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3,538,277

HIGH VOLTAGE CIRCUIT BREAKER WITH RESISTANCE MEANS

Filed June 13, 1968

2 Sheets-Sheet 1

FIG. 1.

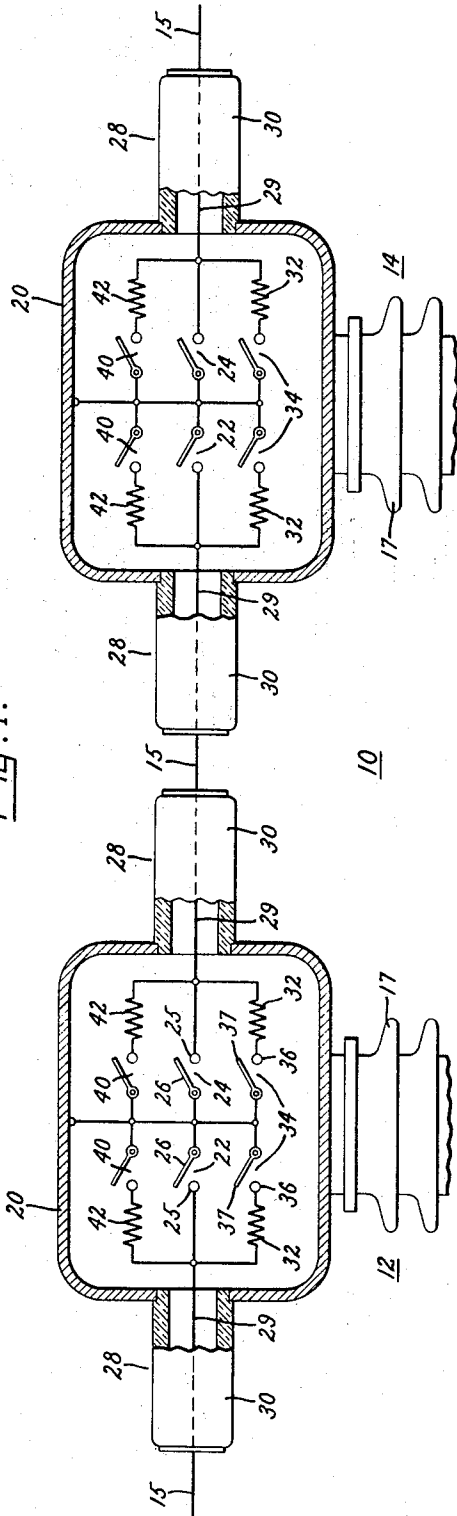


FIG. 2.

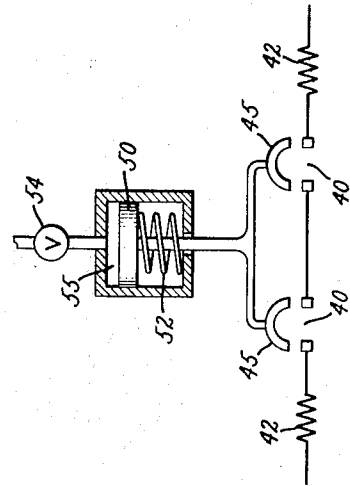
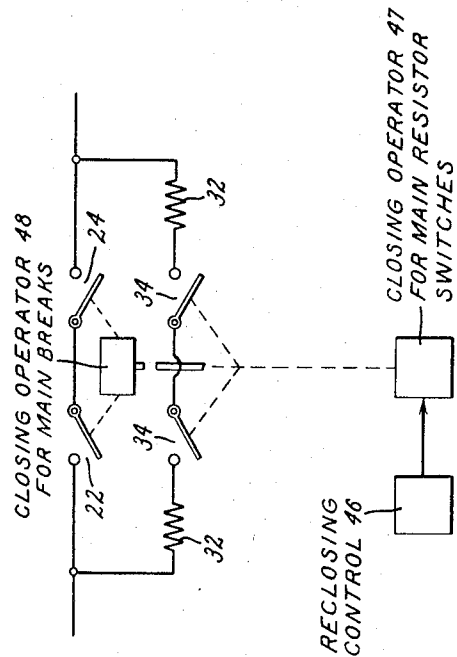


FIG. 1a.



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Fig. 3.

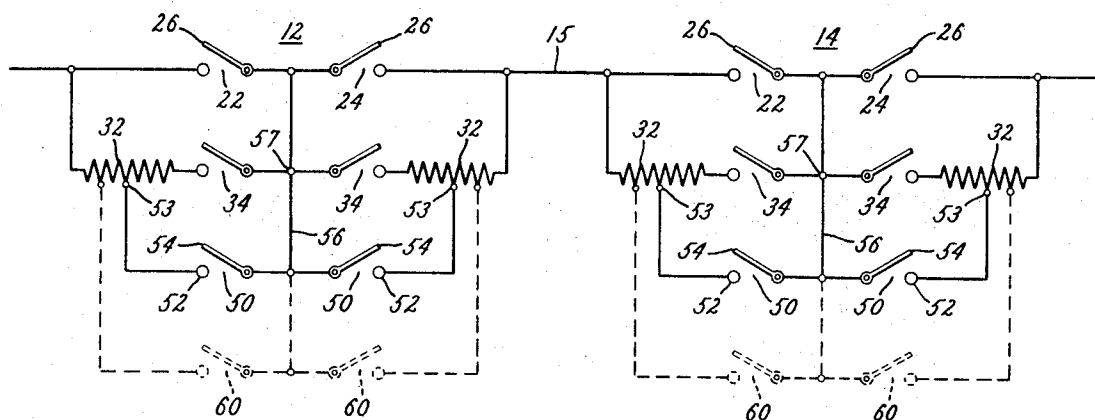
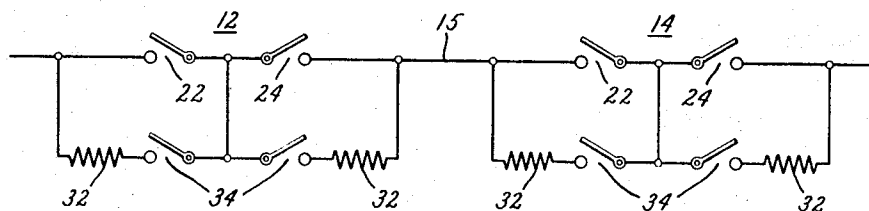


Fig. 4.



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HIGH VOLTAGE CIRCUIT BREAKER WITH RESISTANCE MEANS

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U.S. Cl. 200—144

11 Claims

ABSTRACT OF THE DISCLOSURE

A high voltage electric circuit breaker in which resistance is preinserted in parallel with the breaker's contacts during a closing operation in order to reduce the severity of the voltage surge produced by closing. During the closing operation and while the contacts are still disengaged, a first value of resistance is connected in parallel with the contacts, after which this value of resistance is reduced; and thereafter the contacts are engaged.

This invention relates to a high voltage electric circuit breaker and, more particularly, to a high voltage circuit breaker in which resistors are preinserted in the circuit during closing to reduce the severity of the switching surge produced by the closing operation.

BACKGROUND

When a circuit breaker is closed to energize or reclose a transmission line, voltage surges of relatively high magnitude can be produced. One well-known method of reducing the magnitude of such surges is to preinsert a resistance of suitable low value in the circuit during the closing operation just prior to the instant at which the main contacts engage. For example, see U.S. Pat. 3,291,947—Van Sickle; or the paper by Hedman et al. entitled "Switching of EHV Circuits, II—Surge Reduction with Circuit Breaker Resistors," IEEE Transactions on Power Apparatus and Systems, December 1964, pages 1196–1205; or U.S. patent application S.N. 434,270—Miller, filed Feb. 23, 1965, now Pat. No. 3,390,239, and assigned to the assignee of the present invention.

The circuit breakers described in these references typically include series-connected main breaks and, for each main break, a closing resistor that is switched into the circuit in parallel with its break just before the main contacts of the break engage. By selecting a suitable value of resistance, it is possible to limit the peak line-to-neutral surge voltage on closing to about 2.0 per unit under most circuit conditions; but in some applications this is still too high.

SUMMARY OF THE INVENTION

An object of my invention is to limit this peak surge voltage on closing or reclosing to a value substantially less than that obtainable by prior resistor-preinserting arrangements, e.g., to less than about 1.7 per unit under most circuit conditions.

In carrying out my invention in one form, I provide a high voltage circuit breaker for opening and reclosing the circuit through a power line. The circuit breaker comprises a plurality of series-connected pairs of main contacts, the contacts of each pair being separable to establish a gap therebetween during a circuit-opening operation. Automatic reclosing means is provided for re-engaging said main contacts following a circuit-opening operation within 40 electrical cycles of said opening operation. Resistance means are respectively associated with said pairs of main contacts. First switching means is operable to connect at least a portion of said resistance means across their associated gaps during a reclosing

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operation prior to reengagement of said main contacts, thereby providing a first predetermined effective value of resistance in parallel with said gaps. Second switching means is provided for subsequently reducing the effective resistance in parallel with said gaps during a later portion of said reclosing operation prior to reengagement of said main contacts.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a schematic side elevational view of a circuit breaker embodying one form of my invention.

FIG. 1a is a schematic view showing more details of the circuit breaker of FIG. 1.

FIG. 2 is a schematic showing of the operating mechanism for the auxiliary resistor switches used in the circuit breaker of FIG. 1.

FIG. 3 is a schematic view of a modified form of my invention.

FIG. 4 is a schematic view of another modified form of my invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a high voltage circuit breaker 10 comprising a pair of circuit-controlling assemblies 12 and 14. Each circuit controlling assembly comprises a metal tank 20 at a high voltage with respect to ground and a hollow insulating column 17 supporting the tank 20 and insulating it from ground. At its lower end each insulating column 17 is fixed to a suitable frame (not shown). The circuit-controlling assemblies 12 and 14 are electrically connected in series in one of the phases or lines 15 of a high voltage A-C circuit.

Each of the circuit-controlling assemblies is, for the most part, constructed in the manner disclosed and claimed in the aforesaid Miller application 434,270. Since the details of the circuit-controlling assemblies form no part of the present invention, many of the components have been omitted from the drawing, and those that are included are shown in a simplified schematic form.

In the schematic showing of FIG. 1, a wiring diagram is provided to illustrate the components of the circuit-controlling assembly 12 or 14 that are located within the high voltage tank 20. More specifically, disposed within each tank 20 are two serially connected pairs 22 and 24 of relatively-movable main contacts. Each pair of main contacts comprises a stationary contact 25 and a movable contact 26. The two stationary contacts are supported on terminal bushing 28 projecting through opposite ends of metal tank 20. These bushings comprise conductive studs 29 for carrying current to and from the stationary contacts 25 and tubular insulators 30 for insulating conductors 29 and the stationary contacts 25 from tank 20 when the circuit breaker is open, as shown in FIG. 1.

Shunting each pair of main contacts in FIG. 1 is the series combination of a main resistor 32 and a main resistor switch 34. Main resistor switch 34 comprises a stationary contact 36 and a movable contact 37. Resistors 32, when connected across the main contacts 22 and 24, serve to control the rate of voltage build-up across the main contacts during a circuit-opening operation and also to control the magnitude of the surge voltage developed when the circuit breaker is closed.

For performing this latter control function, each resistor switch must be closed slightly ahead of the main contacts which it shunts. In addition, the resistor switches in the two circuit-controlling assemblies must be closed substantially simultaneously in order to reduce the

chances for a flashover of the insulation paralleling the last switch to close. In this latter respect, it is required in certain circuit breakers that all the resistor switches 34 make contact within approximately two milliseconds of each other during a closing operation. In the aforesaid Miller application and in U.S. Pat. 3,333,071—Oppel et al., means are shown and claimed for effecting this substantially simultaneous closing of the resistor switches at a point prior to main contact engagement, and such means (to be referred to later) may be used in my circuit breaker.

By selecting suitable values for resistors 32, it is possible to limit the peak line-to-neutral surge voltage on closing to a maximum of about 2.0 per unit under most circuit conditions, but for some applications this is still too high. As pointed out hereinabove, an object of my invention is to limit this peak surge voltage on closing to a substantially lower value, e.g., 1.7 per unit.

In the embodiment of my invention shown in FIG. 1, I accomplish this objective by preinserting across each pair of main contacts two different values of resistance at different points during the closing operation prior to engagement of the main contacts, the second resistance being considerably lower than the first resistance. More specifically, at a point at least 240 electrical degrees before the main contacts engage, I close the resistor switches 34 substantially simultaneously to connect resistors 32 across their respective breaks 22, 24, 22, 24. At an instant at least 120 electrical degrees later, I close another set of resistor switches 40 to preinsert auxiliary resistors 42 across the main breaks 22 in parallel with the already-inserted main resistor 32. Thereafter, the value of resistance across each break is the effective resistance of the parallel combination of resistors 42 and 32, which is, of course, less than the value of resistance initially preinserted. I have found that this reduction in resistance following initial resistor preinsertion and before main contact engagement makes it possible to reduce the peak surge voltage very substantially compared to the peak surge voltage developed without the intermediate reduction in resistance.

Extensive studies with analog and digital computers have been made to establish the optimum values of resistance for the two resistors 42 and 43 that will hold the peak surge voltage on closing or reclosing to the lowest level. It appears from these computer studies that the effective total value of the resistances 32 first inserted should be about 2.2 to 3.3 times the surge impedance of the transmission line being closed upon and the effective total value of the resistance across the breaks 22, 24 after the auxiliary resistor switches have closed should be about 0.4 to 0.8 times the surge impedance. In one typical circuit breaker, rated at 765 kv., and assumed to be used in a circuit having a surge impedance of 360 ohms, the optimum effective resistances appear to be about 1000 ohms on the first step and about 200 ohms on the second step. The 200 ohm effective resistance on the second step is obtained by using resistors 42 that have a total resistance of 250 ohms. The main resistors 32 can each be of equal size; and thus, in this specific embodiment, each has a resistance of 250 ohms. The auxiliary resistors 42 likewise can each be of equal size and, thus, in this specific embodiment each has a resistance of 62.5 ohms. The computer studies indicate that a circuit breaker equipped with such resistors will limit the peak line-to-neutral surge voltage to about 1.6 per unit upon closing or reclosing a circuit having the assumed surge impedance.

It is important that at least 120 electrical degrees be allowed to elapse between the successive steps of the circuit breaker closing operation, i.e., between insertion of resistor 32 and insertion of resistor 42 and between insertion of resistor 32 and closing of the main contacts. The reason for this is that each step produces voltage surges which tend to persist; and unless sufficient time

is allowed for damping out these surges, one surge will be superimposed upon the other and even higher total voltage will result. By allowing at least 120 degrees to elapse between successive steps, sufficient damping occurs to largely avoid this problem.

A type of switching duty which can be particularly severe from the standpoint of producing high surge voltages is closing on a line with trapped charges thereon. This situation is most commonly encountered with automatic reclosing breakers, which are typically reclosed within 40 electrical cycles after an opening operation, and, in some cases, in a much shorter time. In dry weather, the trapped charge on an open line can remain within a few percent of its initial value at the end of even a second or more. Thus, substantially the full trapped charge may be present on an unfaulted line when the circuit breaker recloses. As is known, the presence of this charge increases the severity of the switching surges produced by closing. But with my special resistor preinsertion arrangement, I can still limit the maximum line-to-neutral surge voltage on reclosing to less than 1.7 per unit despite the trapped charge.

Another type of switching duty is the closing or reclosing of transmission lines which have shunt reactor compensation. The interaction of the shunt reactor and transmission line capacitance results in an oscillating voltage on the transmission line, typically of from 30 to 58 hertz, when the line is deenergized. With my special resistor preinsertion arrangement, I can limit the maximum line-to-neutral surge voltage on reclosing a shunt-reactor-compensated transmission line to less than 1.7 per unit.

It is to be understood that although my special resistor preinsertion arrangement has the capability of limiting the peak line-to-neutral surge voltage on closing or reclosing to 1.7 per unit, the invention in its broader aspects is also applicable to circuit breakers which allow this peak surge voltage to reach slightly higher values.

The disclosed circuit breaker is an automatic reclosing circuit breaker and thus includes suitable means, schematically indicated at 46 in FIG. 1a, for producing reclosing of the circuit breaker within 40 electrical cycles after opening. The means for producing automatic reclosing can be of any suitable conventional type, such as shown for example in U.S. Pat. 2,582,027—Goff, assigned to the assignee of the present invention, and its details are therefore not shown. FIG. 1a shows, in schematic form, the reclosing control 46 controlling the closing operator 47, which may be constructed as shown in the aforesaid Miller application. In the Miller application, the closing operator directly controls the resistor switches (as depicted in FIG. 1a). The main breaks are controlled by a separate operator, indicated at 48, which is triggered into operation at a predetermined point in the resistor switch closing stroke.

To avoid unnecessarily complicating the drawing and description, I have not shown the details of the operating mechanism for the auxiliary resistor switches 40, particularly since such details form no part of my present invention. I have, however, shown in FIG. 2 a schematic diagram of a suitable operating mechanism for the auxiliary resistor switches 40 in each tank 20. This mechanism comprises a piston 50 coupled to the movable contact arms 45 of auxiliary resistor switches 40 and an opening spring 52 biasing the contact arms toward open position. A normally-closed control valve 54 controls operation of the piston 50. This control valve normally vents the space 55 above piston 50. At a predetermined point in the circuit breaker closing stroke, control valve 54 is opened to apply pressurized gas to the top of piston 50 and drive contact arms 45 closed. As soon as the associated main contacts 26 reach closed position, the valve 54 is reclosed by suitable means (not shown) to vent the space 55, thus allowing the auxiliary resistor switches to reopen under the influence of their opening spring 52. Thus,

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the auxiliary resistors are taken out of the circuit immediately following closing of the main contacts 26 and before the main contacts can reopen.

By opening the auxiliary resistor switches 40 when the main contacts 22, 24 are closed, I eliminate any need for the auxiliary resistor switches to have interrupting ability. More specifically, since the main contacts 22, 24 are closed when the resistor switches 40 are caused to open, the resistors 42 are not then carrying any current, and therefore no current is passing through the resistor switches 40 when they are opened. Also, by inserting resistors 42 in the circuit only during closing, I can limit the time the resistors are required to carry current and hence can limit their required thermal capacity.

In a modified embodiment of my invention, resistor switches 34 are made to open prior to opening of the main contacts 22, 24 during circuit breaker opening, and the opening of resistor switches 40 is delayed until after opening of the main contacts 22, 24. This causes resistor 42 to be the opening resistor. This results in a lower resistance being present on opening and therefore in a lower rate of voltage build-up across the main contacts 22, 24.

Although FIG. 1 shows only a single auxiliary resistor 42 connectable in parallel with each main break 42, it is to be understood that additional auxiliary resistors for connection in parallel with the main resistor can be provided to permit more gradual reductions in resistance as the closing operation proceeds. This more gradual reduction in resistance enables further reductions in surge voltage to be made; but these reductions appear to be relatively minor, and ordinarily I prefer to use only single intermediate reduction in resistance, as is provided with the arrangement of FIG. 1.

FIG. 3 is a schematic illustration of another embodiment of my invention. This embodiment comprises main contacts 22, 24, main closing resistors 32, main resistor switches 34 of substantially the same form and operating in the same manner as in FIG. 1. Accordingly, these particular parts have been assigned the same reference numerals as corresponding parts in FIG. 1.

In the embodiment of FIG. 3, the reduced resistance during the second step of the closing operation is obtained by shorting out a section of each of the main resistors 32. This is done with a series of auxiliary switches 50, each having one contact 52 connected to an intermediate tap point 53 on resistor 32 and its other contact 54 connected through conductor 56 to a point 57 between adjacent resistors 32.

When each auxiliary switch 50 is closed, it shorts out a portion of its associated resistor 32, thus reducing the effective resistance across the main contacts 22 or 24 to the resistance of the unshorted portion of the resistor. This switching arrangement can be used to provide the same effective resistances across each main break as in FIG. 1 and also the same lapse of time between the switching steps.

The same operating mechanism as schematically shown in FIG. 2 can be used for operating the auxiliary resistor switch 50. This operating mechanism opens the auxiliary resistor switch 50 immediately after the main contacts close, thus excluding the auxiliary resistor switch 50 from any subsequent opening operation in the same way as auxiliary resistor 42 of FIG. 1 is excluded.

It is to be understood that additional steps to provide for a more gradual reduction in resistance are also obtainable with the switching arrangement of FIG. 3. The dotted lines indicate how these additional steps could be obtained. More specifically, each resistor 32 can be provided with an additional tap and an additional auxiliary switch 60 for connecting in this additional tap at an appropriate time after the first tap is connected in. Closing of the additional auxiliary switch 60 shorts out an additional portion of the resistor 32 thereby further lowering the effective resistance across the main break.

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FIG. 4 is a schematic illustration of another embodiment of my invention. Here only a single resistor 32 and a single resistor switch 34 are connected in parallel with each main break. In this arrangement, during a circuit-breaker closing operation, all of the resistor switches 34 are closed substantially simultaneously at an instant at least 240 electrical degrees before all of the main breaks 22, 24 have been closed. In this arrangement, however, the main breaks are not closed substantially simultaneously, as in the other arrangement. First, the main breaks 22, 24 of circuit-controlling assembly 12 are closed; and then, at least 120 electrical degrees later, the main breaks 22, 24 of circuit-controlling assembly 14 are closed. Closing the main breaks of the first circuit-controlling assembly 12 while the main breaks of the other assembly 14 are still open has the effect of shorting out the resistors 32 of assembly 12 while leaving the resistors 32 of the other assembly 14 in series with power line 15. Assuming that resistors 32 are of equal size, this means that the pre-inserted resistance is reduced to one-half of its initial value. At least 120 degrees thereafter, the main breaks 22, 24 of assembly 14 are closed, thus shorting out the remaining resistors and completing the closing operation.

In one typical circuit breaker rated at 500 kv, resistors having a total resistance of about equal to the surge impedance of the line are used. On the second switching step, this resistance is reduced to half this value. In this specific arrangement, the resistors each have a resistance of 100 ohms.

The arrangement of FIG. 4 is simpler than the other arrangements in that it has fewer resistors and resistor switches, but it has the disadvantage of subjecting one of the circuit-controlling assemblies 14 to the entire voltage across the breaker during the interval when its main breaks are still open while the main breaks of assembly 12 are closed. This is ordinarily tolerable where only two circuit-controlling assemblies are connected in series (as in FIG. 4) and each must anyway be designed for at least one-half the full voltage. However, where more than two circuit-controlling assemblies are connected in series, each circuit-controlling assembly is ordinarily designed for lower voltages and cannot tolerate the application of full voltage.

While I have shown and described particular embodiments 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 in the appended claims 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. In a high voltage circuit breaker for opening and reclosing the circuit through an alternating current transmission line,

- (a) a plurality of series-connected pairs of main contacts, the contacts of each pair being separable to establish a gap therebetween during a circuit-opening operation,
- (b) reclosing means for reengaging said main contacts following a circuit-opening operation within 40 electrical cycles of said opening operation,
- (c) resistance means respectively associated with said pairs of main contacts,
- (d) first switching means operable to connect at least a portion of said resistance means across their associated inter-contact gaps during a reclosing operation prior to reengagement of said main contacts, thereby providing first predetermined effective values of resistance in parallel with said gaps,
- (e) and second switching means for subsequently reducing the effective resistance in parallel with said gaps to predetermined second values during a later portion of said reclosing operation prior to reengagement of said main contacts,

- (f) said first and second values of resistance being of a magnitude to consistently limit the peak line-to-neutral surge voltages produced by reclosing to less than 2.0 per unit,
- (g) said second switching means operating at least 120 electrical degrees after said first switching means is operated during said reclosing operation and at least 120 electrical degrees prior to reengagement of its associated main contacts, and
- (h) reengagement of said main contacts shorting out the resistance remaining in parallel with said main contacts.
2. The circuit breaker of claim 1 in which said first and second values of resistance are of a magnitude to consistently limit the peak line-to-neutral surge voltages produced by reclosing to less than 1.7 per unit.
3. The circuit breaker of claim 1 in which:
- (a) the total resistance connected across said main contacts when said first switching means is operated is between 2.2 and 3.3 times the surge impedance of the energized line, and
- (b) the total resistance connected across said main contacts when said second switching means is operated is between 0.4 and 0.8 times the surge impedance of the energized line.
4. The circuit breaker of claim 1 in which:
- (a) each of said resistance means comprises first and second resistors connectable in parallel with its associated pair of main contacts,
- (b) said first switching means, upon operating, connects said first resistor across its associated pair of main contacts,
- (c) and said second switching means operates during said later portion of said reclosing operation to connect said second resistor in parallel with said first resistor across the associated pair of main contacts.
5. The circuit breaker of claim 1 in which said second switching means effects said subsequent reduction in effective resistance by shorting out a portion of the resistance means connected by said first switching means across said main contacts.
6. The circuit breaker of claim 1 in which one of said switching means is opened when said main contacts are reengaged and the other of said switching means remains closed to connect its associated resistance means across said main contacts for use as opening resistance during a subsequent circuit breaker opening operation.
7. In a high voltage circuit breaker for opening and reclosing the circuit through an alternating current transmission line,
- (a) a plurality of series-connected pairs of main contacts, the contacts of each pair being separable to establish a gap therebetween during a circuit-opening operation,
- (b) reclosing means for reengaging said main contacts following a circuit-opening operation within 40 electrical cycles of said opening operation,

- (c) resistance means respectively associated with said pairs of main contacts,
- (d) switching means operable to connect at least a portion of said resistance means across their associated inter-contact gaps during a reclosing operation prior to reengagement of said main contacts, thereby providing a first effective value of resistance in series with said energized line,
- (e) and means for subsequently reducing the effective value of resistance in series with said energized line during a later portion of said reclosing operation prior to reengagement of all said main contacts,
- (f) and means for causing said reduction in the effective value of resistance to consistently occur more than 120 electrical degrees before all of said main contacts reengage and more than 120 electrical degrees after said first resistance is connected in series with said line,
- (g) said first and second values of resistance being of a magnitude to consistently limit the peak line-to-neutral surge voltage produced by reclosing to less than 2.0 per unit.
8. The circuit breaker of claim 7 in which said first and second values of resistance are of a magnitude to consistently limit said peak line-to-neutral surge voltage produced by reclosing to less than 1.7 per unit.
9. The circuit breaker of claim 7 in which said subsequent reduction in the effective value of resistance is effected by closing some of said main contacts more than 120 electrical degrees before the remaining main contacts close, thereby shorting out the resistance in parallel with the main contacts that first close while leaving in the circuit the resistance across the still-open contacts.
10. The circuit breaker of claim 7 in which said reduction in effective resistance is effected by shorting out a portion of the resistance connected across each set of main contacts.
11. The circuit breaker of claim 7 in which said reduction in effective resistance is effected by switching in additional resistance in parallel with the resistance already connected across said main contacts.

References Cited

UNITED STATES PATENTS

730,108	6/1903	Girault	307—136
1,563,833	12/1925	Christensen.	
1,861,129	5/1932	Milliken.	
2,639,357	5/1953	Kesselring	317—116.2
3,052,783	9/1962	Buron	200—148
3,291,947	12/1966	Van Sickle.	
3,333,071	7/1967	Oppel et al.	200—148 X

ROBERT S. MACON, Primary Examiner

U.S. Cl. X.R.

200—145; 317—11; 307—136