

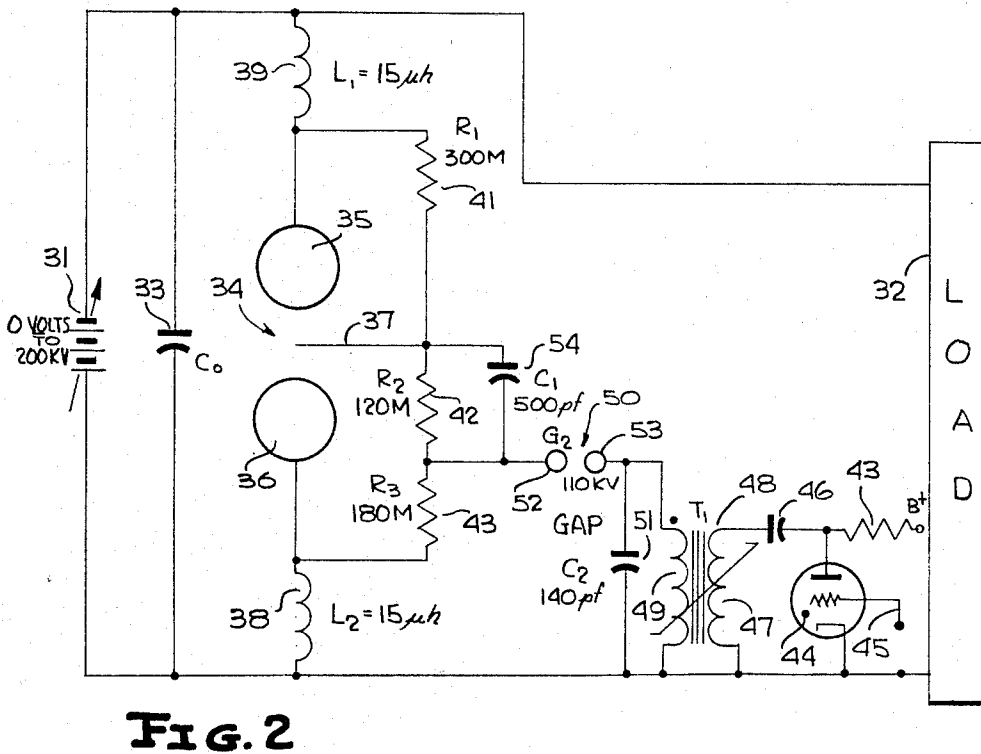
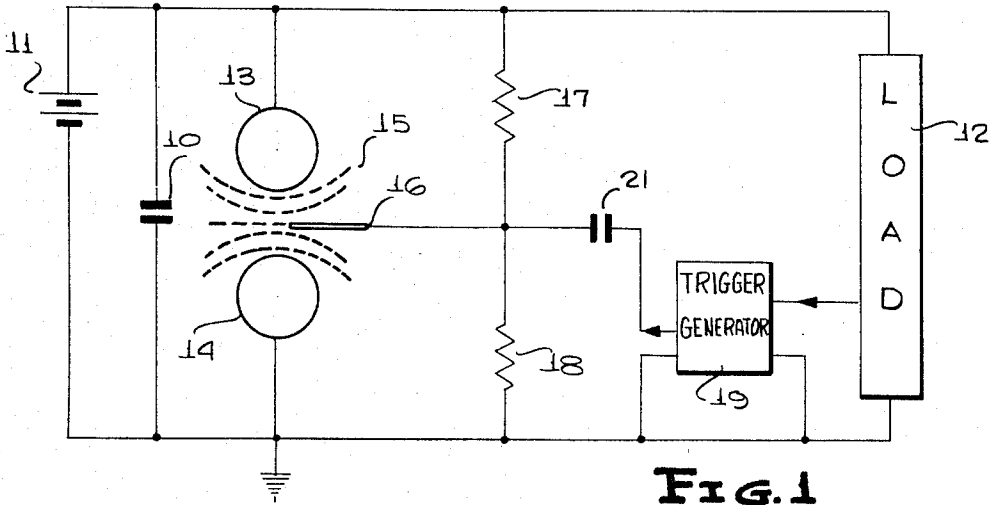
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TRIGGERED ARC GAP OPERABLE OVER A WIDE RANGE OF
SUPPLY VOLTAGE VARIATIONS

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1

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TRIGGERED ARC GAP OPERABLE OVER A WIDE RANGE OF SUPPLY VOLTAGE VARIATIONS

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The present invention relates generally to systems for projecting load circuit from high voltage D.C. power supplies when a load fault occurs and more particularly to a protection system employing an arc gap which includes a pair of opposed electrodes and an intermediate trigger electrode.

In high voltage systems, e.g. high power transmitters, it is necessary to quickly and reliably cut-off the flow of current to the load when a fault occurs therein by diverting the current of the high voltage D.C. power supply from the load. For optimum utilization with high power transmitters, it is required that the fault current be diverted from the load over very wide voltage variations of the supply. This is because with large power supplies, loads can be destroyed by fault currents which flow even when the supply is running at a small percentage of its full rated voltage. Accordingly, it is necessary that the diverting apparatus be capable of operating over wide voltage variations without the need for mechanical or electrical adjustments.

The present invention provides a fault current diverter having these attributes by utilizing an arc gap discharge device. While I am aware of the prior use of arc gap discharge devices as fault diverters, I know of no arc gap device capable of achieving the great variations in voltage ranges which the present system attains. In addition, the present device is relatively simple, reliable, and is capable of being repetitively fired without deleterious effects on its components.

In the present device, the arc gap device includes a pair of opposed spherical electrodes connected across the high voltage source and an intermediate needle electrode located on the equipotential plane equi-distant from the spheres. The needle is normally biased to the same potential as the plane in which it lies so that it causes no distortion of the electric field between the spheres. When a fault occurs, a pulse of sufficient magnitude to break down the gap between the needle electrode and one of the spheres is coupled to the needle. This causes the needle to be maintained at the same potential as the specified sphere, hence the supply potential, which potential is sufficient to break down the gap between the needle and the other sphere. With this arrangement it is possible to achieve triggering without substantial needle erosion over power supply voltage variations in excess of four to one.

In another embodiment, arc gap triggering is obtainable over an infinite range of power supply voltage variations. This is accomplished by modifying the basic device to include an oscillatory source having both positive and negative peak amplitudes in excess of the needle to sphere breakdown voltage. The oscillatory source includes an auxiliary arc gap connected in series with a capacitor and a separate inductance connected between each sphere and a terminal of the supply.

For very low supply voltages, an arc is struck between the needle and either one of the spheres when the auxiliary gap breaks down. Due to the inductance, the conducting sphere is maintained at the needle potential, not the potential of the supply terminal to which it is connected. In consequence, an arc is then formed between the needle and the other electrode and the current from the supply is diverted. For slightly larger supply potentials, i.e. those less than one quarter of the arc gap breakdown,

2

the positive and negative swings of the oscillatory voltage establish the arcs between the needle and the spheres. As the supply voltage increases beyond one quarter of the designed gap breakdown potential, the arc is established between the needle and spheres in the same manner as in the first embodiment.

It is accordingly an object of the present invention to provide a new and improved high voltage fault diverter capable of functioning over wide ranges of input potential.

Another object of the present invention is to provide a new and improved high voltage fault diverter which is simple, reliable, and is capable of being repetitively fired without deleterious effects on its components.

An additional object of the present invention is to provide an arc gap fault diverter employing a pair of opposed electrodes and an intermediate needle electrode which is not subject to erosion even though it is repetitively fired and the D.C. power supply to be diverted varies over a wide voltage range.

A further object of the present invention is to provide an arc gap fault diverter capable of satisfactory operation over an infinite range of D.C. power supply voltages to be diverted.

Yet an additional object of the present invention is to provide an arc gap fault diverter having a pair of opposed electrodes and an intermediate triggering electrode which is biased so that it does not normally distort the electrostatic field between the opposed electrodes.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a circuit diagram of one embodiment of the present invention in which satisfactory triggering occurs with supplies varying over a voltage range of at least 4 to 1; and

FIGURE 2 is a circuit diagram of another embodiment of the present invention in which satisfactory triggering occurs with supplies varying over an infinite voltage range.

Reference is now made to FIGURE 1 of the drawing upon which is illustrated a high voltage D.C. power supply 11 that is connected to high voltage load 12, e.g. a high power radio transmitter, and filter capacitor 10. Connected to the terminals of supply 11 is a pair of opposed spherical, metal electrodes 13 and 14 which form an arc gap. With the supply 11 connected across electrodes 13 and 14, a plurality of equipotential surfaces 15 are formed. At the equipotential plane equidistant from spheres 13 and 14, a needle electrode 16 is positioned. Needle 16 is biased by a voltage divider which includes equal value resistors 17 and 18 having their opposite ends connected across the terminals of supply 11 and their common terminal connected to the needle. Thereby, needle 16 is maintained at the same potential as the equipotential plane between electrodes 13 and 14 and there is normally no distortion of the hold-off characteristics between spheres 13 and 14. Thus, the needle does not lower the breakdown voltage between spheres 13 and 14.

It is to be understood that each of the circuit elements is sufficiently removed from the gap so they negligibly affect the electric field between electrodes 13 and 14.

Trigger generator 19 has its input terminals connected to load circuit 12 so that it develops a large voltage change of a polarity opposite to that of source 11, i.e. negative, in response to a fault being sensed in the load. The high voltage change is coupled as an arc gap firing impulse through capacitor 21 to trigger electrode 16. In response to this pulse being applied to needle electrode 16, the electrostatic field configuration between electrodes 13 and 14 is changed so that breakdown between needle 16 and sphere 13 is determined by the needle point to sphere

geometry and the potential difference between electrodes 13 and 16.

The voltage coupled through capacitor 21 is sufficiently negative to drive needle 16 to a low enough potential so that breakdown between the needle and sphere 13 is achieved. This causes a short circuit to develop between sphere 13 and needle 16, thereby bringing the latter to the positive potential of supply 11. Since the potential of supply 11 is sufficiently great to cause breakdown between sphere 14 and needle 16, another arc is struck between these electrodes. Thereby, an arc is formed between electrodes 13 and 14 and the voltage of supply 11 is shunted to ground and is prevented from reaching load 12.

In proper operation, the arcs between needle 16 and spheres 13 and 14 only form off of the tip of the needle, thereby limiting current conduction through the needle to the current coupled through capacitor 21 in response to trigger generator 19 activation. Accordingly, needle erosion is very slight and long life is attained. It has been experimentally noted that when the gap is triggered near the lower voltage extreme of its designed breakdown there is a possibility of at least one of the arcs being formed on the needle at a point other than at its tip. The resulting erosion due to conduction through the needle has not been excessive particularly when it is realized that the possibility of load faulting is considerably reduced for low power supply voltages. In a system designed to operate with supplies which vary between 50 kv. and 200 kv., no needle erosion was observed when a bank of 20 microfarad capacitors charged to 150 kv. was discharged through the gap twenty times. When the same gap was used to discharge a 20 microfarad capacitor bank maintained at 50 kv., the slight needle erosion was not deleterious.

Reference is now made to FIGURE 2 of the drawing upon which is illustrated D.C. power supply 31, having variable capabilities between zero and -200 kv. Connected across supply 31 is a load 32, a voltage filtering capacitor 33, and an arc discharge device 34. Arc discharge device 34 is identical with the arc discharge device of FIGURE 1 and includes opposed spherical electrodes 35 and 36, as well as needle electrode 37 which is positioned in the equipotential plane equidistant from the spheres.

Connected between electrodes 35 and 36 and the positive and negative supply terminals are equal valued inductances 38 and 39, respectively. A voltage divider including series connected resistors 41, 42 and 43 is connected between electrodes 35 and 36. The resistor values are selected so that the tap between resistances 41 and 42, connected to needle 37, is normally maintained at one half the supply potential for the same reasons discussed in connection with FIGURE 1.

To trigger electrode 37 when a fault occurs in load 32, a positive voltage is coupled to the control grid of thyatron 44 via lead 45. The anode of thyatron 44 is connected to a source of B+ via load resistor 43 while the cathode thereof is connected directly to ground. Connected between the anode and cathode of thyatron 44 is a coupling capacitor 46 and the primary winding 47 of step-up transformer 48.

The secondary winding 49 of transformer 48 is connected across energy storage capacitor 51 so that a phase inversion of the signal coupled to winding 47 occurs across the secondary, as indicated by the dot convention on the drawing. Connected to secondary winding 49 is an auxiliary arc gap 50 which includes spherical electrodes 52 and 53 and is designed to break down at a predetermined voltage, e.g. 110 kv. for source 31 having a maximum value of -200 kv. Pulse coupling capacitor 54 is connected between electrode 52 and needle 37 across resistor 42 so that the pulse developed when auxiliary arc gap 50 breaks down is fed to the needle.

In operation, thyatron 44 is rendered conductive when

a fault occurs in the load so that a negative voltage pulse is coupled to primary winding 47 via capacitor 46. This negative voltage pulse is increased in amplitude and inverted in phase by transformer 48. The voltage across secondary 49 builds up a potential across capacitor 51 of sufficient magnitude to break down auxiliary gap 50 in about 0.75 microsecond. In consequence, a positive 110 kv. pulse is coupled through capacitor 54 to needle electrode 37. If supply 31 is at zero potential at this time, there is equal probability of arcing between the needle and either of spheres 35 or 36. If it is assumed that an arc is struck between the needle 37 and sphere 35, a short circuit is developed between these electrodes and the sphere is maintained at the needle potential. The needle does not assume the normal potential of sphere 35 because inductance 39 is a substantially infinite impedance to the very high frequency current in the arc as it is formed. Accordingly, the sudden voltage change coupled to sphere 35 appears across inductance 39 and the needle and sphere potentials are substantially +110 kv. With needle 37 at this potential, an arc is then formed between it and sphere 36 so that a discharge path is established between the opposite terminals of supply 31.

As the magnitude of supply 31 is increased to drive upper sphere 35 to more negative D.C. potentials, the probability of arcing to this sphere is increased. Also, it becomes more difficult to pull sphere 35 and needle 37 to the large positive potential necessary to strike an arc between the needle and lower sphere 36. However, the trigger signal applied to sphere 35 is oscillatory at a frequency determined substantially by inductance 39 and the series combination of capacitances 51 and 54. Since the arc maintains both electrodes 35 and 37 at the same potential, they will both be negative with respect to sphere 36 at the end of one half cycle of trigger oscillation by a voltage sufficient to break down the gap between needle 37 and sphere 36. This voltage equals that of source 31 plus a large fraction of the break down voltage between electrodes 52 and 53, the fraction being determined by the amount of oscillation damping.

Capacitor 51 and the auxiliary arc gap provide a source of sufficiently high amplitude trigger pulses and of low enough output impedance to insure reliable arcing between spheres 35 and 36 for any values of source 31. The oscillatory triggering action established by inductance 39 and capacitors 51 and 54 is needed only for the first quarter of the possible ranges of supply 31, i.e. between 0 and 50 kv. for a main arc gap designed for 200 kv., because triggering will occur as described in connection with FIGURE 1 for higher voltages. In consequence, the maximum voltage applied to needle 37 need not be much in excess of one-half of the designed arc breakdown.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. A system for protecting a load circuit from a high voltage source when a fault occurs in the load circuit, comprising:

an arc gap discharge arrangement including a pair of opposed spherical electrodes and an intermediate needle electrode;

means for connecting said opposed spherical electrodes to opposite terminals of said source for causing an electric field to be produced between said opposed electrodes;

said connecting means comprising inductance means serially connected between each of said opposed electrodes and a respective terminal of said source;

said intermediate electrode being physically disposed only on an equipotential surface of said electric field; means for normally maintaining said intermediate elec-

5

trode at the potential of said equipotential surface whereby said electric field between said opposed electrode is not disturbed;

trigger means for changing the potential of said intermediate electrode so as to distort said electric field when a fault occurs in the load circuit, said trigger means including a voltage pulse generating means having a supply of power independent of said high voltage source, whereby said protection system is operative over a wide range of voltage variations of said high voltage source.

2. The system according to claim 1 wherein said intermediate electrode is physically disposed on the plane equidistant from said opposed electrodes.

3. The system according to claim 1 wherein said means for normally maintaining said intermediate electrode at the potential of said equipotential surface comprises a voltage divider electrically connected across said pair of opposing electrodes and having a voltage tap connected to said intermediate electrode.

4. The system according to claim 3 wherein said voltage divider comprises a tapped resistance connected across said pair of opposing electrodes.

5. The system according to claim 1 wherein said trigger means includes first and second auxiliary spark gap electrodes electrically coupled to said intermediate electrode and said voltage pulse generating means respectively, said generating means being responsive to a fault in the load circuit to fire said auxiliary spark gap electrodes whereby said normal potential on said intermediate electrode is changed sufficiently to cause a discharge between said intermediate electrode and one of said opposing electrodes.

6. The system according to claim 5 wherein said gen-

6

erating means comprises an electric discharge device having an anode, a cathode, and a control electrode; said anode and cathode being electrically connected in circuit relation to said independent supply of power and to means coupling said discharge device to said auxiliary spark gap electrodes;

said discharge device being triggerable through said control electrode in response to the occurrence of a fault in said load circuit.

7. The system according to claim 6 wherein said coupling means includes a transformer means having a primary and a secondary winding; said primary winding being in series circuit relation to said anode and said cathode; a capacitance connected in shunt across said secondary winding and electrically coupled to said second auxiliary electrode; and said first auxiliary electrode being capacitively coupled to said intermediate needle electrode.

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