CURRENT LIMITING SPARK GAP WITH MEANS FOR REGULATING GAP VOLTAGE

ABSTRACT: A lightning arrester having a current limiting spark gap assembly with means therein for regulating the movement of arcs established within the assembly so that the arcs are prevented from building a high voltage when they are discharging a current in excess of a predetermined value. The regulating means are also effective to allow low current arcs to rapidly and consistently build high voltages.
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**LIMITING SPARK GAP WITH MEANS FOR REGULATING GAP VOLTAGE**

This invention relates to electric current interrupters and more particularly to improvements in spark gaps for electric power system lightning arresters.

Conventional lightning arresters typically comprise a spark gap whereby unit series connected with a negative slope resistance voltage characteristic type of valve between ground potential and an electric conductor whose insulation is to be protected by the arrester against damage from overvoltage surges. In the operation of such a lightning arrester, at normal line voltage essentially no discharge current passes through the arrester and essentially full line voltage appears across the series connected spark gap assembly. When a surge voltage in excess of the lightning arrester's breakdown rating occurs on the protected conductor, the spark gap assembly breaks down, or sparks over, and allows current to discharge through the arrester to ground. Since the initial electrical resistance of an arc between the respective electrodes of the spark gap assembly is low, compared to the resistance of the gaps when there is no arc, most of the surge voltage then appears across the series connected valve resistance. Due to the negative slope resistance voltage characteristic of this valve, the series resistance almost instantaneously drops to a very low value. Accordingly, the lightning arrester can discharge high current surges to ground while preventing the line voltage from exceeding a predetermined value at which arc stabilisation might occur. After a lightning arrester has operated in this fashion to discharge a dangerously high surge current to ground, the normal line voltage of the protected conductor tends to maintain a flow of power current through the arrester; however as the voltage on the valve resistor drops toward line voltage level, the resistance of the valve increases greatly and, thus, reduces the magnitude of power follow current that is allowed to flow through the arrester before it is cleared by the combined operation of the valve resistor and series connected spark gaps, which extinguish the series arcs formed between the respective spark gap electrodes and reestablish line voltage across the spark gap assembly.

As normal line voltages of today's power systems have continually increased to ratings of 345 kvolts and more and as the length of transmission lines has increased, the need for high energy absorbing, arresters has increased dramatically. Part of this added energy absorbing demand was imposed on lightning arrester spark gap assemblies by incorporating a current limiting action in them to reduce the size of series connected valve units necessary to provide adequately fast clearing action for the arresters. It is well known in the lightning arrester field that the current limiting action of the gaps may be obtained by use of series connected magnetic coils and other means to force arcs formed in a spark gap assembly of the arrester to move rapidly into contact with the peripheral arc-cooling walls of the assembly and thereby rapidly increase the respective arc voltages or arc resistance up to a relatively high value compared with the values attainable in similar gaps not provided with such arc cooling means. The advent of such current limiting gap action has made it possible to build arresters which will operate on DC circuits since such gaps can be made, by incorporating proper cooling means in them, to generate such a high arc voltage that power follow current interruption in a DC circuit can be obtained.

Serious serious problems may be encountered when current limiting gaps are used in arresters subjected to high energy (long duration) discharges. For example, (1) If relatively high current flows through too much material in contact with a collaring surface of appreciable length, the combined arc voltage thus developed plus the voltage drop across the valve material may exceed the protective level of the arrester. Conversely, if too little arc cooling is achieved, the gaps do not absorb a sufficient portion of the total arrester energy and the nonlinear valve material may explode. (2) For a very long duration discharge, such as are encountered on long transmission lines, the arcs may play on the peripheral arc cooling walls of a spark gap chamber to such an extent as to cause permanent erosion of or damage to, the walls, thus compromising the ability of the gaps to perform their proper current limiting function; (3) Even if permanent damage is not done by long duration surges being discharged through the gaps, the gap walls may become temporarily heated to the extent that effective current limiting capability is temporarily lost so the gaps cannot force a clearing as soon as they should. Such faulty operation is particularly detrimental in DC arresters because if clearing is not obtained as soon as the overvoltage surge is dissipated the gaps get continually hotter and clearing may never be accomplished.

Prior to the invention disclosed below, no completely satisfactory means was known for overcoming these basic problems. Briefly stated, in accordance with a preferred embodiment of the invention, these major problems have been overcome by providing new and improved spark gap assemblies for lightning arresters that are particularly adapted for use in protecting extra high voltage transmission systems. It will be appreciated as the description of the invention proceeds that the advantages of the invention are particularly useful in arresters for DC circuits as well as being useful in lower voltage lightning arresters and in other surge voltage arresting devices. A spark gap assembly constructed pursuant to the present invention is characterized by having arc containing chambers that are provided with means for regulating the movement of an arc from horn gap electrodes in the chambers to contact with the arc-cooling peripheral walls of the chambers in a manner such that high current arcs are prevented from contacting the arc-cooling surfaces of the walls. Furthermore at least some parts of the walls are shielded from the main arc chamber in a manner such that deterioration of the arc-cooling surfaces due to deposition and condensation of the erosion products in the arc chamber on them is prevented. In one form of the invention the arc movement regulating means comprises a block of insulating material disposed in each of the arc containing chambers between the horn gap electrodes and the arc-cooling wall surfaces of the chambers. A further characterizing feature of the present invention is the ability of spark gap assemblies constructed pursuant to its teaching to discharge high energy arcs many times without materially altering the characteristics of the spark gap.

Accordingly, a primary object of the invention is to provide a new and improved spark gap unit.

Another object of the invention is to provide a lightning arrester having current limiting means therein, for maintaining relatively low but controlled arc voltages when arc current is high and for building high arc voltages when arc current is relatively lower.

A further object of the invention is to provide a lightning arrester spark gap having improved durability and protective characteristics.

Yet another object of the invention is to provide a lightning arrester having a current limiting spark gap structure that prevents the lightning arrester from exhibiting excessive voltage due to development of high arc voltages when high arc current exists during the long-duration surge voltage discharge cycle of the arrester.

A further object of the invention is to provide a current limiting spark gap having means for preventing destruction of its arc-cooling surfaces by high current arcs discharged through the gap.

Still another object of the invention is to provide an arrester employing current limiting spark gaps in which the degree of current limitation is easily and accurately controlled for all levels of discharge current such that an optimum balance is maintained in the fraction of the total arrester energy that is absorbed by the gaps and by the arrester's nonlinear valve resistance.

A still further object of the invention is to provide an arrester for DC circuits employing current limiting spark gaps which are capable of discharging long duration, and/or high energy, surges while retaining its capability to clear current against the normal DC line voltage after the surge is dissipated.
The invention will be better understood from the following description taken in conjunction with the accompanying drawings and its scope will be pointed out with particularity in the appended claims.

In the drawings:

Fig. 1 is a side elevation view of a current limiting spark gap assembly with its associated arc-driving electromagnetic coil and a block of negative-resistance valve material connected electrically in series therewith, and incorporating arc movement regulating means of the present invention.

Fig. 2 is a top view of one of the arc chamber defining plates of the spark gap assembly shown in Fig. 1, illustrating an arc in its initial stages of its contact with arc movement regulating means constructed pursuant to the present invention.

Fig. 3 is a top plan view of the same spark gap plate shown in Fig. 2 illustrating the position assumed by an arc approaching the later stages of its contact with the arc movement regulating means of the invention.

Fig. 4 is a top plan view of the same gap plate shown in Figs. 2 and 3 illustrating the position of an arc after it has moved into contact with the peripheral arc-cooling inner wall of the arc chamber.

Fig. 5 is a top plan view of an insulating plate defining an arc chamber similar to that utilized in the assembly of Fig. 1 but illustrating a second embodiment of the invention and also showing the position of an arc in contact with this form of arc movement regulating means during the relatively early stages of an arc discharge cycle.

Fig. 6 is a side elevation view taken in cross section along the plane 6-6 in Fig. 3 and also showing an arc chamber cover plate of insulating material in its normal assembled position, wherein an arcing chamber is defined between the two illustrated plate members.

Referring now to Fig. 1 of the drawing, there is shown a spark gap assembly 1 comprising a plurality of insulating plate members 2, 3, 4, 5, 6, and 7. The insulating plates 2-7 may be of any conventional form and they may be made of any suitable insulating material, such as that described more fully in U.S. Pat. No. 3,151,273 to Stetsen et al., filed Dec. 27, 1961. A pair of electrically conductive end plates 8 and 9 are disposed on the top and bottom surfaces of the spark gap assembly 1. A block of nonlinear resistance valve material 10 is placed in electrical contact with terminal plate 9 and rests on a third terminal plate 11, which is adapted to be connected to ground potential. It will be understood by those skilled in the art that each adjacent pair of insulating plates 2-7 are formed to define the wall means for arcing chambers therebetween in any suitable manner, such as that disclosed in greater detail in the above mentioned Stetsen et al. patent. For the purpose of describing the present invention, it is only necessary to realize that each of the arcing chambers contains a pair of horn gap electrodes that operate to move arcs initiated between the respective electrodes outward therefrom into contact with the peripheral inner walls of the arcing chambers to increase the back voltage of the arcs and thus cause extinction of the arcs.

In Fig. 1 of the drawing there is shown, in phantom, electrodes 12, 13, 14 and 15 electrically connected in series between plates 8 and 9 by a plurality of copper pins 16, 17, 18, 19, 20 and 21 in a manner well known in the lightning arrester art. Although not fully depicted in the drawing, it will be understood that the ends of coil 22 are connected, respectively, to pins 18 and 19 so that coil 22 is electrically connected in series with the discharge path formed by the electrodes 12-15 through the spark gap assembly 1.

In order to understand the present invention, it is only necessary to study it in perspective with a single spark gap unit, such as assembly 1, but it will be understood that in normal practice a plurality of spark gap assemblies and associated nonlinear valve resistors will be stacked upon each other to form a plurality of series connected assemblies that will have an overall breakdown rating directly proportional to the number of such assemblies in the stacked arrangement. Also, as is well known in the art, such a stacked assembly will be housed in a suitable insulating housing, which is conventionally formed of a porcelain cylinder having conductive terminals mounted at its upper and lower ends. For purposes of illustrating the present invention, such a housing is diagrammatically depicted by chain line 23 in Fig. 1.

The particular structural arrangements and elements described above with reference to Fig. 1 are relatively conventional and well known in the present development of the lightning arrester art and it will become apparent from the following description that modifications can be made in these elements without effecting the operation of the present invention undesirably if care is taken, in the manner described below pursuant to the invention, to adjust its arc movement regulating means to compensate for such modification of the more conventional elements of the lightning arrester with which it is associated.

Referring now to Fig. 2 of the drawing, there is shown the top surface of insulating plate member 3, which has a pair of horn gap electrodes 12 and 12a mounted thereon. A preionizer device 24, which may conveniently, but not necessarily be constructed pursuant to the teaching of U.S. Pat. No. 3,223,874 to Carpenter, is shown electrically connected in parallel with a grading resistor 25 and in parallel with the gap 12b defined by electrodes 12 and 12a. The preionizer device 24 is connected to pins 16 and 17 by any suitable electroconductive metallic means such as conductive straps 26 and 27, respectively. The upper surface of plate member 3 comprises generally flat recessed area 28 surrounded by a raised peripheral area 29. Within the flat recessed area 28, the electrodes 12 and 12a are mounted, and arc-stretching teeth 30, 31, 32, 33 are disposed around the periphery of the arc chamber in a manner more fully described in the above referenced Stetsen et al. patent. It will be understood that any conventional means of defining an arc-cooling and stretching surface on the inner peripheral wall of an arcing chamber may be utilized in conjunction with the present invention without departing from its true scope. However, the castellated form of teeth 30-33 illustrated in the preferred embodiment of the invention has been found to produce optimum arc clearing results at high voltage levels.

Before proceeding with a description of the novel features of the invention, it may be helpful to refer to Fig. 6 of the drawing which depicts, in cross section, the arcing chamber defined in part by plate member 3. The upper wall of this arcing chamber is defined by wall means comprising plate member 2, which is formed to fit in interlocking fashion with the raised peripheral portion 29 on plate member 3 and which is also provided with a plurality of castellated teeth 31, one of which is shown in cross section in the area designated by the numeral 34. It should be understood that the teeth portions on plate member 2 are arranged to fit in interlocking engagement in the areas between the respective teeth 30-33 on plate member 3.

Pursuant to the present invention, wall means 35, illustrated in Fig. 2 and in cross section in Fig. 6, are disposed in the arcing chamber defined by the wall means of plates 2 and 3 between the arc initiating electrodes 12 and 12a and the arcing surface defined by the castellated teeth 30-33. In the preferred form of the invention, the wall means 35 comprises a boss integrally molded on the upper surface of plate member 3 and formed to extend substantially the entire vertical distance between the surface of depressed portion 28 and the bottom wall surface of plate member 2, as shown more particularly in Fig. 6. It should be understood that for proper operation of the invention, the wall means 35 may be formed of either insulating or electrically conductive material, but in the preferred embodiment of the invention the plate members 2 and 3 are formed of porous insulating material and, since the wall means 35 is integrally molded as a portion of plate member 3 in this embodiment of the invention, it also is a porous insulating member. The purpose of wall means 35 is to arrest the movement of a relatively high current arc outward from the arc establishing electrodes 12-12a under the in-