Dec. 10, 1940. J. SLEPIAN 2,224,749

PROTECTIVE-GAP DEVICE

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Fig. 1.

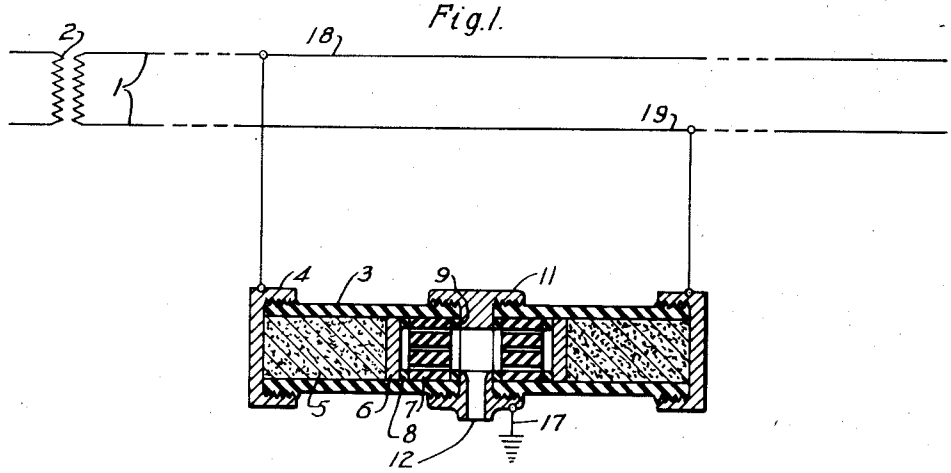
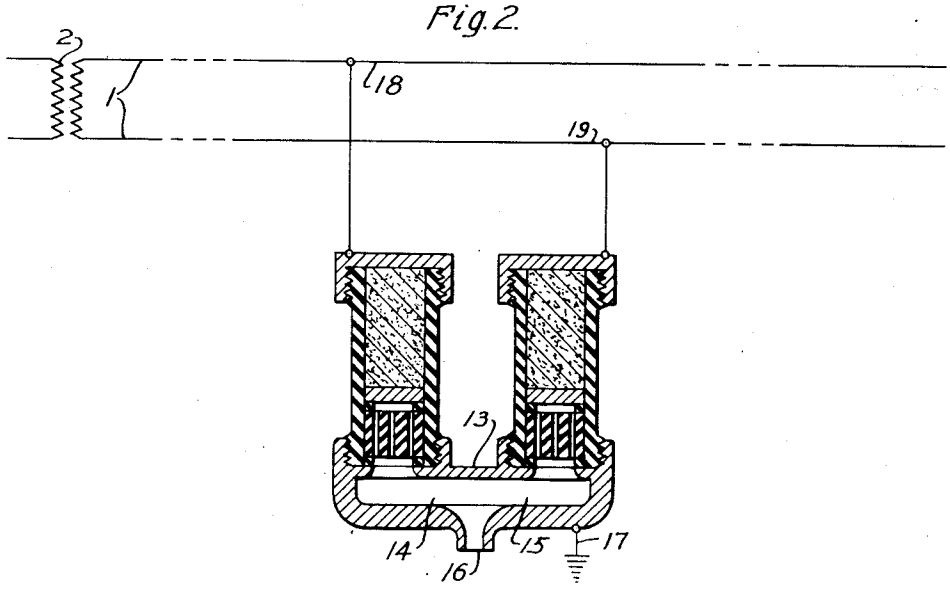


Fig. 2.



WITNESSES:

N. F. Susan.

Wm. C. Groome

INVENTOR

Joseph Slepian.

BY O. B. Buchanan

ATTORNEY

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PROTECTIVE-GAP DEVICE

Joseph Slepian, Pittsburgh, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

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7 Claims. (Cl. 175—30)

My invention relates to excess-voltage protective devices of the form which is sometimes referred to as the expulsion-gas discharge-tube type, in which an arc is formed within an insulating tube in the presence of arc-responsive gas-evolving insulating material which operates to create a blast which extinguishes the arc at the termination of the excess-voltage conditions which produced the arc. Such tubes have a rating dependent upon their breakdown-voltage and their ability to interrupt arcs of a certain range of current-values, the maximum current-rating being generally determined by the ability of the tube to withstand the rupturing forces of the excessive internal gaseous pressures which are produced by a heavy discharge, and the minimum current-rating being determined by the ability of the relatively feeble low-current blast to extinguish the low-current arc after the subsidence of the excess-voltage surge which originally initiated the discharge.

My invention has particular reference to discharge-tubes, of the above-described character, which are utilized, for protection against excess-voltage surges, in a connection, or on a system, in which neither the surge-current which is discharged during the existence of the surge, nor the so-called power-follow current, which tends to continue to flow in the ionized space created by the surge-discharge, is sufficient to result in a reasonably prompt extinction of the arc.

It is an object of my invention to combine such a discharge-tube device with another discharge-tube device which is differently electrically connected, and which is closely physically associated with the first discharge-tube device, so that there is an intercommunication of the blasts of ionized gases between the two discharge-tube devices. Thus, the arcing of the one will sufficiently ionize the other to initiate an arc therein, the electrical connections of the second discharge-tube device being such that it will then discharge with an arc of a higher current-intensity, so that it will produce a blast which is strong enough, not only to extinguish its own arc, but to communicate itself to the arc in the first tube, and thus extinguish both arcs.

One place where such a double-gap protective means is needed is on a substantially ungrounded electric power-system, by which I mean a system which is either normally insulated from ground, or which is normally connected to ground through a high impedance, either the grounding impedance or (in a three-phase system) the total zero-phase-sequence line-impedance, however composed. In such a system, the power-follow current which may flow in an arcing ground, may be very small, ranging from merely the charging-current resulting from the capacity between the line-conductor and ground, to various magnitudes of ground-current depending upon the zero-phase-sequence impedance of the line, which impedance may be very high.

My invention is illustrated, in two illustrative forms of embodiment, in the accompanying drawing, wherein the two figures are cross-sectional views of two different forms of the protective-gap assembly, respectively, with diagrammatic representations of a simple example of an electrical system to which the gap-assembly may be connected.

For simplicity of explanation and illustration, I show my invention, in both Fig. 1 and Fig. 2 of the drawing, as being applied to the protection of an ungrounded single-phase power-line 1, although the invention is also applicable to the protection of other electrical devices. The illustrated single-phase line 1 is supplied with power from a transformer 2, and which is protected by means of my present invention. The particular form of tubular gap-device which is utilized is not significant, so long as there are utilized two physically-associated gap-devices having intercommunicating discharge-openings, so that the ionized blast of one device may communicate itself to the other. The particular type of gap-device which is illustrated in both figures of the drawing consists of a fibre tube 3 which is closed, at one end, by a metal terminal-cap 4, the tube 3 being open at the other end. The fibre of which the tube is composed, is an insulating material which has the property of evolving large quantities of substantially non-ionized gases or particles, in the presence of an arc. This insulating tube 3 houses a resistor 5 and an inner metallic electrode 6, with the resistor 5 disposed between the terminal-cap 4 and the electrode 6. The metal terminal-cap 4 and the resistor 5 constitute connecting-means for causing the inner metallic electrode 6, constituting one of the terminal electrodes of the tube, to project or extend inwardly into the tube so as to provide a shorter inside sparkover-distance than the outside sparkover-distance, so that a breakdown or arcover will always occur inside of the tube. Between the electrode 6 and the open end of the insulating tube 5, the particular illustrated tube contains a multi-slotted so-called diffuser plug 7 which is also made of fibre, and which is separated from the electrode 6, and from the open end of the tube 3, by annular spacers 8 and 9, respectively.

In accordance with my invention, I utilize two tubes such as the tube which has just been described, or discharge-gap tubes of any other specific formation, so long as they are of a type in which a blast is produced for extinguishing the arc of the discharge. In Fig. 1, the two tubes are disposed in substantial alignment with each other, with the two open ends of the respective tubes facing each other, so that any blast which

is produced in one tube will blow directly into the other. The two tubes, in Fig. 1, are joined by a piece of metal hardware or coupling 11 which is provided with a lateral opening 12 for venting the two tubes to the outside atmosphere. The two ends of the metal coupling 11 constitute the respective ground-terminals of the two tubes.

In Fig. 2, the two tubes are disposed in side-by-side relationship, with their open ends joined by a pipe-like metal hardware or coupling 13, which provides two substantially aligned passages 14 and 15 for the respective gas-blasts of the two tubes, so that the blast of one tube is communicated readily to the other tube, the coupler 13 being also provided with a lateral vent 16 for venting the tubes to the outside atmosphere.

While the tubes of both forms of embodiment of my invention are vented, as at 12 and 16, respectively, the vents 12 and 16 are laterally disposed and are preferably of such reduced cross-section that material proportions of the gas-pressure and of the kinetic velocity of the gaseous blast, from the tube which breaks down first, will be directed into the other tube. While the fibre insulating material evolves un-ionized gaseous, and possibly event tiny solid, particles, nevertheless the gaseous blast which is expelled from any tube which is discharging is highly ionized, at least as long as the arc is playing within the tube. As a consequence of this, the communication of the blast, from one tube to the other, ionizes the second tube and causes the latter to break down at voltages which are far below the normal breakdown-voltage of the tube.

Various electrical connecting means may be utilized for providing different electrical connections for the two tubes, so that one of the tubes may break down first, and communicate its discharge to the other tube, causing the latter to break down even though abnormal voltage-conditions do not appear on the second tube at the time, the connections being such that, when the second tube breaks down, the amount of current which flows in the resulting arc will be larger than the current which flowed in the first tube before the second tube broke down, thus avoiding the necessity for either tube interrupting its arc at the low current-conditions which were obtained when only the first tube was discharging. These electrical connections can assume various forms, the form of connection which is illustrated in both Figs. 1 and 2 being a simple line-to-ground connection between the two respective line-conductors of the line 1 and ground, the central hardware or coupler 11 or 13 being grounded, as indicated at 17, and the two terminal-caps 4 being connected, one to one of the line-conductors 18 and the other to the other line-conductor 19.

In operation, if an excessive voltage should appear upon one of the line-conductors 18 or 19, either by reason of a direct lightning-stroke, or by induction, or from any other cause, the associated tubular discharge device will break down, momentarily connecting that line-conductor to ground through the resistance 5 and the arc or discharge which forms within the tube between the inner electrode 6 and the grounded electrode 11 or 13, as the case may be. It will be noted that the inner electrode 6, at the inner end of the resistor 5, extends far enough into the tube 3, from the closed end 4, to insure that a breakdown will always occur internally of the tube rather than externally thereof.

In the case of an absolutely ungrounded line, as shown, the power-follow current which follows in the wake of the surge-current discharge will be extremely small, amounting to only the charging-current of the line, so that there would be a strong tendency for a tiny arc or discharge to hang on, in the tube, for possibly a few cycles, or even permanently, after such a surge-current discharge, except for the double-tube arrangement in accordance with my invention, whereby the discharge of one of the tubes, under the circumstances mentioned, will immediately communicate itself to the other tube, ionizing the discharge-space of the second tube so that the second tube breaks down, even though an excessive voltage is not impressed across its terminals 4 and 11 or 13, as the case may be. As soon as the second tube breaks down, there will be two arcs in series, forming a low-resistance conducting path, through the two tubes, between the two line-conductors 18 and 19, thus producing a line-to-line short-circuit on the line 1, and drawing a heavy power-follow current which is of sufficient magnitude to enable the tubes to practically instantaneously extinguish their arcs.

While I have illustrated my invention in only two forms of construction, and with only a single form of electrical connection, I wish it to be understood that such illustration is only illustrative, so far as the general broader principles of my invention are concerned, and that many changes and substitutions may be made by those skilled in the art, without departing from the broader aspects of my invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language and the prior art.

I claim as my invention:

1. Excess-voltage protective apparatus for an electrical device to be protected, comprising a plurality of physically closely related expulsion discharge-tubes; means for electrically differently connecting said tubes to different conductors of said protected electrical device, one of said tubes being susceptible of breaking down, at times, before another of said tubes; each tube comprising a tubular insulating housing-structure and a pair of normally electrically insulated terminal electrodes therefor, connecting-means for causing at least one of said electrodes to project into the tube for a distance sufficient to insure that a breakdown shall always occur internally of the tube rather than externally thereof, the internal discharge-space or spaces between the two electrodes within the bore of each tubular housing-structure including arc-responsive gas-evolving insulating material; a physical communication-means for causing ionized particles from one of said tubes, which may be discharging, to be communicated to another of said tubes, which may not be discharging, whereby the latter tube may be caused to discharge; and venting-means physically associated with said plurality of tubes.

2. Excess-voltage protective apparatus for an electrical device to be protected, comprising tube-means comprising a plurality of physically closely related expulsion discharge-tubes; means for electrically connecting said tube-means to said protected electrical device, said tube-means and said connecting means providing a plurality of different discharge-paths within said tube-means, at least one discharge-path being responsive to line-to-ground voltage while another discharge-path is responsive to line-to-line voltage; each tube comprising a tubular insulating housing-structure and a pair of normally electrically insulated terminal electrodes therefor, connecting-

means for causing at least one of said electrodes to project into the tube for a distance sufficient to insure that a breakdown shall always occur internally of the tube rather than externally thereof, the internal discharge-space or spaces between the two electrodes within the bore of each tubular housing-structure including arc-responsive gas-evolving insulating material; a physical communication-means for causing ionized particles from one of said tubes, which may be discharging, to be communicated to another of said tubes, which may not be discharging, whereby the latter tube may be caused to discharge; and venting-means physically associated with said plurality of tubes.

3. The combination, with a substantially ungrounded multi-conductor electrical line, of excess-voltage protective apparatus comprising a plurality of physically closely related expulsion discharge-tubes; means for connecting one of said tubes between one conductor of said line and ground; means for connecting another of said tubes between another conductor of said line and ground; each tube comprising a tubular insulating housing-structure and a pair of normally electrically insulated terminal electrodes therefor, connecting-means for causing at least one of said electrodes to project into the tube for a distance sufficient to insure that a breakdown shall always occur internally of the tube rather than externally thereof, the internal discharge-space or spaces between the two electrodes within the bore of each tubular housing-structure including arc-responsive gas-evolving insulating material; a physical communication-means for causing ionized blasts to be intercommunicated between said tubes and venting-means physically associated with said plurality of tubes.

4. Excess-voltage protective apparatus for an electrical device to be protected, comprising a plurality of physically closely related expulsion discharge-tubes; means for electrically differently connecting said tubes to said protected electrical device, a first one of said tubes being subject to a relatively weak initial power-follow current if it breaks down first, while a second one of said tubes is subject to a power-follow current heavier than said initial power-follow current if said second tube breaks down last, the discharge of the second tube causing the discharge of the first tube to clear itself; each tube comprising a tubular insulating housing-structure and a pair of normally electrically insulated terminal electrodes therefor, connecting-means for causing at least one of said electrodes to project into the tube for a distance sufficient to insure that a breakdown shall always occur internally of the tube rather than externally thereof, the internal discharge-space or spaces between the two electrodes within the bore of each tubular housing-structure including arc-responsive gas-evolving insulating material; a physical communication-means for causing ionized blasts to be intercommunicated between said tubes; and venting-means physically associated with said plurality of tubes.

5. Excess-voltage protective apparatus for an electrical device to be protected, comprising two substantially aligned expulsion-blast discharge-tubes, each tube having an open end, and the two open ends being disposed facing each other; and means for electrically differently connecting said tubes to said protected electrical device, one of said tubes being susceptible of breaking down, at times, before another of said tubes; each tube comprising a tubular insulating housing-structure and a pair of normally electrically insulated terminal electrodes therefor, connecting-means for causing at least one of said electrodes to project into the tube for a distance sufficient to insure that a breakdown shall always occur internally of the tube rather than externally thereof, the internal discharge-space or spaces between the two electrodes within the bore of each tubular housing-structure including arc-responsive gas-evolving insulating material.

6. Excess-voltage protective apparatus for an electrical device to be protected, comprising a plurality of physically closely related expulsion discharge-tubes; means for electrically differently connecting said tubes to different conductors of said protected electrical device, one of said tubes being susceptible of breaking down, at times, before another of said tubes; each tube comprising a tubular insulating housing-structure and a pair of normally electrically insulated terminal electrodes therefor, connecting-means for causing at least one of said electrodes to project into the tube for a distance sufficient to insure that a breakdown shall always occur internally of the tube rather than externally thereof, the internal discharge-space or spaces between the two electrodes within the bore of each tubular housing-structure including arc-responsive gas-evolving insulating material; and a common intermediate venting-outlet for venting both tubes so that ionized blasts are intercommunicated between the two tubes.

7. The combination; with a protected electrical device having first voltage-output terminals capable of delivering a relatively large power-current when short-circuited and second voltage output terminals capable of delivering a relatively smaller power-current when short-circuited; of excess-voltage protective apparatus comprising a plurality of physically closely related expulsion discharge-tubes; each of said tubes comprising a pair of electrodes having spaced arcing-terminals, there being a separate arcing-space between its own individual pair of spaced arcing-terminals for each of the tubes, tubular insulating means surrounding the respective arcing-spaces, and connecting-means for causing at least one of the arcing-terminals bounding each arcing-space to project into the tubular insulating means a distance sufficient to insure that a breakdown shall always occur internally of the tubular insulating means rather than externally thereof, each arcing-space including arc-responsive gas-evolving insulating material; connecting-means for connecting two of said tubes in series-circuit relation across the first voltage-output terminals of the protected device; and connecting-means for connecting one of said two tubes but not the other of said two tubes in a circuit across the second voltage-output terminals of the protected device; the discharge of said one of said two tubes causing a discharge of the other one of said two tubes.

JOSEPH SLEPIAN.