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REDUNDANT TRIGGERING CIRCUIT FOR A CROWBAR ARC DISCHARGE SWITCH

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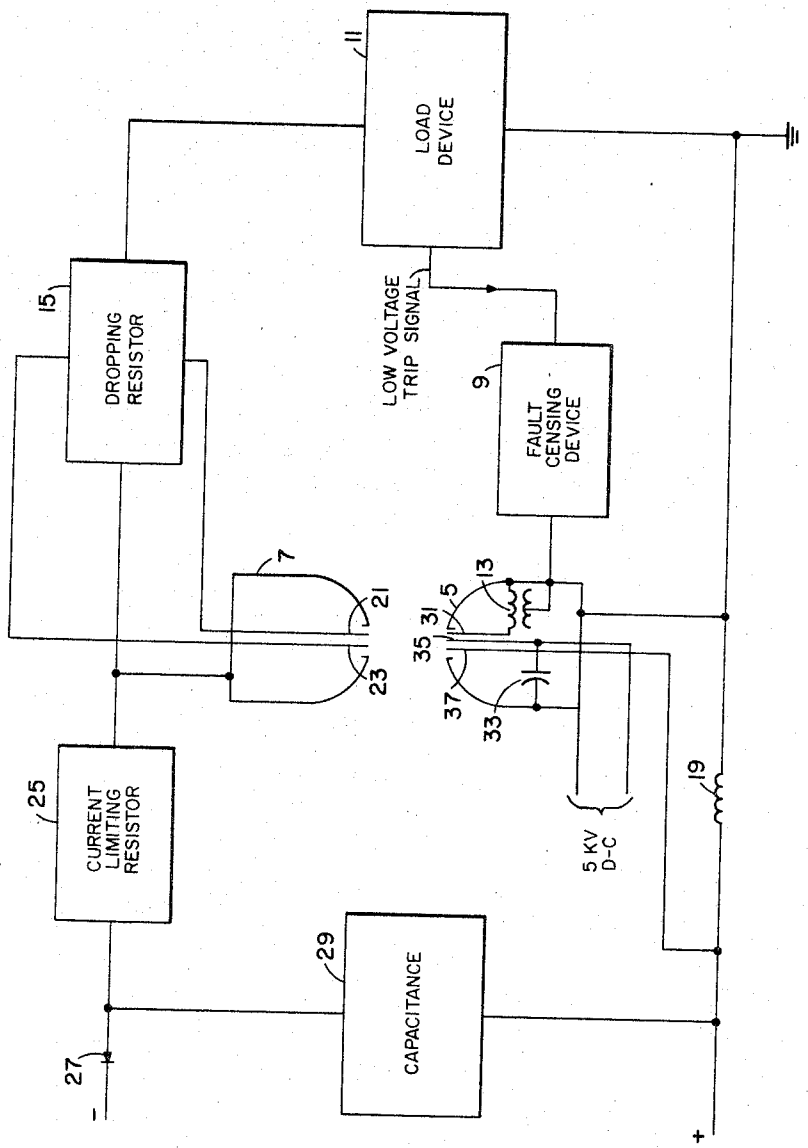

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REDUNDANT TRIGGERING CIRCUIT FOR A CROWBAR ARC DISCHARGE SWITCH

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ABSTRACT OF THE DISCLOSURE

A crowbar arc discharge switch having a plurality of arc triggering electrodes for its arc discharge electrodes. The various triggering electrodes trigger the arc in response to various undesirable changes in voltage and current.

The invention described herein relates to a triggering circuit for an arc discharge switch and more particularly to a redundant triggering circuit for a crowbar arc discharge switch.

In the application of a crowbar arc discharge switch an arc is created in the sphere gap between two arc discharge spheres to establish an arcing short circuit across a load device thereby creating a discharge path for the energy stored in a capacitor bank to prevent damage to the load device under fault conditions. As damage in the load is directly proportional to the time required to apply the crowbar fault, the speed of fault detection and triggering of the crowbar arc is of prime importance.

In order to shorten this time of fault detection and triggering, there is needed a redundant triggering circuit which will detect a fault and initiate a crowbar arc in less than the present minimum time of approximately 6 microseconds, thus improving the performance of the crowbar arc discharge switch in protecting load devices from the energy stored in a capacitor bank or available in the power circuit supplying the load.

In view of these facts, an object of this invention is to provide a faster operating crowbar arc discharge switch.

Another object of this invention is to provide a more reliable crowbar arc discharge switch.

A further object of this invention is to provide a device which employs the inductive voltage generated in an inductance device connected in series with the load to trigger the crowbar arc gap.

Various other objects and advantages will appear from the following description of the preferred embodiment of the invention, and the most novel features will be particularly pointed out hereinafter in connection with the appended claims and the accompanying drawing of the claimed invention where in the single figure is a schematic illustration of a preferred embodiment of the invention.

In the preferred embodiment of the present invention a crowbar arc is established between arc discharge spheres **5** and **7** to relieve a sensed fault condition in a connected load device. The arc is triggered redundantly by a fault sensing device **9** connected between the load device **11** and impulse transformer **13**, a voltage rise across a dropping resistor **15**, and a voltage rise due to inductance **19** in the current return path.

Referring now to the drawing, arc discharge spheres **5** and **7** are disposed adjacent forming an arc discharge switch. The switch is connected in parallel with load device **11**, with arc discharge sphere **7** connected to the negative side of load **11** and arc discharge sphere **5** connected to the positive grounded side of load **11**. A dropping resistor **15** is connected between sphere **7** and load **11**, with taps at predetermined points on resistor **15** connected to electrodes **21** and **23** disposed in an aperture in sphere **7**. A potential source is connected across the arc discharge switch with the negative side connected to sphere **7** and the positive side to sphere **5**. Connected between sphere **7** and the negative side of the potential source is current limiting resistor **25** in series with diode **27**. A capacitance bank **29** is connected between diode **27** and resistor **25** and the positive side of the potential source. An inductance **19** is connected between the positive side of the potential source and sphere **5**. This inductance may be the inherent inductance of the conductor itself or added inductance in the form of a coil or iron coupled around the conductor. This value of inductance should be approximately 3 microhenries for optimum performance. Arc discharge sphere **5** has electrodes **31**, **35** and **37** disposed in an aperture in sphere **5** and connected to form a trigger arc in the vicinity of the arc gap. An impulse transformer **13** has its output coil connected between electrode **31** and sphere **5**. The input coil of transformer **13** is connected to a fault sensing device **9** which is triggered by a low voltage trip signal responsive to a fault in load device **11**. A capacitance **33** is connected between electrode **35** and sphere **5** and is charged by a 5 kilo-volt D-C source connected thereto. Electrode **37** is connected to the positive side of the potential source and senses the inherent L *di/dt* voltage rise due to the rapid change of current flow through inductance **19** when a fault occurs in load device **11**.

Referring back to fault sensing device **9**, a thyratron is used in the preferred embodiment to actuate impulse transformer **13**. The thyratron is turned on by a low voltage trip signal detected in load device **11**.

In operation, when a fault condition occurs in load device **11**, there is a rapid increase in current flow through the circuit. This increased current flow through dropping resistor **15** impresses a voltage between the electrodes **21** and **23** and arc discharge sphere **7** and the electrodes are so disposed to initiate a trigger arc when the fault current reaches a predetermined value. This means of triggering an arc is delayed an equivalent amount of time for the fault current to reach a predetermined valve at which the voltage drop across the tapped dropping resistor **15** is adequate to initiate the trigger arc plus the time for the crowbar arc to be established. Further, a low voltage fault signal initiates "firing" of the grid of a hydrogen thyratron fault sensing device **9** which dumps energy into the primary of impulse transformer **13** resulting in a secondary voltage of about 20,000 volts to initiate a trigger arc between electrode **31** and sphere **5**, thus ionizing the gap of electrode **35** and sphere **5** causing a high-current discharge of capacitor **33**. This blast into the sphere gap initiates the main crowbar arc in the overall time of 8–12 microseconds.

Still further, to shorten the time required to establish the main crowbar arc a third electrode **37** is disposed in the aperture in sphere **5**. When a fault occurs in the load circuit, the resultant high rate-of-change of current through the inductance **19** will cause a rapid rise in the potential between electrode **37** and sphere **5**. This L *di/dt* voltage will cause a discharge which will ionize the capacitor **33** trigger gap thereby initiating the high-current blast from the discharge of capacitor **33** and the arc in the crowbar sphere gap. All of these triggering means together provide a redundant triggering circuit for a crowbar arc discharge switch which will operate in less than 6 microseconds.

Referring back to electrode **37**, it is also noted that the circuit would operate by connecting electrode **37** to the grounded side of the load device and connecting an inductance between sphere **5** and load device **11**, thus reversing the polarity of electrode **37** with respect to sphere **5**. Although the circuit would operate in this manner, the time would be longer and the range of voltage

over which it would operate reliably for any gap setting would be lower.

It is to be understood that the form of the invention that is herein shown and described is to be taken as a preferred example of the same, and that various changes and modifications may be resorted to, without departing from the spirit of the invention, or the scope of the subjoined claims.

What is claimed is:

1. A crowbar arc discharge switch for protecting a load device comprising: a crowbar arc gap having first and second arc discharge spheres disposed adjacent; an aperture in each of said first and second arc discharge spheres at their closest points; and an arc triggering means having a plurality of electrodes disposed predeterminately in said apertures whereby said electrodes establish an arc responsive to at least one of a plurality of voltages induced across said electrodes upon the occurrence of a fault in a load device, said arcs ionizing said crowbar arc gap.

2. The device as set forth in claim 1, wherein said electrodes of said arc triggering means includes first and second electrodes in said aperture of said first arc discharge sphere; a tapped dropping resistor connected in series with said load device; and said electrodes connected to said taps on said dropping resistor.

3. The device as set forth in claim 1, wherein said electrodes of said triggering means includes first and second electrodes disposed in said aperture of said second arc discharge sphere; an impulse transformer having its output connected between said first electrode and said second arc discharge sphere; a fault signal input means responsive to a fault in said load device connected to the input of said impulse transformer; a capacitance connected between said second electrode and said second arc discharge sphere; and a D-C potential connected across said capacitance for charging said capacitance; whereby upon detection of a fault in said load device an arc is established between said first electrode of said second arc discharge sphere and said second arc discharge sphere thus ionizing the region allowing the capacitance to discharge forming an arc between said second electrode of said arc discharge sphere and said arc discharge sphere.

4. The device as set forth in claim 2, wherein said trigger means further comprises: a third electrode disposed in said aperture of said second arc discharge sphere; said load device having one end connected to ground potential; said crowbar arc discharge switch being connected in parallel with said load device; said second arc discharge sphere connected to said grounded side of said load device; said first arc discharge sphere being connected to the other side of said load device; a potential source connected across said load device; an inductance connected in between said second arc discharge sphere and said potential source; and said third electrode of said second arc discharge sphere being connected to said potential source whereby an ionization arc is established between said third electrode of said second arc discharge sphere and said second arc discharge sphere due to the induced voltage in said first and second inductances from a fault current flowing through said inductance.

5. A redundant triggering circuit for a crowbar arc discharge switch which detects faults in a load device and initiates a crowbar arc thereby creating a discharge path for energy available to the load device comprising: a crowbar discharge switch having a first arc discharge sphere and a second arc discharge sphere; a negative potential source; a series circuit consisting of a diode connected in series with a current limiting resistor; said series circuit being connected between said first arc discharge sphere and said negative potential source; a load device connected between one side of a tapped dropping resistor and ground potential; another side of said tapped dropping resistor connected to said first arc discharge sphere; said second arc discharge sphere connected to said ground potential; a positive potential source; an inductance connected between said positive potential source and said second arc discharge sphere; a capacitance bank connected to a junction between said diode and said current limiting resistor and said positive potential source; said first and said second arc discharge spheres being disposed in close proximity forming an arc gap; said first arc discharge sphere having an aperture therethrough located at a point closest to said second arc discharge sphere; said first arc discharge sphere further comprising a first and a second electrode disposed in said aperture in said first arc discharge sphere; said first and said second electrode being connected to taps on said dropping resistor, whereby the potential rise due to a fault current passing through said dropping resistor will be apparent at said first and said second electrodes for aiding in initiating an arc discharge by creating a trigger arc when the fault current reaches a predetermined value; said second arc discharge sphere having an aperture therethrough located at the point closest to said first arc discharge sphere; said second arc discharge sphere further comprising a first, second and third electrode predeterminately disposed in said aperture in said second arc discharge sphere; an impulse transformer having its output coil connected between said first electrode and said second arc discharge sphere; a fault signal input means connected to the input of said impulse transformer; a capacitance between said second electrode and said second arc discharge sphere; a D-C source connected across said capacitance for charging said capacitance; and said third electrode being connected to said positive potential source, whereby when a fault occurs in said load device, the resultant high rate-of-change of current through said inductance causes a rapid rise in the potential between said second arc discharge sphere and said third electrode, thus causing an arc between said second arc discharge sphere and said third electrode of said second arc discharge sphere which ionizes the gap between said first electrode and said second electrode of said second arc discharge sphere, thus allowing said impulse transformer and said capacitance to establish a trigger arc between said first arc discharge sphere electrodes and said second arc discharge sphere electrodes, thus establishing an arc between said first arc discharge sphere and said second arc discharge sphere to relieve a fault condition in said load device.

6. A device as set forth in claim 5 wherein said fault signal input means is a thyratron responsive to a low voltage trip signal; and said trip signal derived from a fault in said load device.

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