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PROTECTIVE APPARATUS FOR HIGH VOLTAGE ELECTRICAL EQUIPMENT

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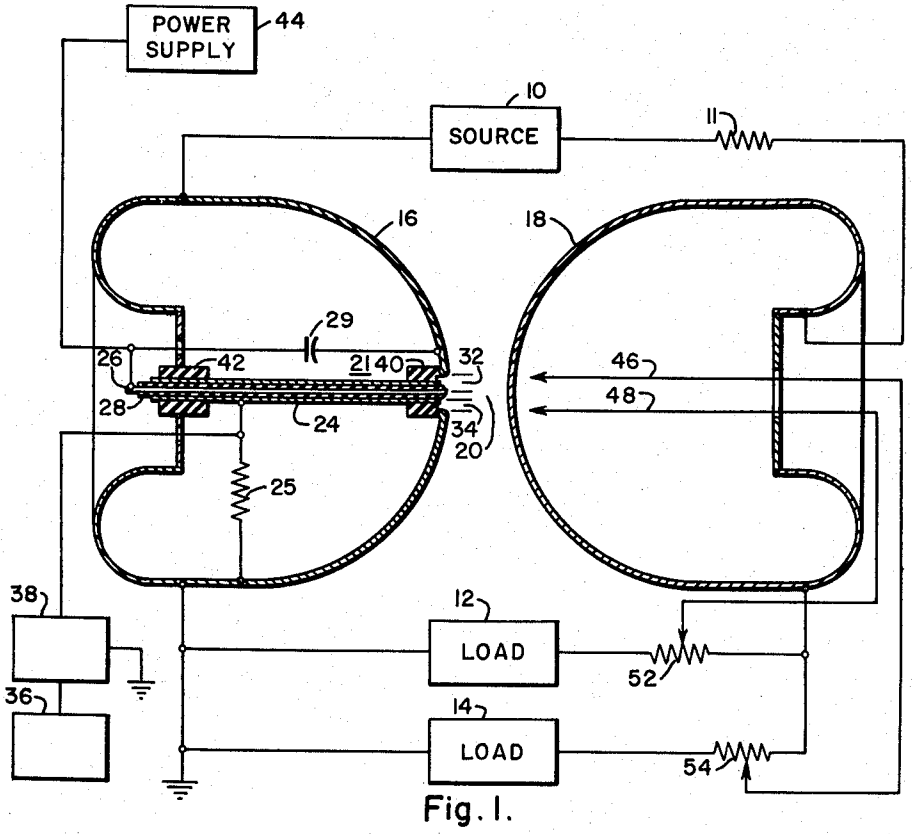


Fig. 1.

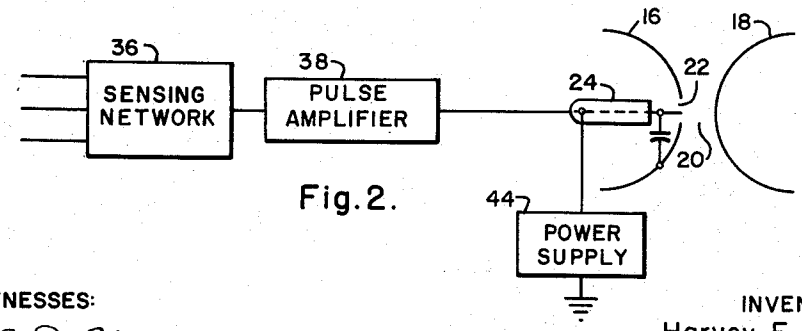


Fig. 2.

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PROTECTIVE APPARATUS FOR HIGH VOLTAGE ELECTRICAL EQUIPMENT

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The present invention relates to a discharge gap structure, and more particularly to a discharge gap structure having an improved auxiliary tripping gap electrode for controlling high voltage discharge in a main power circuit.

High voltage discharge gaps employing auxiliary or tickler electrodes mounted adjacent the face of one of the main electrodes of the discharge gap have been known in the art for some time. The so-called tickler electrode is provided to reduce the working voltage of the main gap. For example, if the spacing of the main gap electrodes is such as to cause the breakdown or sparkover of voltage at some fixed voltage, as for example 100 kv., it can be triggered by a small spark between the tickler electrode and one of the main gap electrodes so that it will break down at some lower voltage as, for example, 80 kv. The function of the tickler gap is to ionize the main discharge gap. Increasing the current increases ionization. If the current in the tickler gap is increased the voltage at which the main gap will break down is lower. In order to operate this gap upon a low voltage electrical signal from a device to be protected, or from electronic amplifiers and timers, large high power amplifiers which may introduce considerable time delays are required since it is necessary to provide extremely high current to the tickler gap.

Under certain circumstances, as for example, protecting high voltage electronic tubes of considerable size, it is desirable to provide a system which permits the gap to be fired by small electronic systems in a very short time interval.

The principal object of the present invention is to provide an improved electrode system that permits a main discharge gap to be fired by small electrical signals in extremely short time intervals.

Another object of the invention is to provide an improved discharge gap electrode system which is responsive to an initiating potential of considerably smaller magnitude than the sparkover voltage of the main gap structure.

A further object of the present invention is to provide an improved discharge gap electrode system adapted to be connected in a main circuit of high voltage in which auxiliary control electrodes are provided to substantially reduce the main sparkover potential upon a voltage signal of much lower potential than the sparkover voltage of the main gap.

Other objects and advantages of the invention will be apparent from the following detailed description, taken in connection with the accompanying drawings, in which:

FIGURE 1 is a circuit diagram including a cross-section of the discharge gap electrodes of this invention employed in a protective circuit having a high voltage source and an electron tube load; and

FIG. 2 is a block diagram of the firing circuit.

Shown in the drawings is a voltage source 10 supplying loads 12 and 14 connected in parallel. Shunted across the voltage source 10 are a pair of main discharge electrodes 16 and 18, respectively, forming a discharge gap 20. The main discharge electrodes 16 and 18 may be, preferably of spherical configuration having smooth polished surfaces of conducting material.

An opening 22 is provided centrally in main discharge electrode 16. Extending to a point adjacent the periphery of the opening 22 of the discharge gap 16 is a cylindrical tickler electrode 24 concentric with the main discharge electrode 16. Disposed within and concentric with the tickler electrode 24 is a trigger electrode 26 which may be of solid cylindrical form and which is spaced from the hollow cylindrical tickler electrode 24 by insulation 28. A current discharge means is connected between the main discharge electrode 16 and the trigger electrode 26, as for example, the discharge capacitor 29 which is of low inductance in order to provide a high current discharge in the trigger gap 32 formed by the trigger electrode 26 and the main discharge electrode 16. Another discharge gap, the tickler gap 34, is formed by the tickler electrode 24 of hollow cylindrical shape and either the main discharge gap 16 or the trigger electrode 26. Depending on the appropriate spacing and polarity the tickler discharge gap 34 may spark over either to the main discharge electrode 16 or to the trigger electrode 26. The electrode assembly 21 formed by the tickler electrode 24, the trigger electrode 26 and the insulation 28 therebetween is supported adjacent the end of the electrode assembly by an insulating member 40. The insulating member 40 adjacent the opening 22 may be an insulation disc having a central opening for receiving the electrode assembly 21.

As shown in FIG. 2, a sensing network 36 of any suitable type may be provided to sense faults or other undesirable characteristics in the voltage source or the load. When sensing network 36 detects a fault it supplies a relatively low voltage signal to a pulse amplifier 38. The pulse amplifier in turn amplifies and applies its output to the tickler electrode 24.

It can be seen, therefore, that the trigger electrode 26 when energized by the power supply 44 during the normal operating condition of the circuit maintains a voltage stress between the trigger electrode 26 and the main discharge electrode 16 in the trigger gap 32. When a low voltage pulse from the pulse amplifier is applied to the tickler electrode 24, tickler gap 34 sparks over. This sparkover ionizes the air in the trigger gap 32. The ionized air in this region reduces the sparkover potential of trigger gap 32 causing it to sparkover at its normally electrically biased potential. This sparkover in turn causes the capacitor 29, which is a low inductance capacitor, to discharge at high current relative to the tickler gap current. This high current discharge is sufficient to ionize the air in the main discharge gap thereby sufficiently reducing the sparkover potential of the main discharge gap 20 to cause it to sparkover at between fifty and eighty percent of the normal sparkover potential of the main discharge gap. Sparkover of the main discharge gap shunts the load thereby applying the source voltage across the gap. The device drops the voltage across the gap to the low arc voltage as long as current flows from the source through the gap. It should be noted, however, that the discharge gap 20 will continue to conduct until some external equipment is applied to open the source voltage circuit.

In an operating embodiment of the invention, the gap spacing of main discharge gap 20 is such as to provide a predetermined sparkover voltage during normal operation which is greater than the source voltage. The trigger electrode 26 is biased by the power supply 44 to maintain a voltage stress in the trigger gap 32 such that it is normally non-conducting. The tickler electrode 24 is connected to main electrode 16 through a high resistance 25. Thus it is electrically unbiased relative to the main

discharge electrode 16. The electrode 18 may be a simple spherical electrode having a smooth surface and of a shape and size similar or identical to the electrode 16, or it may have an auxiliary control electrode or a plurality of control electrodes, as for example control electrodes 46 and 48 as shown in FIG. 1.

As shown in FIG. 1 the loads 12 and 14 operate in parallel from the power source 10. The control electrodes 46 and 48 are operated from the tops of two similar impedance elements shown as resistances 52 and 54 so that when a fault develops in either load 12 or load 14, the voltage across the resistor in series with the load will produce a trigger spark between the corresponding one of control electrodes 48 or 46 and the main electrode 18 to fire the main discharge gap 20. The spacing between the electrode 18 and the electrode 46 as well as between 18 and the electrode 48 should be smaller than the spacing between the electrodes 46 and 48. This is essential to avoid sparkover between the two control electrodes.

The control electrodes 46 and 48 may serve to spark over the main discharge gap 20 in case of failure of the control electrode assembly 21 in the main electrode 16. They may also be employed to sense internal faults in the load to which the sensing network 36 may not be responsive. They may be responsive to a high rate of change of current in the load particularly if the impedances 52 and 54 are inductive. This type of main electrode and its associated control electrodes, illustrated by 18, 46 and 48 in the drawing, is more fully described and claimed in my copending application Serial No. 145,403, filed October 16, 1961, and assigned to the Westinghouse Electric Corporation.

While a specific electrode 18 has been shown and described for the purposes of illustration, and although this is a novel electrode which by itself or in combination with electrode 16 has many advantages, it will of course be understood that any suitable electrode 18 may be used in combination with the improved electrode 16. If desired, electrode 18 may be similar or identical to electrode 16. It may be fired by the same or other impulse signals.

In operation the particular gap described herein will operate as hereinafter described but it should be understood that the values of current, voltage and components are set forth as examples only and that other working values are possible. Then sensing network 36, upon occurrence of a fault to which it is designed to respond, will apply a 20 volt pulse to the pulse amplifier 38. From the output of the amplifier 38 a 10,000 volt signal will be applied to the tickler electrode 24.

A sparkover in the order of 100 amperes will occur in the tickler gap 34 which will in turn ionize the trigger gap. The sparkover potential of the trigger gap 32 will be reduced to less than 5000 volts, the bias potential of the trigger electrode 26 relative to the main electrode 16. The trigger gap will sparkover causing the capacitor 29 to discharge at a current in the order of 10^4 amperes. A 10^4 ampere discharge in the trigger gap 32 will ionize the main gap sufficiently to reduce the sparkover potential to a potential considerably lower than the output voltage of the source. Under these circumstances the main discharge gap 20 will sparkover, shunting the load and removing the source voltage 10 from the load 12 and 14. The main gap sparkover will occur within 8 microseconds or less after the sensing network responds to a fault at a substantially lower voltage than its normal sparkover voltage.

A current transformer may be applied to the circuit of the gap 20 to sense the current flowing through the gap thereby operating a breaker to open the voltage source.

The following circuit constants may be employed in the device shown in the drawings and are illustrative of a specific application of the invention:

Component:	Value
Current limiting resistor 11_____ohms__	6
Capacitor 29_____microfarads__	18
Voltage source 10_____kv. D.C__	300
Supply 44_____do____	5
Sensing network output_____volts__	20
Pulse amplifying network output____do____	10,000

It will be apparent that an improved high voltage discharge gap with an auxiliary control electrode assembly has been provided by this invention which incorporates the desirable features of conventional gaps and in addition has the ability to rapidly sparkover in response to a relatively low voltage signal, relative to the source voltage, without time loss due to high current electronic circuitry. A gap has been provided which permits the main gap to be fired by a small electronic system.

Certain specific embodiments of the invention has been shown and described for the purpose of illustration, but since various other embodiments and modifications are possible within the scope of the invention, it is to be understood that the invention is not limited to specific details or construction shown but in its broadest aspects it includes all equivalent embodiments and modifications.

I claim as my invention:

1. A gap assembly for electrical apparatus having a main electrical circuit, said gap assembly comprising a pair of main discharge electrodes spaced apart to form a discharge gap between them, a trigger electrode spaced from one discharge electrode of said pair of electrodes to form a trigger spark gap, a tickler electrode spaced from said trigger electrode and said one discharge electrode to form a tickler spark gap, the spacing between said pair of discharge electrodes being substantially greater than the spacing between said trigger electrode and said one discharge electrode and also substantially greater than the spacing between said tickler electrode and said one discharge electrode, and means for initiating sparkover between said tickler electrode and one of the other of said electrodes, between said trigger electrode and said one of said pair of main discharge electrodes and between said pair of main discharge electrodes, in succession.

2. A gap assembly for electrical apparatus having a main electrical circuit, said gap assembly comprising a pair of main discharge electrodes spaced apart to form a main discharge gap between them having a predetermined sparkover potential, a trigger electrode and a tickler electrode arranged concentrically and disposed adjacent said main discharge gap and spaced from one of said main electrodes a distance substantially smaller than the smallest distance between said pair of main discharge electrodes, said trigger electrode and said tickler electrode each constituting one electrode of a trigger gap and a tickler gap, respectively, means for providing a high current discharge across said trigger gap upon sparkover thereof, said tickler gap effective to sparkover at a voltage considerably lower than said trigger gap when a sufficient voltage signal is applied thereacross, said tickler gap being effective to ionize said trigger gap, thereby reducing the sparkover voltage thereof, and said high current discharge effective to cause said main discharge gap to sparkover at a potential substantially smaller than said predetermined potential.

3. A gap assembly for electrical apparatus having a main electrical circuit, said gap assembly comprising a pair of main discharge electrodes spaced apart to form a main discharge gap between them, a trigger electrode spaced from one discharge electrode of said pair of electrodes to form a trigger spark gap, a tickler electrode spaced from said trigger electrode and said one discharge electrode to form a tickler spark gap, the sparkover potential of said trigger gap normally being greater than the sparkover potential of said tickler gap and the sparkover

potential of said main discharge gap normally being substantially greater than the sparkover potential of said trigger gap, means for initiating sparkover of said tickler gap thereby reducing the sparkover potential of said main gap, means for providing a high current discharge relative to said tickler gap discharge current, upon sparkover, in circuit with said trigger gap, thereby reducing the sparkover potential of said main discharge gap.

4. A gap assembly for electrical apparatus having a main electrical circuit, said gap assembly comprising a pair of main discharge electrodes spaced apart to form a main discharge gap between them, a trigger electrode spaced from one discharge electrode of said pair of electrodes to form a trigger spark gap, a tickler electrode spaced from said trigger electrode and said one discharge electrode to form a tickler spark gap, the sparkover potential of said trigger gap normally being greater than the sparkover potential of said tickler gap and the sparkover potential of said main discharge gap normally being substantially greater than the sparkover potential of said trigger gap; a low inductance capacitance device in series with said trigger gap to provide high discharge current relative to said tickler gap discharge current, means for initiating sparkover of said tickler gap thereby reducing the sparkover potential of said trigger gap, a voltage supply for biasing said trigger gap to a potential less than its normal sparkover potential but greater than its sparkover potential subsequent to the sparkover of said tickler electrode.

5. A discharge gap device comprising a pair of main electrodes spaced apart to form a main discharge gap between them, a trigger electrode associated with one of said main electrodes and spaced therefrom to form a trigger gap therewith, the spacing of said trigger gap being less than the spacing of said main gap, means for normally maintaining said trigger electrode at a potential less than the sparkover potential of the trigger gap, a tickler electrode associated with said one main electrode and said trigger electrode, the spacing between the tickler electrode and said one main electrode and between the tickler electrode and the trigger electrode being less than the spacing of said main gap to form a tickler gap, and means for applying a voltage to the tickler electrode to effect sparkover of the tickler gap with resultant rapid, successive sparkover of the trigger gap and the main gap.

6. A discharge gap device comprising a pair of main electrodes spaced apart to form a main discharge gap between them, a trigger electrode associated with one of said main electrodes and spaced therefrom to form a trigger gap therewith, the spacing of said trigger gap being less than the spacing of said main gap, a capacitor connected across the trigger gap, means for charging said capacitor to a voltage less than the normal sparkover voltage of the trigger gap, a tickler electrode associated with said one main electrode and said trigger electrode, the spacing between the tickler electrode and said one main electrode and between the tickler electrode and the trigger electrode being less than the spacing of said main gap to form a tickler gap, and means for effecting sparkover of the tickler gap to cause discharge of said capacitor across the trigger gap with resultant rapid sparkover of the main gap.

7. A discharge gap device comprising a pair of main electrodes spaced apart to form a main discharge gap between them, the opposed surfaces of said main electrodes being generally spherical, a hollow tickler electrode mounted coaxially of the spherical surface of one of the main electrodes and insulated therefrom, one end of the tickler electrode being disposed adjacent a central opening in said one main electrode and spaced therefrom a distance substantially less than the spacing of the main gap, and a trigger electrode mounted coaxially within said hollow tickler electrode and insulated therefrom, one end of the trigger electrode being disposed adjacent said one end of the tickler electrode and spaced therefrom a distance substantially less than the spacing of the main gap.

References Cited in the file of this patent

UNITED STATES PATENTS

2,508,954	Latour et al.	May 23, 1950
2,946,923	Fitch	July 26, 1960
3,030,547	Dike et al	Apr. 17, 1962