

April 17, 1962

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3,030,547

HIGH VOLTAGE, HIGH CURRENT SPARK GAP SWITCH

Filed May 24, 1960

2 Sheets-Sheet 1

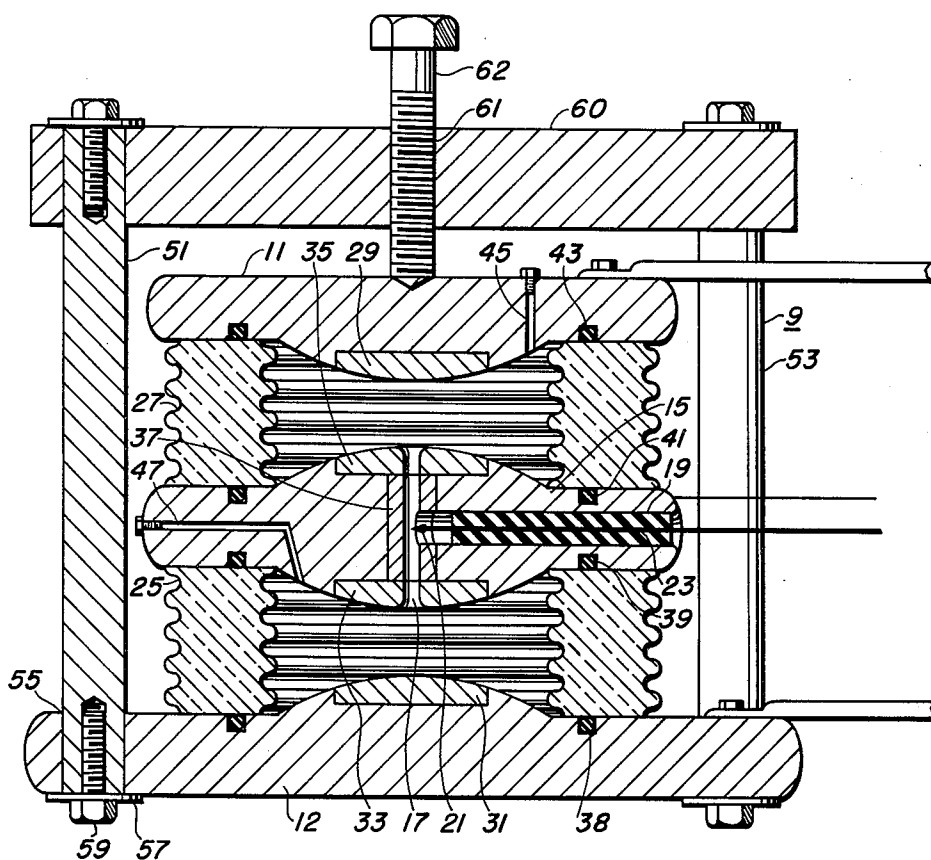


Fig. 1

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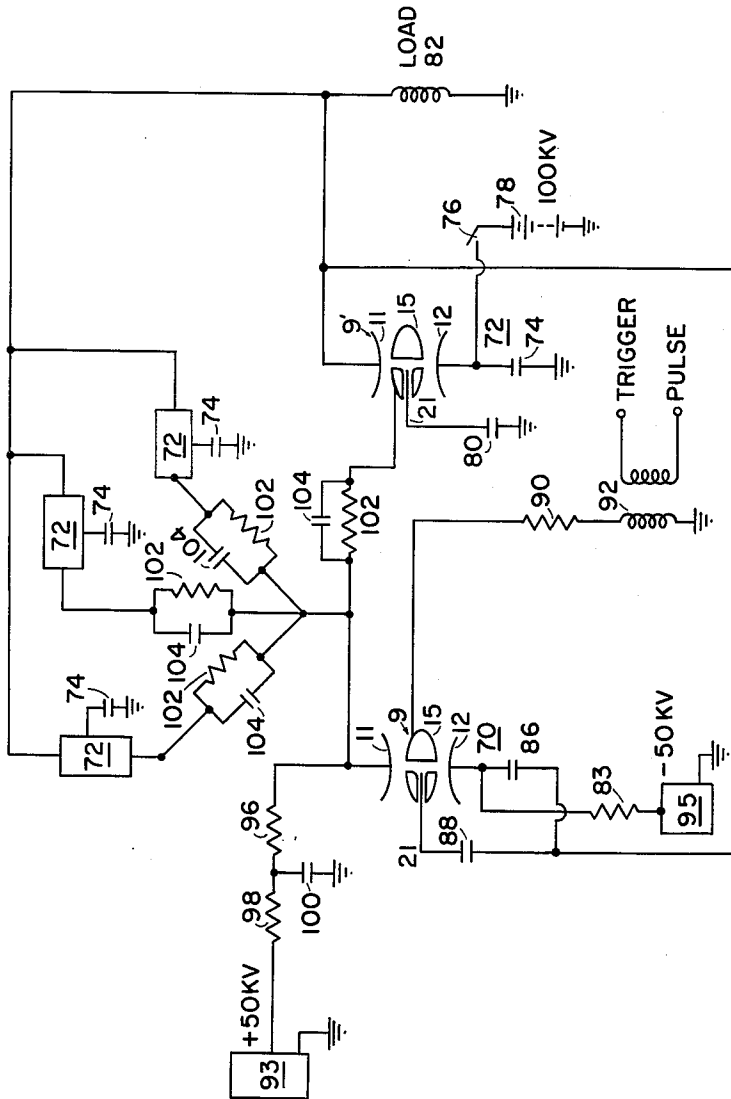


Fig. 2

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HIGH VOLTAGE, HIGH CURRENT SPARK
GAP SWITCH

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United States Atomic Energy Commission
Filed May 24, 1960, Ser. No. 31,502
10 Claims. (Cl. 315-168)

The present invention relates to an improved triggered spark gap switch particularly adapted for the switching of very large amounts of power with precise time control.

For high power circuits, there have been developed various gaseous discharge devices, such as the thyatron and ignitron, for controlling the time of circuit switching; however, these devices are limited in power capacity so that for the precise switching of even greater power the spark gap is more suitable. Hitherto, a hindrance to the use of spark gap switches has been the inability to obtain exact timing of discharge and to prevent spurious discharge where large amounts of power are to be switched.

The present invention provides a spark gap switch which overcomes the above-mentioned and other deficiencies of the spark gap switches of the prior art through the accomplishment of the following objectives.

It is an object of the present invention to provide a spark gap switch which has precisely controllable firing time while switching very large amounts of power.

It is another objective of the present invention to provide a spark gap switch which may be utilized to switch a source of power and to be used in conjunction with a plurality of similar arrangements and to permit the precise simultaneous switching of all of such arrangements.

Still another object of the present invention is to provide an improved spark gap switch having a structure such that spurious arcing is avoided.

Another object is to provide a spark gap switch having a structure such that it does not appreciably deteriorate through many operations.

Numerous other advantages and possible objects of the invention will become apparent to those skilled in the art from the following description of a preferred embodiment of the invention taken together with the accompanying drawing.

In the drawing, FIGURE 1 is a longitudinal sectional view of the switch and FIGURE 2 is a schematic circuit diagram showing a manner of utilization of the switch.

The spark gap switch of the present invention in general comprises three main electrodes and an irradiation electrode. The switch is versatile in that it is adaptable for operation at any selected working potential merely by selecting appropriate length insulators for separating and supporting said electrodes. The three electrodes are so supported that one of the electrodes, hereinafter termed "the middle electrode," is supported midway between the other two electrodes. This middle electrode, which is normally maintained at a potential intermediate the outer electrodes, is provided with a central axial aperture and a radial aperture. An irradiation electrode is insulatingly supported in the radial aperture with its firing tip extending into the axial aperture. The application of a negative pulse on the middle electrode results in two operations.

The potential between the middle electrode and one of the end electrodes is increased to or beyond the breakdown value of the gap, and the irradiation electrode being held at the original potential of the middle electrode is caused to generate a burst of ionized gas in said perforation at the same time. The practically instantaneous change of potential of said middle electrode to that of

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the end electrode, with which it is in conducting relation, establishes the full potential between the said middle electrode and the other end electrode and this, plus the ionized atmosphere, completes the practically instantaneous discharge throughout the spark gap switch, that is, from one end electrode to the other.

Referring to the drawing for a consideration of the invention in detail, the illustrated spark gap switch 9 is seen to include a pair of circular plano-convex end electrodes 11 and 12 which are axially aligned and spaced apart with convex surfaces in opposed relation. Intermediate these electrodes and aligned with the same is a middle convex-convex electrode 15. Middle electrode 15 is provided with an axial aperture 17 aligned with the axis of electrodes 11 and 12. Middle electrode 15 is also provided with a radial aperture extending from the axial aperture through its perimeter. Supported insulatingly within the radial aperture is an irradiation electrode 21. The irradiation electrode is supported within electrode 15 by a thick sheath of insulation 23. Although various insulation materials may be used to support the irradiation electrode, it has been found that insulation material consisting essentially of mica is most durable and is therefore preferred.

Electrodes 12 and 15 are spacedly supported in alignment by a cylindrical insulator 25. Electrodes 15 and 11 are likewise supported in insulated spaced relation by cylindrical insulator 27. In the embodiment shown, substantial currents of the order of thousands and even millions of amperes are switched, thereby necessitating electrode faces which can sustain localized heating without deterioration. To this end, electrodes 11 and 12 are provided with tungsten alloy inserts 29 and 31, respectively, and electrode 15 is provided with tungsten alloy inserts 33 and 35. The cylindrical perforation of electrode 15 is also provided with a tungsten alloy sleeve 37.

The tungsten alloy is a powder metallurgy product hydrostatically pressed and sintered. It has a density of approximately 16.5 and contains 89.3% tungsten, 3.0% copper, 7.0% nickel and 0.7% zirconium. This material has sustained little or no appreciable pitting after considerably more than 5,000 switching operations at 150,000 amperes.

In some circumstances of utilization it is desirable to seal and partially evacuate or pressurize the spark gap switch, in which case O-rings 38, 39, 41 and 43 are provided to hermetically seal the contacting surfaces of the electrodes with the insulators. Also, in some instances of utilization it is desirable to purge the interior of the switch of nitrous oxide or other gases and to this end purge passages 45 and 47 are provided. The entire switch assembly is compressed and held together by a stirrup of insulating material. The stirrup comprises at least two columns 51 and 53 of dielectric material. These columns are secured to the base end electrode of the switch by any suitable means, such as apertures 55, washers 57 and bolts 59. A heavy bar 60, which may be metal or dielectric, spans the dielectric columns 51 and 53 at the opposite end of the switch assembly and is secured to the columns in a manner similar to that utilized at the base ends thereof. The midpoint of the spanning dielectric bar is provided with a threaded hole 61 and a clamping bolt 62 which is turned in the appropriate direction to compress the various elements of the switch together.

For convenience in the further explanation of the structure and function of this switch, the bottom electrode shown shall be termed "the base-end electrode." This base-end electrode 12 is obviously adaptable to be secured directly to a capacitor and, in fact, to become directly one of the terminals of a capacitor. Each of the electrodes 11, 12, 15 and 21 are provided with connections to facilitate the application to external circuitry.

Although this switch is susceptible to application in electric circuits in various modes, single or multiple, FIGURE 2 is a schematic diagram of a preferred embodiment utilized in practice to simultaneously discharge a plurality of capacitors through a single load. In this circuitry one of the switches is utilized as a triggering source to simultaneously trigger similar switches in individual power source circuits. Switch circuit 70 utilizes triggering switch 9 and switch circuit 72 is an example of the utilization of switch 9' in power source circuits. Switch circuit 72 includes serially connected capacitor 74 which may have any selected capacitance and be charged to whatever potential the application requires. The capacitor is charged by any suitable switching mechanism which may be manual or automatic and which in the drawing is shown to be manual switch 76 connected in series with a power source 78. One terminal of the capacitor is grounded and the other terminal is connected to the base-end electrode of spark gap switch 9'. Irradiation gap electrode 21 of switch 9' is connected in series with a capacitor 80 and to earth. The other gap switch end electrode 11 is connected to one end of a load 82 and the remaining end of the load is grounded. Spark gap switch 9' is triggered by pulse excitation of middle electrode 15 in a manner presently to become apparent.

Triggering switch 9 has its base-end electrode connected through an isolation resistor 83 to a potential of -50 kilovolts. This electrode is also connected to one terminal of capacitor 86 and the other terminal of capacitor 86 is grounded through the load 82. The irradiation gap electrode 21 of spark gap switch 9 is connected to one terminal of capacitor 88 and the other terminal of capacitor 88 is likewise direct-current grounded through load 82. Middle electrode 15 of spark gap switch 9 is connected to a pulse source of triggering potential through series resistor 90 and pulse transformer 92. The other main electrode 11 of spark gap switch 9 is connected through an isolation and filtering circuit to a source of positive potential 93. This filtering circuit comprises resistors 96 and 98 and capacitor 100. Also coupled to electrode 11 of spark gap switch 9 is the triggering electrode 15 of spark gap switch 9' and as many other middle electrodes of similar spark gap switches as may be utilized. Each of the middle electrodes 15 of the spark gap switches in the power circuits 72 are connected to electrode 11 of spark gap switch 9' by pulse coupling circuits comprising capacitor 104. The spark gap switch 9' of middle electrode 15 is D.C.-biased to a potential midway between the potentials of the end electrodes by connection to potential source 93 by resistors 102, 96 and 98.

Operation of the circuit of FIGURE 2 is as follows: In the quiescent condition spark gap switch 9 is impressed with -50 kv. on its lower base electrode, with +50 kv. on its other end electrode and with zero or ground potential on its middle electrode. The irradiation electrode 21, has assumed the same potential as middle electrode 15 by virtue of ionization conduction. It is, therefore, seen that middle electrode 15 has a potential which is midway between the potentials on base electrode 12 and end electrode 11, i.e., the potentials between middle electrode 15 and the end electrodes are substantially equal.

Referring to switch 9', base electrode 12 is connected to capacitor 74 which has previously been charged so that electrode 12 is at +100 kv. Middle electrode 15 is impressed with a potential of +50 kv. and upper end electrode 11 is at ground potential. Irradiation electrode 21 of spark gap switch 9' has assumed a potential of +50 kv. by ionization conduction and capacitor 80 is, therefore, charged to this potential.

Upon the impression of a trigger pulse through resistor 90 to middle electrode 15 of the triggering spark gap switch 9 with such polarity as to drive electrode 15 in a positive direction the gap between electrodes 12 and 15 breaks down. The potential on electrode 15 then becomes very nearly that of electrode 12, i.e., -50 kv. The charge in capacitor 80 connected to the irradiation electrode 21

simultaneously causes the end of electrode 21 to discharge in the middle electrode axial aperture and thereby generate a burst of ionized gas and photons along the axis of and in the direction of the main electrodes 11 and 12. This burst of ions and photons from trigger electrode 21 occurs as soon as there is any appreciable shift of potential of electrode 15 due to the trigger pulse. Therefore, breakdown of the spark gap electrodes occurs in an almost simultaneous fashion between 12 and 15 and 11 and 15 in response to a specific amplitude of the input trigger pulse.

Breakdown of the triggering spark gap switch 9 results in a negative pulse of substantially 100 kv. being generated at electrode 11. This negative pulse is coupled through capacitors 104 to the respective middle electrodes 15 of the various spark gap switches 9' in the load circuits. This negative pulse on middle electrode 15 of the spark gap switch 9' results in an action similar to that described with respect to the triggering spark gap switch. The generation of ions and photons in the axial bore of middle electrode 15 by the difference in potential created between the irradiation electrode 21 and the middle electrode causes switch 9' to break down essentially instantaneously and capacitor 74 is discharged through load 82. This action takes place simultaneously in all the individual power source circuits 72.

The switching system above described is one embodiment for the utilization of the spark gap switch of the present invention which has been found to be entirely satisfactory in operation. The value of the components utilized for 100 kilovolt operation is as follows:

The spark gap switch:

Electrode faces contoured to a 10.5 in. spherical radius over a 6 in. diameter

Separation of electrode faces—1¾-in.

Resistors:

90—15K non-inductive

83, 98—300K, 600 w.

102—9 meg.

96—5K non-inclusive

Capacitors:

86, 100—0.1 µf., 125 kv.

74—0.86 µf., 125 kv.

80, 88—100 µµf., 70 kv.

104—300 µµf., 70 kv.

Pulse transformer 92—3.1 ratio

Voltage sources:

95—50 kv.

93—+50 kv.

78—+100 kv.

While the salient features of the present invention have been described in detail with respect to a single preferred embodiment, it will be apparent that numerous modifications may be made within the spirit and scope of this invention and it is, therefore, not desired to limit the invention to the exact details shown except insofar as they may be defined in the following claims.

What is claimed is:

1. A high voltage, high current spark gap switch comprising two main electrodes insulatingly supported in opposed spaced relationship, a middle electrode supported medially between said main electrodes symmetrically about the median line of said main electrodes, said middle electrode having a perforation therethrough aligned with said median line, an irradiation electrode insulatingly supported in the body of the middle electrode normal to said median line and protruding into said perforation.

2. The device of claim 1 in which said main electrodes have opposing convex faces and said middle electrode has a convex face opposed to each adjacent main electrode face.

3. The device of claim 2 in which each of said electrode convex faces comprises a tungsten metal insert.

4. The device of claim 3 in which said middle electrode aperture is lined with a tungsten metal insert.

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5. A high voltage, high current switching circuit comprising a spark gap switch having insulatingly supported main electrodes in spatial opposition, a middle electrode supported between said main electrodes, said middle electrode having an aperture therethrough aligned with a medial line passing through said main electrodes, said middle electrode having an irradiation electrode insulatingly supported therein and protruding into said aperture, an impedance connected to one of said main electrodes, a source of high positive potential connected through said impedance to said main electrode, a trigger pulse source connected to said middle electrode, a source of high negative potential connected to said other main electrode, said irradiation electrode being connected to one terminal of a capacitor and the other terminal of said capacitor being connected to a potential source having a value midway between said high positive and said high negative sources of potential, whereby the impression of a trigger pulse upon said middle electrode simultaneously generates an ionizing potential between said middle electrode and said irradiation electrode and generates a breakdown potential between said middle electrode and said main electrodes.

6. A high voltage, high current spark gap switch in combination with a high voltage, high current source and a load, comprising a spark gap switch having two main electrodes having convex opposed surfaces and being supported in spaced insulated relationship, a middle electrode insulatingly supported between said main electrodes and having convex faces facing the convex faces of said main electrodes, said middle electrode having an aperture passing therethrough and aligned with the axis of said convex surfaces, said middle electrode having an irradiation electrode insulatingly supported therein and extending into said central aperture, said high voltage, high current potential source being connected directly between one of said main electrodes and ground, said irradiation electrode being connected serially with a capacitor and ground, said other main electrode being connected in series with a load and said middle electrode being connected to a triggering pulse source whereby the impression of a trigger pulse on said middle electrode generates an ionizing potential between said irradiation electrode and said middle electrode and also generates simultaneously a breakdown potential between said middle electrode and said main electrodes.

7. The device of claim 6 in which the opposing faces of

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the electrodes in said spark gap switch comprise tungsten metal inserts.

8. The device of claim 7 connected in parallel with a plurality of similar devices and to said source of triggering pulse.

9. An electrical switching circuit for simultaneously applying a plurality of high voltage, high current sources to a single load comprising a trigger pulse circuit and a plurality of spark gap power switching circuits, said trigger pulse and said power switching circuits each comprising a spark gap switch having main electrodes insulatingly supported in opposed relationship, a middle electrode supported between said main electrodes, an irradiation electrode insulatingly supported in said middle electrode having an aperture aligned with the medial line passing through said main electrodes and protruding into said aperture, said spark gap switch in the trigger pulse circuit having its middle electrode connected to ground through a trigger pulse source, said trigger pulse spark gap switch having one of its main electrodes connected to a negative source of potential and having the other of its main electrodes connected to a source of positive potential equal numerically in magnitude to the said negative source of potential and the trigger pulse spark gap switch irradiation electrode being connected to ground serially through a capacitor, said spark gap power switching switch having one main electrode connected to a high voltage, high current power source, having its middle electrode coupled to the main electrode of the trigger pulse spark gap switch which is connected to the source of positive potential and said load spark gap switch having its irradiation electrode connected serially to ground through a capacitor and having the other of its main electrodes connected serially to ground through a load.

10. The device of claim 9 in which a plurality of said spark gap power switching devices are similarly coupled to the main electrode of the trigger pulse spark gap electrode which is connected to the source of positive potential and to said load.

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