Sept. 15, 1964 W. RABUS 3,149,263

ELECTRIC OVERVOLTAGE ARRESTER WITH LARGE CAPACITIVE SPARK GAP

Filed Oct. 24, 1958

Fig.1

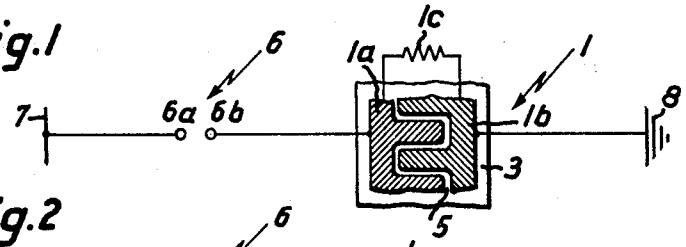


Fig.2

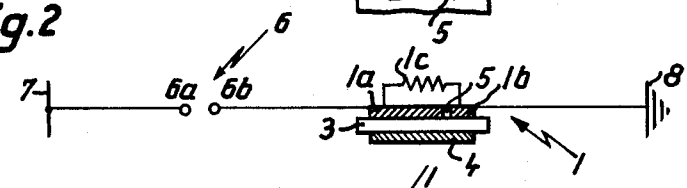


Fig.3

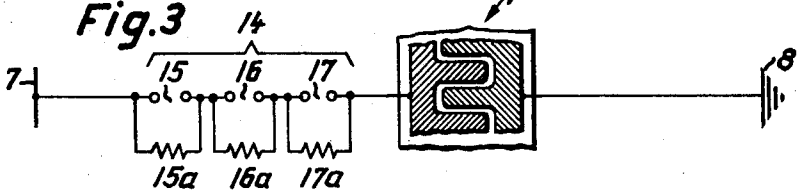


Fig.4

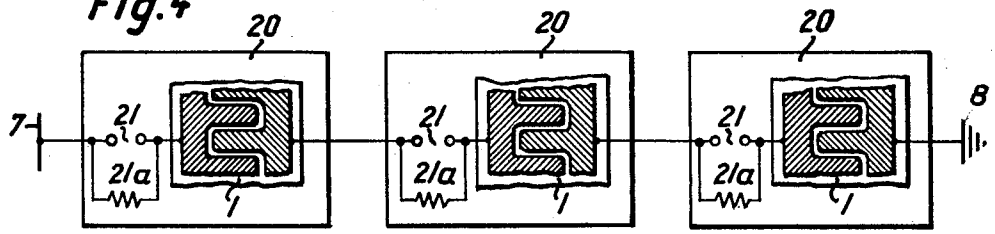


Fig.5

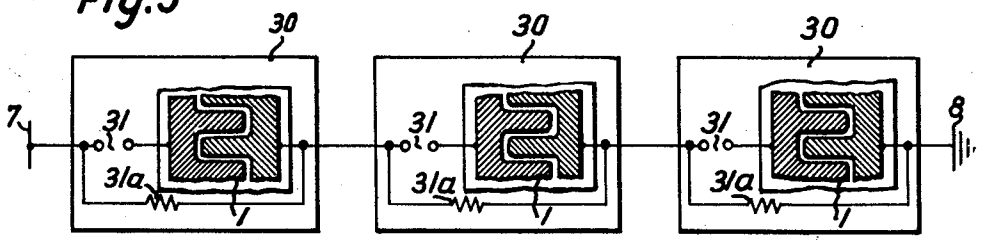
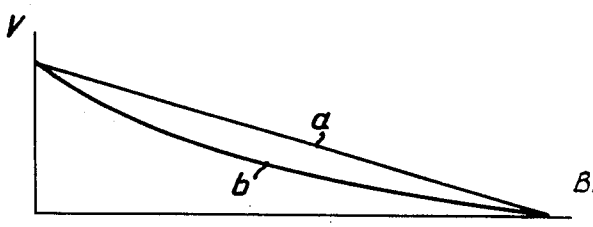


Fig.6



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United States Patent Office 3,149,263 Patented Sept. 15, 1964

3,149,263

ELECTRIC OVERVOLTAGE ARRESTER WITH LARGE CAPACITIVE SPARK GAP

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Filed Oct. 24, 1958, Ser. No. 769,479
Claims priority, application Germany, Oct. 25, 1957, L 28,915
10 Claims. (Cl. 317—69)

The present invention relates to electric overvoltage arresters.

There exist high voltage electric overvoltage arresters which comprise non-linear resistors that are serially connected to a quench or spark gap. These arresters are generally connected between the high voltage line and ground, and serve to protect the transmission line as well as various apparatus connected thereto against overvoltages.

No current normally flows through such arresters, when one discounts the very small and generally negligible current which flows through the control resistors which are sometimes connected in parallel with the spark gaps. However, when an overvoltage appears between ground and the point at which the arrester is connected to the high tension lines, which overvoltage is above the operating voltage of the quench gap, the latter having a flashover point or breakdown voltage of the order of 1.8 to 2.5 times the rated voltage of the arrester, electric breakdown takes place and an electric connection is established between the high tension line and ground. Thus, the electric charge which causes the overvoltage is grounded, thereby reducing the overvoltage. The residual voltage remaining across the arrester is a function of the magnitude of the overvoltage surge and of the resistance characteristics of the voltage-dependent resistor of the arrester, as well as of the surge impedance of the high tension line.

In the high voltage art, it is very desirable to maintain the residual voltage which remains across the arrester after a surge has been grounded, as small as possible. This factor is limited by the capacity of the quench gap and the commercially attainable sufficiently safe resistance characteristics of the nonlinear resistors. The latter must be so selected that after an overvoltage the resistance again becomes sufficiently high so that the spark gap extinguishes the discharge and the normal voltages of the network will not be grounded.

The present state of the art is such that arresters rated at 125 kv. reach a residual voltage of approximately 375 kv., where the current through the protector is 10,000 a.

Several overvoltage arresters have been designed in which the residual voltages is somewhat less. To this end a large number of specially constructed spark gaps are connected in parallel, and under certain circumstances also in series, the arrangement of these spark gaps being such that they include electrodes vaporized onto an insulator, at least one of which electrodes is partly destroyed whenever the spark gaps are subjected to an electric arc. Such an arrester, which is connected between the high voltage line and ground, normally carries no appreciable current, the capacitative current through this type of arrester being negligible. The spark gaps conduct only when an overvoltage is applied, and arc extinction takes place when part of the electrodes are burnt out and thus destroyed. In such arresters, the residual voltage is not substantially higher than the operating voltage.

Once a sparkover has occurred, the particular discharge path is of no further use inasmuch as the flashover potential or breakdown point of this path is substantially increased. Therefore, a large number of discharge paths must be available to render the arrester practical and useful. Furthermore, if the arrester is to be used on very high voltages, a number of paths must be connected serially, so that the total number of discharge paths which must be provided may be extremely high.

An arrester of the above type having a rated voltage of about 125 kv. can be set for a starting voltage of 135 kv. (effective). Under these conditions, the residual voltage, which is hardly ever exceeded even when high voltage surges are encountered, will not be substantially greater than $135 \times \sqrt{2}$, or 192 kv. peak value.

One disadvantage of the above arrester is that in use more and more of the discharge paths are destroyed so that after a certain time the operating voltage of the arrester will be substantially higher than the 10% or 20% increase for which allowance is normally made. Consequently, the arrester must be replaced, and the necessity therefor arises all the sooner inasmuch as due to the lower operating and residual voltage, the arrester will conduct, i.e., breakdown will occur, quite frequently at relatively low overvoltages at which it is not absolutely essential that protection to the system be available. Now it is true that this particular disadvantage could be overcome simply by increasing the operating or rated voltage of the arrester, but this would require the provision of larger and more costly burning out spark gaps. Furthermore, the residual voltage would be increased.

It is, therefore, an object of the present invention to provide an overvoltage arrester which overcomes the above disadvantages, and, with this object in view, the present invention resides mainly in an electric overvoltage arrester which comprises first spark gap means having two electrodes a portion of at least one of which is burned out when this spark gap means is subjected to an electric arc, and second spark gap means having electrodes which remain substantially unaffected when subjected to an electric arc, which second spark gap means are connected serially with the first spark gap means and have a flashover potential or breakdown point which is higher than that of the first spark gap means.

Additional objects and advantages of the present invention will become apparent upon consideration of the following specification when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagrammatic illustration of an electric overvoltage arrester according to the present invention;

FIG. 2 is a side view of the arrester shown in FIG. 1;

FIGS. 3 to 5 are diagrammatic illustrations of modified electrical overvoltage arresters according to the present invention; and

FIG. 6 is a voltage distribution curve.

Referring now to the drawings, and to FIGS. 1 and 2 thereof in particular, there is shown an electric overvoltage arrester incorporating two serially connected spark gap means **1** and **6** which are interposed between a high tension line **7** and ground **8**. The spark gap means **1** comprises two metal electrodes **1***a* and **1***b* which are vaporized onto one side of an insulator **3**. The electrodes **1***a* and **1***b* are spaced from each to form between themselves a meandering or otherwise suitably shaped gap **5**. At least one of these electrodes is of the type that part of it is vaporized and thus burned out when the spark gap **1** is subjected to an electric arc. Accordingly, either or both of the electrodes may be in the form of a vaporizable coating made of aluminum, zinc or the like, or alloys thereof.

The opposite side of the insulator **3** carries a counter coating **4** which pre-ionizes the air gap **5** and thus creates a condition conducive to an electric discharge, so that the discharge may readily take place in the gap **5**.

A suitable control resistor **1***c* of the order of several kilo-ohms up to about some hundred kilo-ohms may be

connected across the electrodes 1*a* and 1*b* of the spark gap 1 for the purpose described below.

The second spark gap 6 includes two electrodes 6*a* and 6*b* which are of a type that is not burned out or destroyed by an arc, i.e., the electrodes 6*a* and 6*b* remain substantially unaffected by an electric arc across the spark gap 6. These electrodes may be in the form of spheres made of copper or copper alloy, such as brass, or be of any other suitable form.

According to the present invention, this last-described spark gap 6 has a flashover potential which is higher than that of the first spark gap. By selecting the flashover potential or breakdown voltage sufficiently high, the arrester will not become effective, i.e., will not conduct, at the relatively harmless overvoltages that frequently occur, but only when the overvoltage is such as to render it potentially dangerous to the line or equipment. Thus, premature wear of the arrester unit as a whole is prevented.

For a more detailed explanation of the above, the following should be noted: The operating voltage of the arrester unit as a whole depends upon the flashover potential of the spark gap 6. Here it should be borne in mind that the spark gaps are in effect capacitors with the capacitance of the spark gap 1 being a substantial multiple of the capacitance of the spark gap 6. This, then, means that when the protector unit as a whole is subjected to an overvoltage, practically the entire overvoltage will appear across the spark gap 6. Since the flashover point of this last-mentioned spark gap is higher than that of of the spark gap 1, an arc occurs first across the spark gap 6 and this is followed by an arc across the spark gap 1, and the residual voltage, i.e., the voltage which is due to the current flowing through the arrester upon breakdown thereof, is determined by the overvoltage between the electrodes 1*a* and 1*b*. The arc across these electrodes is then extinguished due to the vaporization of that portion of either or both of the electrodes at which the arc occurs, it being in this way that the arc discharge path is lengthened to an extent at which the arc is longer maintained.

After the arc between the electrodes 1*a* and 1*b* is extinguished, the arc between the electrodes 6*a* and 6*b* is likewise extinguished, so that the original condition of the arrester is restored.

It is at this point that the above-mentioned resistor 1*c* across the electrodes 1*a* and 1*b* is of use, since the latter affords a path through which residual charges on the electrodes 1*a* and 1*b* may be discharged. This discharge current may be of the order of several milliamperes.

The above-described overvoltage arrester is so arranged that it is the spark gap 6 rather than the spark gap 1 which is nearer to the line 7, i.e., that it is the spark gap having the destructible electrodes which is nearer to ground 8. Thanks to the invention, that means the arrangement of the gap 6*a* and 6*b* before the gap 1*a* and 1*b*, the normal operating voltage of the line 7 will not be impressed across the spark gap 1, and it will be understood that this result would not be obtained if the spark gap 6 were not interposed between the spark gap 1 and the line 7. Consequently, without the interposition of the spark gap 6, the spark gap 1—which, as set forth above, is in effect a capacitor—would have to be so constructed as to be capable of withstanding the normal operating voltage of the line 7, and this, in turn, would necessitate a substantially greater amount of insulation than is required in the case of a spark gap that has connected between itself and the line 7 the quench gap constituted by the spark gap 6. Thus, the spark gap 1 may, according to the present invention, be built with the use of relatively little material, since the spark gap 6 is easily capable of withstanding the ordinary operating voltage of the line 7. In other words, it is sufficient if the spark gap 1 be capable of withstanding short pulses of voltages of the order of the line voltage, or a direct current potential corresponding to the peak value of the maximum permissible voltage of the network to which the arrester is connected.

FIG. 3 shows an electric overvoltage arrester according to the present invention which may be used in conjunction with a high tension line the voltage of which is greater than one or two kilovolts. To this end the spark gap 6 of the above described embodiment is replaced by a spark gap means indicated generally at 14 and composed of a plurality of individual spark gaps 15, 16 and 17 across which resistors 15*a*, 16*a* and 17*a*, respectively, are connected. The purpose of the latter is to distribute the voltage to which the spark gap means 14 is subjected among the spark gaps 15, 16 and 17 in any desired proportion; without these resistors, such distribution, particularly when the network to which the arrester is connected is a direct current one, would be dependent upon the resistance of the several spark gaps, and this resistance is usually but a matter of chance.

The resistors 15*a*, 16*a* and 17*a* may be either constant-value resistors or nonlinear resistors; in the latter case, they may be made of silicon or boron carbide. A further discussion of nonlinear resistors may be found in a publication entitled "AEG Ueberspannungsschuz" of February 1954.

FIG. 4 shows a protector arrangement which may be used in conjunction with extremely high tension systems. Accordingly, a plurality of arrester units 20 are connected serially between the line 7 and the ground 8, each unit being a complete entity comprising spark gaps 1 and 21, the latter having a resistor 21*a* connected across it. For lower voltage ratings, these resistors 21*a* may be constant-value resistors whereas nonlinear resistors may be used when higher voltages are involved.

FIG. 5 shows an arrangement similar to that illustrated in FIG. 4 except that in each of the serially connected units 30 the same resistor 31*a* is connected across the two spark gaps 1 and 31.

FIG. 6 is a voltage distribution curve which shows the distribution of the voltage among serially connected arrester units under conditions when the overvoltage is of the frequency of the line as well as when the arresters are subjected to a short pulse-type overvoltage. In explanation thereof, it should be noted that there exist frequency dependent overvoltage arresters incorporating two spark gaps and nonlinear resistors. The second spark gap of such an arrester may, when subjected to an overvoltage at, say, 50 c.p.s., have a flashover potential of about 2.2 times the rated voltage of the arrester, e.g., in an overvoltage arrester having a rated voltage of 110 kv., the second spark gap would arc over when the effective value of the alternating voltage is approximately 242 kv., which is equivalent to a peak value of about 340 kv. However, if such an arrester is subjected to a normal impulse of short duration, as, for example, a surge or impulse wave of about one microsecond front time and about 50 microseconds to half value, this shock potential would have an equivalent frequency of about 230 kilocycles per second, and the voltage at which the arrester would commence conducting would not be equal to 340 kv., or any higher value which would be the case if the pulse factor were greater than 1, but would, due to the frequency dependency of the starting voltage, be less than 1, such as 0.8, but sparks over at 340×0.8, or about 270 kv. peak value. As a result, the arrester is very sensitive under impulse conditions, and this increases the protective characteristics of the device. Suitable control rings, such as shielding or screening rings arranged at the head of the arrester, may be provided for additionally controlling the voltage at which the arrester commences to conduct under impulse conditions.

The above principle can be applied to an arrester according to the present invention, by providing resistors the values of which are so selected as to be sufficient to distribute linearly among the respective arresters an overvoltage which is of the frequency of the network to

which the protecting arrangement is connected but is insufficient to maintain such linear distribution when the overvoltage is of the short impulse-type, so that the current flowing through the resistors is small in comparison to the charging currents which effect the capacitative control of the spark gaps.

If desired, additional control rings may be provided for further influencing the voltage at which the arrester commences to conduct under impulse conditions.

The abscissa of FIG. 6 is shown in alignment with the arrester units **30** of FIG. 5, and *a* represents the voltage distribution among the several units when the system is subjected to an overvoltage at line frequency, while *b* represents the distribution under short impulse-type conditions.

It will be understood that the present invention is susceptible to modification in order to adapt it to different usages and conditions, and, accordingly, it is desired to comprehend such modifications within this invention as may fall within the scope of the appended claims.

What is claimed is:

1. An electric overvoltage arrester comprising: first spark gap means having two electrodes which remain substantially unaffected when subjected to an electric arc, one of said two electrodes of said first spark gap means provided for connection to a line of high electrical voltage potential relative to ground; and second spark gap means having a large capacitance and comprising an insulator member, a first electrode on one side of said insulator member, said insulator member being connected to the other one of said two electrodes of said first spark gap means, a second electrode on said one side of said insulator member and defining an electrically non-conductive, narrow and elongated gap with said first electrode on said member, said second electrode on said member being connected to ground, and an electric conductive layer on the other side of said member beneath said first and second electrodes thereon, at least one of said first and second electrodes on said member being consumable when said second spark gap means is subjected to an electric arc.

2. An electric overvoltage arrester, as claimed in claim 1, wherein said first and second spark gap means are connected serially and said first spark gap means has a flashover potential which is higher than that of said second spark gap means.

3. An electric overvoltage arrester, as recited in claim 2, and further comprising an electrical resistance connected across the electrodes of said second spark gap means.

4. An electric overvoltage arrester, as recited in claim 2, wherein said first spark gap means comprises a plu-

rality of serially connected first spark gaps with each spark gap having electrodes which remain substantially unaffected when each first spark gap is subjected to an electric arc.

5. An electric overvoltage arrester, as claimed in claim 2, wherein said second spark gap means comprises a plurality of serially connected second spark gaps, each comprising two electrodes, a portion of at least one of which is consumed when said second spark gap means is subjected to an electric arc.

6. An electric overvoltage arrester, as claimed in claim 2, wherein said first spark gap means are so controlled by means of parallel resistors that the breakdown of the protector is dependent upon frequency.

7. An electric overvoltage arrester arrangement comprising a plurality of arresters, as defined in claim 2, and connected serially with each other, a plurailty of resistor means associated with said arresters with a resistance being connected across at least first spark gap means of its respective arrester, the values of said resistors being so selected so as to distribute linearly among the respective arresters an overvoltage which is of the frequency of the network to which the protecting arrangement is connected but is insufficient to maintain such linear distribution when the overvoltage is of the short impulse type.

8. An electric overvoltage arrester arrangement, as claimed in claim 7, and further comprising control ring means for controlling the flashover point in the event of a short impulse type overvoltage.

9. An electric overvoltage arrester, as claimed in claim 2, wherein the electrodes of said second spark gap means are so insulated from each other that this insulation is able to withstand for a short time only the rated voltage of the network to which the arrester is connected.

10. An electric overvoltage arrester, as claimed in claim 2, wherein the electrodes of said second spark gap means are so insulated from each other that said second spark gap means is capable of withstanding a direct current potential corresponding to the peak value of the maximum permissible voltage of the network to which the arrester is connected.

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