T. F. GODLOVE

SPARK GAP TRIGGER CIRCUIT

Filed June 22, 1961

INVENTOR

TERRY F. GODLOVE

BY

Melvin I. Crane, Attorney
P. H. Reed, Attorney
3,141,111
SPARK GAP TRIGGER CIRCUIT

Terry F. Godlove, Suitland, Md., assignor to the United States of America as represented by the Secretary of the Navy

Filed June 22, 1961, Ser. No. 119,251
Claims. (Cl. 315—181)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention is directed to an improved auxiliary spark trigger gap and more particularly to a simple trigger gap circuit capable of causing breakdown in a main switch gap at voltages below normal breakdown threshold.

Therefore various methods and systems have been employed to facilitate breakdown of a main gap switch in an electrical circuit; however, these systems have their drawbacks with deleterious effects on the switches due to the trigger sparks. Prior art systems use main switch spark gaps which are triggered by a high-voltage pulse applied to one of the electrodes or to a trigger pin in one electrode. Such systems use trigger pins imbedded in the cathode electrode or a trigger pin secured in the spacing between the electrodes of the main circuit with a high voltage pulse applied thereto. Another system makes use of a three electrode switch which is triggered by means of carefully adjusting the overvoltage on each gap. In the use of trigger pins, there is a strong interaction between the trigger circuit and the main gap circuit. In switches where the trigger pin is located in the center of the main gap, the spark is visibly distorted by the presence of the trigger pin and contacts the trigger pin. Where the trigger electrode is located in a hole in one electrode, the spark will travel from one electrode of the main gap to the trigger electrode and then to the other electrode of the main switch. This energy transfer takes the form of transients or oscillations superimposed on the main gap output pulse which form depends on the detailed circuit conditions.

The present invention overcomes the drawbacks of the prior art by triggering a spark gap without the use of triggering pins secured on the main switch electrodes. This invention makes use of a source of intense ultraviolet light having a copious emission in the wavelength region where the maximum number of cathode photoelectrons can be produced, i.e., a wavelength of about 1100 Angstrom units. The duration of the light to trigger a main gap switch need be about 6 nanoseconds to about 20 nanoseconds depending on the rise time limitation which depends on the size of resistors and capacitors in the spark trigger gap supply line. The present invention has a pulse rise time which permits gap breakdown in a time corresponding to one avalanche.

It is therefore an object of the present invention to provide a spark gap trigger which is relatively simple with good time stability.

Another object is to provide a spark gap trigger which yields a useful stable voltage range in the main gap circuit.

Still another object is to provide a spark gap trigger which can be used in open construction as well as in a gaseous medium.

Yet another object is to provide a spark gap trigger which has no electrical interaction between the spark gap trigger circuit and the main switch gap circuit.

Other and more specific objects of this invention will become apparent upon a more careful consideration of the following detailed description when viewed together with the accompanying drawings in which:

FIG. 1 illustrates a spark gap trigger circuit positioned relative to a main gap switch of the main circuit; and

FIG. 2 illustrates the lower curve the gap voltage vs. time applied to the trigger gap in the upper curve the voltage (or current) delivered to the load of the trigger gap circuit.

The present invention makes use of a simple trigger gap circuit which is capable of producing a very high rate of ultraviolet photon emission at a power of about 0.02 Joule. The trigger gap is positioned relative to the main gap switch such that photons produced in the trigger gap strike the cathode of the main gap switch and flood the gap between the electrodes. The photons incident on the main gap switch causes voltage breakdown across the main switch gap spacing to control the main circuit. It has been determined that a breakdown can be caused in a time of the order of one electron crossing time, thereby giving a time stability in the nanosecond (10−9 sec.) region and with operation of the main circuit at voltages below the normal breakdown threshold.

Now referring to the drawing there is shown for illustrative purposes in FIG. 1 a simple electrical spark gap triggering circuit with the spark gap of the triggering circuit positioned relative to the switch gap of the main electrical circuit. The spark gap triggering circuit includes a 6587 or 5C22 thyatron waveform generator 11 which is controlled by grid 12 that has a grid leak resistor 13 connected between the grid and ground and a charging resistor 14 connected between the load and the anode 15 with the cathode 16 connected to ground. The anode is connected to the center wire 17 of a coaxial cable transmission line 18 through a capacitor 21 and a resistor 22 connected in series, respectively. A resistor 23 is connected to provide a ground return for one side of capacitor 21. This resistor 23 is connected to the conductor line from the cathode to the outer conductor 24 of the coaxial cable 18. At the opposite end of the coaxial cable 18, one electrode 25 of a spark gap connects with the center conductor 17, and the outer conductor 24 connects with the outer conductor 26 of another transmission line 27 wherein the center conductor 28 of the transmission line 27 connects with the other electrode 29 of the spark gap triggering switch. An attenuator 30 is connected at the other end of transmission line 27, whose impedance matches that of the transmission lines 18 and 27.

The main circuit as shown has an applied source, V, which connects to a coaxial cable 31 through a charging resistor 32. The opposite end of the transmission line connects with the main spark electrodes 33 and 34 through a load resistor 35 wherein the load resistor has an impedance which matches that of the transmission line 31. The main spark gap electrodes are made of brass, stainless steel, or any other suitable material. The main circuit is typical and is for illustrative purposes only. Other main circuits such as a capacitor bank circuit may equally well be triggered with the triggering circuit of the present invention. The triggering spark gap switch is positioned relative to the main gap switch such that the distance is less than one arc of about 70 degrees or less with respect to the axis of the main gap switch electrodes such that ultraviolet light produced by the trigger switch shines onto the negative electrode of the main switch.

FIG. 2 illustrates gap voltage vs. time for the voltage breakdown across the triggering gap circuit. The lower line illustrates the curve in which no breakdown occurs whereas the upper curve illustrates the pulse output or the voltage delivered to the attenuator 30.

For operation, the basic idea is to overvoltage the...
triggering gap in a time shorter than the time it takes to break down under the applied peak voltage. The limiting breakdown time of the type 6587 hydrogen thyratron has been determined to be about 10 nanoseconds with a shield to reduce inductance. Thus the rise of voltage on the trigger gap depends on the resistor \( R_2 \), and the combination of capacitor \( C_1 \) and the control inductance \( L_1 \). A capacitance of 67 microfarads and a resistance of 100 ohms is adequate for most applications. Higher resistance can be used for applications requiring the ultraviolet light to be cut off sharply whereas lower resistance may result in deleterious multiple reflections in line 18. The stored energy of the capacitor is just greater than the energy required to produce the pulse across the trigger gap electrode. The time required for breakdown of the trigger gap depends on the overvoltage with a preferred overvoltage of at least 50–100%. This can be assured by reducing the spacing of the trigger gap, if necessary. It is necessary that peak voltage be reached prior to break- down, however, the required jitter and stability dictates the amount of overvoltage and the circuit parameters. In any case the rise time of the ultraviolet producing pulse must be less than the time corresponding to one electron driftin across the main gap spacing for good timed spatial overlap.

The main supply voltage \( V \) should be adjusted to be below the normal sparking threshold of the main gap, called \( V_s \), which threshold depends on the main gap spacing used. Denoting the difference \( V_s - V \) by \( V \) then the fractional reduction \( V_s/V \) may be set from about 1% to about 7% for air and up to about 15% if the gaps are enclosed and oxygen is used. The greater the percentage reduction the greater will be the time delay between the trigger spark and the main spark, hence the greater the timing uncertainty. A reduction of 15% will be most widely applicable.

The trigger gap of the present invention can be used for systems which require an accurate timed firing of a main source line which may use low or high repetition rates. For the purposes of this invention the system will be described in combination with a pulse generator which supplies pulses of current at a fixed repetition rate to develop a pulsed magnetic field which bends a beam of electrons as they enter a “donut.”

In operation, a separate voltage supply is applied to the trigger gap control circuit and the main circuit. The voltage applied to the control grid is changed to trigger the thyatron tube. Triggering the thyatron tube produces a high voltage pulse on the trigger gap. This high voltage pulse on the trigger gap causes it to break down and produce a source of ultraviolet light, some of which is incident on the cathode of the main gap switch. The ultraviolet light must be of sufficient intensity to produce a large number of photoelectrons in the main switch gap. These photoelectrons by means of space-charge distortion of the field cause a voltage breakdown between the main electrodes which permits the main circuit to operate. Space charge distortion is necessary to cause breakdown at voltages below normal threshold. An elec- trical pulse will develop across the load of the main cir- cuit and when the discharge is complete the voltage across the main gap is not sufficient to maintain the current in the main circuit. After the main gap recovers another pulse from the trigger gap circuit triggers the operation of the main circuit to cause another pulse across the load. This operation is continued with a repetition rate of about 10 per second which depends on the capacitance. buildup time in the main circuit. The trigger circuit is capable of operating up to about 500 pulses per sec- ond with the circuit shown and higher with a smaller resistance \( R_2 \). The pulses in each circuit are shaped by using the principle of reflection from an open-ended transmission line and the length of the transmission line of the main circuit must be of a length which will main-

- 2,141,111

- 3,141,111

- 3,141,111