United States Patent

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[73] Assignee **General Electric Company**

[54] **HIGH-VOLTAGE MULTIBREAK CIRCUIT BREAKER WITH MEANS FOR ACCELERATING RESTORATION OF NORMAL VOLTAGE DISTRIBUTION FOLLOWING SPARKOVER AND CLEARANCE OF ONE BREAK**
4 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** ..... **200/144 AP,** 200/145 R
[51] **Int. Cl.** **H01h 33/02**
[50] **Field of Search** ..... 200/145, 146, 144 AA

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ABSTRACT: A high-voltage multibreak electric circuit breaker that has capacitors connected across its series breaks to uniformly distribute voltage across the breaks when the breaker is open. Should one of the breaks of the open circuit breaker sparkover and immediately clear, restoration of normal voltage distribution across the breaks is accelerated by a plurality of very high ohmic resistors respectively connected in parallel with the capacitors.

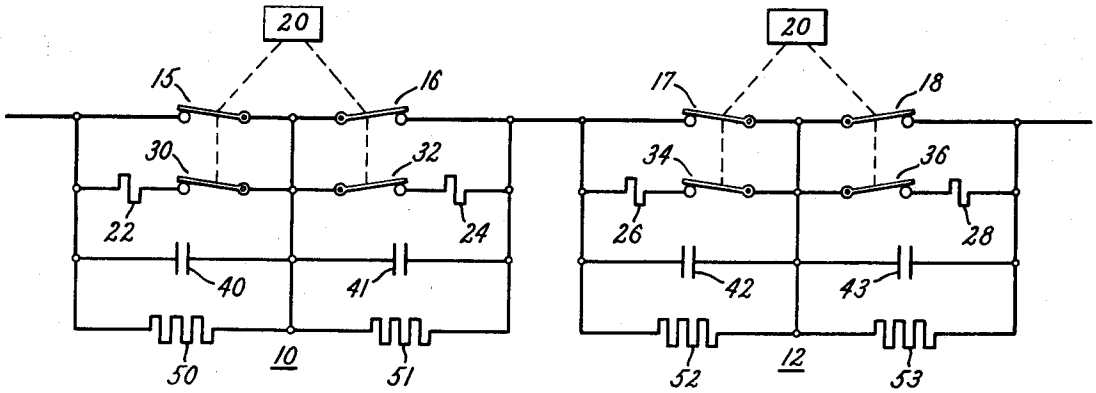


Fig. 1.

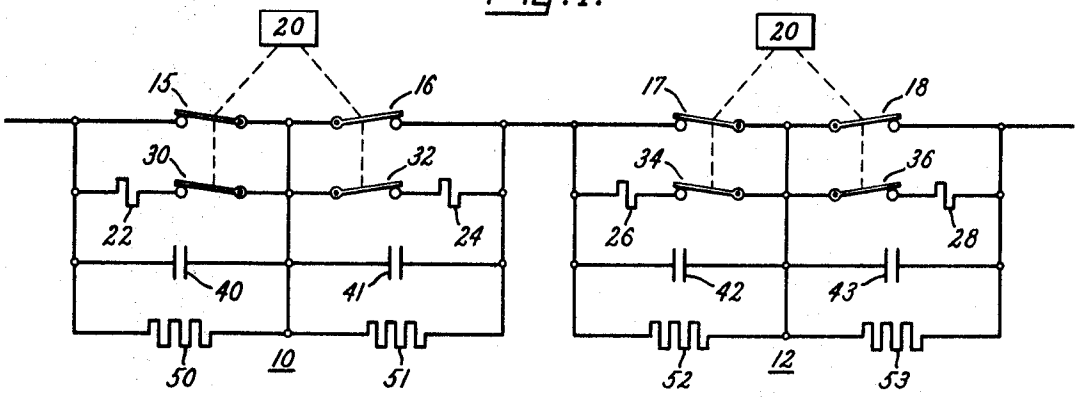


Fig. 2.

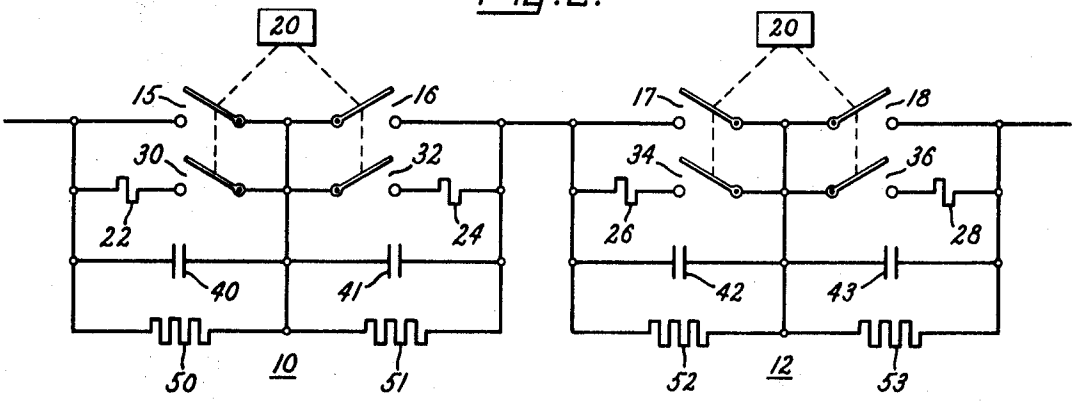
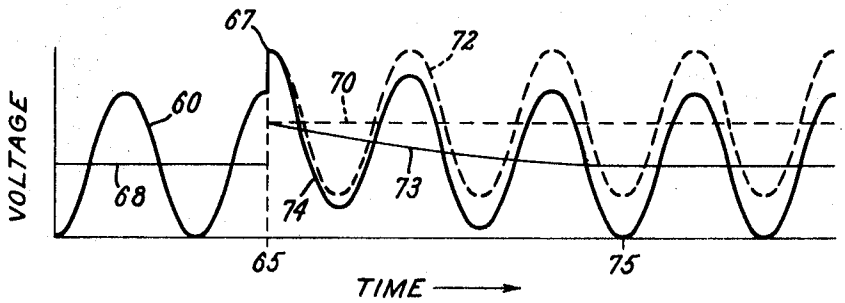


Fig. 3.



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HIGH-VOLTAGE MULTIBREAK CIRCUIT BREAKER WITH MEANS FOR ACCELERATING RESTORATION OF NORMAL VOLTAGE DISTRIBUTION FOLLOWING SPARKOVER AND CLEARANCE OF ONE BREAK

This invention relates to a high-voltage electric circuit breaker of the multiple-break type that uses capacitors shunting its breaks for more evenly distributing voltage between the breaks when the circuit breaker is open.

When a circuit breaker interrupts a predominantly capacitive circuit, a pulsating alternating voltage having a peak value of approximately twice normal crest voltage appears across the open breaks of the breaker for a relatively long period following interruption. Because of its high peak value, this pulsating voltage imposes high electrical stresses on the circuit breaker which can produce a sparkover of one or more of these open breaks. If one of the breaks does spark over, the remaining breaks must withstand the full voltage for a relatively long time if a complete electrical breakdown is to be prevented. Even if the sparked-over break clears before any remaining break sparks over, an extended period must intervene before normal voltage distribution among all the breaks can be restored; and during this period of abnormal voltage distribution, there is a greater likelihood of one of the remaining breaks sparking over.

An object of my invention is to increase the likelihood that the remaining breaks will be able to withstand the voltage appearing thereacross in the event that one of the breaks has sparked over during the period immediately following interruption of a capacitive circuit.

Another object is to shorten the time period required to restore normal voltage distribution to the breaks following sparkover of one of the breaks and subsequent clearance of the spark current.

Still another object is to attain the objectives of the two immediately preceding paragraphs with a minimum of added mechanical complications, such as disconnect switches which open immediately following interruption, and without significantly increasing the small current that normally flows through the open circuit breaker.

In carrying out the invention in one form, I provide in parallel with each of the voltage-distributing capacitors that shunt the breaks of the multiple-break circuit breaker a very high ohmic resistor. Each of these high ohmic resistors has a value such that the time constant of a loop circuit comprising said resistor and the capacitor across which said resistor is connected is between 0.2 and 5 cycles on a 60 -cycle-per-second basis. The resistors remain connected in parallel with said capacitors during and following a breaker-opening operation and are of sufficiently high values that the total current through the open breaker is no more than about 30 percent greater than the current therethrough with said resistors absent.

For a better understanding of the invention, reference may be had to the following description taken in conjunction with the accompanying drawing, wherein:

FIG. 1 is a schematic illustration of a circuit breaker embodying one form of my invention. The circuit breaker is shown in the closed position.

FIG. 2 is a schematic illustration of the circuit breaker of FIG. 1 in the open position.

FIG. 3 is a graphic illustration of certain voltage relationships that are present in the circuit breaker of FIGS. 1 and 2 during a capacitance switching operation. A portion of FIG. 3 illustrates the voltage that would be present without the resistors.

Referring now to FIG. 1, there is schematically shown a high-voltage circuit breaker of the general type shown in detail in U.S. Pat. No. 3,390,239 Miller, assigned to the assignee of the present invention. This circuit breaker comprises a pair of series-connected interrupting units 10 and 12. Each of these interrupting units comprises a pair of main breaks electrically connected in series. These breaks are respectively designated 15, 16, 17 and 18. Each break comprises a stationary contact and a movable contact. The two movable contacts of each interrupting unit are simultaneously actuated by a single operator 20 coupled thereto. The two operators 20 are caused to operate in unison, thus opening all of the main breaks substantially simultaneously during a circuit-breaker-opening operation.

In parallel with each of the main breaks is a low ohmic resistor which is used for reducing the rate of rise of the recovery voltage during an interrupting operation. These resistors are respectively designated 22, 24, 26 and 28. At a predetermined instant following opening of the main breaks, the circuit through the shunting resistors is opened by means of a series of resistor switches having breaks designated 30, 32, 34, and 36, respectively. Each of these resistor switches comprises a movable contact which is suitably coupled to the movable contact of the main break which it shunts. Each of these couplings is indicated by a dotted line between the movable resistor switch contact and its associated movable main contact.

For uniformly distributing voltage across the series-connected breaks of the circuit breaker when the circuit breaker is opened, a plurality of series-connected capacitors 40, 41, 42, and 43 are provided. These capacitors 40, 41, 42, and 43 are respectively connected in parallel with main breaks 15, 16, 17 and 18. Capacitor 40 also parallels the series combination of resistor 22 and resistor switch 30; whereas capacitor 41 parallels the series combination of resistor 24 and resistor switch 32; capacitor 42 parallels the series combination of resistor 26 and resistor switch 34; and capacitor 43 parallels the series combination of resistor 28 and switch 36.

The circuit breaker as described up to this point is conventional. My circuit breaker differs from such a circuit breaker by including a series of very high ohmic resistors 50, 51, 52 and 53 connected in parallel with the capacitors 40, 41, 42 and 43, respectively. The purpose of these high ohmic resistors will soon be described in greater detail. Assume now that the circuit breaker of FIG. 1 is used for interrupting a capacitive circuit. The main breaks 16, 16, 17, and 18 are opened substantially simultaneously, and a short time thereafter, e.g., one or two cycles, the resistor switch breaks 30, 32, 34, and 36 are opened to interrupt the residual current through the resistors 22, 24, 26, 28. The circuit breaker is then in the open condition depicted in FIG. 2. Immediately following opening of the resistor switch breaks, a pulsating voltage corresponding to that shown in FIG. 3 at 60 appears across each of the breaks of the circuit breaker. This voltage has a frequency corresponding to that of the normal system voltage. Assume now that one of the resistor switch breaks, e.g., break 32, sparks over in response to this voltage, say at an instant 65, and that it immediately clears following spark over. Immediately following such spark over, the voltage across break 32 would have collapsed to zero and the total voltage would be borne by the three remaining breaks, thus causing the voltage across each of these remaining breaks to sharply increase to a value 67. Thereafter, the voltage across each of the remaining breaks would continue to pulsate at power system frequency but about a DC component that is more offset than the DC component that was present before sparkover. If the resistors 50, 51, 52 and 53 were absent, this DC component, as shown at 70, would remain substantially constant for an extended period, e.g., one second or even more, and the voltage across each of the breaks that had not sparked over would appear as shown by the dotted line curve 72. But with the resistors 50–53 present, I am able to force a prompt decay in the DC component of voltage to substantially its original value, in the manner depicted by the solid line 73. As a result, the voltage 74 across the intact breaks returns to substantially its original wave form by the instant 75. By forcing the DC component promptly to decay, as depicted at 73, and to remain at a lower value than the DC component depicted at 70, I am able to substantially reduce the instantaneous and peak voltages to which the remaining breaks are subjected, thus substantially reducing the likelihood that one of these remaining breaks will spark over.

The resistor **50–53** make possible the above-described more rapid return to normal voltage conditions because: (1) they provide a path **50, 51, 52, 53** through the circuit breaker through which the direct current component can flow to build up voltage across the resistor **51** that shunts the previously sparked-over break **32**, and (2) they provide discharge paths across the capacitors **40, 42** and **43** that shunt the nonsparked-over breaks through which each of these capacitors can partially discharge to return the voltage across the capacitor to the values corresponding to those present before break **32** had sparked over.

The effectiveness of the resistors in permitting current to flow in the manner described in the preceding paragraph can be related to the time constant of each of the loop circuits that is constituted by one of the capacitors and the resistor connected thereacross. One of these loop circuits, for example, is constituted by the capacitor **43** and the resistor **53** connected thereacross; another by the capacitor **42** and the resistor **52** connected thereacross; another by the capacitor **41** and the resistor **51** connected thereacross; and still another by the capacitor **40** and the resistor **50** connected thereacross. In one embodiment of the invention, the capacitors are of equal values and the resistors are also of equal values. Thus, the time constants are substantially the same for each of these loop circuits. In accordance with my invention, I make this time constant between 0.2 and 5 electrical cycles, considered on a 60-cycle-per-second basis. The higher this time constant, the slower will be the decay of the DC voltage component depicted at **73**. To assure return of this DC component to substantially its original value of **68** within a few cycles, I make this time constant no higher than 5 cycles.

The lower limit of the time constant is determined by the maximum current permissible through the open circuit breaker. In this respect, it is desirable to avoid any significant increase in the current that will flow through the circuit breaker when it is open, as compared to the open breaker current in the hereinabove described conventional breaker. Even without the resistors **50–53**, a small amount of alternating current will flow through the capacitors **40–43** when the breaker is opened. The impedance of these capacitors is so high that this current is typically no more than a few tenths of an ampere. The values of the resistors **50–53** are made so high that the total current flowing through the open circuit breaker with the resistors present is no more than about 30 percent higher than that flowing when the resistors are absent. By keeping this total current very low, I avoid the need for any disconnect switch in series with the circuit breaker for interrupting this current.

In one specific embodiment of the invention, I use capacitors **40–43**, each having a capacitance of about 600×10^{112} farads and resistors **50–53** each having a resistance of about 28×10^{6} ohms. The RC time constant of a loop circuit including such a resistor and capacitor is the product of these two quantities, or about 0.0168 seconds, which is about 1 cycle on a 60-cycle-per-second basis.

I am aware that resistors have heretofore been used to shunt the breaks of a multibreak interrupter, but these resistors have been of a much lower value than I am using in the present application and have served entirely different purposes from my resistors. For example, I am aware of resistors being used for distributing the voltage among the breaks on a normal steady-state basis or during switching surges or during certain impulse conditions, but these resistors have much lower values than mine. My resistors have such high values that they would not provide any significant improvement in voltage distribution under these conditions. As a matter of fact, it seems unlikely that one of ordinary skill in this field who was not familiar with my invention would see any reason at all for shunting resistors of such high values.

I am also aware of shunting resistors that are used to reduce the rate of rise of the recovery voltage immediately following interruption and of shunting resistors that are used to reduce trapped charges on the line during capacitance switching, but these resistors are of even lower values than the voltage-distributing resistors referred to in the preceding paragraph.

It is to be understood that nonlinear resistors can be used in place of the linear resistors referred to hereinabove. If the nonlinear resistor values are selected to permit the same total r.m.s. current through the open breaker under steady state conditions as is permitted through by the linear resistors, then under conditions where one break sparks over following interruption, the nonlinear resistors will return voltage distribution to normal more rapidly than linear resistors. Conversely, one could select a slightly higher value of nonlinear resistance and realize less total current through the open breaker but still retain effective control to return voltage division to normal as rapidly as with the linear resistors.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects; and I, therefore, intend herein to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. A high-voltage electric circuit breaker comprising:
   a. a plurality of main-interrupting breaks electrically connected in series, said breaker being of the type that during normal opening operations relies upon said breaks to withstand the full open-circuit voltage without assistance from a series-connected disconnect switch,
   b. a plurality of series-connected capacitors respectively connected across said breaks for distributing voltage among the breaks when the circuit breaker is open,
   c. a plurality of high ohmic resistors connected in series with each other and respectively connected across said capacitors during and following a breaker-opening operation,
   d. each of said resistors having a value such that the time constant of a loop circuit comprising said resistor and the capacitor across which said resistor is connected is between 0.2 and 5 cycles on a 60-cycle-per-second basis,
   e. the values of said resistors being sufficiently high that the total current through the open circuit breaker is no more than substantially 30 percent greater than the current through said open circuit breaker with said resistors absent.

2. A circuit breaker as defined in claim 1 and further comprising:
   a. in parallel with each of said main-interrupting breaks the series combination of a resistor switch and a low ohmic resistor for reducing the rate of rise of the recovery voltage during interruption,
   b. each of said resistor switches being closed during the initial portion of an interrupting operation to permit current to flow through said low ohmic resistors but being opened during a subsequent portion of the interrupting operation to interrupt said resistor current,
   c. said capacitors being respectively connected across said series combinations of resistor switch and low ohmic resistor.

3. A high-voltage electric circuit breaker comprising:
   a. a plurality of main-interrupting breaks electrically connected in series, said breaker being of the type that during normal opening operations relies upon said breaks to withstand the full open-circuit voltage without assistance from a series-connected disconnect switch,
   b. a plurality of series-connected capacitors respectively connected across said breaks for distributing voltage among the breaks when the circuit breaker is open,
   c. a plurality of high ohmic nonlinear resistors connected in series with each other and respectively connected across said capacitors during and following a breaker-opening operation,
   d. each of said nonlinear resistors having resistance characteristics such that the resistors are capable of returning voltage distribution across said open breaks to normal fol-

lowing clearance of a sparked-over break more quickly than could linear resistors respectively connected across said capacitors in loop circuits, each with a time constant of 5 cycles on a 60-cycle-per-second basis,

e. the steady-state resistance of said nonlinear resistors being sufficiently high that the total r.m.s. current through the open circuit breaker is no more than substantially 30 percent greater than the current through said open circuit breaker with said resistors absent.

4. A circuit breaker as defined in claim 3 and further comprising:

a. in parallel with each of said main-interrupting breaks the series combination of a resistor switch and a low ohmic resistor for reducing the rate of rise of the recovery voltage during interruption,

b. each of said resistor switches being closed during the initial portion of an interrupting operation to permit current to flow through said low ohmic resistors but being opened during a subsequent portion of the interrupting operation to interrupt said resistor current,

c. said capacitors being respectively connected across said series combinations of resistor switch and low ohmic resistor.