between said circuits through said valves, and ignition means for rendering and maintaining said valves conductive comprising a source of current connected with said excitation anode means for supplying excitation current to each of said cathodes, of means responsive to an operating condition of said valves for rendering said ignition means inoperative and thereafter causing opening of said switch.

18. The combination with a supply circuit, an output circuit, a plurality of electric valves each having an anode and a cathode connected with said circuits for the flow of current therebetween and each having excitation anode means, a switch for controlling the connection between said circuits through said valves, and ignition means for rendering and maintaining said valves conductive comprising a source of current connected with said excitation anode means for supplying excitation current to each of said cathodes, of timing means responsive to the operation of said ignition means for rendering said ignition means inoperative and thereafter causing opening of said switch after a predetermined time interval.

19. The combination with a supply circuit, an output circuit, a plurality of electric valves each having an anode and a cathode connected with said circuits for the flow of current therebetween and each having excitation anode means, ignition means distinct from said excitation anode means severally associated with each of said valves for rendering said valves conductive, and excitation means comprising a source of current connected

with said excitation anode means for supplying current to each of said cathodes to maintain said valves continuously conductive independently of said ignition means, of relay means responsive to failure of the flow of excitation current through any one of said valves for causing operation of the ignition means associated with said one of said valves, and timing means responsive to continued operation of said relay means during a predetermined time interval for rendering the ignition and excitation means of all said valves inoperative.

20. The combination with a supply circuit, an output circuit, a plurality of electric valves each having an anode and a cathode connected with said circuits for the flow of current therebetween and each having excitation anode means, a switch for controlling the connection between said circuits through said valves, ignition means severally associated with each of said valves for rendering said valves conductive, and excitation means comprising a source of current connected with said excitation anode means for supplying current to each of said cathodes to maintain said valves continuously conductive, of relay means responsive to failure of the flow of excitation current through any one of said valves for causing operation of the ignition means associated with said one of said valves and timing means responsive to continued operation of said relay means during a predetermined time interval for rendering the ignition and excitation means of all said valves inoperative and for thereafter causing opening of said switch.

SAMUEL R. DURAND.