LIGHTNING ARRESTER SPARKOVER CONTROL

Fig. 1

Fig. 2

Fig. 3

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Fig. 4

Fig. 5

Fig. 6

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ABSTRACT OF THE DISCLOSURE

A lightning arrester including first and second main gap means, shunted by substantially equal nonlinear resistance means and auxiliary gap operable to reduce the shunt resistance of one main gap means. The sparkover voltage of the auxiliary gap is less than that of the main gap so that, when a low frequency voltage impulse is applied to the arrester, the auxiliary gap will spark over to place a greater proportion of the applied voltage across the second spark gap to produce a cascading breakover effect in the main gaps.

BACKGROUND OF THE INVENTION

This invention relates to lightning arresters and, more particularly, to high voltage lightning arresters having reduced low frequency voltage sparkover.

In high voltage transmission systems, transient voltages that occur as the result of switching operations can exceed the basic insulation level of equipment in the system. Protection of the system from these transient voltage surges is a major consideration in the design of lightning arrestor sparkover characteristics. Conventional valve-type lightning arresters generally include one or more spark gaps which are connected in series with a current limiting resistance having nonlinear characteristics in that it will present a relatively high impedance to normal 60-cycle power current and a relatively low impedance to high voltages resulting from lightning or transient voltage surges. The gaps normally isolate the system from ground but sparkover when subject to predetermined voltages so that lightning and transient voltage surges are passed to ground through the current limiting resistance. Because the nonlinear resistance presents a relatively high impedance to 60-cycle power current which follows the voltage surges, the voltage across the gaps is reduced to a value which is insufficient to maintain arcing, and the system is again isolated from ground.

The voltage at which the arrester gaps will spark over as the result of a lightning surge is governed by the physical configuration of the spark gaps, grading resistors which normally shunt the spark gaps and stray capacitance that exists within the lightning arrester assembly. The degree to which each of these parameters affects the arrester sparkover voltage depends upon the frequency or rate of rise of the applied voltage wave. The frequencies of switching surge voltage waves are substantially lower than those of voltage waves generally associated with lightning phenomena. At the relatively low frequencies of switching surge voltage waves, the impedance of the stray capacitance of the lightning arrester is relatively high and, hence, has little effect on arrester sparkover when compared with that of the grading resistances while at the relatively high frequencies associated with lightning surges, the stray capacitance of the arrester has a significant effect on sparkover. As a result, the switching surge sparkover of arresters is controlled, to a great extent, by the gap grading resistors.

It is an object of the invention to provide a new and improved sparkover control means for lightning arrester spark gap units.

Another object of the invention is to reduce the power frequency sparkover voltage of lightning arresters without impairing the arrester's operation at its normal operating voltage.

Yet another object of the invention is to provide a lightning arrester in which the variation in the low frequency sparkover voltage between successive operations is substantially reduced.

These and other objects and advantages of the instant invention will become more apparent from the detailed description thereof taken with the accompanying drawings and the description of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view, with parts broken away, of a lightning arrester incorporating the instant invention;

FIG. 2 is a circuit diagram schematically illustrating the lightning arrester shown in FIG. 1;

FIG. 3 shows the operating characteristics of the lightning arrester illustrated in FIG. 1;

FIG. 4 is a fragmentary view, with parts broken away, showing an alternate embodiment of the instant invention;

FIG. 5 is a circuit diagram schematically illustrating the lightning arrester shown in FIG. 4;

FIG. 6 is a fragmentary view, with parts broken away, of yet another embodiment of the instant invention; and

FIG. 7 is a circuit diagram schematically illustrating the lightning arrester shown in FIG. 6.

SUMMARY OF THE INVENTION

A lightning arrester including, first and second main gap means, nonlinear resistance means in series circuit relation with said main gap means, first and second resistance means respectively shunting the first and second main gap means, auxiliary gap means having a sparkover voltage less than the main gap means and constructed and arranged to reduce the resistance of the first shunt resistance means, so that when an increasing voltage is applied to the arrester the auxiliary gap will spark over to place a greater proportion of the applied voltages across the second spark gap to cause the second spark gap to flash over.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows the lightning arrester 10 according to the preferred embodiment of the instant invention to include a hollow, generally cylindrical housing 11 with a suitably insulating material, such as porcelain or glass and which is closed at its upper and lower ends by end assemblies 12 and 13.

The housing 11 is provided with a central cylindrical bore 18 for receiving one or more nonlinear resistance elements 19 and spark gap assemblies 20 and 21. Those skilled in the art will appreciate that, in high voltage station-type lightning arresters, a plurality of resistance elements 19 and spark gap assemblies 20 and 21 may be arranged in a series circuit relation within an elongate housing and that a plurality of such housings may be physically connected by suitably joining the end assemblies 12 and 13.

The resistance elements 19 may have a generally cylindrical configuration and may be composed of a material such as silicon carbide, which has a nonlinear voltage characteristic whereby it presents a lower resistance to surge currents and a high resistance to the normal power current of the system. The elements 19 are coaxially arranged within the housing 11 and are separated from each other and from the spark gap assemblies 20 and 21 by conductive end plates 22, 22 and 22c.
A metallic compression spring 24 may be disposed between the upper end assembly 12 and the uppermost conductive end plate 22a to firmly hold the assembly in position and in good electrical engagement, and spring 24, in turn, may be electrically shunted by a conductive shunt member 25.

The spark gap assemblies 20 and 21 may be of any type well known in the art, and the details thereof will not be discussed in detail for the sake of brevity. For a more complete description of spark gap assemblies 20 and 21, reference is made to U.S. Pat. No. 3,242,376, issued Mar. 22, 1966, and assigned to the assignee of the instant invention.

A nonlinear grading resistor R27 is mounted between the end plates 22a and 22b on each side of the spark gap assembly 20 and is supported by a metallic, generally cup-shaped terminal member 26 which is suitably secured to the end plates 22 in an opposed coaxial arrangement. This places the grading resistor R27 in a parallel circuit arrangement with the spark gap assembly 20, as seen in FIG. 2. A grading resistor R28 is similarly connected in a parallel circuit arrangement with the spark gap assembly 21. The grading resistors R27 and R28 thereby shunt the main gaps 20 and 21 to assure uniform distribution of 60-cycle voltage across the spark gap assemblies 20 and 21 and the nonlinear resistance elements 19. A nonlinear resistance element R30 is also shown in FIG. 1 to be supported by a terminal member 26 from the upper end plate 22a to extend a partial distance toward the next succeeding end plate 22b and in general parallelism with the nonlinear resistance element R27. Extending upwardly toward the terminal end of the nonlinear resistance element R30 is a conductive rod 32 which is affixed at its lower end to the end plate 22a. The element R30 and the rod 32 are disposed in a generally coaxial aligned relation, and their terminal ends are separated by a gap 33. A tubular insulating member 35 extends upwardly from the end plate 22b and in surrounding relation to the rod 32 and the gap 33 and the lower end of the nonlinear resistance element R30. This electrically isolates the rod 32 from the intermediate portions of the grading resistor R27.

With reference to FIG. 2, it can be seen that the grading resistance R30 and the spark gap 33 are connected in series with the circuit related to the grading resistor R27 and the main gap 20.

During a lightning surge, which has a steep front or high frequency, a capacitive impedance path across the gaps 20 and 21 is relatively much lower than the path provided by the grading resistors R27 and R30. As a result, lightning surges will follow the low impedance path through the main spark gaps 20 and 21 which are over and through the nonlinear resistances 19 which present a relatively low impedance to surge currents. Because of the nonlinear resistance characteristic of the resistors 19, they readily pass the surge current and then restore the system to its normal operating condition after the voltage across the device has returned substantially to the line voltage of the system by limiting the flow of current to a value which is insufficient to sustain the arcing in the spark gap assemblies 20 and 21. The spark gap assemblies 20 and 21 thereby will again isolate the line conductor 36 connected to the upper end assembly 12 from the grounded lower end assembly 13.

As stated hereinabove, the rate of rise or frequency of switching surge voltage waves is relatively lower than those associated with lightning phenomena. As a result, the switching surge voltage wave is of longer duration. In the gap voltage of FIGS. 4.7 alternate methods are illustrated for reducing the resistance parallel with the gap 33 which are capable of preserving an unbalanced voltage condition. More specifically, in the embodiment of FIGS. 4 and 5 the auxiliary spark gap 45 is formed by a generally L-shaped conductive rod member 46 which has a transversely extending portion 47 which terminates adjacent approximately low voltages across the gaps 20 and 21. In addition, the voltage developed across resistor R27 is also impressed across the gaps 33 which are connected in parallel with resistor R27. The breakdown voltage of gap 33 is chosen so that it will be at some voltage greater than the normal operating voltage of the resistor R27, whereby the latter will retain its voltage grading function.

Assume, for the sake of illustration, that the sparkover voltage of the control gap 33 is 6000 volts and that of each of the main gaps 20 and 21 is 8500 volts. A typical voltage and current characteristic for such a lightning arrester is illustrated in FIG. 3. Here the characteristic 40 represents the voltage across the resistors R27 and R28 connected in series, the characteristic 41 represents the voltage across the resistor R27 and characteristic 42 represents the voltage across the parallel combination of resistor R27 and resistor R30 after the gap 33 has broken down; and the characteristic 43 is the total voltage across the resistors R27 and R28 connected in series and resistor R30 connected in parallel with resistor R27 or, in other words, is the sum of the arrester associated with each instant.

Under normal operating conditions the voltage will divide equally across resistors R27 and R28, as represented by the curve 40. Should a low frequency switching surge occur, the voltage across the resistors R27 and R28 would begin to rise until the voltage reaches 12 kV, as represented by point A in characteristic 40. At this point 6000 volts would appear across each of the resistors R27 and R28 and across the gap 33. At 6000 volts the spark gap 33 is calibrated to spark over, whereby resistor R30 is connected in parallel with resistor R27, as represented by characteristic 43. This decreases the series resistance to increase the current so that the voltage characteristic of the device would now be at point B in characteristic 43 which is the sum of the voltages across resistor R28 as represented by point C in characteristic 41 and the voltage across the parallel combination of resistors R27 and R30, as represented by point D in characteristic 42. As seen in FIG. 3, the voltage across the gaps 20 and 21 will now become unbalanced with approximately 6950 volts across gap 21 and 5050 volts across gap 20. As the voltage of the device continues to rise along characteristic 43, the voltage across the gaps 20 and 21 will rise along the characteristics 42 and 41, respectively. When the voltage characteristic reaches point E on curve 43, the voltage across the gap 21 will be at point F which is equal to 8500 volts, and the voltage across gap 20 will be at point G which is equal to 6200 volts. Since 8500 volts is the sparkover voltage of gap 21, it will fire, thereby placing the entire 14.7 kV across the gap 20 which also fires. In this manner the switching surge is passed to ground.

It can be seen from the foregoing example that the control gap 33 allows the lightning arrester to operate on switching surges equal to 14.7 kV. If the control gap 33 had not switched the resistor R30 into the circuit, the switching surge sparkover voltage of the lightning arrester would have been twice that of the two gaps or 17 kV. In this manner, the lightning arrester according to the instant invention is able to pass switching voltage surges which are substantially less than the normal sparkover voltage of the arrester. Because voltage surges associated with lightning occur in a relatively brief interval, a peak voltage of predetermined magnitude is not as potentially destructive to the system as switching voltage surges of the same magnitude.

In the embodiment of the invention shown in FIGS. 1 and 2 the resistance in shunt with one of the main spark gaps was reduced by placing a second resistance in parallel with the other two. In the embodiment of FIGS. 4 and 5 alternate methods are illustrated for reducing the resistance parallel with each of the spark gaps to create an unbalanced voltage condition. More specifically, in the embodiment of FIGS. 4 and 5 the auxiliary spark gap 45 is formed by a generally L-shaped conductive rod member 46 which has a transversely extending portion 47 which terminates adjacent approximately low voltages across the gaps 20 and 21.
jacent the midpoint of the resistor $R_{27}$. When the voltage across resistor $R_{27}$ is equal to the sparkover voltage of the gap $20$ it will fire to short circuit a portion of resistor $R_{27}$ and thereby to unbalance the voltages across the gaps $20$ and $21$. In this manner the gaps $21$ and $20$ will spark over successively in a manner similar to that discussed with respect to the embodiment of FIG. 1.

In yet a further embodiment of the invention shown in FIGS. 6 and 7, the main gaps $20a$ and $20b$ are each shunted by a resistance $R_{27a}$ and $R_{27b}$ and the midpoints of each of the latter are connected to rods $50$ and $51$ which are separated to form an auxiliary spark gap $52$. When the combined voltage across the gaps $20a$ and $20b$ exceeds the sparkover voltage of the auxiliary gap $52$, it will fire to short a portion of each of the resistors $R_{27a}$ and $R_{27b}$, thereby placing a greater proportion of the total voltage across the spark gaps $21a$ and $21b$. Here again, a greater voltage will appear across main gaps $21a$ and $21b$ than across the gaps $20a$ and $20b$ so that the former will spark over when the total voltage across the lightning arrester is less than the total sparkover voltage of all the gaps.

While the invention has been shown and described with respect to a particular number of spark gaps and grading resistors, those skilled in the art will appreciate that it is also intended to encompass greater numbers of such components as well. In addition, while only a few embodiments of the invention have been shown and described, it is not intended to be limited thereby, but only by the scope of the appended claims.

1. A lightning arrester including a plurality of main spark gap means, a plurality of first resistance means each shunting a different one of said main spark gap means, and isolated modifying means in circuit with said first resistance means and responsive to a predetermined voltage to modify the effective resistance of one of said first resistance means, said predetermined voltage being less than the sparkover voltage of said main gaps.

2. The lightning arrester set forth in claim 1 wherein said modifying means is an auxiliary spark gap means whose sparkover voltage is less than that of said main spark gap means.

3. The lightning arrester set forth in claim 1 including nonlinear second resistance means connected in series circuit relation with said main spark gap means.

4. The lightning arrester set forth in claim 1 wherein said first resistance means comprises nonlinear resistance means.

5. The lightning arrester set forth in claim 2 wherein said auxiliary spark gap is operative to reduce the effective resistance of said one of said first resistance means.

6. The lightning arrester set forth in claim 2 wherein said auxiliary spark gap means is connected in a shunt circuit relation with at least a portion of the first resistance means shunting one of said main gap means.

7. The lightning arrester set forth in claim 5 and including nonlinear second resistance means connected in series circuit relation with said main spark gap means.

8. The lightning arrester set forth in claim 7 wherein said first resistance means comprises nonlinear resistance means.

9. The lightning arrester set forth in claim 8 wherein said auxiliary spark gap means is connected in a shunt circuit relation with at least a portion of said nonlinear first resistance means shunting one of said main gap means.

10. The lightning arrester set forth in claim 6 wherein additional resistance means is connected in a series circuit relation with said auxiliary spark gap means, said auxiliary spark gap means being operative to connect said additional resistance means in shunt with said first resistance means to reduce the effective resistance thereof.

11. The lightning arrester set forth in claim 10 wherein said additional resistance means comprises a nonlinear resistance material.

12. The lightning arrester set forth in claim 10 wherein said additional resistance means includes an elongate body of nonlinear resistance means supported at one side of said one of said main spark gap means and said auxiliary spark gap means comprises a conductive rod supported at the other side of said one of said main spark gap means and disposed in general alignment with said resistance material and spaced therefrom.

13. The lightning arrester set forth in claim 6 wherein said spark gap means includes a first conductive member connected to an intermediate portion of a first one of said resistance means and a second conductive member connected to an intermediate portion of the next adjacent resistance means, said members being disposed in general alignment and in spaced relation to form a spark gap.

14. The lightning arrester set forth in claim 6 wherein said auxiliary spark gap comprises a conductive member connected to one side of said one main gap means and having a portion disposed in closely spaced relation to an intermediate portion of said one first resistance means.

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