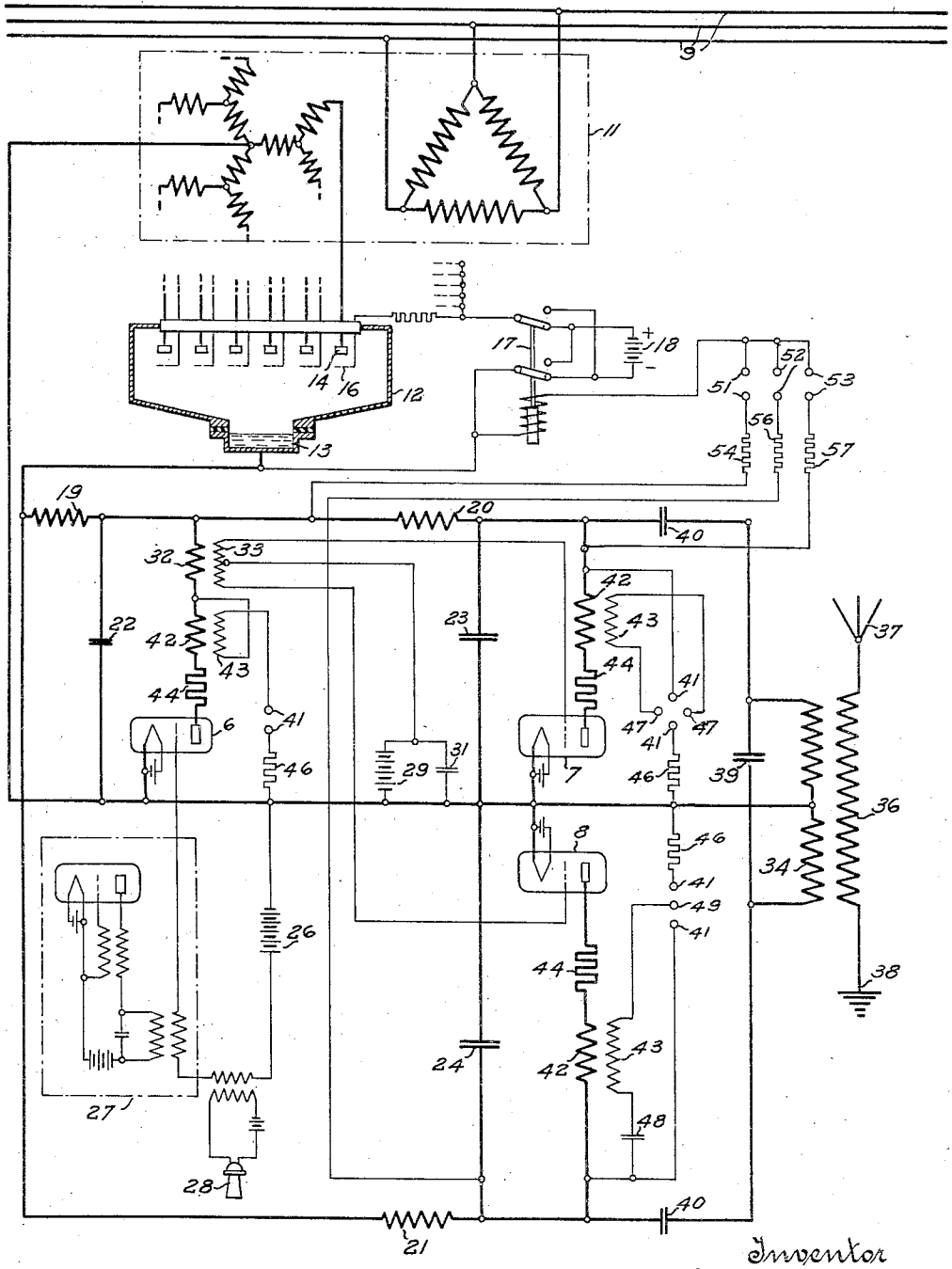
Jan. 28, 1936. F. MERTENS 2,029,270

ELECTRIC VALVE PROTECTIVE SYSTEM

Filed March 14, 1935



Inventor

F. Mertens

by G. J. Gilvin

Attorney

Patented Jan. 28, 1936 2,029,270

UNITED STATES PATENT OFFICE

2,029,270

ELECTRIC VALVE PROTECTIVE SYSTEM

Franz Mertens, Mannheim, Germany, assignor to Aktiengesellschaft Brown Boveri & Cie., Baden, Switzerland, a joint-stock company of Switzerland

Application March 14, 1935, Serial No. 10,984
In Germany November 11, 1933

11 Claims. (Cl. 250—27)

This invention relates in general to protective systems, and more particularly to means for preventing the continued flow of current through an electric valve following an abnormal decrease of the impedance thereof.

It is well known that electric valves of the high vacuum type present an impedance to the flow of current between the electrodes thereof which impedance may be controlled between predetermined limits by the use of conductivity controlling means such as grids. It occasionally happens that the conductivity of the valve suddenly increases to an extent such that the valve substantially constitutes a short circuit for the source of current connected therewith. The causes of such phenomenon are not well understood, but it may be surmised that excessive local heating at a point of the cathode causes metal therefrom to be evaporated at a rate such that a path capable of conducting an arcing discharge is established thereby. If the resulting flow of current is prevented from reaching too high a value, and if such flow of current is rapidly interrupted, the valve is generally not materially damaged and may be immediately put back in operation so that the continuity of operation of the valve is only inappreciably disturbed. Such result is most advantageously obtained by shunting the valve by a gap so connected as to break down upon collapse of the impedance of the valve. If the valve is supplied with current from an electric current rectifier, the flow of current through the gap may then be interrupted by momentarily energizing the control electrodes of the rectifier at a negative potential and the system may be returned to the normal operating condition thereof upon return of the gap to the insulating condition. As the breakdown of the gap occurs with a certain time lag, it is desirable to reduce the rate of increase of the flow of current through the valve, so that the current is prevented from reaching too high a valve before the breakdown of the gap. Such result is obtained by connecting a reactor in series with the valve.

It is, therefore, among the objects of the present invention to provide a protective system for an electric circuit by which the flow of current is diverted from such circuit upon occurrence of abnormal operating conditions therein.

Another object of the present invention is to provide an electric valve protective system by which the rate of increase of the flow of current through the valve upon collapse of the impedance thereof is reduced to the greatest possible extent.

Another object of the present invention is to provide an electric valve protective system by which the flow of current through the valve is diverted therefrom upon breakdown of the impedance of the valve.

Another object of the present invention is to provide an electric valve protective system by which the flow of current diverted from the valve may be interrupted to thereby restore the normal operating condition of the system.

Objects and advantages other than those above set forth will be apparent from the following description when read in connection with the single figure of the accompanying drawing which diagrammatically illustrates three embodiments of the present invention severally applied to the protection of electric valves employed in a radio transmitting system.

Referring more particularly to the drawing by characters of reference, reference numerals 6, 7 and 8 designate electric valves of the three electrode high vacuum type utilized in a radio transmitting system. Such valves may be connected in any circuit known in the art, typical connections being shown therebetween only for the purpose of making the drawing complete and thereby facilitating the understanding of the invention. Valves 6, 7 and 8 are supplied with direct current from a rectifying system energized from an alternating current supply line 9, and comprising a transformer 11 and a valve 12 of any suitable type. Valve 12 is represented as being of the vapor type having a cathode 13 which is maintained in current conductive condition by any suitable means, such means being well known in the art and therefore not shown. Valve 12 is provided with a plurality of anodes 14 severally connected with transformer 11, the operation of each anode being controlled by means of an associated control electrode 16. Anodes 14 thus sequentially carry current when the associated control electrodes are at a positive potential with respect to the potential of cathode 13, such sequential flow of current being interrupted by bringing the control electrodes to a negative potential with respect to the potential of cathode 13. In the present system, valve 12 is accordingly operative when the control electrodes are connected, through the contacts of a relay 17 with the positive terminal of the battery 18 having the negative terminal thereof connected with cathode 13. The flow of current through valve 12 ceases when the connections of battery 18 are reversed as a result of operation of relay 17.

The output terminals of the rectifying system

are located at cathode 13 and at the neutral point of the secondary winding of transformer 11. One of such terminals is connected with a plurality of reactors 19, 20 and 21, of which some may be serially connected such as reactors 19 and 20. Each valve 6, 7 and 8 is connected between the terminal of one reactor furthest from the source and the terminal of the rectifying system with which the reactors are not connected. A plurality of capacitors 22, 23 and 24 are severally connected in parallel with valves 6, 7 and 8. Valve 6 functions as an amplifying valve, the control electrode thereof being connected with the associated cathode through a bias battery 26 and through the output circuit of an oscillating system 27 of any suitable type operable to produce electrical oscillations of a frequency within the range of frequencies utilized for the production of electromagnetic waves. The connection between oscillator 27 and the control electrode of valve 6 may be controlled by a signaling key, or the oscillations may be modulated by means of a microphone 28 for the purpose of transmitting speech or other sounds.

Valves 7 and 8 are connected in the so-called push-pull connection, the control electrode of each valve being connected with the associated cathode through a common bias battery 29 shunted by a capacitor 31, and through one of the portions of the secondary winding 33 of a transformer having a primary winding 32 connected in series with valve 6. Such transformer transmits to the control electrode circuits, modulated oscillations from oscillator 27 amplified by the action of valve 6. The voltages across valves 7 and 8 are impressed on the primary winding 34 of a transformer having a secondary winding 36 connected between an antenna 37 and ground at 38. Winding 34 is preferably shunted by a capacitor 39 tuned therewith for the frequency of oscillator 27, and the connections between valves 7 and 8 and winding 34 preferably include blocking capacitors 40 preventing the undesired flow of direct current from rectifier 12 through winding 34.

The circuits provided for protecting valves 6, 7 and 8 against excessive flows of current resulting from breakdown of the impedance of the valves are arranged somewhat differently for each valve, for the purpose of illustrating a few of the different ways in which their connections can be effected. Each valve is associated with a pair of electrodes 41 defining a gap connected in parallel with the associated valve. Valve 6 is connected in series with the primary winding 42 of a transformer having a secondary winding 43 connected in series with the associated gap 41. A resistor 44 may be inserted in series with the valve and with winding 42, and another resistor 46 may be connected in series with gap 41 and winding 43. The winding 43 associated with valve 7 is not connected in series with associated gap 41, but is connected with a second pair of electrodes 47 defining a gap partly coextensive with gap 41. The winding 43 associated with valve 8 is connected in series with a capacitor 48 across a gap defined by one of electrodes 41 and another electrode 49, such gap being partly coextensive with gap 41. The coil of relay 17 is connected between cathode 13 and the terminals of reactors 19, 20 and 21 farthest from the cathode through gaps defined by electrodes 51, 52 and 53 serially connected with resistors 54, 56 and 57.

During normal operation of the system, relay 17 being in the position shown and line 9 being energized, transformer 11 and valve 12 operate as a rectifying system equivalent to a source of direct current supplying current to valves 6, 7 and 8. The current flowing through such a system generally contains alternating components in addition to the desired unidirectional component, and the flow of such alternating components through valve 6 is substantially prevented by the cooperating action of reactor 19 and capacitor 22. The flow of current is likewise maintained substantially uniform through valve 7 by the cooperating action of reactors 19 and 20 and of capacitor 23, and also through valve 8 by the cooperating action of reactor 21 and capacitor 24.

The oscillations produced by oscillator 27 and modulated by microphone 28 are impressed between the cathode and the control electrode of valve 6 to cause the conductivity of valve 6 to vary within a predetermined operating range. The inductance of reactor 19 preventing the flow of current therethrough from varying in response to the variations of conductivity of valve 6, such variations of conductivity resulting in successive charges of capacitor 22 and discharges thereof through reactor 19 through valve 6, to thereby cause the appearance in winding 32 of alternating voltages similar to the voltages impressed between the control electrodes and cathode of valve 6, but at greater amplitude. During such operation, the flow of current from rectifier 12 through reactor 19 and valve 6 remains substantially constant, and alternating currents may circulate between valve 6 and capacitor 22 irrespective of the rectifying action of valve 6 for the reason that the total current flowing through valve 6 remains unidirectional.

The voltages induced in winding 33 and impressed between the control electrodes and cathodes of valves 7 and 8 cause the conductivities of valves 7 and 8 to vary to an extent greater than the conductivity of valve 6. Reactors 19, 20 and 21 prevent variation in the flow of current from rectifier 12 to valves 7 and 8 in response to such variations of conductivity, and such conductivity changes therefore result in charges and discharges of capacitors 23 and 24 through valves 7 and 8 similar to the charges and discharges of capacitor 22 through valve 6, but at greater amplitude. As a result the terminal voltages of valves 7 and 8 and capacitors 23 and 24 oscillate at the frequency of oscillator 27, the amplitude of such oscillations being in accordance with the modulation introduced by microphone 28, and the thus modulated voltages are impressed on winding 34 through capacitors 40 to cause antenna 37 to radiate electromagnetic waves.

Upon occurrence of a sudden accidental breakdown of the impedance of valve 6, capacitor 22 immediately discharges through the valve. As a result of such discharge, the flow of current through valve 6 suddenly increases at a rate considerably greater than any rate of increase resulting from increases in conductivity caused by the control electrode during normal operation of the valve. Such rate of the increase of the flow of current causes the appearance in winding 42 of a voltage proportional thereto and inducing a corresponding voltage in winding 43. The voltage of winding 43, superimposed on the voltage of winding 42 and the voltage in valve 6, is impressed on gap 41 to cause the gap to break down.

Gap 41 is so arranged as to offer less impedance to the flow of current than valve 6 even when such valve is in the broken down condition, so that the flow of current through valve 6 ceases

and is transferred to gap 41. To obtain such result it may be necessary to insert a resistor 44 in series with valve 6 to increase the voltage drop in the circuit thereof and cause transfer of the flow of current to gap 41. Resistor 44 should, of course, be of such low value as not to adversely affect the normal operation of valve 6. Windings 42 and 43 are so arranged that gap 41 breaks down before the discharge current of capacitor 22 through valve 6 reaches more than a few times the value of the normal current of valve 6, so that the flow of current may be transferred to gap 41 before reaching the maximum value thereof. As the breakdown of gap 41 is not instantaneous but generally occurs with a certain time lag, it may be desirable to somewhat reduce the rate of increase of the flow of current through valve 6 by increasing the inductances of windings 42 and 32, such inductances being however always of magnitude too low to have any detrimental effect on the normal operation of the system. A resistor 46 may also be connected in series with gap 41 to cause damping of the discharge of capacitor 22 through the gap.

As a result of the breakdown of valve 6 and of gap 41, an actual short circuit is provided for the flow of current from rectifier 12 and also for the discharge of capacitors 23 and 24. During the initial flow of excessive current through valve 6 and the transfer of the flow of current to gap 41, reactor 19 prevents a material increase in the flow of current supplied to valve 6 from valve 12, reactor 20 prevents any material discharge of capacitor 23 through valve 6, and reactors 21 and 9 prevent any material discharge of capacitor 24 through valve 6. Valve 6 accordingly carries only substantially the discharge current of capacitor 22 during such period, thereby reducing to the greatest possible extent the danger of damage to the valve resulting from the breakdown thereof.

During such operation, substantially the entire voltage of rectifier 12 is impressed across reactor 19, the impression of such voltage causing gap 51 to break down, whereby the magnetic energy stored in reactor 19 is dissipated by the flow of induced current from reactor 19 through resistor 54, gap 51 and the coil of relay 17. Relay 17 accordingly operates to reverse the connections of battery 18 to thereby cause interruption of the flow of current through rectifier 12. Such interruption is obtained without difficulty because the magnetic energy stored in reactor 19 is dissipated and therefore does not tend to maintain the flow of current through rectifier 12. Such flow of current therefore ceases upon the following passage through zero of the voltage impressed on the anode carrying current at the time of operation of relay 17. Upon complete dissipation of the magnetic energy of reactor 19, relay 17 returns to the position shown to reestablish the flow of current through rectifier 12. In the meanwhile, capacitors 22, 23 and 24 having completely discharged through gap 41, the gap and valve 6 have returned to their normal operating condition and the entire system is thus returned to normal operation within a period of time which need not exceed a small fraction of one second.

If the impedance of valve 7 accidentally collapses, the voltage resulting from the discharge of capacitor 23 impressed on gap 47 causes such gap to break down. Gap 41, which is partly coextensive with gap 47 is accordingly rendered conductive, and capacitor 23 can discharge through the associated gap 41 instead of through valve 7. The system is thereafter returned to the normal operating condition in the manner above described with respect to valve 6. The present embodiment presents the advantage that there is no reactance in circuit with gap 41, and the flow of current through gap 41 may therefore be established very rapidly. In the present instance, reactors 19, 20 and 21 substantially prevent the flow of current from rectifier 12 and the discharge of capacitors 22 and 24 through valve 7.

If the impedance of valve 8 breaks down, the voltage appearing in winding 43 as a result of the incipient discharge of capacitor 24 through valve 8 is of sufficient magnitude to cause the space between electrode 49 and one of the electrodes 41 to break down, so that gap 41 becomes conductive and discharges capacitor 24, thereby diverting the flow of current from valve 8. Capacitor 48 is connected in series with winding 43 to prevent the application, between electrode 49 and one of the electrodes 41, of the full voltage of rectifier 12 which would be sufficient to cause the breakdown of the space between such electrodes.

Although but a few embodiments of the present invention have 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.

It is claimed and desired to secure by Letters Patent:

1. In a protective system, an electric circuit, a source of electric current connected with said circuit to cause flow of current therethrough, an inductive winding in the connection between said source and said circuit, an incompletely conductive circuit connected in parallel with said circuit, and means responsive only to changes in the magnitude of the flow of current through the first said circuit when occurring at a rate greater than a predetermined rate to cause completion of said incompletely conductive circuit.

2. In a protective system, an electric circuit comprising an element of variable conductivity to be protected against the flow of excessive current therethrough, a source of current connected with said circuit for supplying current thereto, means for limiting the rate of change of flow of current in said circuit comprising a reactor included in the connections of said source therewith, means for diverting the flow of current from said circuit upon the occurrence of a disturbance therein comprising a pair of electrodes defining a spark gap connection in parallel with said circuit, and means operable responsive to the magnitude of the rate of increase of flow of current in said circuit to cause breakdown of said spark gap.

3. The combination with an electric valve comprising a cathode and an anode having connections with a source of electric current and constituting spaced electrodes for the flow of current therebetween, and means for limiting the rate of change of said flow of current comprising a reactor included in the connections of said source of current with said electrodes, of means for diverting said flow of current from said valve upon the occurrence of a disturbance therein comprising a pair of electrodes defining a spark gap, and a transformer having a primary winding connected in series with said anode and cath-

ode and a secondary winding connected in series with said gap in a circuit connected in parallel with said primary winding and the said anode and cathode, whereby said gap breaks down upon the occurrence of an increase of said flow of current at a rate greater than a predetermined rate.

4. In a protective system, an electric valve adapted to be connected to a source of electric current, through a reactor to limit the rate of change of the flow of current therebetween, a pair of electrodes defining a spark gap, a transformer having a primary winding connected in series with said gap in a circuit connected in parallel with said primary winding and said valve whereby said gap breaks down upon increase of the flow of current through said valve above a predetermined rate, and a resistor connected in series with said valve to cause the flow of current through said valve to be diverted to said gap upon breakdown of said valve.

5. The combination with a source of direct current, a capacitor connected with said source of current to be charged therefrom, an electric valve comprising a cathode and an anode connected in circuit across said capacitor and receiving current from said source, means comprising a reactor included in the connections between said source and said capacitor and said circuit for limiting the rate of changes of flow of current thereto, of means for diverting said flow of current from said valve comprising a pair of electrodes defining a spark gap connected in another circuit across said capacitor, a transformer having windings severally included in said circuits to impress potential across said spark gap of such magnitude as to cause breakdown of said gap upon the occurrence of a flow of current increasing at a rate above a predetermined value through said valve, and a resistor in series connection with said gap to damp the discharge of said capacitor through said gap upon breakdown thereof.

6. The combination with an electric valve comprising a cathode and an anode having connections with a source of electric current and constituting spaced electrodes for the flow of current therebetween, and means comprising a reactor serially included in the connections between said source and said electrodes for limiting the rate of change of said flow of current, of means for diverting said flow of current from said valve upon the occurrence of a disturbance therein comprising a transformer having a primary winding connected in series with said electrodes and having a secondary winding, a pair of electrodes connected with said secondary winding and defining a spark gap adjusted to break down upon increase of said flow of current at a rate above a predetermined value, and a second pair of electrodes connected across said cathode and anode and said primary winding and defining a spark gap partly coextensive with the first said gap to become conductive upon breakdown of the first said gap.

7. The combination with a source of direct current, a variable conductive electric valve comprising a cathode and an anode having connections with a source of electric current and constituting spaced electrodes for the flow of current therebetween, and means comprising a reactor serially included in the connections of said source of current with said electrodes for limiting the rate of change of said flow of current, of means for diverting said flow of current from said electrodes upon a disturbance in said valve comprising a transformer having a primary winding connected in series with said electrodes and having a secondary winding, a capacitor having connections with one terminal of said source and with said secondary winding, a pair of electrodes defining a gap connected across said secondary winding and said capacitor and adjusted to break down upon increase of said flow of current at a rate above a predetermined value, and another electrode connected with the other terminal of said source and defining with the said electrode connected with the said one terminal of said source another spark gap partly coextensive with the first said gap and becoming conductive upon breakdown of the first said gap.

8. In combination, an electric valve of variable conductivity comprising a cathode and an anode constituting spaced electrodes for the flow of current therebetween, a source of direct current connected with said electrodes to supply current thereto, a reactor included in the connections of said source for maintaining the current supplied therefrom at a substantially constant value, a capacitor connected in parallel with said electrodes and cooperating with said reactor for maintaining the flow of current supplied by said source at a substantially constant value and for supplying a variable component thereof to said electrodes in response to variations of the conductivity of said valve, and means for diverting the said flow of current from said valve upon the occurrence of abnormal conditions therein comprising an incompletely conductive circuit bridging said electrodes, and means operable responsive to a sudden abnormal increase of the conductivity of said valve above a predetermined value for causing the said circuit to become completely conductive.

9. In combination, a source of alternating current, an electric valve of controllable conductivity connected with said source for converting current supplied therefrom into current of unidirection, a second electric valve of variable impedance comprising a cathode and an anode connected with the first said valve and receiving current of unidirection therefrom, a reactor included in the said connections between said valves and tending to maintain the flow of current of unidirection therebetween at a substantially constant value, a capacitor connected with the first said valve through said reactor to cooperate therewith in maintaining substantially uniform the flow of current between said valves and to supply a variable component thereof to said cathode and anode of the said second valve in dependence on variations of the impedance thereof, means operable in response to a sudden lowering of the impedance of the said second valve below a predetermined value for bridging the said cathode and anode by a circuit of such value as to divert said flow of current of unidirection from the said second valve, and means operating coordinately with the first said means for rendering the first said valve non-conductive, whereby the flow of current through said circuit is interrupted.

10. In combination, a source of alternating current, an electric valve of controllable conductivity connected with said source for converting current supplied therefrom into current of unidirection, a second electric valve of variable impedance comprising a cathode and an anode connected with the first said valve and receiving current of unidirection therefrom, a reactor included in the connections between said valves and tending to

maintain the flow of current of unidirection at a substantially constant value, a capacitor connected with the first said valve through said reactor to cooperate therewith in maintaining substantially uniform the said current of unidirection and to supply a variable component thereof to the said cathode and anode of the said second valve in dependence on variations of the impedance thereof, means for diverting said flow of current of unidirection from the said second valve upon a sudden lowering of the impedance thereof below a predetermined value comprising a pair of electrodes forming a spark gap, a transformer having a primary winding connected in series with the said cathode and anode and a secondary winding connected in series with said gap in a circuit parallel with said primary winding and the said cathode and anode, and means operable upon said sudden lowering of the impedance of the second said valve to render the first said valve non-conductive, the last said means comprising a relay and electrodes defining another spark gap serially connected across said reactor.

11. In combination, a source of direct current, a plurality of reactors connected with one terminal of said source, a plurality of electric valves of variable impedances each comprising a cathode and an anode connected between the other terminal of said source and the terminal farthest from said source of a different one of said reactors and constituting spaced electrodes for the flow of current supplied from said source therebetween, a plurality of capacitors severally connected in parallel with said valves, means for diverting current from one of said valves comprising a pair of electrodes defining a spark gap connected in parallel with the said cathode and anode thereof, a transformer having a primary winding in series connection with the cathode and anode of the said one of said valves and a secondary winding in series connection with said gap, whereby said gap becomes conductive upon a sudden decrease of the impedance of the said one of said valves to divert the resulting discharge current of the associated one of said capacitors therefrom, the said reactors delaying the discharge of the others of said capacitors and the increase of current from said source through the said cathode and anode of the said one of said valves and the said gap, and means operable responsive to the occurrence of breakdown of the impedance of the said one of said valves to cause interruption of the said flow of current supplied from the said source.

FRANZ MERTENS.