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C. G. SUITS ET AL
ELECTRIC PROTECTIVE APPARATUS

2,292,174

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Fig. 1.

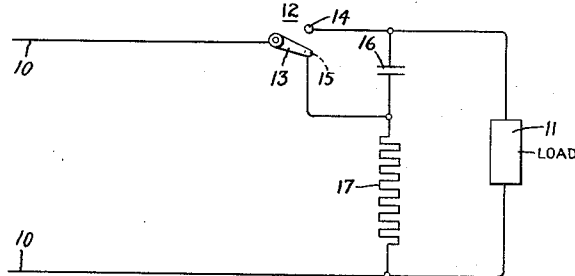


Fig. 2.

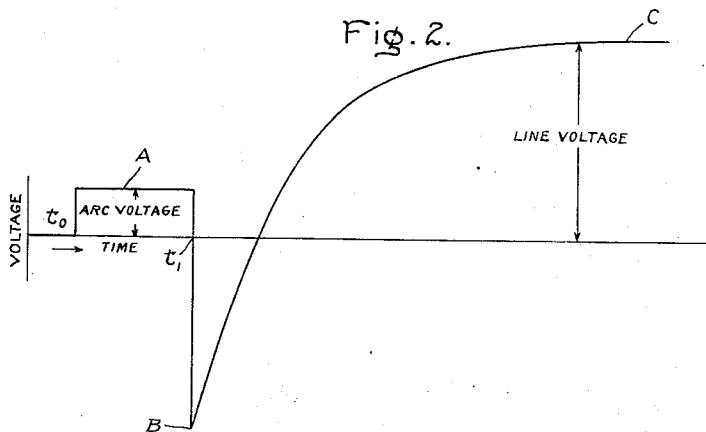


Fig. 3.

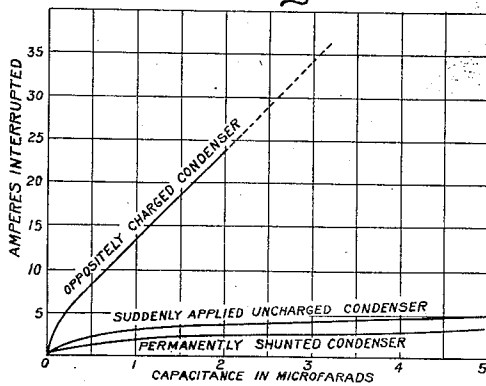
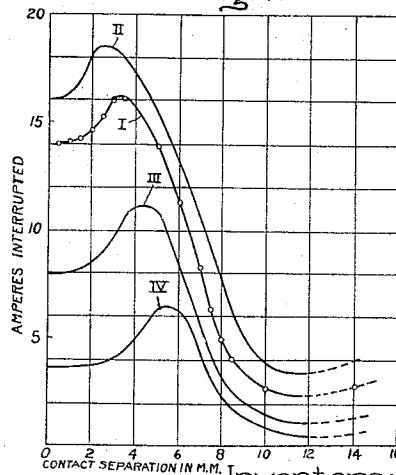


Fig. 4.



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ELECTRIC PROTECTIVE APPARATUS

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4 Claims. (Cl. 175-294)

Our invention relates to an electric protective apparatus for circuit interrupters and more particularly to the suppression of arcs which are formed upon the opening of contacts in electric circuits, especially direct-current circuits.

It is an object of our invention to provide new and improved means for quickly and effectively extinguishing the arc or discharge ordinarily accompanying the interruption of an electric circuit.

It is another object of our invention to provide a new and improved electric protective device for suppressing arcs in electric switches so as to adapt switches to interrupt more severe arcs than can be extinguished by mere separation of contacts.

It is a further object of our invention to provide a simple and compact circuit-interrupting apparatus which is arranged to produce an effective current zero in direct-current circuits so that interruption with minimum arcing will occur.

Further objects and advantages of our invention will become apparent as the following description proceeds and the features of novelty which characterize our invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of our invention, reference may be had to the accompanying drawing in which Fig. 1 is a schematic diagram of a circuit embodying our invention, Fig. 2 represents an operating characteristic of the arrangement disclosed in Fig. 1 in order to aid in the understanding of the invention, and Figs. 3 and 4 represent certain test data obtained in order to illustrate the advantages of our invention.

Several different arrangements have been proposed for suppressing and extinguishing the arcs accompanying the operation of electric switches. The interruption of alternating-current circuits is readily accomplished because the arc or discharge occurring upon the separation of the switch contacts tends to extinguish itself automatically when the alternating current passes through the zero point of the current wave. However, in a direct-current circuit, a different situation obtains for there is no tendency for the arc to extinguish itself since the current never goes through zero and, therefore, the interrupting ability of a given switch when used in connection with such direct-current circuits is generally very much less than when used in alternating current circuits.

It would be desirable, therefore, to be able to obtain a switching device for interrupting direct-current circuits which would cost approximately

the same as one for interrupting alternating-current circuits while still having the same interrupting capacity. This is especially true in connection with many of the modern appliances which are provided with universal motors to operate either from a direct-current or an alternating-current source. In apparatus of this type, it has been necessary to incorporate an expensive switch of the high-speed break type so that the circuit may be interrupted properly in the event that the apparatus is operated from a direct-current source, whereas, if it were only to be operated from an alternating-current source, a much cheaper switch of the slow-break type could be utilized.

Methods and apparatus have been proposed whereby the cheaper slow-break type of switches could be used effectively to interrupt direct-current circuits. For example, it has been suggested to connect a serially connected resistor and condenser across the contact points of the switch. However, this switch arrangement has proven satisfactory only when the capacity of the condenser and the value of the resistor have been carefully adjusted to the particular switch and load. A change in either of these factors requires new adjustments of the condenser or resistor values.

It has also been suggested to shunt a condenser permanently across the contacts of the switch or to suddenly apply either an uncharged condenser or a similarly charged condenser, i. e., a condenser charged to a potential so as to tend to increase the current flowing through the arc at the switch contacts. These methods have tended to increase the interrupting capacity of the switch and, therefore, were a step in the right direction insofar as providing an interrupting device which would be satisfactory in applications such as mentioned above. The results of tests which we conducted as set forth in Fig. 3, however, show that, if a condenser charged to a polarity opposite to that of the potential across the switch contacts when the circuit is interrupted were suddenly applied in opposition to this first mentioned potential, the interrupting capacity of the switch for the same size of condenser could be increased ten or more times over that of a switch wherein a permanently shunted condenser or a suddenly applied uncharged condenser was used as suggested by the above-mentioned arrangements. For example, with a .7 microfarad condenser, it was discovered that, if this reversely charged condenser were applied across the switch contacts, a circuit of ten amperes could be successfully interrupted a great many times, whereas a current of only one or two amperes could be successfully interrupted when

this same condenser was suddenly applied in the uncharged condition or was permanently shunted across the contacts of the switch. The reversing of the charge of the condenser enables a condenser of relatively small capacity to be used for arc quenching purposes. These tests conclusively prove that a large increase in interrupting capacity and further a considerable saving in capacitance is obtained when the reversely charged condenser method is employed.

In accordance with another feature of our invention, tests which we have conducted show that, for a given circuit voltage, a given capacitance, and a given electrode or contact geometry, that there is an optimum contact separation which should exist at the instant the arc-quenching condenser is connected across the contacts, which will give the highest current-interrupting ability for the apparatus. This is clearly shown in the test data set forth in graph form in Fig. 4. In these tests, using the reversely charged condenser arrangement described above with a condenser having a particular value of capacitance, the preferred separation of the contacts before the shunting of the arc quenching condenser was very definitely determined for maximum current-interrupting ability of the apparatus at a definite value of applied voltage. For example, with an applied voltage of 250, a condenser having a capacitance of one microfarad, and a contact structure wherein the contacts have a diameter of the order of the gap length at optimum contact separation, curve I of Fig. 4 was obtained. This curve represents the current-interrupting ability of the apparatus versus contact separation at the instant of the shunting of the reversely charged condenser across the contacts. A study of curve I of Fig. 4 shows clearly that, for the circuit constants given above, the interrupting ability of the apparatus may vary by a factor as great as ten depending upon the contact separation at the instant of inserting the condenser into the circuit for arc-quenching purposes. With a contact separation of three and one-half millimeters at the instant the reversely charged condenser is connected across the contacts, the apparatus was capable of reliably interrupting sixteen amperes, whereas, with a gap length of ten millimeters, only two amperes could be reliably interrupted. This remarkable increase in interrupting ability with decrease in maximum contact separation is an unexpected new fact, which, however, has been thoroughly established in careful tests and agrees with the knowledge of the thermal properties of arcs as set forth in the theory below.

Curves II, III, and IV of Fig. 4 are similar to curve I except that the applied voltages differ. Hence, a family of curves is obtained, one for each different applied voltage. It will be obvious to those skilled in the art that, unless a designer utilizes the fact that, for given circuit constants, there is an optimum contact separation which must be obtained before inserting the reversely charged condenser into the circuit for arc-quenching purposes, the interrupting ability of the apparatus might differ from the maximum obtainable for the optimum contact separation by a very large factor. It will also be understood by those skilled in the art that, although the test data set forth in graph form in Fig. 4 is based on the use of a reversely charged condenser shunted across the contacts after a predetermined separation thereof, there is also an optimum contact separation when a suddenly applied similarly charged or uncharged condenser is utilized.

It is our belief that the reason for the results indicated by Fig. 4 showing that there is a preferred contact separation that should be obtained before the arc-quenching condenser is connected across the contacts resides in the following two factors involved in arc interruption, namely, the cooling of the arc and the likelihood of restriking of the arc. It is obvious, of course, the higher the applied voltage the greater the danger of restriking of the arc with small contact separation and the less the danger of restriking with relatively large contact separation. On the other hand, the greater the arc cooling, the easier it is to interrupt such arc. In the short arc, the heat lost from the arc column is by free conduction and convection to the relatively cool contact surfaces whereas, in the long arc column obtained by greater electrode separation, the heat loss is chiefly by the relatively inefficient convection and conduction to the surrounding gas. In this latter case, a volume of uncooled, ionized gas remains between the electrodes and favors the restriking of the arc. The shape of the curves of Fig. 4 can, therefore, be explained on this basis since, at a relatively small contact separation, the arc-cooling factor is the most important although the likelihood of restriking is greater. The greater the contact separation prior to shunting the condenser for arc-quenching purposes, the less the arc cooling and the lower the interrupting ability due to this factor. On the other hand, the likelihood of restriking of the arc is decreased and so the interrupting ability in this respect is increased. These two factors combine, therefore, to provide an optimum contact separation for maximum interrupting ability of the apparatus for a particular value of applied voltage, thus explaining the family of curves obtained in Fig. 4.

In connection with the use of circuit-interrupting devices for the applications referred to above, it is often essential that such devices be very compact since many times the space factor in apparatus of the type described above is an important consideration. Accordingly, our invention is concerned not only with the use of a reversely charged condenser but also its combination with a switch arranged to have a definite contact separation for a particular value of applied voltage and arc-quenching capacitance so that maximum interrupting ability of the apparatus is obtained, which is simple and cheap to manufacture, which requires a minimum amount of space and which will satisfactorily interrupt larger values of direct and alternating current with a minimum amount of arcing than was heretofore considered possible.

Referring now to Fig. 1, we have illustrated our invention as associated with a power supply circuit 10, which is preferably a direct-current circuit, and a load circuit including schematically shown load device 11. A single-pole double-throw switch 12 of the slow-break type is provided comprising a moving contact 13 and a pair of stationary contacts 14 and 15, respectively. When moving contact 13 is engaged with stationary contact 14, power supply circuit 10 is connected so as to energize load device 11. When moving contact 13 is in engagement with stationary contact 15, a reversely charged condenser 16 permanently connected across stationary contacts 14 and 15 is arranged to be connected across the arc drawn between moving contact 13 and stationary contact 14 thereby causing high-speed interruption thereof. It is desirable that the separation of the stationary

contacts 14 and 15 be relatively small from the standpoint of the space requirement and also to reduce the arcing time since condenser 16 is not applied across contacts 13 and 14 until contact 15 is engaged by movable contact 13. However, this spacing is primarily determined from the data discussed above in connection with Fig. 4 so that the optimum separation for maximum interrupting ability is used.

In order that condenser 16 may be charged to a potential the polarity of which when suddenly applied across the contacts of switch 12 is opposed to the potential across the switch contacts 13 and 14, we provide a high resistance 17 serially connected with capacitor 16 which series combination is connected permanently across the load circuit. By this arrangement, a full charge on condenser 16 is assured and, therefore, the advantages portrayed by Figs. 3 and 4 are at all times available. An appreciable charging time is, of course, required for the condenser but, in practical cases, the values of capacitance 16 and resistance 17 are such that this charging time is negligibly small in comparison to the period determined by the frequency of operation. Furthermore, connecting this condenser through its resistor permanently across the load is greatly superior to an alternative arrangement of switching the condenser from the load circuit to the arc circuit by means of additional contacts since the malfunctioning of these additional switching contacts, as for example, due to excessive contact resistance may prevent the charging of the condenser and, hence, its proper arc-quenching functioning.

The operation of our invention will be obvious to those skilled in the art but will be discussed briefly with reference to Fig. 2. When moving contact 13 engages stationary contact 14, load circuit 11 is energized from power supply circuit 10. At the same time, condenser 16 is charged through high resistance 17 to a potential, the polarity of which is opposite to the potential of the arc drawn between contacts 13 and 14 when switch 12 is open and condenser 16 is connected thereacross. Upon separating the contacts 13 and 14, represented by time t_0 in Fig. 2, an arc is drawn between said contacts, the potential of which is represented by the portion A of the curve illustrated in Fig. 2. At the time t_1 in Fig. 2, moving contact 13 engages with stationary contact 15 whereupon reversely charged condenser 16 is connected across the arc. The condenser discharge current opposes the arc current and reduces the arc drop to a large negative value, as indicated by B in Fig. 2. Thereafter, the voltage across the arc again rises and, if the arc has been extinguished, the voltage across the contacts will rise to line voltage represented by C in Fig. 2. By using the proper value of capacitance for condenser 16, the arc will not be reestablished and a current zero is effectively provided for a direct-current circuit.

We have, therefore, provided a simple and very compact circuit-interrupting device for direct-current circuits utilizing an optimum contact separation and employing a reversely charged capacitor for suppressing arcs during circuit interruption so as to produce an effective current zero for direct-current circuits somewhat analogous to the recurring current zero of alternating-current circuits.

It should be understood that our invention is not limited to the specific details and arrange-

ment thereof herein illustrated and we intend in the appended claims to cover all such changes and modifications as fall within the spirit and scope of our invention.

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

1. In combination, a source of electrical energy, a load circuit, a switch including a plurality of contacts for connecting and disconnecting said source and said load circuit, a condenser, means for shunting said condenser across said switch contacts during said disconnecting operation only after said contacts have been separated to a predetermined distance, the distance to which said contacts are separated before shunting said condenser being of such a value relative to the potential of said source and the capacitance of said condenser as to obtain maximum current interrupting ability of said switch.

2. In combination, a source of electrical energy, a load circuit, a switch including a plurality of contacts for connecting and disconnecting said source and said load circuit, a condenser arranged to be charged to a potential having a polarity opposite to the polarity of the potential across said switch when disconnecting said source and said load circuit, means for shunting said reversely charged condenser across said switch contacts during said disconnecting operation only after said contacts have been separated to a predetermined distance, the distance to which said contacts are separated before shunting said condenser being of such a value relative to the potential of said source and the capacitance of said condenser as to obtain maximum current interrupting ability of said switch.

3. In combination, a source of electrical energy, a load circuit, a switch including a plurality of contacts for connecting and disconnecting said source and said load circuit, a condenser, means for shunting said condenser across said switch contacts during said disconnecting operation only after said contacts have separated to a predetermined distance, said contacts being separated between three and five millimeters before shunting said condenser for arc-quenching purposes, the distance of separation in order to obtain maximum current-interrupting ability of said switch being dependent upon the potential of said source and the capacitance of said condenser.

4. In combination, a source of electrical energy, a load circuit, a switch including a plurality of contacts for connecting and disconnecting said source and said load circuit, a condenser arranged to be charged to a potential having a polarity opposite to the polarity across said switch contacts when disconnecting said source from said load circuit, means for shunting said reversely charged condenser across said switch contacts during said disconnecting operation only after said contacts have been separated to a predetermined distance, the distance to which said contacts are separated before shunting said condenser in order to obtain maximum current interrupting ability of said switch falling within the range of two to five millimeters depending upon the potential of said source and the capacitance of said condenser, said contacts having a diameter of substantially the same order as the separation between said contacts when the load circuit is disconnected from said source.

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