Jan. 30, 1968 E. C. SAKSHAUG 3,366,822

CURRENT REVERSAL COUNTING SPARK GAP

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Fig. 1.

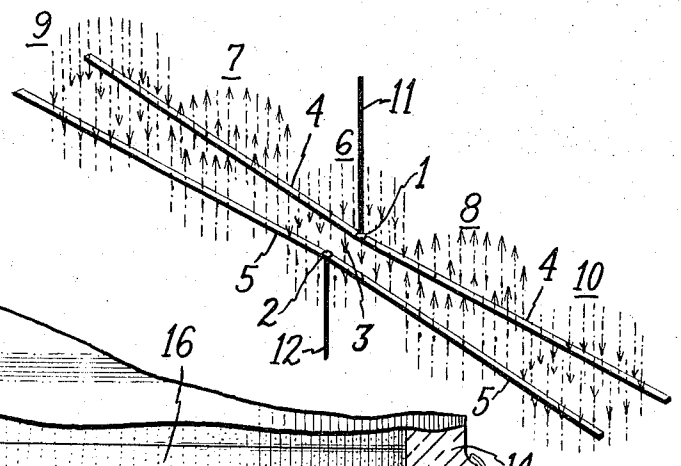


Fig. 2.

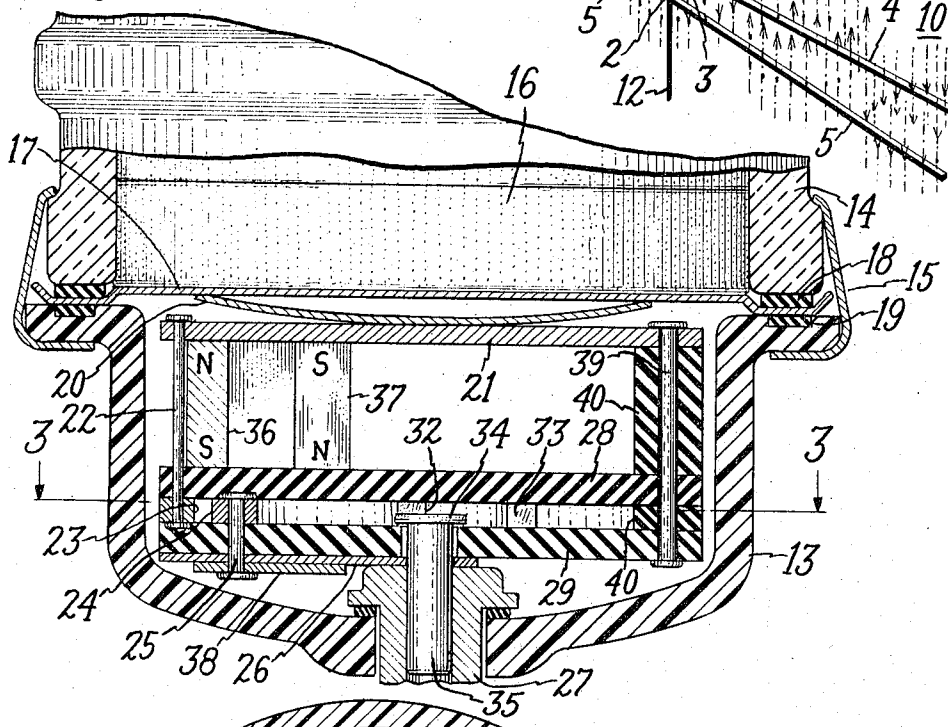
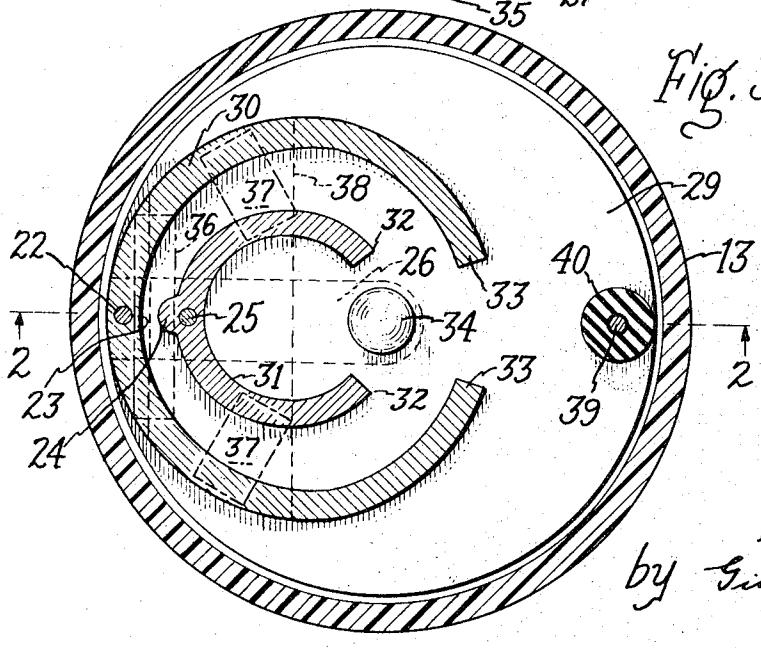


Fig. 3.



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Fig. 4.

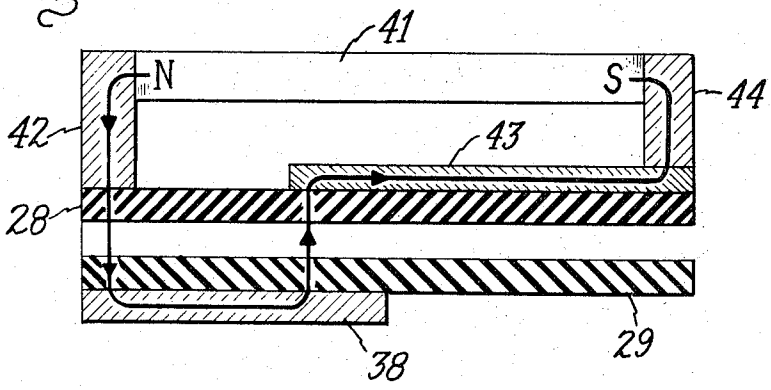
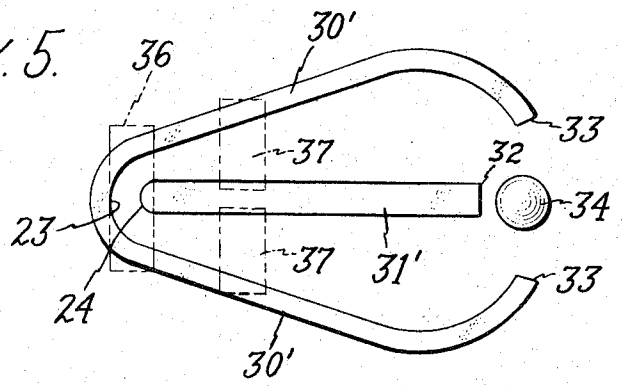


Fig. 5.



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CURRENT REVERSAL COUNTING SPARK GAP

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9 Claims. (Cl. 313—154)

This invention relates to spark gaps and more particularly to spark gaps for lightning arrester disconnectors.

A lightning arrester is an electrical safety valve. It protects electrical insulation from transient overvoltages such as are caused by lightning or by switching surges on electric power systems.

A lightning arrester disconnector is a device for opening an arrester's circuit if and when the arrester fails. Usually the disconnector is connected in series with the arrester and thus carries the latter's discharge current as well as its power follow current and what can be called its failure current. While discharge current can be relatively high in magnitude, it is relatively short in duration (a few millionths of a second) so that it is easy to make a disconnector which is sluggish enough not to respond to the highest discharge current. However, power follow current can last as long as a half cycle (about a hundredths of a second at 60 cycles per second) and it is not so easy to make a disconnector which will be sluggish enough to ignore power follow current and still act fast enough to isolate a failed arrester before further damage is done.

Heretofore that has not been a problem because power follow current has been substantially lower in magnitude than failure current so that the disconnector could easily distinguish between the two on the basis of their difference in magnitude. However, this difference in magnitude has steadily been decreasing as a result of reducing the arrester resistance in order to limit its discharge voltage because that increases its power follow current.

In accordance with this invention, there is provided a novel and simple spark gap device which will count current reversals and thus can be used in a disconnector to distinguish between power follow current which is interrupted at the first current zero and therefore lasts no longer than a half cycle and failure current which, of course, will last many cycles or indefinitely if the arrester is not isolated. While such a device is particularly useful in lightning arrester disconnectors, it may also be used to count any desired number of current reversals or to respond after any desired number of current reversals to perform any useful function.

It is, therefore, an object of this invention to provide a new and improved current reversal counting spark gap device.

Another object of this invention is to provide novel and simple means for distinguishing between lightning arrester power follow current and lightning arrester failure current.

It is a further object of this invention to provide a new and improved disconnector for lightning arresters.

The invention will be better understood from the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawings,

FIGURE 1 is a schematic view of a generalized embodiment of the invention for explaining its principle of operation,

FIGURES 2 and 3 are vertical and horizontal orthographic sectional views taken respectively on line 2—2 of FIGURE 3 and line 3—3 of FIGURE 2 of a lightning arrester disconnector or isolator embodying another form of the invention,

FIGURE 4 is a view generally similar to FIGURE 2 of a modification having a single relatively long permanent magnet, and

FIGURE 5 is a view generally similar to FIGURE 3 of a modified electrode configuration.

Referring now to the drawings and more particularly to FIGURE 1, there is shown therein a pair of electrodes 1 and 2 forming therebetween a spark gap 3. The electrodes 1 and 2 are provided with arc runners 4 and 5 respectively which are shown extending in opposite directions away from the gap 3. A local unidirectional magnetic field passing through the gap 3 normal to its plane is indicated by the group of lines 6. Similarly spaced local unidirectional magnetic fields between the arc runners 4 and 5 and normal to their plane are indicated by the groups of lines 7, 8, 9, and 10. These local unidirectional fields are of alternately opposite polarity or direction as indicated by the direction of the arrows on the lines representing them so that if the fields 6, 9 and 10 are in a downward direction as illustrated, the magnetic fields 7 and 8 are in the upward illustrated direction. The electrode 1 is connected to a lead 11 and the electrode 2 is connected to a lead 12. These leads are for the purpose of supplying to the electrodes 1 and 2 a sparkover potential and an arc sustaining current. As will be explained later, the leads should extend approximately perpendicular to the plane of the gap 3, i.e., parallel to the magnetic field 6.

The runners 4 and 5 are shown extending divergingly from the gap electrodes 1 and 2. This is not essential and is done only as one way to ensure initial sparkover at the gap 3. Other ways of accomplishing that result which do not require diverging runners are well known to those skilled in the art.

The operation of FIGURE 1 is as follows. If and when the gap 3 is sparked over the resulting arc current will interact with the local magnetic field 6 to produce a force for moving the arc in one direction or the other along the arc runners 4 and 5. The direction will depend upon the direction of the arc current between the electrodes 1 and 2. It is to be noted that the force will be produced entirely by the interaction of the arc current and the local external field 6 and will not be contributed to by the magnetic field of current flowing in the leads 11 and 12. In other words, the arrangement of the leads 11 and 12 relative to the electrodes 1 and 2 is different from that of an ordinary horn gap in which the current flowing into and out of the sparkover gap electrodes produces the initial electromagnetic driving force for starting arc movement along the runners. However, as soon as the arc starts to move out along the runners, current will flow in the runners between the arc and the electrodes 1 and 2 which then will produce a so-called current loop or kink which will produce an additional or added force driving the arc in the same direction outward, i.e. away from the electrodes 1 and 2 along the runners 4 and 5. This action will continue until the arc encounters the next adjacent opposite polarity unidirectional field, i.e., either field 7 or field 8 as the case may be. Such next field, of course, produces an opposite direction force on the arc and thus blocks its further outward movement along the runners. However, the arc will be stopped beyond dead center, so to speak, between any two adjacent local fields of opposite polarity because of the added outward force supplied by the current loop or inherent horn gap effect. Consequently if and when the arc current passes through zero and reverses direction the blocking field will become a propelling field and the arc will be moved onward through it until it encounters the next outer opposite polarity field 9 or 10 as the case may be, where the preceding action will be repeated in that the arc will be driven past dead center

between local unidirectional fields of opposite polarity and will be held there until the arc current reverses direction whereupon it will rapidly be propelled forward again.

The presence of an arc between any pair of opposite points on the arc runners **4** and **5** can, of course, be detected or recorded by any well-known means and thus by using any desired number of local magnetic fields any number of arc current reversals can be detected or recorded.

If the initial direction of current at sparkover between electrodes **1** and **2** were always the same it would, of course, be unnecessary to have the arc runners **4** and **5** extend on both sides of the gap because then magnetic field **6** could have such polarity as always to drive the arc in the proper direction along a single pair of diverging arc runners.

The local magnetic field **6–10**, etc., can of course be produced by any well-known means such as by permanent magnets or electromagnets.

Referring now to FIGURES 2 and 3, there is shown therein a lightning arrester disconnector in the form of a cup shaped housing **13** of insulating material which is clamped or otherwise suitably sealed to the normally grounded end of a lightning arrester housing **14** by any suitable means such as a metallic band **15** whose edges are spun over shoulders or flanges on the housings **13** and **14** respectively. The bottom of the lightning arrester housing **14** is shown occupied by discs **16** of valve resistor material and the housing **14** is closed by a conductive metal plate **17** with a gasket **18** between it and the rim of the lightning arrester housing **14**. A similar gasket **19** may be employed between the plate **17** and the mating flange or edge of the disconnector housing **13**.

The electric circuit of the disconnector is from the bottom plate **17** of the lightning arrester through a dished spring contact disk **20**, a conductive pate **21**, a connecting rivet or bolt **22**, to spark gap electrode **23**, across the gap to electrode **24**, a conducting rivet or bolt **25**, a conductive strap **26** to an external conductive terminal post **27** which is normally connected to ground. The gap electrodes **23** and **24** are mounted between plates of insulating material **28** and **29**. As shown most clearly in FIGURE 3, the electrodes **23** and **24** are provided with arcuate shaped arc runners **30** and **31** extending in opposite directions from the electrodes **23** and **24** and terminating respectively in tips **32** and **33** adjacent the detonating cap end **34** on an explosive cartridge **35** passing through the insulating plate **29**, the conductive strap **26** and seated in the grounding terminal **27**.

For producing a unidirectional local magnetic field in the gap between the electrodes **23** and **24**, there is provided a permanent magnet **36** and for producing local magnetic fields between the arc runners **31** and **32** intermediate their tips and the gap producing electrodes **23** and **24** there are provided permanent magnets **37** of the same polarity relative to each other and of opposite polarity relative to magnet **36**. For strengthening the local fields produced by the permanent magnets **36** and **37** they are provided with armatures of magnetic material for their return flux and for concentrating their fluxes in the gap spaces between the gap electrodes and the arc runners. Thus the conductive member **21** is also made of magnetic material such as steel and likewise an armature plate of magnetic material **38** is attached between the head of the rivet **25** and the conductive strap **26** for collecting flux from the lower end of the permanent magnet **36** which passes through the gap space between the electrodes **23** and **24** and distributing it laterally as return flux through the permanent magnets **37** in the opposite direction.

The internal assembly of the disconnector may be held together by a suitable means such as a rivet **39** and insulating spacers and/or washers **40**.

The magnets **36** and **37** while above the section line **3—3** on FIGURE 2 on which FIGURE 3 is taken have been shown in phantom in FIGURE 3 and likewise the conductive strap **26** and the armature or keeper plate **38** while below the insulating disc **29** and therefore invisible in FIGURE 3 have nevertheless been shown in phantom in FIGURE 3 for more clearly illustrating the horizontal orientation of these various parts.

The operation of the embodiment of the invention illustrated in FIGURES 2 and 3 is as follows. As has previously been explained lightning arrester discharge current and lightning arrester power follow current do not reverse direction, the former being of comparatively short duration and the latter being extinguished at the first current zero of the normal alternating current system voltage. Consequently an arc between the electrodes **23** and **24** carrying either discharge current or power follow current cannot be propelled by the field of magnet **36** combined with the propelling effect of the horn gap action beyond the magnetic field of a blocking magnet **37** so that the disconnector will not respond to or be actuated by power follow current regardless of its magnitude. On the other hand, lightning arrester failure current persists as the failed arrester is incapable of stopping it so that an arc between the runners **30** and **31** sustained by failure current will upon the first current reversal be swept onward by the previously blocking field of the appropriate magnet **37** which, upon current reversal, becomes a propelling field so that the arc sustained by failure current moves to the tips **32–33** of the runners where it plays on the cap end **34** of the cartridge **35** thus heating and detonating it. This forcibly removes the bottom portion of the disconnector so that the ground stud **27** is separated electrically and mechanically from the ground end of the lightning arrester thus disconnecting or isolating the lightning arrester and interrupting further flow of failure current before further damage to or dangerous gas pressures in the lightning arrester can be produced.

In the modification shown in FIGURE 4, a single comparatively long and therefore comparatively strong permanent magnet **41** replaces the separate comparatively short permanent magnets **36** and **37** of FIGURES 2–3. The magnetic circuit of the magnet **41** is through a pole piece **42**, the gap between the insulating plates **28** and **29** where the spark gap electrodes **23** and **24** of FIGURES 2–3 are located, the armature or keeper plate **38**, back through the gap between the insulating plates **28** and **29** in the reverse direction so as to produce initial blocking magnetic fields corresponding to those produced by the permanent magnets **37** of FIGURES 2–3, through an additional magnetic armature or keeper plate **43** and a second pole piece **44**. It will be understood that the electrode-runner construction of FIGURES 2–3 will be in the space between the plates **28** and **29** of FIGURE 4 as it is in FIGURES 2–3.

FIGURE 5 illustrates a modified electrode arc runner configuration in which the electrode **23** and the runner **30'** are generally similar to the electrode **23** and the arcuate runner **30** of FIGURE 3 but the runner **31'** between the spark gap electrode **24** and the tip **32** can be a simple straight bar symmetrically located with respect to the runner **30'**. In this construction, when the gap between the electrodes **23–24** is sparked over the arc will be driven in one direction or the other by the field of the magnet **36** or the magnet **41** of FIGURE 4 depending on the direction of the current flow and will thus be extended as it moves out between the runners **30'** and **31'**, the remaining action being essentially the same as has been previously described in connection with the FIGURES 2–3 species.

It will, of course, be understood that the electrode structures of either FIGURE 3 or FIGURE 5 can be inserted in the space between the insulating plates **28** and **29** of either FIGURE 3 or FIGURE 4 wherein their orientation will correspond to those shown in FIGURE 3 or FIGURE 5 relative to the oppositely directed unidirectional magnetic fields existing at different locations in the space between those insulating plates **28** and **29**.

While there have been shown and described particular embodiments of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention, and therefore it is intended by the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a delayed action arc extending spark gap with arc runners extending from the gap electrodes, means for producing separate unidirectional local magnetic fields of opposite polarity normal to the plane of the gap space and arc runner separation, one of said fields being in said spark gap and another being between intermediate opposite points on said runners.

2. A gap as in claim 1 provided with direct electrical connections to said gap electrodes extending approximately normal to said plane.

3. A device for ignoring a first half cycle but responding to the next half cycle of alternating current comprising, in combination, an arc gap, arc runners extending from said gap, means for producing a first magnetic field in said arc gap for driving an arc out along said runners, means for producing a second magnetic field in a space between said runners of such polarity as to block passage of said arc thereacross until the next half cycle of current and propelling said arc thereacross during said next half cycle of current, and means responsive to said arc passing said second magnetic field.

4. Apparatus for counting a predetermined number of half cycles of alternating electric current comprising, in combination, a pair of elongated divergently spaced electrodes in a common plane, leads connected to the ends of said electrodes which are closest together for supplying a sparkover potential and arc sustaining current, said leads extending in a plane approximately normal to said common plane, means for producing a predetermined number of spaced local unidirectional magnetic fields of alternately opposite polarity between said electrodes in a direction normal to said common plane, one of said fields being between the ends of said electrodes which are closest together, whereby an arcing current of a given half cycle between said electrode ends which are closest together is driven along said electrodes until it encounters the next adjacent field which blocks its onward movement until the succeeding half cycle when these actions are repeated between the next pair of adjacent local fields, and means for detecting the existence of an arc between any pair or pairs of adjacent local fields.

5. Apparatus for counting a predetermined number of electric current reversals of direction over a wide range of frequency and wave shape comprising, in combination, a pair of elongated electrodes spaced so as to provide an infinite series of adjacent spark gaps between said electrodes including one gap which has a lower sparkover potential than the others, leads connected respectively to said electrodes for supplying them with a sparkover potential and arc sustaining current, means for producing a plurality of spaced local unidirectional magnetic fields of alternately opposite polarity in a plurality of said gaps including the one having the lowest sparkover potential, the direction of said fields being such as to drive an arc in them along said electrodes whereby an arc struck across said gap having the lowest sparkover potential is driven by its local magnetic field along said electrodes toward an adjacent magnetic field of opposite polarity which blocks further arc movement along said electrodes until the arc current reverses whereupon the arc is again propelled forward, and means responsive to a reversed current arc passing any particular local field or fields.

6. A gap device for detecting a reversal of arc current initiated with either polarity comprising, in combination, two pairs of diverging electrodes extending in opposite directions in a common plane from a common zone of minimum spacing, current and voltage supply conductors connected respectively to said electrodes at said common zone of minimum spacing and extending normal to said plane, means for producing a local unidirectional magnetic field at said common zone of minimum electrode spacing with a direction normal to said plane, and means for producing a separate pair of local unidirectional magnetic fields with a common direction normal to said plane and with a common polarity opposite to the polarity of the field at the common zone, said separate pair of local fields being respectively at intermediate locations at said oppositely extending pairs of diverging electrodes whereby an arc struck between said electrodes at their point of minimum spacing is driven outward by the local field at the common zone along one or the other pair of diverging electrodes depending on the direction of the arc current and is stopped by the opposite polarity local field at said intermediate location on said pair of diverging electrodes unless and until the arc current reverses direction.

7. A gap as in claim 6 provided with means responsive to an arc between either pair of diverging electrodes reaching their ends of greatest divergence.

8. A gap as in claim 6 in which said oppositely extending pairs of diverging electrodes extend arcuately so that their respective ends of greatest divergence come into proximity on opposite sides of a second common center, and means at said second common center responsive to an arc between either pair of diverging electrodes reaching their ends of greatest divergence.

9. A lightning arrester disconnector for alternating current circuits, said disconnector having arrester failure current activated actuating means for interrupting said failure current, and means responsive to reversal of direction of arrester power current following a short duration discharge of surge current for preventing such arrester power current from activating said actuating means until after at least the first reversal of such power current which reversal indicates that such arrester power current is then abnormal arrester failure current and no longer normal arrester follow current.

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