Dec. 12, 1933. J. J. TOROK 1,939,090

DISCONNECTING SWITCH

Filed June 3, 1929 2 Sheets-Sheet 1

Fig. 1.

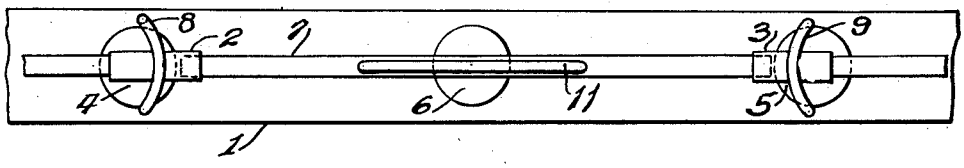


Fig. 2.

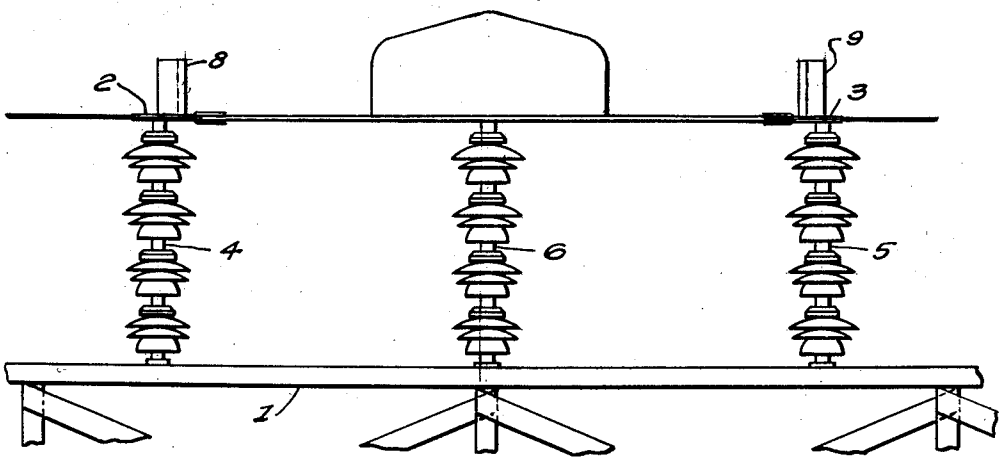


Fig. 3.

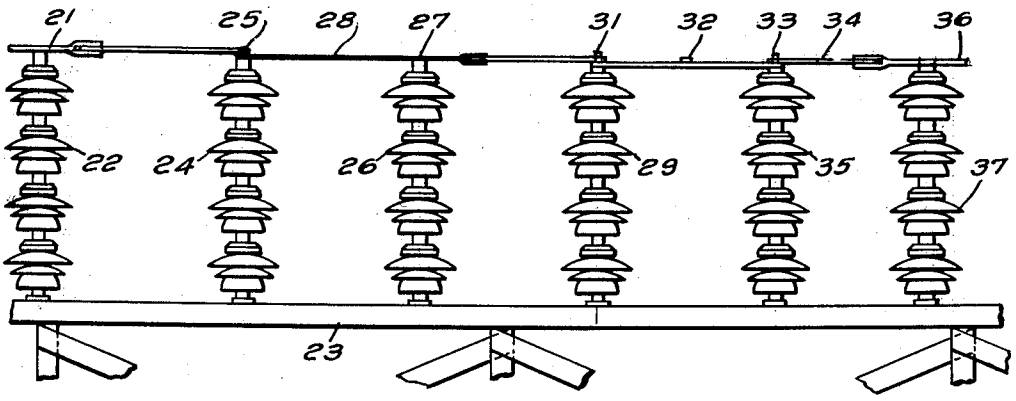
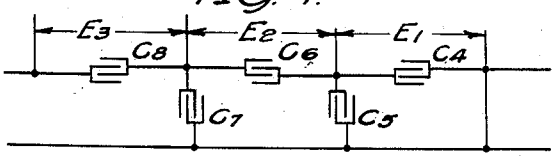


Fig. 4.



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Fig. 5.

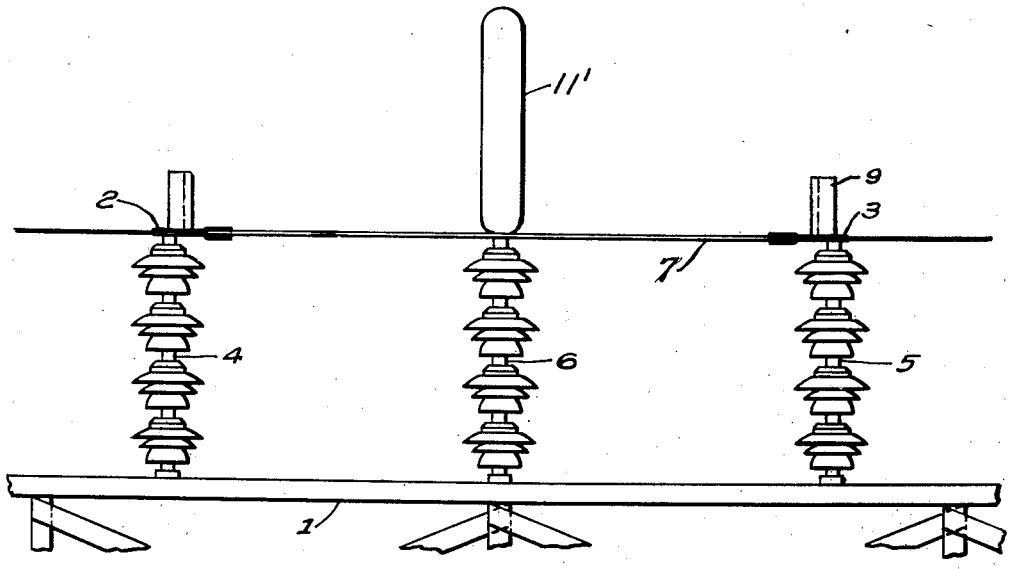


Fig. 6.

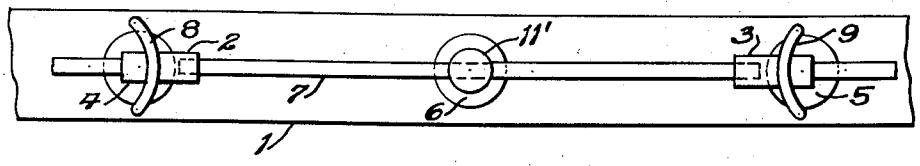
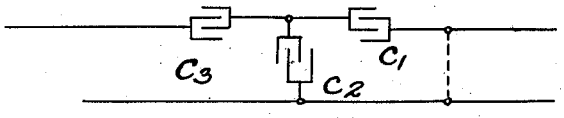


Fig. 7.



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DISCONNECTING SWITCH

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Application June 3, 1929. Serial No. 367,886

12 Claims. (Cl. 200—48)

My invention relates to electrical switches and particularly to switches of the type in which two or more breaks are interposed in the path of current flow.

One object of my invention is to provide a means of increasing the line potential which a switch of given dimensions is able to withstand when employed to isolate an electric circuit connected to a source of electromotive force from a circuit which is unenergized.

Another object of my invention is to provide means to increase the line potential which a switch of given dimensions is able to withstand when employed to isolate an electric circuit connected to a source of electromotive force from a circuit which stands at ground potential.

Another object of my invention is to provide a switch of the type in which an insulated movable bridging member is employed to interconnect two stationary contact members, one or both of which may be connected to a source of electromotive force.

Another object of my invention is to provide means to increase the line voltage which may be withstood without arc-over by a switching apparatus in which two or more breaks in series are interposed in circuit between a source of electromotive force and a circuit which tends to acquire the same potential as the frame-work of the switching apparatus.

A further object of my invention is to provide a method of increasing the voltage rating of switching apparatus of the above-mentioned types readily, inexpensively, and with only such structural modifications thereof as may readily be made in the field or to installations which are already in service.

Other objects of my invention will become apparent upon reading the following specification, taken in connection with the drawings, in which

Figure 1 is a plan view of a disconnecting switch embodying my invention.

Fig. 2 is a view, in elevation, of the form of disconnecting switch embodying the principles of my invention shown in Fig. 1, and

Fig. 3 is a view, in elevation, of a switching apparatus embodying the principles of my invention.

Fig. 4 is a diagram utilized herein to explain certain features of my invention.

Fig. 5 is a view, in elevation, showing an alternative structure to that of Fig. 1 for embodying the capacitances desired between the switch members.

Fig. 6 is a plan view of the structure shown in Fig. 5.

Fig. 7 is a diagram utilized herein to explain the principles of my invention.

In many classes of service, more particularly on high-voltage lines, it is desirable to employ switching apparatus in which two or more gaps are interposed in the circuit when the switch is opened. Frequently, such apparatus takes the form of a pair of stationary contact members adapted to be connected to a source of electromotive force and to a load, respectively, and an insulatingly-supported bridging member which is moved to bridge across the gap between said terminals when the circuit is closed.

In certain instances, notably, in the case of disconnecting switches for high-voltage lines, little or no current flows at the time the switch is opened; and the open gaps interposed in the circuit need not be wide enough to extinguish a power arc, but are only required to be wide enough to insulate against the potential differences imposed when the switch is standing open.

It is, of course, evident that it is economical to build switches for a service of a given voltage that shall have gaps as small as may be possible without preventing or impairing successful operation; or, conversely stated, a switching apparatus of the foregoing type is adapted to the highest voltage service consistent with its gap dimensions when these gaps are stressed electrically by the maximum potential gradients which they will withstand without arc-over. Arc-over across the gaps is accordingly one of the limiting factors in the economical design of the switching apparatus.

In order to explain the principles of my invention, a switch of the general structure shown in Figs. 1 and 2 will be considered as comprising a pair of stationary terminals supported on insulators from a supporting frame and a bridging member rotatably mounted on a central insulator to close and open the circuit between the stationary terminals. If a source of electromotive force is connected to one stationary terminal, say the left-hand one, and a load such, for example, as a transformer, is connected to the other stationary terminal, the latter will, when the switch is open and no current is flowing to the load, be substantially at ground potential; in other words, at the same potential as the supporting frame on which the insulators are mounted. There will, of course, be a certain electrostatic capacity between the left-hand stationary terminal and the rotatable bridging member;

there will be a nearly equal electrostatic capacity between the bridging member and the right-hand (ground terminal) and there will also be an electrostatic capacity between the bridging member and the framework of the switch. A moment's consideration will show that Fig. 7 shows relationship of the above-described capacitances, that is to say, the capacitances C_1 and C_2 are in parallel with each other, and the compound capacitance thus constituted is in series with the capacitance C_3, which exists between the live terminal and the bridging members. The line potential is, therefore, impressed across the net-work of capacitances thus composed.

Measurements have shown that the capacitances C_1 and C_3 are approximately equal, but that the capacitance C_2 is several times either one of these. In accordance with well-known electrical laws, the compound capacitance of C_1 and C_2 is several times the capacitance C_3 and, since the line voltage is impressed upon this pair of unequal equivalent capacitances in series, it will sub-divide in inverse ratio to their magnitudes. Consequently, the capacitance C_3 will be subjected to almost the entire line potential. The result of this is that the line potential against which the switch can insulate may be only slightly greater than the arc-over value of the gap between the bridging member and one stationary terminal. In other words, the gap between the bridging member and the other stationary terminal is being utilized at a low efficiency as an insulator. If, as is usual, it is made of the same dimensions as the gap intervening between the bridging member and the line terminal, the design of the switch, as regards economy of space and material, (a matter of considerable practical importance) is poor.

In accordance with the principles of my invention, the dimensions of the various elements of a switching system are made such that the various gaps intervening between structural elements which stand at different potentials when the switch is open are all worked at the maximum electrical gradients at which they are safe against arc-over.

The foregoing broad principle may be embodied in various structural arrangements. Thus, in the arrangement illustrated in Figs. 2 and 5, additional capacitances are provided between the bridging member and the stationary terminals, so that the capacitances C_1 and C_3 of Fig. 7 are large, as compared with capacitance C_2; and, accordingly, line potential at any instant is divided with substantial equality between the two stationary terminals and the bridging member. In the arrangement illustrated in Fig. 3, on the other hand, the gap intervening between the bridging member and the load (ground) terminal is made shorter than the gap intervening between the bridging member and the line terminal in just the ratio required, in view of the capacitances of the various terminals, to subject all gaps to their maximum safe potential gradients.

With the foregoing principles in mind, the switch illustrated in Figs. 1 and 2 comprises a frame-work 1, upon which are mounted a line terminal 2 and a load terminal 3, the terminals being supported, respectively, on insulating pillars 4 and 5. Between the pillars 4 and 5 is positioned an insulating pillar 6, which supports a bridging member 7 that is to be turned into alignment with the stationary terminals 2 and 3 to conductively interconnect them when the circuit is closed; and to be rotated at right angles to the foregoing position when the circuit is opened.

In order to insure that the capacitance between the bridging member 7 and the framework 1 shall be small relative to that between bridging member 7 and terminals 2 and 3, capacitance areas, which may comprise metallic sheets or screens 8, 9 and 11 of substantial area, are conductively mounted on the members 2, 3 and 7, respectively. By making the areas of the members 8, 9 and 11 sufficiently great, the capacitances corresponding to capacitances C_1 and C_3 of Fig. 7 may be made as large as desired relative to the capacitance between the member 11 and the framework 1, which corresponds to the capacitance C_2 of Fig. 7. In order that the capacitance between the bridging member and the framework, corresponding to C_2, may not be increased materially due to the addition of the condenser plate 11, it is positioned on the bridging member 7 on edge so that as the switch opens, the area of the plate 11 facing the terminals is large compared to its area facing the structural members forming the framework. This makes the impedance across the two gaps small as compared to the impedance between the bridging member and the adjacent structural members so that the amount of current flow across the pair of gaps is large compared to the amount of leakage current flow between the bridging member and the adjacent structural frame. By thus making the amount of leakage current small compared to the current flow across the gaps, the amount of current flow in each gap is substantially equal and, since, as shown in the drawings, the condensers across each gap are similar, the voltage drop in each gap will be substantially the same and thus equalization of the division of potential between the gaps will have been accomplished, still keeping the capacitances across the two gaps equal. This is desirable, since it is then not necessary that one side of the switch always be the line side and the other side the ground side, and makes it possible to use the switch in networks where the direction of current flow in any particular line of the system may be different at different times. In order to avoid unnecessary loss through corona at high potentials, the members 8, 9 and 11 may be so formed that no point of their surface exposes a sharp edge or has a radius of curvature smaller than a predetermined value.

That the division of potential between the two gaps of the interrupter is made more equal by the addition of capacitance members of equal area is shown by the following illustrative computations, in which the symbols used have the same meanings as when used in the specification of this application. Measurements have been made on disconnecting switches of standard types, and it is found that the capacitance across the gaps is of the order of 25 to 30 micro-microfarads and that the capacitance between the movable bridging member and ground is of the order of 75 to 90 micro-microfarads, so that the capacitances in the equivalent circuit of Fig. 7 are:

C_1=25 m.-mf.
C_2=75 m.-mf.
C_3=25 m.-mf., and
(C_1+C_2)=100

The potential between the two gaps divides inversely in the ratio of (C_1+C_2) to C_3 so that:

$$E_1:E_3=C_3:(C_1+C_2)=25:100=1:4$$

The total potential across the switch, therefore, divides between the two gaps with only 20% of the voltage impressed across one gap and with the other gap overstressed with 80% of the voltage.

By applying applicant's invention, the capacitance between each terminal and the movable bridging member may be increased to 250 micro-microfarads or more without substantially increasing the capacitance to ground so that:

C_1=250 m.-mf.
C_2=75 m.-mf.
C_3=250 m.-mf., and
(C_1+C_2)=325

The division of potential between the two gaps is then:

$$E_1:E_3=C_3:(C_1+C_2)=250:325=1.0:1.3$$

The addition of the capacitance members increasing the capacitances C_1 and C_3, but keeping them equal, therefore, gives a distribution of potential with 56% across one gap and 44% across the other, as compared with 80% and 20% before the capacitance members were added. The addition of similar capacitance members to the gaps, therefore, does make the potential distribution between the two gaps more equal.

The switching elements above-described may be otherwise arranged in accordance with the usual practice of the art and may be provided with actuating devices too well-known to require detailed description here.

The switching arrangement illustrated in Fig. 3 comprises a plurality of switches in series interconnected through an intermediate conductor, the various parts being insulatingly-mounted on supporting frames which are conductively connected and which, accordingly, acquire a common electrical potential which may be that of the ground. Thus, a line terminal 21 is mounted upon an insulating pillar 22, which, in turn, is supported upon the frame-work 23. A second insulating pillar 24 supports the hinge jaw 25 of a movable switch blade adapted to make and break contact with the terminal 21. A third insulating pillar 26 supports the stationary contact 27 of a second switch, the contact 27 being connected to the hinge jaw 25 by a conductor 28. A fourth insulating pillar 29 supports the hinge jaw 31 of a second switch and the latter is connected, by a conductor 32, to the hinge jaw 33 of a third switch 34 mounted on the insulator 35. A stationary terminal 36 is mounted on an insulator 37 and is adapted to cooperate with the blade of switch 34 and to be connected to an electrical load. The series of three switches above-described may, if desired, be provided with means for simultaneously opening and closing them.

When the three switches are opened, the line terminal 21 is connected to a source of electromotive force, and the line terminal 36 is connected to an electrical load which has no counter electromotive force when not supplied with energy through the switching system. The arrangement will be seen to comprise a network of capacitances similar to, but more complicated than, that illustrated in Fig. 7. Thus, the terminal 36 will be, like frame-work 21, at ground potential. There will be a capacitance between conductor 32 and frame-work 21 and, in parallel thereto, a capacitance represented by the open gap between hinge jaw 33 and terminal 36. Similarly, the gap between contact 27 and hinge jaw 31 will constitute one capacitance, and the capacitance between conductor 28 and frame-work 21 will constitute another capacitance. The gap between terminals 21 and 25 will, in turn, constitute a simple capacitance; and the line potential will, accordingly, be sub-divided between the single capacitance last mentioned and the capacitance network described in the two preceding sentences. It will be evident that, in any switching system comprising more than three gaps, similar principles will apply; namely, there will be the simple capacitances corresponding to the gap immediately adjacent to the live line terminal in series with a network of multiple capacitances, comprising the capacitances of the other gaps and the capacitances between each interconnecting conductor and the ground. Fig. 4 shows the network corresponding to the capacitances just described in connection with Fig. 3.

As was stated in connection with Figs. 1 and 2, the capacitance between such interconnecting conductors as 28 and the grounded frame will usually be several times the capacitance between the terminals of an open switch. Accordingly, the line potential relative to ground will be very unevenly divided between the various switch gaps, and, if the latter have identical lengths, there will be a very uneconomical use of space and material in the design.

In accordance with the principles of my invention, the lengths between terminals of the various switches in the series may be made proportional to the actual potentials which will be impressed across them when they are considered as such network of capacitances as is illustrated in Fig. 4. In order to show the method of determining the various arcing-over voltages for which the different switches must be designed, the latter figure may be referred to.

In that figure, it will be seen that the capacitance C_4 corresponds to the gap switch 34, capacitance C_5 to the capacitance between conductor 32 and framework 21, capacitance C_6 to that between terminals 27 and 31, capacitance C_7 to that between conductor 28 and framework 21, and capacitance C_8 to that between terminals 22 and 25. In accordance with the well-known electrical laws, the total capacity current in the conductors 28 and 32 must be zero, since they are isolated in space. Calling E_1 the potential difference between the terminals of switch 34, charging current must flow out of conductor 32 to charge capacitances C_4 and C_5 to potential E_1. Correspondingly, calling E_2 the potential difference between terminals 27 and 31, the current required to charge capacitance C_6 to voltage E_2 must flow into conductor 32; and the sum of outflow and inflow current to 32 must be zero. Accordingly, the two currents may be equated as follows:

$$E_1(C_4+C_5)=E_2C_6 \qquad (1)$$

Similarly, the current required to charge C_6 to potential E_2 and to charge C_7 to potential (E_1+E_2) must flow out of conductor 28; and the current necesary to charge capacitance C_8 to potential E_3 must flow into 28. Similarly equating these two charge currents, we may write

$$E_2C_6+(E_1+E_2)C_7=E_3C_8 \qquad (2)$$

Since $E_1+E_2+E_3$ must equal the line potential there are three equations from which the various arc-over voltages E_1, E_2 and E_3 may be determined. It is, accordingly, possible to make the length of the gaps between the terminals of the

three switches in the structure of Fig. 3 such that their arc-over voltages will be proportional respectively to the values E_1, E_2 and E_3 thus determined with the result that material and space will be economized by the imposition upon each switching gap of its arc-over potential. It will be seen that the foregoing method is general and may be extended, without difficulty, to switching apparatus comprising any number of gaps in series. Since the capacitance between terminals of the various switches may depend upon the distance between their terminals, it may be desirable to express both C_4 and E_1, as functions of the distance X_1 between terminals 33—36; C_6 and E_2 as functions of the distance X_2 between terminals 27—31; and C_8 and E_3 as functions of distance X_3 between terminals 21—25. By substituting these expressions in the foregoing three equations, the length of various switches may be determined directly. It is obvious that the Fig. 2 arrangement may be treated by this method also.

While the foregoing method is one way in which switches embodying my invention may be designed, it will sometimes be preferable to employ gaps of the same length at each switch of the series and to so evalulate the capacitances C_4, C_6 and C_8 as to produce equal potential drops between the terminals of the various switches; in other words, $E_1=E_2=E_3$. Then C_4 may be given any arbitrary value, and Equation (1) above, will serve to determine C_6 since E_1, E_2, C_4 and C_5 are all known quantities. Similarly, Equation (2) above, will serve to determine C_8, since all the other quantities entering into it are known. The capacitances C_6 and C_8 may be made to have the values thus determined by providing them with capacitance areas such as elements 8 and 11, described in connection with Fig. 2. The method of extending the foregoing calculation to switching systems having any number of gaps in series will be readily apparent.

In Figs. 5 and 6 is shown a modified embodiment of my invention in which the intermediate capacity area 11' has the form of a cylinder with rounded ends, the radius of curvature being at no point of the surface less than that of the line conductor. The reference numerals refer to the corresponding elements to those designated by the same numerals in Fig. 2 and no separate description of such elements is considered necessary.

It will be evident that the foregoing principles are applicable to oil-immersed circuit breakers as well as to air switches. It will also be evident that, while I have described one particular method of providing any desired capacitative impedance between the elements of a series of switch gaps, other methods will be found available and it may even be desirable to adjust the potential differences through the agency of impedance elements other than the capacitances here described.

In accordance with the patent statutes, I have described the particular embodiments of my invention, but it will be understood that these are merely illustrative of the broad principles thereof, and that many other arrangements will be evident to those skilled in the art. I desired, therefore, that the following claims shall be subject only to such limitations as are expressed in their terms or are imposed by the prior art.

I claim as my invention:

1. A circuit-interrupting apparatus comprising two terminal members, a supporting framework, and a movable insulated intermediate member, the capacitance between said intermediate member and one terminal member being approximately equal to the sum of the capacitances from said intermediate member to said other terminal member and to said framework.

2. A circuit-interrupting apparatus comprising two stationary terminal members, a supporting framework and a bridging member, the mutual capacitance and gaps between said bridging member and said framework and said terminal members being so related that the product of the capacitance between said bridging member and one terminal member by the arc-over voltage between the last said members is approximately equal to the product of the net capacitance from said bridging member to said framework and said other terminal member by the arc-over voltage between said bridging member and said other terminal member.

3. A circuit interrupter comprising line terminals, adjacent structural members and a movable bridging member, the capacitance between said bridging member and one terminal member being approximately equal to the sum of the capacitances from said bridging member to said structural members and to said other terminal member.

4. A circuit interrupter comprising line terminal members, a supporting framework, a bridging member and capacitance members mounted on said terminal and bridging members for causing the capacitance between said bridging member and said framework to be small as compared with the capacitance between said bridging member and said terminal members.

5. In a circuit interrupter, a pair of fixed contact members, conducting means for bridging across said fixed contact members, said bridging means being movable to initially open the circuit with a pair of gaps between the ends of said bridging means and said fixed contact members, and impedance members electrically connected to the circuit between said fixed contact members, said impedance members approximately equalizing the division of potential between said gaps.

6. In a circuit interrupter, a pair of fixed contact members, conducting means for bridging across said fixed contact members, said bridging means being movable to initially open the circuit with a pair of gaps between the ends of said bridging means and said fixed contact members, and impedance members electrically connected to the circuit between said fixed contact members, said impedance members approximately equalizing the division of potential between said gaps, said impedance members providing substantially the same value of impedance across each of said gaps.

7. In a circuit interrupter, a supporting framework, a pair of terminal members, one or more intermediate insulated members for completing the electrical circuit between said terminal members, said intermediate members being movable to open the circuit at a plurality of points, and the capacitance between each insulated member and said framework being small compared with the capacitance between said insulated members and said terminal members.

8. In a circuit interrupter, a pair of terminal members, adjacent structural members, a bridging member for completing the circuit between said terminal members, said bridging member being movable to open a pair of gaps in the circuit between said terminal members, and im-

pedance members permitting an amount of current to flow across said gaps that is large compared to the leakage current flowing between said bridging member and said adjacent structural members.

9. In a circuit interrupter, a pair of terminal members, adjacent structural members, a bridging member for completing the circuit between said terminal members, said bridging member being movable to open a pair of gaps in the circuit between said terminal members, and impedance members permitting an amount of current to flow across said gaps that is large compared to the leakage current flowing between said bridging member and said adjacent structural members, said impedance members comprising condensers having substantially equal capacitances at each of said gaps.

10. In a circuit interrupter, a pair of terminal members, adjacent structural members, a bridging member for completing the circuit between said terminal members, said bridging member being movable to open a pair of gaps in the circuit between said terminal members, and a condenser plate mounted on said movable bridging, said condenser plate having a large area facing said terminal members and a small area facing said adjacent structural members, whereby the capacitance between said bridging member and said terminal members is made greater than the capacitance between said bridging member and said adjacent structural members.

11. In a circuit interrupter, a pair of terminal members, adjacent structural members, a bridging member for completing the circuit between said terminal members, said bridging member being movable to open a pair of gaps in the circuit between said terminal members, and an impedance device electrically connected across each of said gaps, said impedance devices each having substantially the same impedance, and the impedance of each of said impedance devices being small compared to the impedance between said bridging member and said adjacent structural members, whereby the amount of current flow across said gaps is large compared to the amount of current flow between said bridging member and said adjacent structural parts and the potential is more nearly equally divided between said gaps than if said impedance devices were not provided.

12. In a circuit interrupter, a pair of terminal members, adjacent structural members, a bridging member for completing the circuit between said terminal members, said bridging member being movable to open a pair of gaps in the circuit between said terminal members, and an impedance device electrically connected across each of said gaps, said impedance devices each having substantially the same impedance, and the impedance of each of said impedance devices being small compared to the impedance between said bridging member and said adjacent structural members, whereby the amount of current flow across said gaps is large compared to the amount of current flow between said bridging member and said adjacent structural parts and the potential is more nearly equally divided between said gaps than if said impedance devices were not provided, and said impedance devices comprising capacitances having one end conductively connected to one of said terminal members and the other end conductively connected to said bridging member.

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