

[54] **OVERVOLTAGE SURGE ARRESTER WITH IMPROVED VOLTAGE GRADING CIRCUIT**

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[51] Int. Cl. H02h 9/06

[58] Field of Search 315/36; 317/68, 69, 70

[56] **References Cited**

UNITED STATES PATENTS

3,091,721	5/1963	Yost.....	317/70
3,313,978	4/1967	Miller	315/36
3,611,044	10/1971	Osterhout et al.	317/70

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[57] **ABSTRACT**

An overvoltage surge arrester for relatively high voltage applications is provided with a voltage grading circuit comprising a relatively low exponent resistor in parallel with a relatively high exponent resistor, for preventing spurious operation of the arrester under conditions in which the outside surface of the porcelain housing becomes contaminated with a conductive film. A linear resistor is additionally connected in series with the high exponent non-linear resistor of the above circuit to prevent excessively high current in the high exponent resistor near the sparkover voltage of the arrester.

8 Claims, 6 Drawing Figures

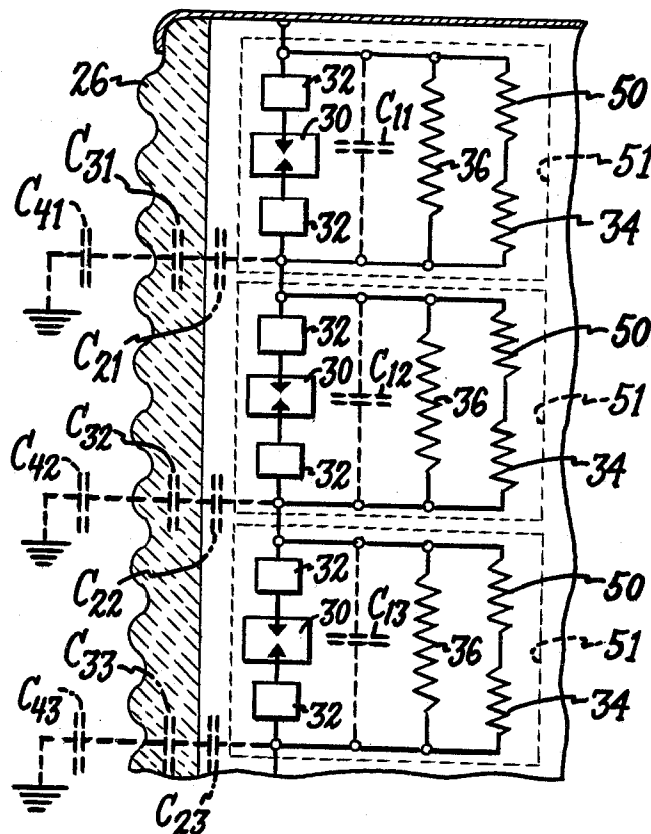


Fig. 3.

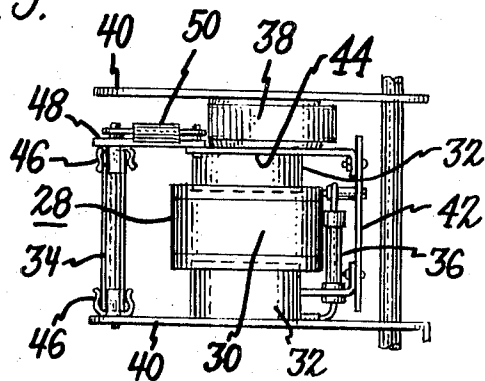


Fig. 4.

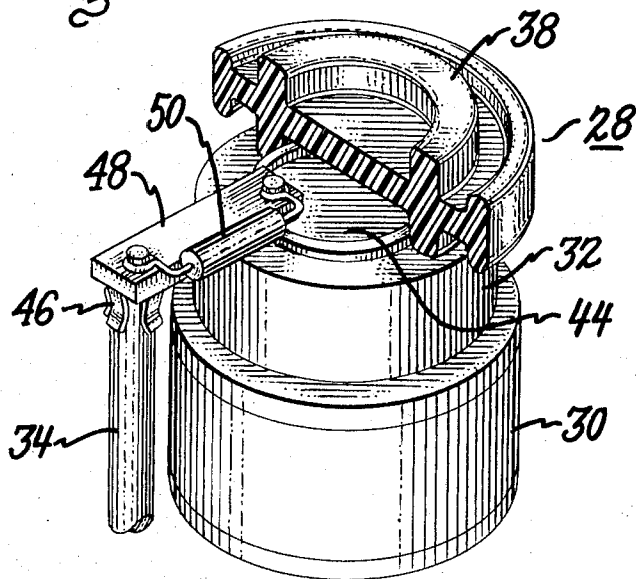


Fig. 5.

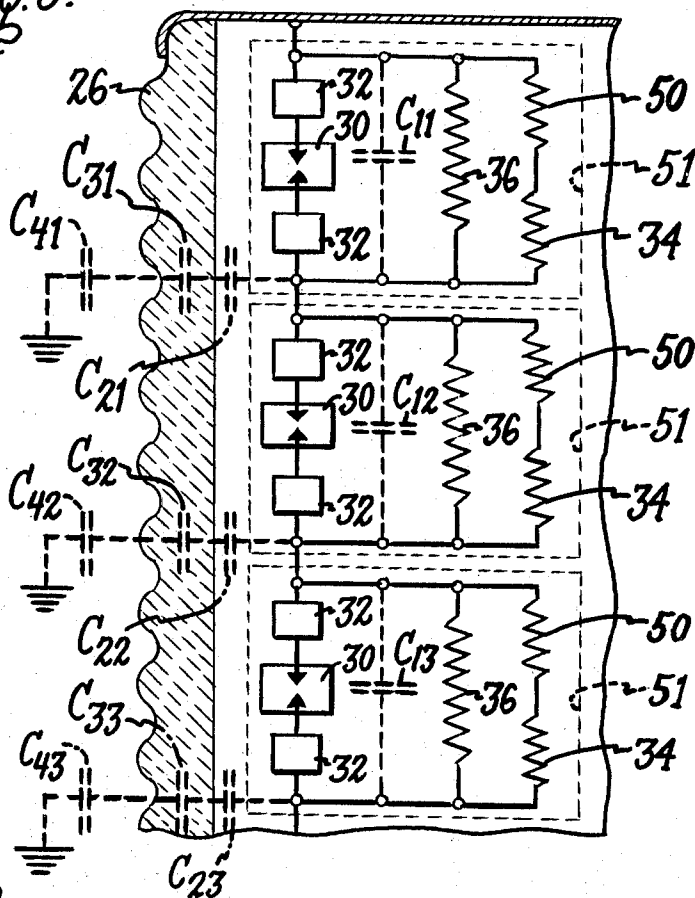
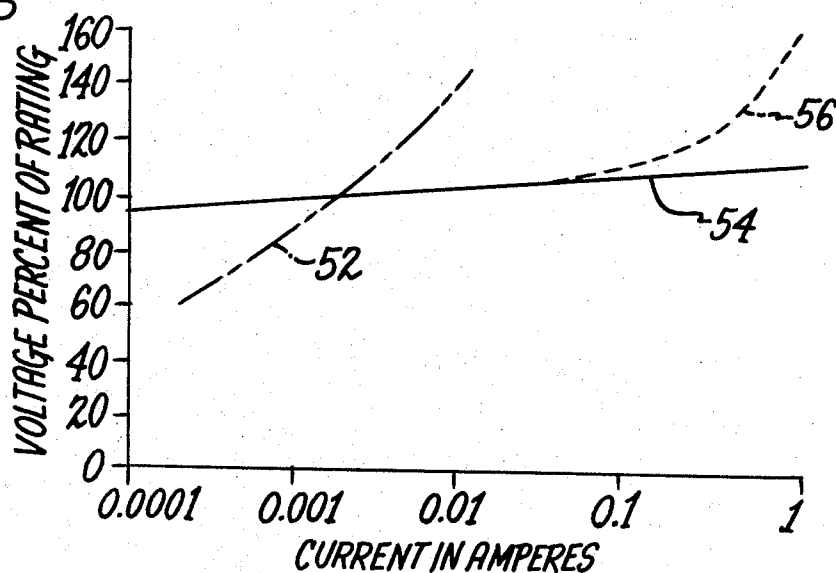


Fig. 6.



OVERVOLTAGE SURGE ARRESTER WITH IMPROVED VOLTAGE GRADING CIRCUIT

BACKGROUND OF THE INVENTION

The present invention relates generally to electrical overvoltage surge arresters and relates particularly to, but is not limited to, such arresters for use at relatively high voltages and which are provided with a plurality of spark gaps electrically connected in series.

An overvoltage surge arrester for relatively high alternating current voltages of 3 kv (kilovolts) or higher typically includes a number of individual and similar arrester modules stacked in electrical series inside an elongated, hollow porcelain housing cylinder which is closed at both ends by top and bottom metal end caps, respectively. The top cap is in contact with the top of the uppermost module and is connected to the power line. The bottom cap is in contact with the bottom of the lowermost module and is connected to ground.

Each arrester module includes one or more electrode gaps connected in series with one or more nonlinear resistance current-limiting elements, or valve blocks. A non-linear grading resistor is commonly connected in parallel with the gap of each module to maintain a uniform voltage distribution among the modules. Additional components may be connected in or among the modules to further enhance the operation of the arrester.

The individual modules are designed to normally have across them an "operating voltage." Each module also has a characteristic "sparkover voltage," somewhat above the operating voltage, at which the gap sparks over to initiate an active operation of the arrester. Typically, the sparkover voltage is on the order of 1.7 times the operating voltage. The operating voltage and the sparkover voltage of an entire arrester are simply the sum of the respective such voltages of the modules which are connected in series in the arrester. Thus, the arrester is designed to have an operating voltage equal to the normal line-to-ground voltage of the line which is to be connected to the arrester.

A serious problem with high voltage arresters of the type described above can arise when the outside surface of the porcelain housing becomes contaminated with an electrically conductive film of, for example, salt spray or wetted cement dust. Various effects of such contamination are described for example in the following U.S. Pat. Nos.:

2,179,297 issued Nov. 7, 1939 to F. B. Johnson

3,467,936 issued Sept. 16, 1969 to E. Nasser

3,510,726 issued May 5, 1970 to J. E. Harder

3,683,234 issued Aug. 8, 1972 to A. Rodewald

2,688,715 issued Sept. 7, 1954 to S. A. Vorts et al.

Contamination of the porcelain may cause the arrester to fail by sparking over at the operating voltage, rather than at the appropriate higher sparkover voltage. Such erratic operation frequently results in destruction of the arrester.

For an understanding of the above-described failure mode it is useful to consider the alternating current leakage due to capacitive coupling of the arrester. To facilitate the discussion of such capacitive leakage, there is shown in FIG. 1 of the drawings a schematic representation of a fragment of a prior art arrester 10. The arrester 10 includes three of a number of arrester modules 12 inside a housing cylinder 14 provided with an upper end cap 16. Each module 12 is outlined by a

dashed rectangle 13 and includes an electrode gap section 18, two valve blocks 20 to either side of the gap section 18, and a grading resistor 22 connected across the remote sides of the valve blocks 20.

The capacitive coupling associated with each of the modules 12 is attributable primarily to four capacitive components, which are represented in FIG. 1 by an equivalent circuit of dashed lines and dashed capacitors. The dashed lines and capacitors are used here to avoid confusion of the coupling capacitances with actual capacitors which are sometimes included in an arrester.

The first coupling components C_{11} , C_{12} , C_{13} . . . of the first, second, and third modules, respectively, beginning with the uppermost, are the capacitance of the module 12 itself, including, for instance, the capacitance between the electrodes of the gap section 18.

The second coupling components C_{21} , C_{22} , C_{23} . . . of each respective module 12 are the capacitance due to the coupling of the internal parts of the arrester 10 with the housing 14.

The third coupling components C_{31} , C_{32} , C_{33} . . . of each respective module 12 are the capacitance of the porcelain housing cylinder 14 itself.

The fourth coupling components C_{41} , C_{42} , C_{43} . . . of each respective module 12 are the capacitance due to coupling of the porcelain housing cylinder 14 to ground.

During normal operation of the arrester 10, the voltage across C_{11} , and therefore across the gap section 18 of the first module 12, is greater than the voltage across C_{12} , because C_{11} and the grading resistor 22 of the first module 12 must carry all the capacitive leakage and the normal grading currents for all the other modules 12 down the line. The grading resistors 22 are typically chosen so that during normal operation the grading current through them is much larger than the capacitive leakage current. Thus, the voltage across a given gap section 18 is held by the resistors 22 at very nearly the same value as across every other gap section 18. At normal line voltages, the total capacitive leakage current is typically on the order of, for instance, 0.01 milliamperes, while the grading current through the grading resistors 22 is typically on the order of 1 milliamperes.

When the surface of the arrester housing 14 is contaminated with a conducting contaminant, such as salt, cement dust, fly ash etc. and the contaminant is wetted so that it becomes capable of conducting current and initiating discharges on portions of the surface, the currents through capacitances C_{21} , C_{22} , C_{23} . . . increase considerably. The reason for the increase is that the voltage distribution on the porcelain surface becomes extremely nonuniform at times from rapidly changing nonuniform surface conductivity of the contaminant film due to uneven wetting and from the effects of discharges on the wetting patterns. Since the current in a capacitor is proportional to the rate of change of voltage across it, such rapidly changing voltage distributions result sporadically in substantially increased capacitive leakage currents being forced through the grading resistors 22, particularly those nearest the line voltage. Peak leakage currents of tens of milliamperes or higher may be coupled into the arrester 10 under severely contaminated conditions. Such relatively large sporadic capacitive leakage currents through the grading resistors 22 can result in a voltage drop across the grading resistors 22 high enough to cause a spurious

sparkover voltage to appear across the parallel connected gap electrodes of the gap section 18 at the operating voltage, with consequent failure of the arrester 10.

One approach to preventing the above failure mode of arresters is to provide for each module a low exponent and a high exponent grading resistor electrically connected in parallel with each other and with the gap section of the module. This approach is described in application Ser. No. 433,655, entitled "*Overvoltage Surge Arrester With Improved Voltage Grading Circuit*," filed in the name of E. C. Sakshaug on the same date and assigned to the same assignee as is the present application. The term "exponent" as used herein refers to the value of the current-voltage characteristic exponent n of the voltage in the current-voltage relationship for a resistor given by $I=KV^n$, where I represents the current through the resistor, K represents a constant, and V represents the voltage across the resistor. When an arrester provided with such low and high exponent parallel grading resistors is operating in a steady state at operating voltage, the low exponent grading resistors allow a grading current on the order of milliamperes to flow through them, such that any capacitance effect in the absence of contamination on external surface of the housing is not significant at line voltage frequencies. Consequently, the voltage is relatively uniformly graded over the gap section. The current through the high exponent grading resistors is very small, in the order of only microamperes. This is not enough current to present a significant risk of instability failure of relatively stable compositions of such high exponent resistors. When contamination of the arrester results in substantially increased capacitive leakage current to be sporadically forced through the grading resistors, the bulk of this current is passed through the high exponent resistors. Because of the high exponent of the resistors, this current can be passed without sparking over the gap section, since the resistive voltage drop can be maintained at well below the sparkover voltage.

A high current problem exists with the above parallel low and high exponent grading resistor arrangement when the desired sparkover voltage is made relatively high as compared to the operating voltage. If the high exponent grading resistor is chosen to pass a current on the order of a milliamperes at the rated voltage, as is desired for it to be effective as described above, then the current will be unreasonably high as sparkover is approached. In addition, since in most modern multi-gap arresters at least some of the gaps are cascade gaps which are set to have a sparkover substantially higher than other gaps which are set to trigger the total arrester sparkover, this high current problem is even more serious for the high exponent grading resistors paralleling these so-called cascade gaps. The high currents passed through the high exponent grading resistors just prior to and during sparkover of the arrester resulting from an overvoltage surge can be so large as to cause instantaneous heating damage to the high exponent resistor material. such heating damage can lead to failure of the high exponent resistor.

SUMMARY OF THE INVENTION

The novel arrester comprises a gap having in parallel with it both a relatively low exponent grading resistor and a relatively high exponent grading resistor, connected in parallel relationship to one another. A sub-

stantially linear grading resistor is connected in series with the high exponent resistor and in parallel with the low exponent resistor. The linear resistor prevents excessively high current in the high exponent resistor near the sparkover voltage, while leaving the function of the high exponent resistor substantially unaffected at lower voltages.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side sectional view of a fragment of a prior art arrester and including a schematic representation of an electrical circuit therein.

FIG. 2 is a side sectional view of a fragment of an overvoltage surge arrester in accordance with the preferred embodiment of the invention.

FIG. 3 is a side view of an arrester module of the arrester of FIG. 2 seen at 90° with respect to the view of FIG. 2.

FIG. 4 is a partly sectioned perspective view of a portion of the module of FIG. 3.

FIG. 5 is a side, sectional, partly schematic view of a fragment of the arrester of FIG. 2.

FIG. 6 is a graph illustrating the current voltage characteristics of the grading resistors of the arrester module of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the novel arrester is shown in FIG. 2. The arrester 24 has a porcelain housing 26 sealed at both ends by metal end caps, not shown. Inside the housing 26 and clamped between the end caps is a stack of individual arrester modules 28 paired side by side, only a pair of which are shown entirely in the FIG. 2. Another view of the modules 28 at 90° orientation with respect to the FIG. 2 is shown in FIG. 3. A perspective view of a single module 28 is shown in FIG. 4. All the modules 28 of the arrester 24 are similar and have a 6 kv rating, meaning that they are designed to be subjected to an individual operation voltage of about 4.8 kv. Like reference numerals are used to identify like members of the modules 28 of FIGS. 2, 3 and 4.

Referring now to FIGS. 2, 3 and 4, each module 28 includes a gap section, or unit 30 contacted on each of its faces by a valve block 32. Connected electrically in parallel with the series of the gap section 30 and the valve blocks 32 are a high exponent grading resistor 34 and a low exponent grading resistor 36. The modules 28 are series-stacked in pairs which are clamped on insulating spacers 38 between metal supports plates 40 facing in opposite directions for connection in series as a pair by a diagonal metal strap 42 extending between two thin metal contact plates 44, each located between the spacer 38 and the valve block 32. The gap electrodes of the gap unit 30 are located inside ceramic supporting discs of the gap unit 30 and are not shown in detail, since details of their particular configuration are not essential for an understanding of the present invention. The primary current-carrying gaps of the gap unit 30 are connected in series with the two faces of the gap unit 30.

The low exponent grading resistor 36 is a round rod of a silicon carbide varistor composition provided with metal end caps for electrical contact. It is about 5 cm (centimeters) long, and 1 cm in diameter and has a current-voltage characteristic exponent of about 4.5.

The high exponent grading resistor 34 is a round rod of zinc oxide varistor composition provided with metalizing on a short portion of the ends for electrical contact to receiving clips 46, one of which is mounted on a support plate 40 and the other on a short insulating arm 48 attached to the contact plate 44. A linear resistor 50 is connected between the clip 40 on the insulating arm 48 and the contact plate 44. The high exponent grading resistor 34 is about 10 cm long, about 1.6 cm in diameter and has a current-voltage characteristic exponent of about 45. The linear resistor 50 has a resistance value of about 1,000 ohms and a power rating of about 2 watts.

There is shown in FIG. 5 of the drawings a partially schematic representation of the electrical elements of the arrester 24 and the capacitive coupling alternating current leakage components associated with contamination of the arrester housing 26. The capacitive coupling components are represented by the same symbols used in the discussion above relating to FIG. 1, since the coupling components of FIG. 5 are analogous to those of the earlier discussion. The first arrester module 28 at the top and those following is outlined by dashed lines 51. The first module 28 includes a valve block 32 electrically connected to each side of the gap section 30. Connected in parallel with the remote sides of the valve blocks 32 is the low exponent grading resistor 36. Also connected in parallel with the remote sides of the valve blocks 32 and in series with each other are the high exponent grading resistor 34 and the linear resistor 50.

A graphic representation of the current-voltage characteristics of the low exponent, high exponent, and linear grading resistors 36, 34, 50 of the arrester 10 of the preferred embodiment is presented roughly in FIG. 6 of the drawings. The abscissa of the graph corresponds to the current in amperes through the resistor plotted on a logarithmic scale, while the ordinate corresponds to the rated voltage of the arrester module 28. The operating voltage is, as was mentioned earlier, generally about 80 percent of the rated voltage. The dashed curve 52 shows the behavior of the low exponent resistor 36. As the current rises, the voltage across the resistor 36 also rises at a relatively rapid rate. The solid curve 54 shows the behavior of the high exponent resistor 34. The voltage rises relatively slowly with increasing current. The broken line curve 56 illustrates the manner in which the current through the high exponent resistor 34 is modified by the addition of the linear resistor 50. It can be seen from the two curves 52, 54 that with the nonlinear resistors 34, 36 connected in parallel so that they see the same voltage, almost all the current is carried by the low exponent resistor 36 at the operating voltage of 80 percent rating and the effect of the linear resistor 50 is insignificant at this voltage. As the current increases so that the voltage rises to 100 percent the rated voltage, the current becomes evenly divided between the low and high exponent resistors 36, 34. The major portion of higher currents than those at 100 percent rated voltage is carried by the high exponent resistor 34. Thus, the resultant curve for the parallel resistors 34, 35 can be considered for practical purposes to be the combination of that part of the low exponent curve 52 below the high exponent curve 54, together with that part of the high exponent curve 54 to the right of the low exponent curve 52. Thus, the high exponent resistor 34 becomes a significant current car-

rier only at or above the rated voltage. Since the sparkover voltage of the gap section 28 is generally at least 125 percent of the rated voltage, sparkover of the gap section 28 by spurious leakage currents in the grading resistors 34, 36 is prevented by the high exponent resistor 34. It can be seen from the broken line curve 56 that just below the sparkover voltage, which in this instance is taken to be about 135 percent the rated voltage, the voltage across the linear resistor rapidly becomes significant to limit the current upturn in the high exponent resistor 34 connected in series with it.

GENERAL CONSIDERATIONS

While the exponent of the relatively high exponent grading resistor material in the preferred embodiment was as great as ten times the exponent of the relatively low exponent material, it should be understood that the high exponent material need only have an exponent substantially greater than the exponent of the low exponent material to provide the benefits of the present invention. A "substantially greater exponent" is taken to mean that the exponent is greater by more than the extent to which the exponent normally varies for a given material in the production process. Moreover, the low exponent material is not limited to silicon carbide, but may be of various nonlinear resistance materials which are presently used, or could presumably be used in an arrester for that purpose. For that matter, the relatively low exponent material could in fact be linear, thus having an exponent of unity. For practical reasons, however, silicon carbide and zinc oxide for low and high exponent materials, respectively, are the most likely materials to be used for the foreseeable future.

The description herein of a grading resistor as connected in parallel with a gap includes arrangements in which valve blocks or various other elements, including other gaps, are additionally connected in series with the gap and in parallel with the resistor.

The resistance value and continuous power dissipation capability of the linear resistor should be chosen to provide the desired current limiting action for the particular sparkover voltage of the gap in question, and is not particularly critical. For sparkover voltages on the order of kilovolts, a resistance on the order of 0.5 to 5 kilohms is considered sufficient for various compositions of high exponent resistors. It is generally adequate to use as the linear resistor a carbon composition bulk type resistor having sufficient mass to absorb the energy dissipated within it during an overvoltage event without overheating.

The linear resistor in series with the high exponent resistor need not be absolutely linear, so long as it is substantially linear relative to the high exponent resistor. As a practical matter, the linear resistor should have a current-voltage exponent of less than two. Thus, the term "substantially linear" as used herein to describe a resistor means that the exponent of the resistor has a numerical value of less than two.

The spark gap section, across which the grading resistors are connected, can include a single spark gap assembly of two gap electrodes or a plurality of gap assemblies, and the gap assemblies may be all of the same type, such as a simple gap, or of a complex type, such as a current limiting type. They may also be a mixture of different types of gap assemblies connected together in series, parallel, or combinations thereof. The important consideration is that the gap section be essentially

a voltage-sensitive switch which closes very suddenly at a predetermined voltage higher than the voltage to which it is subjected during normal operation at the operating voltage of the arrester.

I claim:

1. An electrical overvoltage surge arrester of the type including:

a housing comprising at least two conductive terminal members spaced apart by a hollow insulating member;

a spark gap section disposed inside said housing, said spark gap section comprising at least one spark gap assembly electrically connected in series with said terminal members;

a first grading resistor of a first nonlinear resistance material electrically connected in parallel with said spark gap section, the degree of nonlinearity of said first material being indicated by a first numerical exponent for the voltage in an equation describing the general current-voltage characteristics of said first material, and

a second grading resistor of a second nonlinear resistance material electrically connected in parallel with said spark gap section and with said first grading resistor, the degree of nonlinearity of said second material being indicated by a second numerical exponent for the voltage in an equation describing the general current-voltage characteristics of said second material,

said first exponent being substantially greater than said second exponent, wherein the improvement comprises;

a substantially linear resistor electrically connected in series with said first grading resistor.

2. The arrester defined in claim 1 and wherein said first exponent is at least twice the magnitude of said second exponent.

3. The arrester defined in claim 2 wherein said first exponent is about ten times as great as said second exponent and said linear resistor has a resistance value on the order of at least several hundred ohms and a current-voltage characteristic exponent of less than two.

4. The arrester defined in claim 3 wherein said first material is substantially a metal oxide.

5. The arrester defined in claim 4 wherein said first material is substantially zinc oxide and said linear resistor has a resistance value of about 1,000 ohms.

6. The arrester defined in claim 5 wherein said second material is substantially silicon carbide.

7. The arrester defined in claim 6 comprising at least one nonlinear resistance valve block element electrically connected in series between said spark gap and one of said terminal members.

8. The arrester defined in claim 7 wherein said spark gap section comprises a plurality of said spark gap assemblies electrically connected in series between said terminal members.

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