

June 24, 1969

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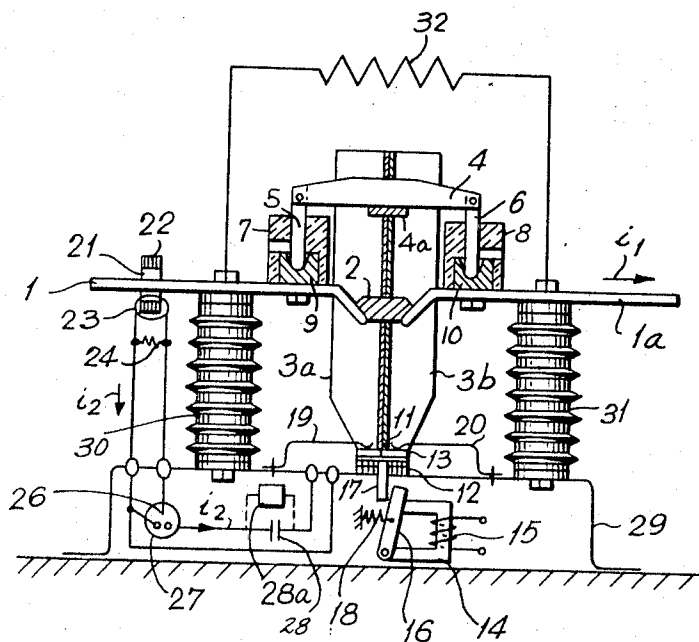
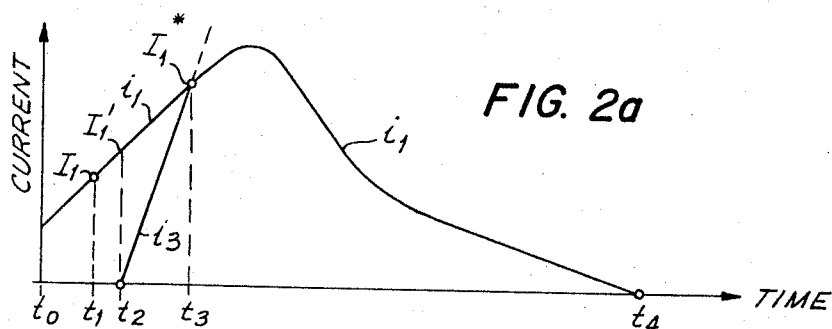
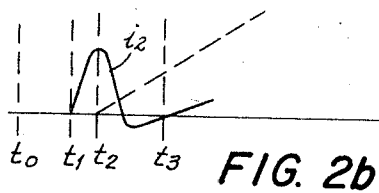
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CURRENT LIMITING CIRCUIT BREAKER

Filed July 1, 1966

Sheet 1 of 2

FIG. 1



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Sheet 2 of 2

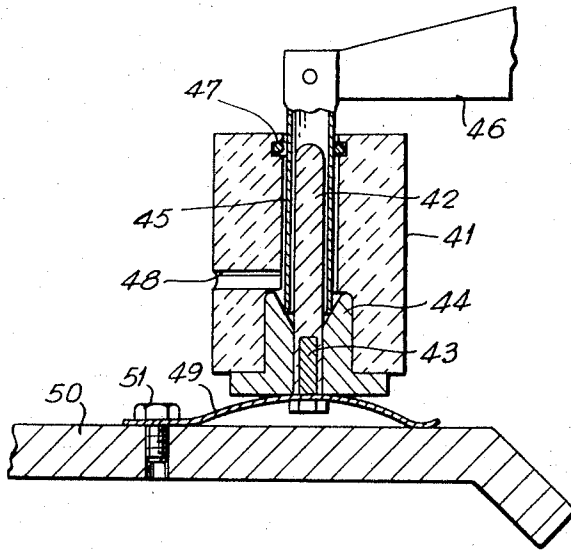


FIG. 3

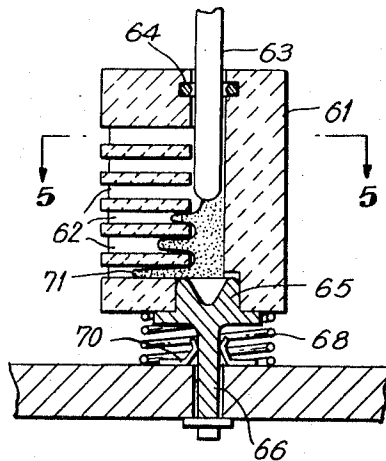


FIG. 4

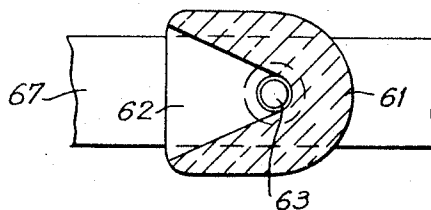


FIG. 5

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1

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CURRENT LIMITING CIRCUIT BREAKER

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4 Claims

ABSTRACT OF THE DISCLOSURE

A current limiting circuit breaker has main contacts, commutating contacts and a positive temperature coefficient resistor. The commutating contacts are provided with arc interrupting means, and are opened after the main contacts open but before the main contacts are separated by 1 millimeter. The arc resistance of the commutating contacts is increased at a rate sufficient to cause a rate of rise of current through the resistor which is at least twice the rate of rise of current flowing into the circuit breaker.

This invention relates to circuit interrupter devices, and more specifically relates to a current limiting circuit breaker which provides a novel cooperation between a main contact, a parallel connected arcing contact and a parallel connected positive temperature coefficient resistor for providing improved circuit interruption operation.

Current limiting circuit interrupters are well known which provide a main pair of contacts which are connected in parallel with a positive temperature coefficient resistor. In such devices, when the main contacts open, the current is shunted into the parallel cold and low resistance resistor. As the resistor is heated, its resistance substantially increases in order to severely limit current flow there-through. A suitable small disconnect-type switch may then be used to interrupt the residual current flow through the hot resistor after this current has been substantially limited in magnitude in order to completely open the circuit.

A pair of commutating contacts are additionally connected in parallel with the main contacts and are opened just after the main contacts are opened. More particularly, the apparatus is so constructed that delay in opening the commutating contacts is such that the voltage drop across the commutating contacts at the instant of their opening will be no more than 15 volts. The structure is further arranged such that the commutating contacts will open after the main switch has moved less than 1 mm., thereby preventing the rise of voltage across the commutating switch to the less than 15 volt value mentioned above.

In addition, and in accordance with an important feature of the invention, means are provided for the commutating contacts to substantially increase their arc voltage to encourage the commutation of current through the current limiting resistor.

In particular and in accordance with the invention, the rate of rise of voltage across the arcing commutating contacts is increased such that the rate of rise of current flow to the resistor is greater than, and preferably twice the rate of rise, of the main current to be interrupted.

It has been found that when these conditions are obtained, successful interruption of the fault current can be accomplished.

In accordance with the invention, various arrangements are provided for increasing the arc voltage at the commutating contacts which, for example, include the provision of arc interruption chambers which contain gas generating wall structures which produce arc extinguishing gas for cooling and deionizing the arc between the

2

commutating contacts. Clearly, various types of arc interruption chambers can be used for this purpose where the arc voltage is increased at a rate sufficiently to cause the rate of rise of commutating current (the shifting current flow from the commutating contacts to the resistor) to be greater than the rate of rise of the current to be interrupted.

Accordingly, a primary object of this invention is to provide a novel current limiting circuit breaker structure having improved interruption characteristics.

Yet another object of this invention is to provide a novel current limiting circuit breaker in which the rate of rise of commutating current forced through a positive temperature coefficient resistor is greater than the rate of rise of the fault current.

These and other objects of this invention will become apparent from the following description when taken in connection with the drawings, in which:

FIGURE 1 is a schematic view partially in cross-section of a synchronous circuit breaker constructed in accordance with the invention.

FIGURE 2a illustrates the various currents within the circuit of FIGURE 1 as a function of time.

FIGURE 2b illustrates the discharge current in the electromagnetic drive coil as a function of time, and further illustrates the velocity of the movable contact as a function of time in dotted lines.

FIGURE 3 is a cross-sectional view of a detail of one type of arcing chamber that could be used for the commutating contact.

FIGURE 4 is similar to FIGURE 3, and illustrates a second embodiment of an arcing contact structure.

FIGURE 5 is a top view of FIGURE 4.

As previously described, current limiting circuit interrupter devices are well known which limit short circuit current by inserting a resistor having a high positive temperature coefficient into the circuit to be interrupted. Resistors of chemically pure iron or tungsten are satisfactory for this purpose. Thus, when using iron for the resistor construction, the resistance value from a cold resistance value to a hot value of about 850° C. can change ten-fold.

The current limiting effect on the current to be interrupted will be proportional to the initial cold resistance of the resistor being inserted in the circuit. Thus, the higher the initial or cold resistance of this resistor, the higher will be its resistance in the hot condition. Residual current will then be correspondingly small and easier to interrupt after the resistor has reduced or limited the fault current value.

In accordance with the present invention, a novel arrangement is provided in which the main contact and its parallel connected positive temperature coefficient resistor are additionally connected in parallel with a pair of commutation contacts. The main contacts and commutation contacts are mechanically connected to one another in such a manner that when the circuit is opened, the main contacts will initially open, and after approximately 1 mm. of motion of the main contacts, the commutation or arcing contacts will begin to open and draw an arc. This delayed opening is sufficiently short that the voltage drop initially appearing across the commutation contacts is preferably less than 15 volts.

These components are further interrelated with one another so that the voltage across the arcing contacts will increase such that the current commutated through the resistor will increase at a rate of rise which is approximately twice the rate of rise of the current which is to be interrupted.

By using this novel structure which operates in the manner described above, it has been found that there will be substantially no burning of the main contacts during

operation, even through these main contacts are not equipped with any type of arc interruption equipment. Moreover, this novel arrangement permits the use of positive temperature coefficient resistors having cold resistances greater than cold resistances used in the prior art, where these initial relatively high resistance resistors can be connected in the circuit even though the short circuit current is rapidly rising. As pointed out previously, the use of a resistor having a somewhat higher initial resistance permits the use of a substantially higher hot temperature and thus improved current limiting operation when the resistance reaches its hot values.

Referring to FIGURE 1, there is illustrated a current limiting circuit interrupter constructed in accordance with the invention which includes main conductors 1 and 1a, the ends of which define depressed contact sections which receive a bridging contact 2 which has a trapezoidal shape. Contact 2 is carried in U-shaped insulation members 3a and 3b, and is suitably secured in their back-to-back connected walls.

The U-shaped insulation members 3a and 3b further carry a bridging conductor 4 which is resiliently connected to members 3a and 3b by means of an elastic insert 4a which could be of rubber and is interposed between the bottom of bridging conductor 4 and the top of the opening in members 3a and 3b through which member 4 is inserted.

The bridging conductor 4 then carries movable arcing contacts 5 and 6 at its respective opposite ends which each are received in surrounding insulation chambers 7 and 8, the walls of which are made of gas generating insulating material and whose lower lower ends receive the fixed contacts 9 and 10, respectively, which cooperate with contacts 5 and 6, respectively.

Chambers 7 and 8, as mentioned above, can be made of any desired gas generating material well known in the circuit interrupter field for generating gas responsive to the existence of an arc, which gas will be used in increasing the voltage drop across the arc and to cool the arc. Typical materials for this purpose would be any of the usual fibers, hard rubber, sulphur and boron compounds, and the like.

The fixed contacts 9 and 10 are then directly secured to the main current conductors 1 and 1a by suitable bolt means.

The operating mechanism for moving contact 2 and bridging contact 4 includes an electrodynamic drive system 11 which consists of a fixed coil 12 which cooperates with a metallic disk 13 carried on the bottom of U-shaped panels 3a and 3b.

In order to latch contact 2 in an open position, a magnetic latching system is provided which includes a magnet 14 having an energizing winding 15 and a movable armature 16 pivoted at the bottom thereof. The armature 16 then cooperates with a movable pin 17 which is movable upwardly through coil 12 along with disk 13. A biasing spring 18 connected to armature 16 then biases armature 16 to a position underlying pin 17 after contact 2 and the insulation carriers 3a and 3b have moved sufficiently upwardly to the circuit open position.

In order to reclose the circuit interrupter, coil 15 is energized to move armature 16 back to the position illustrated, and suitable biasing springs, schematically illustrated as leaf springs 19 and 20 bearing upon disk 13 will bias the movable structure downwardly to return it to the position shown in FIGURE 1.

A current transformer 21 having an iron core 22 and a secondary winding 23 is then arranged around the main conductor 1. A resistor 24 is connected across the secondary winding 23 in the usual manner with the output current of winding 23 being directly proportional to the primary current I_1 flowing through conductors 1 and 1a when contact 2 is closed. The voltage drop across resistor 24 will also be exactly proportional to this primary current I_1 .

The terminals of resistor 24 are then connected to the cathode 25 and firing electrode 26 of the three-electrode spark gap 27. A charged capacitor 28 having a suitable charging circuit, schematically illustrated by block 28a, is then connected in series with fixed driving coil 12 of the electrodynamic drive system and the main electrodes including electrode 25 of the spark gap 27.

A main frame 29 is then provided, as schematically illustrated, which supports the interrupter structure on insulator columns 30 and 31. Note that suitable insulation bushings are provided for bringing connections through frame 29 from the coil 12 and resistor 24. A pure iron resistor 32 is then electrically connected at its opposite ends to conductors 1 and 1a and in parallel with the main contact 2 and with the series connected arcing contacts 5-9 and 6-10.

The operation of the circuit of FIGURE 1 is described as follows with reference to FIGURES 2a and 2b:

It is assumed in FIGURES 2a and 2b that a fault current I_1 initiated at time t_0 flows through conductor 1, contact 2 and conductor 1a. This fault current will have a relatively high rate of rise of current so that the voltage connected between electrodes 25 and 26 of spark gap 27 becomes sufficiently high to fire the spark gap at current value I_1 in FIGURE 2a at time t_1 .

The firing of spark gap 27 permits the discharge of capacitor 28 through coil 12 at time t_1 , as illustrated in FIGURE 2b, whereby the current induced in conductive disk 13 will cause the generation of extremely high repulsion forces between disk 13 and fixed coil 12 to cause the rapid upward acceleration of members 3a and 3b. The initiation of this movement starts at about time t_2 which falls at the peak of current i_2 through coil 12.

FIGURE 2b further illustrates the increasing velocity of members 3a and 3b, and thus contact 2 in the dotted line beginning at time t_2 , when sufficient force has been generated to initiate movement of the movable assemblage.

As soon as the main contact 2 has separated from the ends of conductors 1 and 1a, small arcs will be drawn which have sufficiently high voltage drops to cause the current flowing through contact 2 to commutate through the circuit including contacts 7 and 8. It has been found that the voltage drop between main contact 2 and either of the contacts terminating conductors 1 and 1a may be as high as 15 volts without causing any noticeable burn in the movable main contact 2. Note that since there are two interrupting contacts 5-9 and 6-10, a total of approximately 30 volts may appear between the ends of conductors 1 and 1a, this voltage being divided between the two series connected breakers in parallel with main moving contact 2.

Commutation of current from the main contact 2 to the arcing or commutating contacts will take place only if the product of the current at value I_1 of FIGURE 2a at time t_2 multiplied by the resistance of the closed contact branch including contacts 5-9 and 6-10 is less than 30 volts.

It has also been determined that the arc voltage will be less than 30 volts (less than 15 volts per break) when the arcs for movable contact 2 to the ends of conductors 1 and 1a have a length less than 1 mm. or less, depending upon the inductance in the commutating circuit.

Shortly after the time t_2 of FIGURE 2a, the commutating process in the commutating chambers 7 and 8 begins. That is to say the contact bridge 4 and its movable contacts 5 and 6 are delayed in their movement until contact 2 has opened by some distance less than 1 mm. (corresponding to a less than 30 volt drop) by virtue of the flexibility of cushion 4a working against the mechanical inertia of the mass of contact bridge 4 and its contacts 5 and 6.

Prior to the 1 mm. movement of contact 2, however, contacts 5 and 6 begin to separate from their respective stationary contacts 9 and 10, whereupon arcs are drawn between contacts 5-9 and 6-10.

5

The arcs produced within chambers 7 and 8 then cause the generation of gas from the insulation material containing the arcs, thereby to generate a relatively high gas pressure within these chambers, which gas pressure is vented through small openings 7a and 8a, respectively.

The generation of gas pressure in the arc chambers 7 and 8 substantially increases the arc resistance, and will cause a high field strength in the arc from 300 to 1,000 volts per centimeter and greater. This high voltage drop across the arcs will cause current flowing through the arcing contact circuit to commute through the high positive temperature coefficient resistor 32 which has an initial relatively low cold ohmic value.

The commutation current flowing through resistor 32 is illustrated as current i_3 in FIGURES 1 and 2a. At time t_3 , the commutation of current for the arcing contacts 5-9 and 6-10 has been completed, and the current has reached the value I_1^* with the full current now flowing through resistor 32. The heat generated in resistor 32 due to this current flow will cause its resistance to increase in the normal fashion, thereby exerting a substantial limiting action on the current flow therethrough so that the limited current can now be easily interrupted by some series connected interrupter (not shown) which need only interrupt the small residual current still flowing at time t_4 in FIGURE 2.

In accordance with an important feature of the invention, the rate of rise of increase of current I_3 is preferably greater than the product of the inverse value of the cold resistance of resistor 32 times the rate of rise of the arc voltage across the series connected arcing contacts 5-9 and 6-10. That is to say:

$$\frac{di_3}{dt} \approx \frac{1}{r} \frac{dU_B}{dt}$$

where:

U_B is the sum of the arc voltages of contacts 5-9 and 6-10, and

r is the cold resistance of resistor 32.

Moreover, it is desirable that the rate of rise of current i_3 should be at least twice the rate of rise of the current i_1 which is the current to be interrupted.

In particular, from FIGURE 2a it will be clear that commutation will take place in the circuit of FIGURE 1 only if the current i_3 increases faster than the current i_1 . Thus, the following relation must be fulfilled:

$$\frac{1}{r} \frac{dU_B}{dt} > \frac{di_1}{dt}$$

From the above, it will be clear that a steeply rising arc voltage must be created in the commutating contacts 5-9 and 6-10. This increasing arc voltage is necessary to produce any commutation at all, while the commutation time t_3-t_2 can be made shorter as the rate of rise of commutating current I_3 is increased.

The novel circuit of FIGURE 1 provides means for fulfilling the above noted critical relationships.

The circuit of FIGURE 1 can be used in either A-C or D-C circuits. It is apparent that when used in an A-C circuit, current transformer 21 will act in the manner of a shunt in the main circuit and will develop an output current which is directly related to the instantaneous value of the primary current I_1 . When the system is used for the protection of D-C circuits, it will be apparent that the current transformer 21 should be replaced by any suitable shunt arrangement or magnetic amplifier type of current measuring system for suitably firing tube 27.

While FIGURE 1 illustrates a typical commutation chamber which could be used (chambers 7 and 8), other types of commutation chambers can be used which will produce a rapid increase in the arc voltage drawn between the contacts contained within the chamber.

FIGURE 3 illustrates one such arrangement in detail wherein member 41 is a chamber of suitable insulation

6

material characterized in gasing under the effect of an arc. A fixed pin 42 of a similar gas-emitting material is then secured to conductive stationary contact 44 by a suitable bolt 43. A tubular movable contact 45 which is connected at its upper end to one end of the current bridge 46 (equivalent to bridge 4 of FIGURE 1) is then movable into chamber 41 coaxially with insulation pin 42. A suitable sealing ring 47 is contained within chamber 41 to form a seal about the exterior of movable contact cylinder 45.

A vent 48 is then formed in chamber 41 through which arc products and gases may escape during the interruption operation of the arc drawn between movable contact 45 and stationary contact 44.

Chamber 41 is then mechanically and electrically connected to the end 50 of one of the main current conductors such as conductor 1 of FIGURE 1 by means of a flexible leaf spring 49 which is fixed to member 50 by the screw 51. Note that the right-hand end of spring 49 is free to flex to the right and left.

This arrangement then permits means for obtaining a good pressure connection between the end of tubular contact 45 and the conical depression in contact 44. As previously pointed out, the contact bridge and movable contact 45 will be moved upwardly at high velocity on the occurrence of a fault current which is to be interrupted.

In order to obtain fast commutation of current, it is important that only a very small contact overlap be present (contacts 45 and 44 should remain engaged only for a very short time after the disengagement of main contact 2 of FIGURE 1). This desired effect is obtained by the flexible spacer 4a in FIGURE 1. Note that the flexibility in the support in FIGURE 3 by virtue of leaf spring 49 will have substantially no effect on this timing, since the upward acceleration of the assembly of FIGURE 3 by the compressed spring 49 will be very small compared to the acceleration of contact 45. Thus, interruption will take place immediately, with the inertia of the chamber 41 permitting the immediate withdrawal of contact 45 from the stationary contact 44.

After this initial separation, an arc will strike which burns in the narrow ring-shaped gap between insulation load 42 and chamber 41. Both of these insulation bodies produce gas which can only escape through the narrow opening 48, whereupon a substantial pressure is built up within the ring-shaped gap which can reach values as high as 1,000 atmospheres. In addition to this, there will be an axial flow of gas which further increases the voltage of the arc extending from contact 45 to contact 44.

With arrangements of this kind, it was found possible to reach voltage gradients in the arc of up to 1200 volts per centimeter using a slightly moistened fiber and somewhat lower voltages using other insulation materials in the arc chamber.

The maximum movement of bridge 46 depends to a large extent on the voltage rating of the switch. Thus, for lower voltage ratings which are up to 1,000 volts, it has been found simpler to let the tubular contact 45 stay within chamber 41 in the circuit breaker open position, while at higher voltage ratings, it is advantageous to move contact 45 out of chamber 41 to produce a creepage-free separation distance between chamber 41 and rod 45.

FIGURES 4 and 5 show a further example of a commutation chamber which will cause a rapidly increasing arc voltage by virtue of lengthening the arc path rather than by the generation of high gas pressures.

Referring now to FIGURES 4 and 5, the switching chamber 61 is formed of an insulation material characterized in generating gas under the effect of an arc. One side of chamber 61 is provided with slots 62 which flare outwardly, as best shown in FIGURE 5, which is a cross-sectional view of FIGURE 4 taken across the line 5-5 in FIGURE 4.

The fixed contact 65 then has a rod-shaped extension 66 which is in sliding current connection with member 67

which is equivalent to member 50 of FIGURE 3. The switching chamber 61 is held in position by a suitable compression spring 68 and washer 69 which is fixed to the end of extension 66. The sliding contact between member 67 and contact 65 is obtained by the spring contact 70 which is suitably secured at one end to member 67 and is biased into sliding engagement with extension 66. The main movable contact 63 which is equivalent to contact 45 of FIGURE 3 and contacts 5 and 6 of FIGURE 1 then enters an opening in the top of chamber 61 which is sealed by a suitable gasket 64.

When the circuit breaker is closed, contact 63 enters the conical depression in stationary contact 65 with spring 68 providing the desired contact pressure. During interruption operation, the contact 63 moves toward the position shown in FIGURE 4, whereupon an arc is generated, as shown by the sinuous line 71 extending from the bottom of contact 63 to stationary contact 65. This arc will cause the generation of gases within chamber 61, which gases will tend to blow the arc out through the ports defined by slots 62, thereby to increase the length of the arc 71 and to increase the arc voltage. Note that a small diameter contact rod 63 is desirable, since the use of a smaller diameter for rod 63 permits the generation of higher arc voltages. In particular, a diameter of 5 mm. has been used for rod 63 to cause voltage gradients of up to 500 volts per centimeter in an arrangement of the type shown in FIGURES 4 and 5.

Although this invention has been described with respect to its preferred embodiments, it should be understood that many variations and modifications will now be obvious to those skilled in the art, and it is preferred, therefore, that the scope of the invention be limited not by the specific disclosure herein, but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. A current limiting circuit breaker comprising a main stationary contact, a main movable contact movable between an engaged and disengaged position with respect to said main stationary contact; a pair of commutating contacts connected in parallel with said main movable and stationary contacts; a positive temperature coefficient resistor connected in parallel with said pair of commutating contacts; an energizable operating mechanism means connected to said main movable contact and said commutating contacts; and interrupter structure means enclosing said pair of commutating contacts for rapidly increasing the

field strength of arcs drawn between said commutating contacts; said operating mechanism means sequentially moving said main movable contact to its said disengaged position and thereafter opening said pair of commutating contacts responsive to energization of said operating mechanism means; said operating mechanism initiating opening of said commutating contacts before said main stationary contact moves 1 millimeter from said main movable contact; said interrupter structure increasing the arc voltage between said commutating contacts at a sufficient rate to cause an initial rate of rise of current through said resistor to be at least twice the rate of rise of current flowing into said current limiting circuit breaker.

2. The device as set forth in claim 1 which includes a lost motion mechanism connected between said operating mechanism means and said pair of commutating contacts.

3. The device as set forth in claim 1 wherein said interrupter chamber includes a housing of insulation material characterized in gasing responsive to an arc; said housing having a port therethrough for relieving gas pressure in the interior of said chamber which is sufficiently small to permit pressure generation within said housing of at least 200 atmospheres.

4. The device as set forth in claim 1 wherein said interrupter chamber includes a plurality of arc plates of insulation material characterized in gasing responsive to an arc; said arc plates spaced from one another and defining spaced outwardly diverging ports; said commutating contacts drawing an arc perpendicular to said plates and along one aligned edge thereof whereby gas pressure generated by said arc stretches said arc over a tortuous path defined by said spaced plates.

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U.S. Cl. X.R.

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