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SPARK-GAP CIRCUITS

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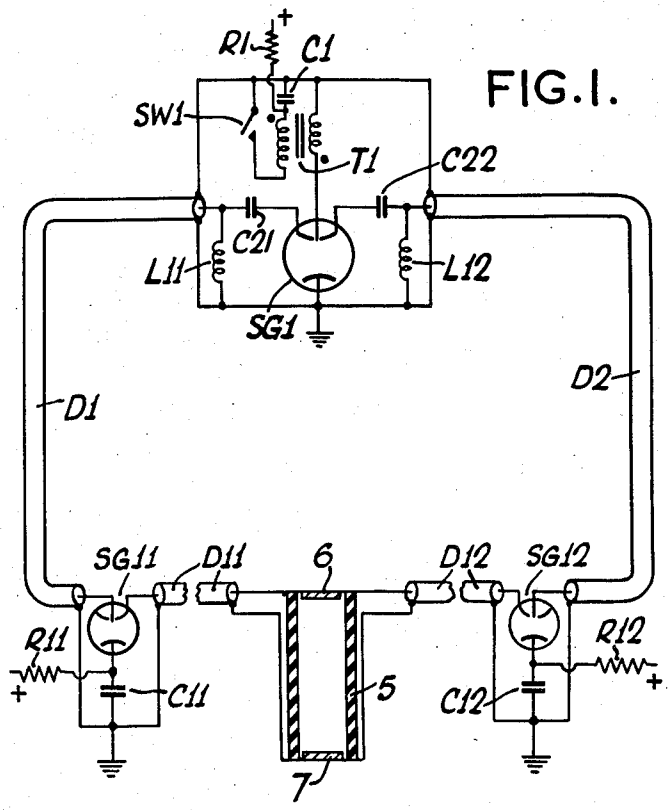

FIG. 1.

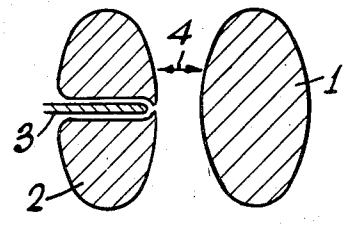

FIG. 2.

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SPARK-GAP CIRCUITS

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5 Claims. (Cl. 315—163)

This invention relates to spark-gap circuits and has particular application where it is desired to trigger a number of spark gaps simultaneously.

Such an application arises, for example, in devices for bringing about thermonuclear reactions in an ionised gas, such devices comprising a discharge tube containing the gas through which a large electric current is passed. One method of producing such a current is to discharge a number of parallel-connected condensers through the gas in the tube. It is desirable that the rate of rise of current through the tube should be as large as possible, and it is therefore necessary to reduce the inductance of the discharge circuit to a minimum.

A form of switch suitable for connecting the condensers to the discharge tube is a triggered spark-gap, but if all the condensers are connected through one large gap, all the discharge currents from the condensers flow through this gap, the inductance of which is relatively large. It would therefore be preferable to discharge each condenser (or perhaps each relatively small group of condensers) through a smaller spark gap, when the inductances of the several smaller gaps would be in parallel and the total inductance correspondingly reduced.

A further advantage of discharging each bank condenser through its own spark gap is that if one condenser fails by reason of an internal short circuit, the other condensers cannot discharge through it (unless the fault develops at the instant the bank is discharged, and even then the amount of energy taken by the condenser in parallel with a low impedance load is small) but discharge slowly through the charging resistor of the faulty capacitor. The discharge of a large condenser bank through such a faulty condenser may cause a dangerous explosion.

However, a difficulty which arises in employing an arrangement of this kind is to ensure that all the smaller spark gaps are triggered within a time interval short enough to ensure the rapid rise of current already referred to. This requires that the breakdown of one gap before the others should not, by cancelling the voltage across the other gaps, prevent them breaking down also. In practice it is not possible to ensure that all the gaps will break down quite simultaneously, and it is one object of the present invention to provide a spark gap circuit in which although all the gaps may not break down simultaneously, the aforesaid cancelling effect is eliminated so that all the gaps will in fact break down.

According to the present invention, in a spark-gap circuit comprising a plurality of electrical energy sources each connected through a connection and spark-gap means to a common load, said spark-gap means comprises a separate spark gap connected between each source and its connection to the load, said separate gaps are arranged to be triggered substantially simultaneously, the connections are of the distributed type and of equal electrical length, and the length of each said connection is sufficient to delay the arrival of the source voltage at the load for a time greater than half the maximum difference in the breakdown times of the several gaps. The sources may be condensers and the distributed connections may be coaxial cables.

Each gap may be triggered substantially simultaneously by a voltage pulse produced by discharging a further energy source, which may be a condenser, through a common master spark-gap into a further distributed connection to said gap.

Said gaps may each comprise two main electrodes and an irradiating electrode, said main electrodes being connected respectively to the source and through the distributed-type connection to the load, and said triggering pulse being applied to said irradiating electrode.

To enable the nature of the present invention to be more readily understood, attention is directed towards the accompanying drawings wherein:

Fig. 1 is a circuit diagram of a condenser bank discharging circuit including by way of example, a spark-gap circuit according to the present invention.

Fig. 2 is a cross section of a spark-gap electrode structure.

Referring firstly to Fig. 1, condensers C11 and C12 represent for simplicity two of a bank which it is desired to discharge in parallel through a load which in the present embodiment is gas discharge tube 5 having upper and lower electrodes 6 and 7. The condensers have separate charging resistors R11 and R12 connected to a positive voltage source. Each condenser is connected to the tube 5 through a separate spark gap and coaxial cable, C11 being connected through the gap SG11 and the cable D11, and C12 through the gap SG12 and the cable D12.

A cross-sectional view of one of these spark gaps is shown in Fig. 2. It consists of two circular main electrodes 1 and 2 having a main gap 4 between them, the electrode 2 having a central hole into which projects an irradiating electrode 3 which does not quite extend to the surface of the latter electrode, where the bore of the hole constricts. The electrodes may operate in air or be sealed in an evacuated or gas-filled tube. The condensers C11 and C12 are connected to the electrodes 1 of their respective spark gaps, the electrodes 2 of which are connected to the electrode 6 of the discharge tube.

The irradiating electrodes 3 of SG11 and SG12 are connected through equal-length coaxial cables D1 and D2, and condensers C21 and C22 respectively, the latter being of relatively low capacity, to the electrode 2 of a master spark gap SG1. The primary winding of a step-up transformer T1 is connected through a switch SW1 across a condenser C1 which is charged through a resistor R1 from a positive voltage source. The electrode 3 of the master spark gap SG1 is connected to the secondary winding. Inductances L11 and L12 are connected between the sides of C21 and C22 remote from SG1 and earth.

Assuming C11 and C12 to be charged to a positive potential insufficient to break down SG11 and SG12, and C1 to be also charged, the circuit is triggered by closing SW1. This results in a positive voltage pulse of relatively slow rise-time being generated in the secondary winding of T1, which charges C21 and C22 through L11 and L12, the charging current producing a preliminary small discharge between electrodes 2 and 3 of SG1 as hereinafter explained. When the voltage across C21 and C22 reaches a sufficiently high voltage, the master gap SG1 breaks down and effectively shorts one side of C21 and C22 to earth. As a result very fast negative pulse travels down each of the cables D1 and D2 to the electrodes 3 of SG11 and SG12, which, since the electrodes 1 are at a positive potential, provides sufficient overvoltage to break down the gap. Rapid initiation of the breakdown is ensured by the configuration of the irradiating

electrode 3 and the central hole in the electrode 2, as a result of which a preliminary field emission initiated discharge takes place between these two electrodes at the constriction, which irradiates the gap 4 with U.V. light and ensures the presence of free electrons therein.

It will be seen that, when for example SG11 breaks down, a voltage front travels down D11 towards electrode 6 and will tend to travel on up D12 towards SG12. If SG12 has not broken down by the time the voltage front reaches it, it will not break down at all, since there is now no voltage between its electrodes 1 and 2. Thus to ensure that SG12 does break down, the time taken for the front to travel along D11 and D12 is made greater than the time interval within which the two gaps break down, i.e. D11 and D12 are each of such a length as to delay the voltage front for a time greater than half the maximum difference in the breakdown time of the gaps. For example, in one embodiment employing 144 1 μf. condensers and 144 spark gaps, the uncertainty in the breakdown time of the gaps was 10 mμ secs. and the coaxial cables joining each gap to the discharge tube were thus each made long enough to delay the voltage front by more than 5 mμ secs. The condensers C21 etc. were each of 250 pf. in this embodiment.

The inductances L11 and L12 are chosen so as to present a low impedance to the charging pulse generated in L1, but a high impedance to the fast pulse produced when SG1 breaks down. SG1, which carries the relatively small discharge currents of C21 and C22, is designed to have a very low inductance so that the over-voltage pulse has a very short rise time. It will be appreciated that the length of the time interval within which SG11, SG12 and the other condensers in the bank are triggered depends largely on this rise time, owing to the variation in breakdown characteristics among the spark gaps. D1 and D11, and D2 and D12 have the same characteristic impedances so that the triggering pulses travel on down D1 and D2 and are not reflected back at the gaps.

Circuits according to the present invention may use spark gaps other than the type described with reference to Fig. 2, and may employ other forms of triggering circuit than the one described. Where a very large number of gaps is to be triggered, the single master gap SG1 may be replaced by a plurality of master gaps each triggering a group of gaps, the master gaps being triggered in turn by a master master gap.

The distributed connections need not be coaxial, but may for example be of the parallel-strip transmission-line type.

In this specification, a condenser is to be taken as including two or more condensers connected in series or parallel.

I claim:

1. A spark-gap circuit comprising a plurality of storage condensers, a load, a spark-gap associated with each storage condenser, each spark-gap having a triggering electrode and two main electrodes, a connection between one main electrode of each spark-gap and one side of its associated storage condenser, a distributed connection between the other main electrode of each spark-gap and the load, and means for triggering the spark-gaps substantially simultaneously, the distributed connections being of equal length sufficient to delay the arrival of the voltage fronts from said storage condensers at the load for a time greater than half the maximum difference in the breakdown times of the associated spark-gaps when triggered.

2. A circuit as claimed in claim 1 wherein the distributed connections are coaxial cables.

3. A circuit as claimed in claim 1 wherein said triggering means comprises a further condenser associated with each spark-gap, equal-length distributed connections between one side of each further condenser and the triggering electrode of its associated spark gap, a master spark-gap having two main electrodes, a connection between the other side of each further condenser and one main electrode of the master spark-gap, a connection having a high impedance for fast pulses connected between said one side of each further condenser and the other main electrode of the master spark-gap, and means for charging said further condensers to the break-down voltage of master spark-gap.

4. A circuit as claimed in claim 1 wherein the triggering electrode of each associated spark-gap is an irradiating electrode.

5. A circuit as claimed in claim 3 wherein said master spark-gap comprises an irradiating electrode and said charging means is connected to said irradiating electrode.

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