June 27, 1967 A. A. ROBINSON 3,328,632

VACUUM-PROTECTIVE SPARK GAP WITH TRIGGER ELECTRODE

Filed Aug. 16, 1965 3 Sheets-Sheet 1

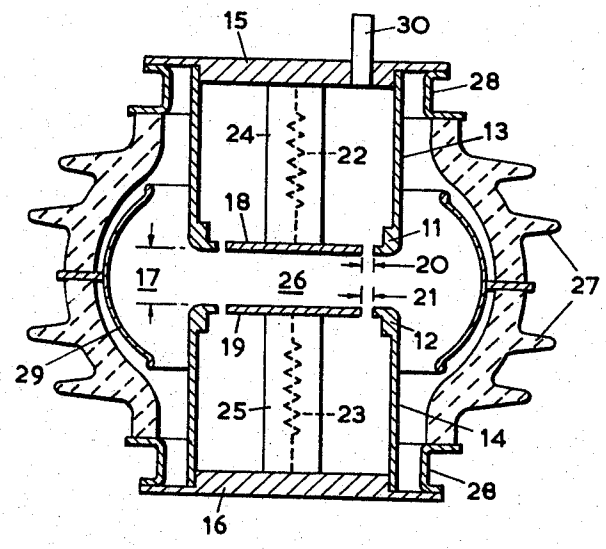


FIG. 1

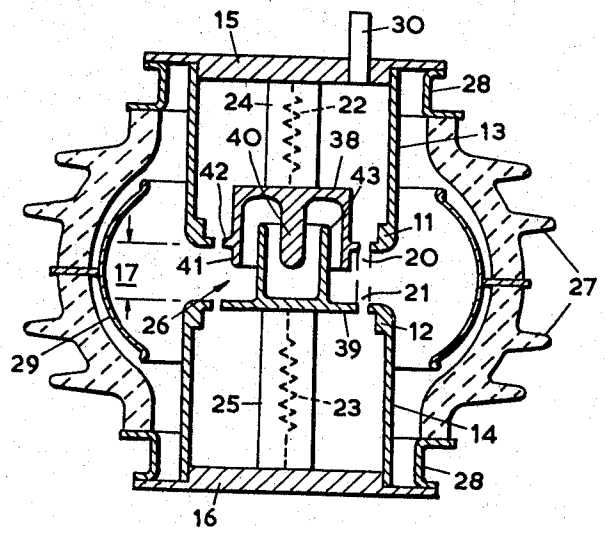


FIG. 2

VACUUM-PROTECTIVE SPARK GAP WITH TRIGGER ELECTRODE

Filed Aug. 16, 1965 3 Sheets-Sheet 2

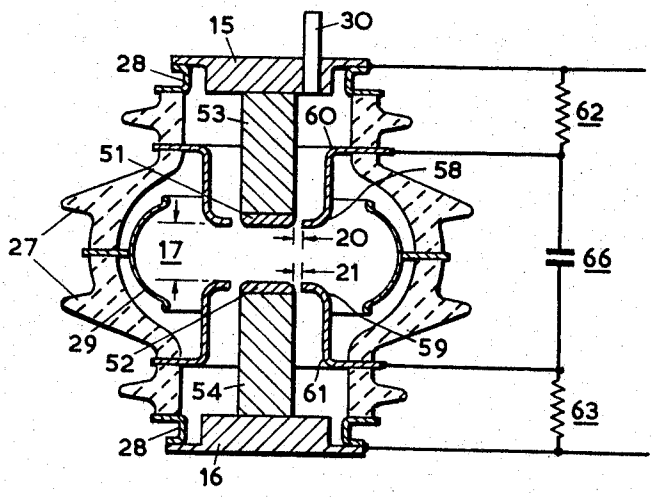


FIG. 3

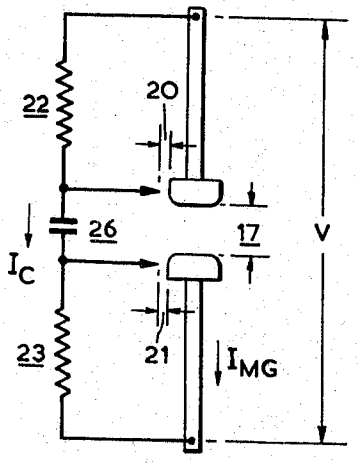


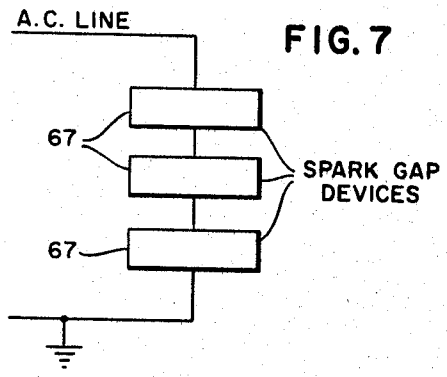
FIG. 4

June 27, 1967 A. A. ROBINSON 3,328,632

VACUUM-PROTECTIVE SPARK GAP WITH TRIGGER ELECTRODE

Filed Aug. 16, 1965 3 Sheets-Sheet 3

FIG. 7



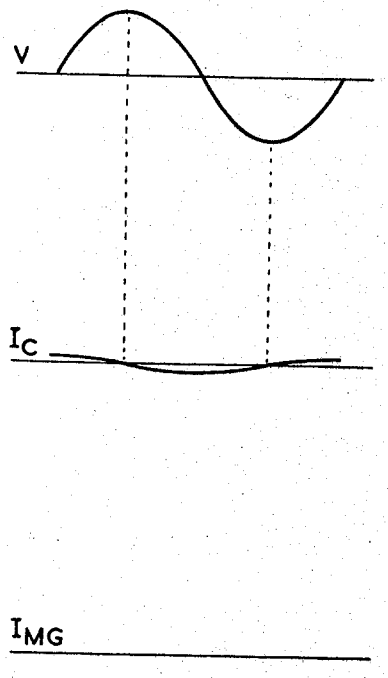


FIG. 5

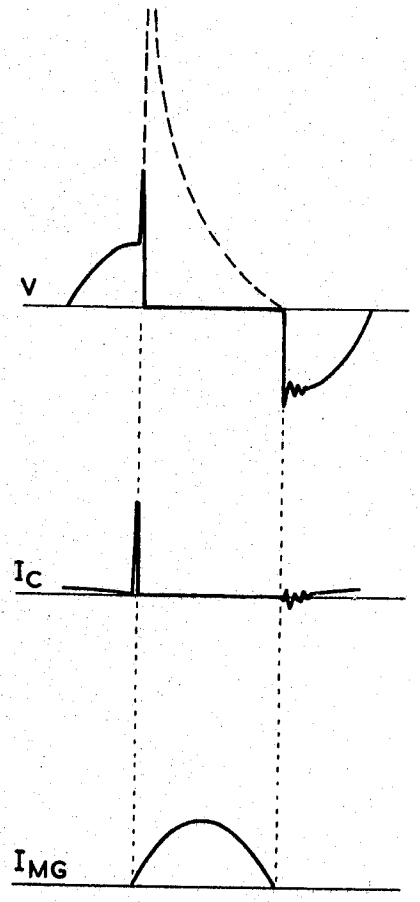


FIG. 6

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VACUUM-PROTECTIVE SPARK GAP WITH TRIGGER ELECTRODE

Alfred Alexander Robinson, Stafford, England, assignor to The English Electric Company Limited, London, England, a British company

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11 Claims. (Cl. 315—60)

This invention relates to protective spark gap devices.

According to this invention, a protective spark gap device for an A.C. transmission system includes a pair of stationary main electrodes insulated from one another in a chamber under high vacuum, one main electrode being adapted to be connected to a high-voltage A.C. power line and the other main electrode being adapted to be connected to earth, the gap between the main electrodes being such that, when the main electrodes are so connected, it does not break down under the normal line voltage, and a pair of satisfactory trigger electrodes having a capacitance between them, each trigger electrode being spaced from the corresponding main electrode by a trigger gap, the trigger electrodes being adapted to be connected each through a resistance to the high-voltage power line and to earth respectively, and the trigger gaps being such as to give field emission in vacuum at a voltage substantially less than the maximum permissible line overvoltage, the arrangement being such that if an impulse voltage appears across the gap between the main electrodes, in addition to the normal line voltage, a current will flow through the capacitance and a substantial proportion of the impulse voltage will appear across the resistances, and thus across the trigger gaps, which will initiate breakdown of the gap between the main electrodes.

A number of embodiments of the invention will now be described by way of example, with reference to the accompanying drawings, of which:

FIG. 1 shows diagrammatically one embodiment of protective spark gap device in accordance with the invention,

FIG. 2 shows a second embodiment, which is a modification of that of FIG. 1,

FIG. 3 shows a third embodiment in which capacitor and resistor elements are external,

FIG. 4 shows the equivalent electrical circuit diagram of the embodiments of FIGS. 1–3,

FIGS. 5 and 6 are diagrams showing voltage and current waveforms in operation of such a device, and FIG. 7 is a schematic view of the invention showing a plurality of spark gap devices in series.

Referring now to FIG. 1, a protective spark gap device for use on high-voltage A.C. transmission systems has a pair of main electrodes **11**, **12**, each of which is connected by a cylindrical conductor **13**, **14** to a corresponding baseplate **15**, **16**. The baseplates conveniently provide the terminals for the protective spark gap unit, and are thus connected respectively to the high-voltage power line and to earth. The main electrodes **11**, **12** are annular and coaxial with one another, the gap **17** between them being set so that it does not break down under normal line voltage conditions.

Trigger electrodes **18**, **19** are provided coaxially within the main electrodes **11**, **12**; the gaps **20**, **21** between the trigger electrodes and the corresponding main electrodes are set during manufacture according to a criterion to be described below. The trigger electrodes **18**, **19** are electrically connected through resistances **22**, **23**, to the corresponding main electrodes **11**, **12**, and may be supported from the baseplates **15**, **16** by insulators **24**, **25**. The resistances **22**, **23** may either be separate elements, or conducting coatings on the insulators, or other known or convenient devices which produce the same effect.

The facing areas of the trigger electrodes **18**, **19** together form a capacitor **26**. Typical values of the resistances **22**, **23** would be 10 to 100 kilohms and of the capacitance 10–100 picofarads.

The values of capacity and resistance required are such that a trigger gap current (followed its breakdown) of the order of several amperes is desirable for reliable operations.

For the majority of system voltages and impulse rates of rise this consideration leads to a $C \times R$ value in the range 250 kilohm picofarads to 25,000 kilohm picofarads.

The electrode arrangement is enclosed in a vacuum envelope which may include a pair of dished, shedded insulators **27** bonded through adaptors **28** to the baseplates **15**, **16**, and bonded togther at their wider ends. A shield **29** may be provided, bonded to the insulators **27**, to protect them from the arc.

Means is provided, as indicated at **30**, for evacuating and sealing off the vacuum envelope at a pressure of the order of 10^{-6} mm. Hg, or lower.

Referring now to FIG. 2, in which the same reference numerals indicate the same parts, the protective spark gap is the same as that shown in FIG. 1 except that the trigger electrodes **38**, **39**, instead of being flat, are formed with interleaved portions to increase the value of the capacitance between them.

As shown, the upper trigger electrode **38** has a central, circular projection **40** and a coaxial cylindrical projection **41**; the latter has an annular flange **42** to define the gap **20** between the trigger electrode **38** and the main electrode **11**. The lower trigger electrode **39** has a cylindrical projection **43** which is interleaved between the projections **40**, **41**, with the appropriate spacing.

In the embodiment of FIG. 3, the resistance and the capacitor form part of an external network. Again, the same reference numerals denote the same parts. In this embodiment the main electrodes **51**, **52** are cylindrical, are supported from the baseplates **15**, **16** by conductors **53**, **54**, and are coaxially within annular trigger electrodes **58**, **59**. The bases of the latter are formed with annular flanges **60**, **61**, which are secured between parts of the insulators **27** so that they may be connected through the external resistances **62**, **63** to the corresponding baseplates **15**, **16**, and thus, through the conductors **53**, **54** to the main electrodes.

An external capacitor **66** is connected between the trigger electrodes **58**, **59** as part of the external network. The resistances **62**, **63** have the same values as resistances **22**, **23**, and the capacitor **66** has the same value as capacitor **26**.

The main electrodes are made of gas-free arc-resistant-materials.

In the equivalent electrical circuit diagram of FIG. 4, the same reference numerals are used as in FIG. 1, but it will be understood that this figure is also equivalent to the construction shown in FIGS. 2 and 3. If the main spark gap **17** is set so that it does not break down under normal line voltage conditions (for example, 132 kv. or 400 kv. at a frequency of 50 c./s.) and the capacitor **26** (or **66**) has the value stated, the current flow through the capacitor will be negligible (less than 1 ma.), and the voltages across the resistances **22**, **23** (or **62**, **63**) will be negligibly small. The trigger gaps **20**, **21** are set during manufacture to give field emission in vacuum at a voltage substantially less than the line voltage, so that if an impulse voltage having a high rate of rise appears across the main spark gap **17** in addition to the normal-frequency line voltage, a current will flow in the capacitor **26** (or **66**) proportional to the differential of the voltage across the main gap with respect to time, and a large proportion of the impulse voltage will therefore appear across the resistances

22, 23 (or 62, 63); the voltage across resistance 22 (or 62) also appears across the trigger gap 20 and that across resistance 23 (or 63) across the trigger gap 21. Field emission and subsequent cathode spot formation at the trigger gaps 20, 21 will initiate rapid breakdown of the main spark gap 17, thus protecting the line from the impulse voltage.

It will be understood that the rate of rise of an impulse voltage resulting, for example, from a lightning strike on the line is very much greater than the rate of rise of voltage in normal operation; the difference may be of the order of 100:1.

Following breakdown of the main spark gap 17, a normal-frequency loop of current will flow, and extinction of the arc and voltage recovery will occur at the next available current zero.

In FIGS. 5 and 6, V represents the line voltage, I_C the current flowing in capacitor 26 (or 66) and I_{MG} the current flowing across the main gap 17. FIG. 5 shows the waveforms under normal line voltage conditions, I_C being very small and I_{MG} zero.

In FIG. 6 the waveforms are shown when an impulse voltage is applied to the line; the solid trace shows the voltage as limited by the protective spark gap device, and the dotted trace the voltage which would otherwise occur; the recovery voltage is also shown. The current I_C flowing in the capacitor may rise to a value of the order of 1.0 A; the third diagram of FIG. 6 shows the arc extinction at the next current zero.

A number of protective spark gap units 67 (FIG. 7) may, if desired, be employed in series, and by this means and by suitable provision for gap adjustment during manufacture, lines having a wide range of system voltages may be protected by the use of standard units.

The device may also be employed to protect from surges individual items of apparatus, e.g. transformers and reactors.

What I claim as my invention and desire to secure by Letters Patent is:

1. A protective spark gap device for an A.C. transmission system, including a pair of stationary main electrodes insulated from one another in a chamber under high vacuum, one main electrode being adapted to be connected to a high-voltage A.C. power line and the other main electrode being adapted to be connected to earth, the gap between the main electrodes being such that, when the main electrodes are so connected, it does not break down under the normal line voltage, and a pair of stationary trigger electrodes having a capacitance between them, each trigger electrode being spaced from the corresponding main electrode by a trigger gap, the trigger electrodes being adapted to be connected each through a resistance

to the high-voltage power line and to earth respectively, and the trigger gaps being such as to give field emission in vacuum at a voltage substantially less than the maximum permissible line overvoltage, the arrangement being such that if an impulse voltage appears across the gap between the main electrodes, in addition to the normal line voltage, a current will flow through the capacitance and a substantial proportion of the impulse voltage will appear across the resistances, and thus across the trigger gaps, which will initiate breakdown of the gap between the main electrodes.

2. A protective spark gap device as claimed in claim 1 in which the main electrodes are annular and co-axially surround the respective trigger electrodes to form annular trigger gaps.

3. A protective spark gap device as claimed in claim 1 in which the trigger electrodes are annular and coaxially surround the respective main electrodes to form annular trigger gaps.

4. A protective spark gap device as claimed in claim 1 wherein said capacitance is formed directly between the trigger electrodes.

5. A protective spark gap device as claimed in claim 4 wherein one trigger electrode is formed with an annular projection which projects into an annular groove in the other trigger electrode.

6. A protective spark gap device as claimed in claim 1 wherein said capacitance is outside said chamber.

7. A protective spark gap device as claimed in claim 6, wherein said stationary trigger electrodes are annular, coaxially surround the respective main electrodes to form annular trigger gaps, and are each formed with an annular flange which passes through the wall of said chamber, and said capacitance is connected between said annular flanges.

8. A protective spark gap device as claimed in claim 1 wherein the resistances are inside the chamber.

9. A protective spark gap device as claimed in claim 8, wherein the resistances are in the form of conductive coatings on insulators by which the trigger electrodes are supported.

10. A protective spark gap device as claimed in claim 1, wherein the resistances are outside said chamber.

11. A plurality of protective spark gap devices as claimed in claim 1, said devices being connected electrically in series between a high-voltage A.C. power line and earth.

No references cited.

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