My invention relates to a novel spark gap, and more specifically relates to a spark gap in which the arc roots are constantly moved during arcing to reduce erosion of the arcing electrodes. Spark gaps are well known for many electrical applications, and typically are used to protect other equipment by arcing over to short-circuit such equipment under predetermined conditions. By way of example, series capacitors are commonly used in transmission lines, and are subject to destructive voltages during the flow of abnormally high current such as that which exists under fault conditions. A typical method for protecting such capacitors against harmful voltages consists of the by-passing of the capacitors with a fast acting switch which, in turn, triggered by some fault sensing device. One form of a fast acting switch would be a calibrated spark gap which is in parallel with the capacitor to be protected where the gap will spark over when the voltage across the capacitor exceeds a predetermined value.

The basic problem which is encountered during the operation of such a gap is the erosion of the arcing electrodes which is produced by the arc and which will affect the calibration of the gap. In order to limit this erosion, it is common practice to form a solid connection across the gap as soon as possible to take current flow away from the arc. However, due to the inertia of moving parts which will be used to establish this solid connection, there is some minimum time during which arcing must exist and during which erosion will occur.

The principle of the present invention is to provide a magnetic field in the arc gap area which will produce continuous motor action on the arc to thereby constantly move the location of the arc roots on the metallic surface of the arcing electrode. Thus, the arc roots will not remain at any location long enough to cause serious burning or pitting of the electrode surfaces. In a preferred embodiment of the invention, the magnetic field that causes the arc to move is produced by windings located directly beneath the electrodes and connected in series with the electrodes. Thus, in the region of the arc, the magnetic field is substantially perpendicular to the current so that it will provide a force on the charged particles that form the arc to cause these particles to move perpendicular to the direction of motion of the charged particles. When the arc gap itself is an annular member, the arc will circulate around the annular arc electrode.

Accordingly, a primary object of this invention is to provide a novel arrangement for reducing the erosion of spark gaps. Another object of this invention is to provide a magnetic field for coating with the arc current of a spark gap to cause the arc root to move across the arcing electrode surface. A further object of this invention is to prevent the change in calibration of a spark gap due to erosion of the arcing surfaces. Another object of this invention is to substantially increase the life of a spark gap.

These and other objects of this invention will become apparent from the following description when taken in connection with the drawings, in which:

FIGURE 1 schematically illustrates two pairs of arc gaps constructed in accordance with the present invention, and electrically connected for the protection of a series capacitor.

FIGURE 2 is a cross-sectional view of an arcing electrode and its magnetic field generating coil which could be used in the arrangement of FIGURE 1.

FIGURE 3 is a top view of the electrode of FIGURE 2.

FIGURE 4 illustrates an arrangement of four arcing electrodes in cross-sectional view which could be used in the arrangement of FIGURE 1.

FIGURE 5 is a top plan view of the lower arcing electrode of FIGURE 4 as seen across the lines 5—5 in FIGURE 4.

Referring now to FIGURE 1, I have illustrated therein a capacitor 10 which is connected in a line 11 which could, for example, be a high voltage transmission line. In order to protect the capacitor 10 by short circuiting it is responsive to predetermined fault conditions in line 11, a series connected pair of spark gaps 12 and 13 is provided in parallel with capacitor 10. In the event of some predetermined fault on line 11, as indicated by an increase in voltage across capacitor 10, the spark gap will arc over and thereby shorten circuit the capacitor 10.

The spark gap 12, as is schematically illustrated, is formed of two electrodes 14 and 15, while gap 13 is formed of a similar pair of electrodes 16 and 17. Each of electrodes 14 through 17 are, as schematically illustrated, provided with insulated windings 18 through 21 wherein the uppermost layer of winding 18 is connected directly to the left-hand side of capacitor 10, while the beginning of winding 21 is connected directly to the right-hand side of capacitor 10. In addition, the uppermost layers of windings 19 and 20 are directly connected, as illustrated. The ends or bottom-most layers of each of windings 18 through 21 are then directly connected to their respective electrodes 14, 15, 16 and 17 respectively.

In operation, when the voltage across capacitor 10 exceeds some predetermined value, the voltage across gap 22 will exceed its break-down value, and the gap will fire. This places the full voltage of capacitor 10 across the remaining gap 13 so that gap 13 fires, followed by the firing of gap 12. Thus, the arcs in gaps 12 and 13, in effect, short-circuit and protect capacitor 10 so long as the over-voltage continues on line 11. It will be noted that other equipment will come into play to restore capacitor 10 in service.

In accordance with the present invention, and since the current in coil 21 must circulate through winding 12 (assuming that the right-hand side of capacitor 10 is positive with respect to the left-hand side), a magnetic field is established by winding 21 in the direction indicated by arrow 30.

The current path from winding 21 now continues through the arc between electrodes 16 and 17, and circulates through winding 20 in a direction opposite to that of winding 21. Therefore, winding 20 sets up a magnetic field in the direction indicated by arrow 31.

From like considerations, a magnetic field 32 is set up around winding 19 while a magnetic field 33 is set up around winding 18.

Assuming that the arc is at the arc position 34 in spark gap 13, it is seen that the magnetic fields 30 and 31 are such that the arc 34 will be caused to rotate about the annularly shaped electrodes 16 and 17, while in the same manner, the arc 35 in gap 12 will be caused to rotate be-
cause of magnetic fields 32 and 33. Thus, the arc roots of arcs 34 and 35 continually move around the surfaces of the arc electrodes so that no one point on the surface is excessively heated and pitted. Accordingly, substantial arc erosion is prevented to thereby substantially increase the life of the arcing electrodes and maintain a true calibration for the arcing electrodes.

One manner in which any of the arc electrodes of FIGURE 1 may be constructed is illustrated in FIGURES 2 and 3.

Referring now to FIGURES 2 and 3, it will be seen that the electrodes may be provided with a support base 40 of an appropriate insulating member, while an insulating ring 41 which retains a ceramic plate 41a in protecting arrangement with respect to the insulating base 40 receives an annular copper ring 42 having an L-shaped cross-section.

A copper disk 43 is then secured to ring 42 by appropriate screws such as screw 44 to complete the electrode construction. The electrode formed of disks 42 and 43 is then secured to base 41 as by a plurality of bolts such as bolt 45 which passes through ring 41 and is thereby received by a tapped opening in disk 42.

By proper positioning of disk 44 and disk 42, a winding 47 which can, for example, have five turns which are appropriately insulated from one another, may be assembled in a bobbin 46 and placed about the upwardly extending arm of L-shaped disk 42 with the disk 43 there-after being secured in position to hold the winding in place.

The innermost conductor of winding 47 is then appropriately electrically connected directly to disk 42 in any desired manner, while the outermost conductor of winding 47 is appropriately connected to a terminal such as the terminal 48, best shown in FIGURE 5.

With this type arrangement, it is clear that the arc current from the electrode surface is carried through winding 47 to generate a magnetic field which surrounds the winding. Moreover, the higher the arc current, the stronger the field will be so that high current, and, therefore, destructive arcs, will be moved more quickly than low current arcs.

A second embodiment of the novel arc gap schematically illustrated in FIGURE 1 is shown in more detail in FIGURES 4 and 5 where this embodiment differs from that of FIGURES 2 and 3 in that it is easier to manufacture.

Referring now to FIGURES 4 and 5, I have illustrated therein the four arcing electrodes 14, 15, 16 and 17 shown in FIGURE 1. Each of the arcing electrodes is provided with an insulation member such as insulating member 60 which has an appropriate coil such as coil 61 connected therein. In a similar manner, electrodes 15, 16 and 17 are provided with insulation supports 62, 63 and 64 which have coils 65, 66 and 67 respectively secured thereto.

Each of the supports 60, 62, 63 and 64 are further provided with cut-out sections therein, shown as cut-out section 68 for insulator 60, which receives a terminal structure 69 to which the inner end of coil 61 is connected.

Each of the electrodes are then provided with steel cover plates 70, 71, 72 and 73 respectively, which are connected to the terminals such as terminal 69 of electrode 14, and are secured to insulation supports by appropriate screws. The opposite surface of each of plates 70 through 73 is connected to the arcing electrode elements, as in FIGURES 4 and 5, are formed of one inch diameter stainless steel pipe or tubing sections 75, 76, 77 and 78 which are welded or brazed to their respective plates.

It will be noted, as in FIGURE 5, that the tubes such as tube 75 are bent around to form a ring which is welded at seam 75a.

The upper and lower electrodes 14 and 17 are then each provided with support sleeves 80 and 81 respectively, which could be of aluminum, by a series of bolts in the flanges of the aluminum sleeves such as the bolts 82, 83 and 84, shown for electrode 14 in FIGURE 5.

In addition, the outer end of coils 61 and 67 are electrically connected to sleeves 80 and 81, as shown by coil end 85 of coil 61 which is taken through a notch 86 in plate 60, and is connected to sleeve 80 by bolts such as bolts 87 and 88. The interior of sleeves 80 and 81 are then threaded to receive support bolts 90 and 91 respectively and adjustment nuts 92 and 93 respectively. The bolts 90 and 91 are then secured to appropriate bushing structures.

With this novel arrangement, it will be understood that the axial position of electrodes 75 and 78 can be adjusted by adjustment of nuts 92 and 93.

The two centrally located electrodes 15 and 16 are each supported from a common insulation support beam 100 by a series of screws such as the screw 101 for electrode 16 and screw 102 for electrode 15.

The inner windings of windings 65 and 66 are, as was previously described, electrically connected to plates 71 and 72 respectively. The outer ends of each of the windings 66 and 65 respectively are taken out to external terminals 105, 106 and 107-108 respectively wherein the terminals 105 through 108 are all electrically connected together.

In operation, it will be understood that the first gap formed by rings 75 and 76 will have its spacing adjusted by adjustment nut 92, while the spacing of the gap formed by rings 77 and 78 is controlled by adjustment of nut 93. The operation of the system of FIGURE 4 is, of course, identical to that previously described for FIGURE 1.

Although I have described my novel invention with respect to its preferred embodiments, many variations and modifications will now be obvious to those skilled in the art, and I prefer therefore to be limited not by the specific disclosure herein but only by the appended claims.

I claim:

1. In a high voltage spark gap comprising first and second spaced electrodes; one of said electrodes having an extended arcing surface defining an extended path for the motion of an arc root; a magnetic field generating means; said magnetic field generating means being stationarily positioned with respect to said extended arcing surface; said magnetic field generating means generating a magnetic field which is at an angle to the direction of an arc extending from any point on said electrode having said extended arcing surface to the other of said first and second electrodes; said magnetic field generating means comprising an electrical winding; said electrical winding being connected in series with said first and second spaced electrodes; said electrical winding having one terminal thereof connected to said extended arcing surface and the other terminal thereof connected to an input terminal for said electrode having said extended arcing surface.

2. In a high voltage spark gap comprising first and second spaced electrodes; one of said electrodes having an extended arcing surface defining an extended path for the motion of an arc root; a magnetic field generating means; said magnetic field generating means being stationarily positioned with respect to said extended arcing surface; said magnetic field generating means generating a magnetic field which is at an angle to the direction of an arc extending from any point on said electrode having said extended arcing surface to the other of said first and second electrodes; said extended surface having a disk shape; said magnetic field generating means comprising an electrical winding; said electrical winding being connected in series with said first and second spaced electrodes; said electrical winding having one terminal thereof connected to said extended arcing surface and the other terminal thereof connected to an input terminal.
for said electrode having said extended arcing surface.

3. In a high voltage spark gap comprising first and second spaced electrodes; one of said electrodes having an extended arcing surface defining an extended path for the motion of an arc root; a magnetic field generating means; said magnetic field generating means being stationarily positioned with respect to said extended arcing surface; said magnetic field generating means generating a magnetic field which is at an angle to the direction of an arc extending from any point on said electrode having said extended arcing surface to the other of said first and second electrodes; said extended arcing surface having a disk shape; said magnetic field generating means comprising an electrical winding; said electrical winding being connected in series with said first and second spaced electrodes; said electrical winding having one terminal thereof connected to said extended arcing surface and the other terminal thereof connected to an input terminal for said electrode having said extended arcing surface; said winding being coaxial with said disk-shaped extending surface.

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DAVID J. GALVIN, Primary Examiner.
ROBERT SEGAL, GEORGE N. WESTBY, Examiners.
D. E. SRAGOW, Assistant Examiner.