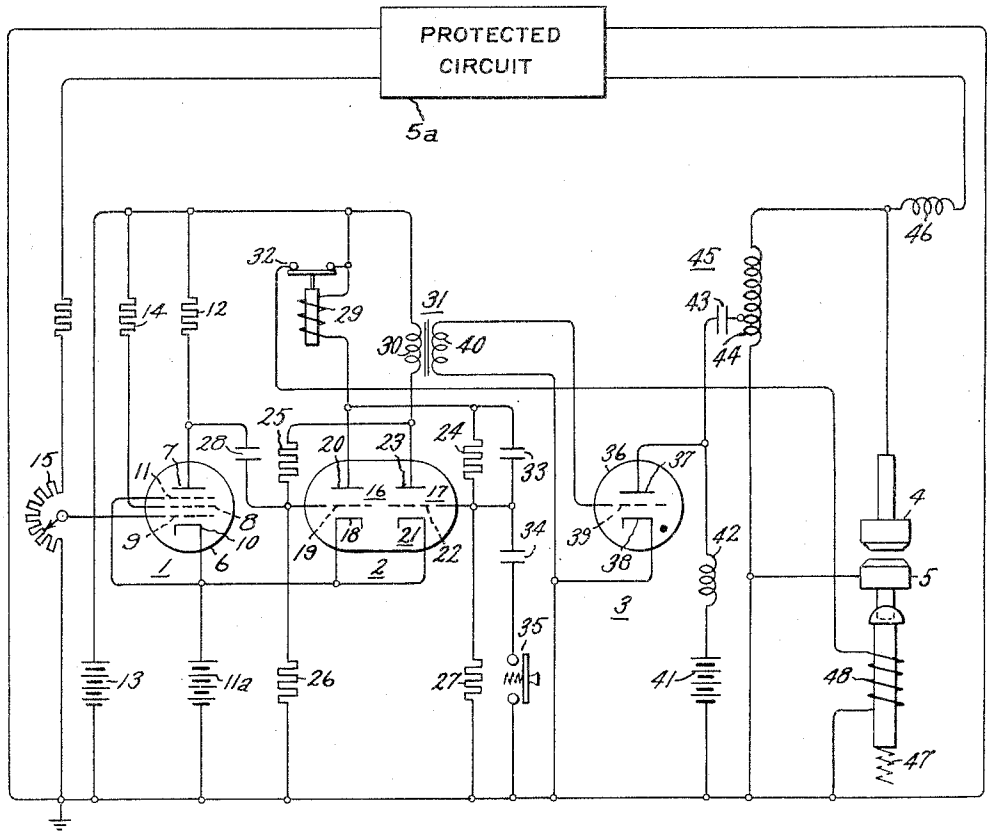
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OVERVOLTAGE PROTECTIVE APPARATUS

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## OVERVOLTAGE PROTECTIVE APPARATUS

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My invention relates to electric protective apparatus and more particularly to automatic overvoltage protective apparatus for electric circuits.

Electric circuits are commonly protected against possible overvoltage conditions by the use of devices which effectively short-circuit the protected circuits when the voltages thereacross exceed predetermined maximum values. A spark gap comprising a pair of spaced electrodes in a dielectric medium is a well-known example of a protective device of this type which has found widespread use in the past. Spark gaps, however, are best suited to circuits operating at relatively high voltages and are generally not capable of precise adjustment of flash-over voltage. In the use of conventional spark gaps at voltages of the order of 20 kilovolts, for example, flash-over may occur at voltages as much as 30 per cent above or below the desired value.

In many applications such a relatively wide tolerance in the voltage at which a protective device functions is not permissible. In the case of a synchrotron magnet, for example, the normal operating voltage may be 20,000 volts, while the maximum safe voltage may be 22,000 volts, or only 10 per cent above the normal voltage. The use of a spark gap in such a case, therefore, does not provide the required degree of protection and it is desirable that a more accurate and reliable protective device be employed.

It is accordingly an object of my invention to provide a new and improved overvoltage protective apparatus for electrical circuits.

It is another object of my invention to provide an overvoltage protective apparatus suitable for use at relatively low voltages and having a high degree of accuracy and reliability.

In accordance with my invention, I provide an overvoltage protective apparatus making use of a spark gap and an associated triggering circuit which causes flash-over of the gap in response to a predetermined voltage signal. A charged capacitor is connected in series with the primary winding of a pulse transformer and an electron discharge device of the gaseous ionization type. The secondary winding of the transformer is connected to a spark gap comprising a pair of electrodes which in turn are connected to the circuit to be protected. A triggering circuit is provided which renders the electron discharge device conducting when the voltage across the protected circuit exceeds a predetermined value, thereby permitting the charged capacitor to discharge through the electron discharge device

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and the primary winding of the pulse transformer. The output voltage of the transformer is of sufficient magnitude to break down the spark gap and short circuit the protected circuit. As an added feature of my invention, an electromagnetic device is provided which mechanically reduces the length of the spark gap simultaneously with the discharge of the charged capacitor.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, in which the single figure is a schematic diagram of an embodiment of my invention.

Referring to the drawing, there is shown an amplifier circuit 1 which is capacity-coupled to a trigger circuit 2. The output of trigger circuit 2 actuates a pulse-generating circuit 3 which breaks down the spark gap across a pair of electrodes 4, 5 and thereby short-circuits a protected circuit 5a.

Amplifier circuit 1 comprises a conventional high-gain electron discharge device 6 of the screen-grid type having an anode 7, a screen electrode or grid 8, a control electrode or grid 9, and a cathode 10. The amplification may be further increased by placing a third or suppressor electrode 11 between anode 7 and screen grid 8. Cathode 10 of device 6 is connected to ground through a source of direct current electromotive force 11a. Anode 7 of device 6 is connected to ground through a series arrangement of a plate resistance 12 and a second source of direct current electromotive force 13. A current-limiting resistance 14 connects screen grid 8 to the common connection of plate resistance 12 and source 13. Control electrode 9 of device 6 is connected to the movable contact of a potential-dividing rheostat 15 which is connected across protected circuit 5a.

Trigger circuit 2 is provided with two electron discharge devices 16 and 17. Device 16 includes a cathode 18, a control electrode 19 and an anode 20, while device 17 is provided with a cathode 21, a control electrode 22 and an anode 23. As illustrated, these devices may be included in a single twin-triode for convenience in assembly and operation. Anode 20 of device 16 is electrically connected to control electrode 22 of device 17 through a coupling resistance 24,

Similarly, anode 23 of device 17 is connected to control electrode 19 of device 16 through a coupling resistance 25. Control electrodes 19, 22 of devices 16, 17 are connected to ground through grid resistances 26, 27 respectively. Cathodes 18, 21 of devices 16, 17 are connected to cathode 10 of device 6, and a coupling capacitor 28 connects anode 7 of device 6 to control electrode 19 of device 16.

The plate impedances of trigger circuit 2 consists of an electromagnet 29 and the primary winding 30 of a pulse transformer 31 connected in series between anodes 20, 23 of devices 16, 17. A switch 32, which is held in a closed position by electromagnet 29 when the magnet is energized, and which opens when the magnet is de-energized, connects direct current source 13 across the terminals of a second electromagnet to be described later. A capacitor 33 connected in parallel with coupling resistance 24 and a capacitor 34 connected in parallel with grid resistance 27 cooperate with a normally-open switch 35 to provide a means of resetting trigger circuit 2.

Pulse generator circuit 3 comprises an electron discharge device 36, preferably of the gaseous ionization type, having an anode 37, a cathode 38, and a control electrode 39. Cathode 38 of device 36 is connected to ground and the secondary winding 40 of transformer 31 is connected between cathode 38 and control electrode 39 of device 36. Connected between cathode 38 and anode 37 of device 36 is a series arrangement of a source of direct current electro-motive force 41 and a choke 42. Connected in parallel with this series arrangement is a capacitor 43 and the primary winding 44 of a pulse autotransformer 45. The secondary winding of autotransformer 45 is connected to electrodes 4, 5. While transformer 45 is shown as an autotransformer, it will be understood that a transformer with separate primary and secondary windings may be employed if desired. A radio frequency choke 46 is provided to protect circuit 5a from high discharge voltage. A biasing spring 47 is normally held compressed by an electromagnet 48 connected across direct current source 13 by switch 32 as previously described. The position of lower electrode 5 relative to upper electrode 4 is controlled by spring 47 and electromagnet 48.

In operation, potential divider 15 is adjusted so that control electrode 9 of device 6 is maintained at a potential below cut-off when the voltage across the protected circuit 5a is less than the maximum safe operating voltage thereof. As the voltage across the protected circuit increases above the predetermined safe operating voltage, the potential of control electrode 9 increases above the cut-off potential and device 6 conducts current. The voltage drop across resistance 12 due to the flow of current therein results in a negative pulse of voltage across grid resistor 26, which stops conduction in device 16. Device 17 is simultaneously rendered conducting due to the sudden increase in potential of anode 20 and a resulting increase in the potential of grid 22. When device 16 ceases to conduct electromagnet 29 is de-energized causing switch 32 to open. Opening of switch 32 de-energizes electromagnet 48, thereby allowing spring 47 to decrease the gap between electrodes 4 and 5.

At the same time, current suddenly flowing through device 17 and primary winding 30 of pulse transformer 31 causes a pulse of voltage to appear between control electrode 39 and cathode 38 of device 36 which initiates conduction therein. Capacitor 43 which was previously charged by direct current source 41 now discharges through device 36 and primary winding 44 of pulse autotransformer 45. The high output voltage of autotransformer 45 is sufficient to break down the spark gap between electrodes 4 and 5 which then short-circuits protected circuits 5a.

Device 36 conducts for a period dependent on the value of capacitor 43, the inductance of winding 44 and choke 42, and the cut-off voltage of device 36. The inductance of choke 42 is preferably made relatively large to assure cut-off of device 36 following discharge of capacitor 43. Following restoration of normal conditions in circuit 5a and interruption of the short-circuit between electrodes 4 and 5, the trigger circuit may be reset by momentarily closing switch 32. Capacitor 43 is again charged by source 41 and the protective apparatus is thus readied for another operational cycle. While I have illustrated and described a particular embodiment of my invention, modifications thereof will occur to those skilled in the art. I desire it to be understood, therefore, that my invention is not to be limited to the particular arrangement disclosed, and I intend in the appended claims to cover all modifications which do not depart from the spirit and scope of my invention.

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

1. An overvoltage protective apparatus comprising a spark gap having a pair of electrodes in spaced relation and arranged for shunt connection across a circuit to be protected, a pulse transformer having a primary winding and a secondary winding, said secondary winding being connected in shunt relation with said gap, a capacitor, means including an inductive choke for charging said capacitor, electron discharge means connected in series relation with said capacitor and said primary winding, a trigger circuit arranged to render said electron discharge means conductive in response to a predetermined voltage signal from said circuit to be protected, said capacitor being discharged from a normally precharged condition through said electron discharge means and said primary winding when said electron discharge means is rendered conductive, a voltage being induced in said secondary winding in response to said discharge to break down said gap and substantially reduce the impedance thereacross.

2. An overvoltage protective apparatus comprising a spark gap having a pair of electrodes in spaced relation and arranged for shunt connection across a circuit to be protected, a pulse transformer having a primary winding and a secondary winding, said secondary winding being connected in shunt relation with said gap, a capacitor, means including an inductive choke for charging said capacitor, electron discharge means connected in series relation with said capacitor and said primary winding, a trigger circuit arranged to render said electron discharge means conductive in response to a predetermined voltage signal from said circuit to be protected, means cooperative with said trigger circuit and including electromagnetic means and biasing means to vary the spacing of said electrodes in response to said predetermined signal, said capacitor being discharged from a normally pre-

charged condition through said electron discharge means and said primary winding when said electron discharge means is rendered conductive, a voltage being induced in said secondary winding in response to said discharge to bring down said gap and substantially reduce the impedance thereacross.

3. An overvoltage protective apparatus comprising a spark gap having a pair of electrodes in spaced relation and arranged for shunt connection across a circuit to be protected, a radio frequency choke connected in series between said electrodes and the circuit to be protected, a pulse autotransformer having a primary winding and a secondary winding, said secondary winding being connected in shunt relation with said gap, a capacitor, means including an inductive choke for charging said capacitor, electron discharge means connected in series relation with said capacitor and said primary winding, a trigger circuit arranged to render said electron discharge means conductive in response to a predetermined voltage signal from said circuit to be protected,



means cooperative with said trigger circuit and including electromagnetic means and biasing means to vary the spacing of said electrodes in response to said predetermined signal, said capacitor being discharged from a normally precharged condition through said electron discharge means and said primary winding when said electron discharge means is rendered conductive, a voltage being induced in said secondary winding in response to said discharge to bring down said gap and substantially reduce the impedance thereacross.

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