April 16, 1968 F. KESSELRING 3,378,727

CIRCUIT BREAKER FOR INTERRUPTING AT ZERO CURRENT AND AUTOMATICALLY RECLOSING AFTER UNSUCCESSFUL INTERRUPTION

Filed May 14, 1965

FIG. 1.

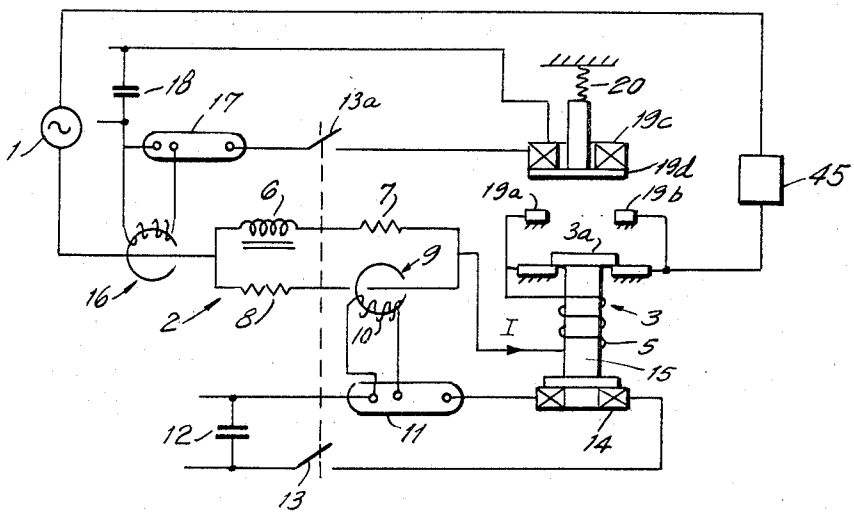


FIG. 3.

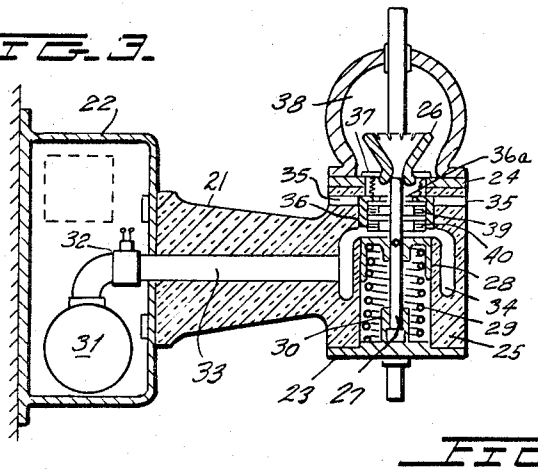


FIG. 2.

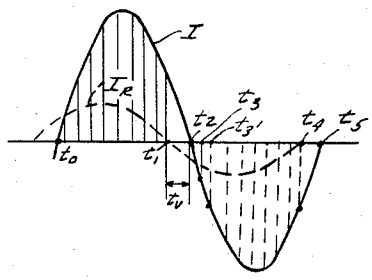


FIG. 1a.

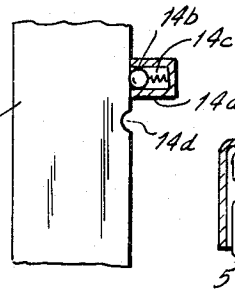


FIG. 5.

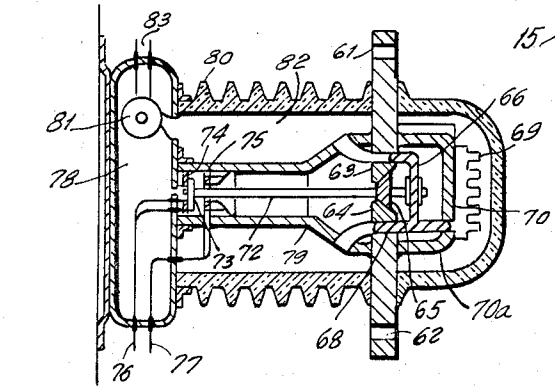
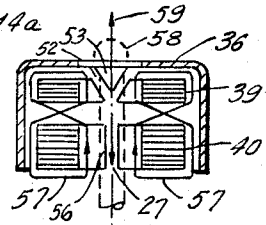


FIG. 4.



INVENTOR.
FRITZ KESSELRING

BY
OSTROLENK, FABER, GERB & SOFFEN

ATTORNEYS

United States Patent Office

3,378,727

Patented Apr. 16, 1968

3,378,727

CIRCUIT BREAKER FOR INTERRUPTING AT ZERO CURRENT AND AUTOMATICALLY RECLOSING AFTER UNSUCCESSFUL INTERRUPTION

Fritz Kesselring, Kusnacht, Zurich, Switzerland, assignor to Siemens Aktiengesellschaft, Munich, Germany, a corporation of Germany

Continuation-in-part of application Ser. No. 27,437, May 6, 1960. This application May 14, 1965, Ser. No. 455,824

3 Claims. (Cl. 317—11)

ABSTRACT OF THE DISCLOSURE

A circuit breaker having a movable contact which is connected to an operating mechanism operated by two separate current sensing structures. The first current sensing structure operates to move the operating mechanism immediately prior to zero current through the contacts in order to open the contacts at substantially zero current. The second current sensing means is responsive to continued current through the contacts after current zero, which indicates a failure for the contacts to interrupt the current, and immediately closes the contacts before the current can rise to substantial values. The operating mechanism may be electrical in nature or pneumatic in nature. The first current sensing means includes a phase shift means which causes a leading relation of the output signal of the current sensing means in relation to the current being measured to permit generation of an output operating signal just prior to current zero.

This application is a continuation-in-part of my copending application Ser. No. 27,437, filed May 6, 1960, now abandoned.

This application relates to a high speed circuit breaker wherein contact disengagement occurs at high speed at a substantially current zero point and is automatically drawn between the disengaged contacts, whereby the circuit breaker disengaging operation is initiated at the next current zero point.

During operation of circuit breakers under high power, circuits of either high or low voltage magnitude are exposed to copious arcing during contact disengagement. In order to properly open the circuit being protected by the circuit breaker, it has, therefore, been necessary to somehow handle the substantial energy in the arc drawn between the disengaging contacts. For example, large air circuit breakers wherein the contacts separate in air are provided with arc chutes and magnetic systems wherein the arc drawn between contacts is moved through a magnetic field which drives the arc into the arc chute where the arc is squeezed and cooled as by notched ceramic arc plates so that the arc may be extinguished. In other applications the arc is exposed to rapidly moving fluid such as compressed air or mixtures of steam and gas which are produced from a liquid dielectric, whereby the arc is blasted through restricted vents in an arc interrupting chamber or ionized arc products are rapidly removed in an attempt to control and subsequently extinguish the arc.

In other applications, the circuit breaker contacts are contained within a vacuum whereby an initial striking of the arc causes metal vapor, and the arc continues to burn in the metal vapor after the contacts are disengaged so that means must be provided again to control the arc.

The seat of the problem or arcing lies in the fact that the circuit breaker contacts are opened or disengaged at an arbitrary point within the current cycle of the current flowing through the contacts. Therefore, an arc is necessarily drawn when the contacts are opened since a substantial current flows through these contacts in a relatively high power circuit.

It has been found that if the contacts can be opened when the current goes through a zero instantaneous value that an arc will not initially be drawn. Preferably, the contacts should be separated immediately prior to the instantaneous zero value so that if a small arc is drawn, this arc will be extinguished when the zero current value is reached.

This concept, however, has never achieved widespread commercial use with the exception of a few isolated applications since there is always the possibility that when the current passes through zero, the arc will restrike and "hang on" in the next half cycle.

Clearly, if this were to happen in a circuit breaker which is not equipped with devices for controlling an arc, it could destroy the equipment during this next half cycle. Furthermore, the arcing during the half cycle will almost certainly continue even after subsequent zero current values.

The essence of the present invention is to provide a circuit interrupting device of the type which operates initially immediately prior to current zero and is equipped with auxiliary means for measuring or sensing contact current after the contact operation at zero current so that if, after zero current and contact disengagement a current is measured (which would necessarily be an arc current), the circuit breaker is immediately reclosed and is not operated to a disengaged position until a subsequent current zero in the circuit being protected.

By immediately reclosing the circuit breaker contacts after it is found that complete circuit interruption has not occurred at a particular current zero point, the contacts will reclose on a relatively small current and thus are not subjected to substantial closing duty.

With this novel concept I have overcome the heretofore existing danger which has limited the use of current zero interrupting equipment which is that an arc may continue to exist between the cooperating contacts throughout the next half cycle and probably continuously thereafter until back-up equipment is operated. That is to say, in the present invention, when it is found that proper current interruption has not occurred at a current zero, the contacts will reclose until the next current zero at which point it again attempts to interrupt. If the interruption at the next current zero again fails, the circuit again will be reclosed and will continue to operate until at a particular current zero successful current interruption without arcing is achieved.

The concept of the present invention can be applied to many different types of high speed interrupters, such as the electrodynamic type of interrupter shown in copending applications Ser. No. 5,066, filed Jan. 27, 1960, now U.S. Patent 3,128,361, and Ser. No. 5,069, filed Jan. 27, 1960, now abandoned, as well as in pneumatically operated circuit breakers. In each there will be a pair of cooperating contacts which are operatively connected to an operating means which becomes operable only immediately prior to a current zero value after a mechanical or automatic initiation of operation of the contacts. That is to say, once a signal is delivered to the mechanism for causing the circuit breaker to disengage, the operating means will delay contact separation until immediately prior to a current zero value. When the current through the circuit breaker contacts reaches a low value and is about to go through zero, the circuit breaker contacts are disengaged. A second auxiliary means then comes into play which will operate responsive to current flow through the contacts after the current zero is passed. If there is no current (so that the circuit was successfully interrupted), there will be no further operation. If, however, a current is measured (indicating arcing at the contacts),

the circuit breaker contacts will be immediately reclosed before the current can rise to a substantial value.

As will be seen more fully hereinafter, the means for operating the circuit breaker prior to current zero can comprise a phase shift network for delivering operating current to the contacts wherein the operating current is phase shifted to lead the circuit current by a predetermined amount. When this leading current reaches a predetermined value, it will inherently contain information as to how much later the main current will pass through zero so that accurate control of disengagement of the contacts a predetermined time before current zero can be achieved.

The reclosing of the circuit after a successful interruption can be controlled either by auxiliary contact means whose operating mechanism is activated upon the generation of an opening signal to the circuit breaker or can be controlled by magnetically influencing the position of a valve in a pneumatically operated circuit breaker. In each of these it will be seen that the control system will be influenced by the current which is to be interrupted so that an initial opening operation occurs prior to current zero and a reclosing operation occurs immediately after current zero in the event that there is an unsuccessful interruption.

Accordingly, a primary object of this invention is to provide a novel high power synchronous circuit breaker.

Another object of this invention is to provide a novel circuit breaker which does not require complex arc extinguishing structure.

A further object of this invention is to provide a novel circuit breaker in which the contacts disengage at a current zero value.

A still further object of this invention is to provide a novel synchronous circuit breaker wherein contact interruption occurs at current zero, and if an arc is drawn during contact disengagement, the contacts are immediately reclosed.

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

FIGURE 1 shows a first embodiment of the invention using a dual electrodynamic type circuit interrupter mechanism.

FIGURE 1*a* shows a detail view of a detent latch used to hold the main contact of FIGURE 1 open.

FIGURE 2 shows current through the circuit breaker contacts of FIGURE 1 as a function of time.

FIGURE 3 illustrates an embodiment of the invention wherein the contacts are pneumatically operated.

FIGURE 4 shows the magnetic control system for pressure control in the embodiment of FIGURE 3.

FIGURE 5 shows a further embodiment of the invention wherein the operating mechanism is a combination of a pneumatic means and an electrodynamic driving means.

Referring now to the drawings and particularly to FIGURE 1, the novel circuit interrupter is operable in a typical circuit to be protected which includes a generator or voltage source **1** which is to supply energy to a load **4** through a measuring circuit **2**, which will be described more fully hereinafter, and a circuit interrupter **3** which includes a movable contact **3***a* which is movable between an engaged and a disengaged position with respect to a relatively stationary contact.

In normal operation, circuit breaker contact **3***a* is held in a closed position by the magnetic field generated in winding **5** which carries the full load current I. That is to say, contact **3***a* may include magnetic material which is responsive to the magnetic field generated by winding **5**. The measuring circuit **2** is provided with a first and second parallel path wherein the upper path includes an inductor **6** and resistor **7**, while the lower path comprises a resistance **8** and a small saturable type reactor **9** which has a primary winding connected in series with resistor **8**. The secondary winding **10** of the reactor is connected in the grid-cathode circuit of a cold cathode tube **11**. The plate cathode circuit of tube **11** is connected in series with a capacitor **12** which is maintained charged to some predetermined D-C voltage by charging means (not shown), a trip switch **13** and the primary winding of an electrodynamic driving coil **14**. Coil **14** is closely coupled to a disc-shaped secondary winding carried by insulating trip rod **15** which is operatively connected to contact **3***a* of the circuit breaker **3**.

This type of electrodynamic operating mechanism of circuit breakers is fully set forth in copending application Ser. No. 5,066, filed Jan. 27, 1960, now U.S. Patent 3,128,361. The operation of such a system is clear to those skilled in the art whereby a rapid rate of change of current forced through coil **14** will induce a substantial current in the disc of conductive material carried by rod **15** and coupled to coil **14** so that an extremely high repelling force will occur between the coupled disc and coil **14** to cause an upward acceleration of the disc, the insulating rod **15** and the contact **3***a*. Any suitable means could be provided to hold the contact **3***a* in its open position against small forces such as those due to gravity. By way of example, FIGURE 1*a* illustrates a ball detent type latch including a housing **14***a* which is fixed with respect to shaft **15**. Housing **14***a* carries a ball **14***b* biased by spring **14***c* which biases ball toward shaft **15**. When contact **3***a* moves to its full open position, detent **14***d* moves under ball **14***b* and the ball seats in detent **14***b* to prevent reclosing of contact **3***a* until a sufficient magnetic field builds up in coil **5** as will be described later. Note that any desired latching type system could be used which is relatively easily released.

A second saturable type reactor **16** has a primary winding which carries the main current I and a secondary winding which is connected to the grid-cathode circuit of cold cathode tube **17**. The plate-cathode circuit of tube **17** is connected in series with a capacitor **18** which may be charged to a predetermined D-C potential by a D-C source (not shown), a tripping switch **13***a* which is ganged to trip switch **13**, and the primary winding of the electrodynamic drive system **19** which has a disc-shaped secondary winding which is movable into bridging engagement with contacts **19***a* and **19***b* against the biasing force of spring **20** which normally extends through the center of primary winding **19***c* and is connected to the movable disc **19***d*.

The operation of the circuit of FIGURE 1 is best understood by reference to FIGURE 2 which shows the main current I plotted against time in solid lines and the current I_r through resistor **8** as a current which leads current I in dotted lines. In order to cause manual circuit interruption, the ganged switches **13** and **13***a* are closed to thereby connect the capacitors **12** and **18** directly in series with tubes **11** and **17**, respectively. The current I_r leads the current I by a time t_v as shown in FIGURE 2 which, for example, may be 1 millisecond. Therefore, at time t_1 and prior to the time that the current I passes through current zero, the flux of saturable type reactor **9** reverses so that a voltage pulse is applied to the grid-cathode circuit of tube **11**. This causes the tube to fire so that capacitor **12** can discharge through winding **5**.

Accordingly, at time t_1, contact **3***a* will be rapidly moved to its disengaged position and held there by ball **14***b* under relatively low current conditions which very rapidly decrease to zero with the generation of little arcing, if any. Assuming, however, that after current zero at time t_2 is passed an arc restrikes, when the current I will continue after current zero. Therefore, the flux of reactor **16** will reverse to generate a voltage pulse in the grid-cathode circuit of tube **17** to fire the tube and thus energize winding **19***c* from charged capacitor **18**. This will cause the ring-shaped winding **19***d* to rapidly move downward and into engagement with

contacts 19*a* and 19*b* against the force of spring 20, this happening at time t_3.

This action, in effect, causes a reclosing of the circuit breaker at time t_3 when the make current is still relatively low. As the current increases and reaches a value of, for example, the value at time t'_3, the current through winding 5 will be large enough to generate a strong enough magnetic field to overcome latch 14*b* and reclose contact 3*a* and relieve the relatively small contacts 19*a*, 19*b* and 19*d* from the current carrying duty. After time t'_3 the energy of capacitor 18 will be decreased to a value small enough to permit spring 20 to move contact 19*d* upwardly to its reset position so that the entire system is now ready for a new synchronous disconnection beginning at time t_4 of FIGURE 2 for an attempted arc extinction at current zero at time t_5.

Note that the circuits used in charging capacitors 12 and 18 is such that they will be sufficiently recharged in the time interval t_1 to t_4. If desired, an auxiliary capacitor circuit can be substituted for the original capacitors for the second interruption attempt.

From the foregoing it is seen that an arc can only occur in the relatively short time interval t_1 through t_3 which is approximately equal to 1 millisecond at a relatively small instantaneous current value. Furthermore, the reclosing at time t_3 takes place under very favorable conditions since the current I is still very small. Since a reclosing occurs, in the event that the attempted interruption is not successful, it will be apparent that the circuit eliminates the heretofore required arc extinguishing devices since a substantial arc will never remain on the contacts.

FIGURE 1 illustrates the invention for the case of a combined switch 3 which is magnetically closed and is opened under the influence of electrodynamic forces wherein the contacts remain open when the magnetic closing force does not reappear or the circuit is successfully interrupted. An auxiliary reclosing means is provided in the pure electrodynamic interrupter 19.

The principle of the invention which is to open the circuit breaker immediately prior to current zero and to thereafter sense the flow of current after current zero indicating the presence of arcing and then reclosing the interrupter may be carried out by other combinations of presently available electrical equipment as well as by new types of equipment specifically designed for this purpose.

In particular, two current responsive means or systems are provided where the first, including measuring circuit 2, applies an output energy to the energizable operating means portions 14–15, while the second, including reactor 16 and tube 17, applies an output energy to the energizable operating means 19*c*–19*d*. Note that the first current responsive system operates just prior to current zero, while the second current responsive means operates just following a current zero. Moreover, each of the current responsive means are normally deactivated by switches 13 and 13*a*, and are activated only when these switches are closed.

A further embodiment of the invention utilizing these basic novel principles is shown in FIGURES 3 and 4 wherein the interrupter is essentially of the pneumatically operated type with a novel magnetic control system for achieving the objects of the invention.

Referring to FIGURE 3, a hollow support insulator 21 is fastened to a casing 22 which is carried from some relatively stationary support structure. Insulator 21 is formed of a general T shape and has connection plates 23 and 24 at each respective end of the cross of the T defined by cylinder 25. A movable contact rod 27 is carried by piston 28 which is movable within cylinder 25 to move contact rod 27 between engaged and disengaged positions with respect to the stationary contact formed by nozzle 26 connected to plate 24. Contact rod 27 is biased upwardly and into engagement with nozzle 26 by spring 29 which is carried within cylinder 25 and bears against the lower surface of piston 28. When the movable contact 27 is engaged in the position shown in FIGURE 3, a relatively gas tight connection is formed at the nozzle.

A sliding contact means 30 which can be formed of a plurality of biased contact spring fingers is formed between contact rod 27 and plate 23 so that the contact rod is always electrically connected to plate 23.

A source of operating pressure such as high pressure air is contained in cylinder 31 and is connectable through the electromagnetically controlled air valve 32, which may be of any standard type, to the central openings 33 of insulator 21 and 34 of cylinder 25. This pressure may be vented from areas 33 and 34 in a controlled manner through vents 35 which are closed by the distributing slide valve 36.

The slide valve 36 and its controlling structure are shown in FIGURE 4 in an enlarged view for purposes of clarity, and it is seen that slide valve 36 is formed of a cup-shaped member having a central opening 36*a* for permitting the passage of contact rod 27. The valve member 36 is normally held in the blocking position shown in FIGURE 3 by springs 37*a* which are distributed around the surface of valve 36. When the valve moves downwardly, it will cover the upper area of piston 28 to prevent connection of high pressure air thereto and also permits communication of any internal high pressure to the external low pressure through vents 35. The control system for adjusting the position of valve 36 includes a magnetic control system including members 39 and 40 which will be described more fully hereinafter.

In order to operate the interrupter of FIGURE 3, the valve 32 is operated either manually or in response to signals generated by a fault in the line being protected by the interrupter. This will permit compressed air to flow into areas 33 and 34 and drive piston 28 downwardly in its supporting cylinder. Piston 28 will move downwardly against the biasingforced of spring 29 until the end of contact rod 27 reaches the bottom of connection plate 23. At this moment the distance most favorable for interruption is reached between the opening of nozzle 26 and the top of the movable contact rod. The compressed air within openings 33 and 34 will, when the rod 27 moves downwardly, pass through the opening in the nozzle 26 and into a relatively low pressure area 38 which can be connected to external pressure by valve means (not shown).

Under normal current conditions, the air blast passing nozzle 26 should be sufficient to extinguish a small arc. In the event of heavy short circuit current, however, it is desired that the unit be reclosed and opened only at the next current zero. This operation is achieved through the control of slide valve 36 which under heavy short circuit current conditions will be moved downwardly by the controlling magnet structures 39 and 40 to cut-off the fluid connection between area 34 and nozzle 26 by causing the bottom rim of valve 36 to completely enclose the top of the cylinder receiving piston 28.

Accordingly, if the arcing current is substantial, the valve 36 will move downwardly and prevent compressed air from acting on piston 28 and thus prevent the opening of the circuit breaker. When, however, the current drops from a high instantaneous value to a substantially zero value, the controlling system including magnetic structures 39 and 40 together with biasing springs 37 will permit slide valve 36 to move upwardly to thereby expose the top of piston 28 to the high pressure in area 34 and thus permit an extremely rapid motion of piston 28 downwardly to disengage contact rod 27 and nozzle 26 under the substantially zero instantaneous current value.

In the event that the fault current is asymmetrical and does not pass through zero after the substantially zero value is achieved prior to zero current passage but rather increases again in the same direction, it will be seen

that the valve 36 will rapidly move downwardly to expose discharge openings or vents 35 to thereby relieve the pressure on the top of piston 28 and permit the rapid reclosing of the contacts under the action of spring 29. Therefore, the circuit breaker will reclose under relatively small instantaneous current values, and the arc problems associated with asymmetric fault currents are avoided. As soon as the current again approaches the zero current value, the distributing slide valve 36 is pulled upwardly by springs 37 so that a synchronous interruption is again started with a correspondingly small circuit breaking load.

The novel magnetic control system for controlling the position of slide valve 36 is best understood from FIGURE 4 which illustrates the first magnetic structure 39 as having a portion of its magnetic circuit including a tapered air gap 52 which cooperates with a wedge-shaped armature 53 which is secured to valve 36. The second magnetic structure 40 is provided with an air gap 56 in its magnetic circuit. Two windings 57 encircle magnetic cores 39 and 40 to carry current in the direction shown by the arrows, whereby cores 39 and 40 are magnetically linked to one another.

In operation, as current through contact rod 26 which operates as a primary winding for each of cores 39 and 40 decreases, electromotive forces are induced in windings 57. The E.M.F. generated by the lower magnetic system associated with core 40 is made to be greater as by controlling the iron cross-sectional area and number of turns so that a current will flow in the direction of the arrows in FIGURE 4. If the resistance of winding 57 is greater than its inductance, the total flux of magnetic core 39 can be controlled to lead the current through contact rod 27. Therefore, armature 53 will be moved downwardly against the biasing force of springs 37 of FIGURE 3 at some predetermined time before the passage of current zero. Thus, the magnetic system of FIGURE 4 operates in the same manner as did the control system of FIGURE 1.

By properly choosing the air gap 52 between magnetic structure 39 and armature 53 and the air gap 56, no detrimental saturation effects occur so that the time lag will always be approximately the same value for different current conditions. This is because at heavier currents, the rate of rise of current will increase in roughly the same manner.

A further embodiment of the invention is set forth in FIGURE 5. The main contacts of FIGURE 5 are shown as contacts 63 and 64 which are electrically connected to terminals 61 and 62, respectively. A movable bridging contact 65 is moved between an engaged and disengaged position with respect to contacts 63 and 64, while a second parallel connected bridge contact 66 is movable between engagement and disengagement with respect to apertures 67 and 68 of contacts 63 and 64, respectively. A parallel resistor 69 has one end connected to contact 63 and its other end connected to bridge 66 by sliding contact 70 in resistor support member 70*a* in the manner described.

Both main movable contact 65 and member 66 are each operated from an electromagnetic drive system as illustrated in copending application Ser. No. 5,066, now U.S. Patent 3,128,361, and are carried by an insulating rod 72 which carries a conductive ring 73 at the left-hand and thereof and is movable between coupling positions with operating windings 74 and 75, respectively. Winding 74 is energizable to move disc 73 and insulated rod 72 to the right for a contact disengaged position, while winding 75 is operable to drive disc 73 and insulating rod 72 to the left to achieve the contact engaged position shown in FIGURE 5.

The operating circuit for winding 74 is connected to the winding from an area external of the interrupter as by taking out its leads 76 through appropriate gasket means. In a like manner, leads 77 are energizable for energizing winding 75. In the embodiment of FIGURE 5 the disc 73 operates both as an inherent part of the electrodynamic drive system as well as a valve member for isolating high pressure chamber 78 and the central portion of insulating housing 79 which is surrounded by a second insulating housing 80. The volume 82 between housings 79 and 80 is maintained at a low pressure by a pump means 81 which also maintains a relatively high pressure in chamber 78. Here again, the electrical energy for operation of pump 81 may be derived from an area external of the interrupter through leads 83.

In operation, when the circuit breaker is in the closed position of FIGURE 5 and it is desired to open the circuit breaker, winding 74 is energized as at time t_1 of FIGURE 2, whereby plate 73 and the insulating rod 72 carried thereby are accelerated to the right to thereby cause high speed disengagement first of bridging contact 65 and then 66. There is no arcing when main contact 65 disengages, since contact 66 is still engaged. At the same time, and after disc 73 has moved away slightly, there will be communication between the high pressure gas within chamber 78 and the interior of chamber 79. With the continued motion of insulating rod 72 to the right and as soon as the upper portion of bridge 66 leaves nozzle 67, a portion of the gas admitted to chamber 79 will flow through nozzle 67 and any arc generated there is quenched at time t_2 of FIGURE 2. This interruption is aided because of the parallel current path provided by resistor 69 which is connected in the circuit when the upper portion of bridge 66 electrically disengages contact 63. From this point a severely limited current flow continues through resistance 69 until the longer lower portion of bridge 66 clears nozzle 68. Once the lower portion of bridge 66 clears nozzle 68 in contact 64, there will be final current interruption at time t_5 of FIGURE 2 with a high pressure gas flow bearing on the nozzle. This relationship between times is controlled by the movement of insulating rod 62 and the relative lengths of the upper and lower extending legs of bridge 66.

In the event that disconnection fails at time t_2 and an arc is drawn between contacts 63, 66 and 64, this failure is sensed as by a suitable sensing circuit such as a reactor 16 of FIGURE 1 (which responds to a high rate of change of current) in the external energizing circuit so that winding 75 is energized to thereby drive disc 73 to the left and reclose the circuit breaker. This reclosing operation again is controlled so that it will occur no later than time t_3 of FIGURE 2.

The device of FIGURE 5 is highly desirable since it can be designed to achieve switching periods of the order of 100 microseconds. Furthermore, the structure is particularly suitable for containing a gas such as sulphur hexafluoride within which contact operation occurs and which gas plays on any arc that may be drawn between contact 65 and stationary contacts 63 and 64 or bridging contact 66 and contacts 63 and 64.

It is to be further noted that while FIGURE 5 in shown as being used with a gaseous medium, it can also be operated in an oil environment where pressure produced by any arc can, through a differential piston system, be used for arc quenching.

Although I have here described preferred embodiments of my novel invention, many variations and modifications will now be apparent to those skilled in the art, and I, therefore, prefer to 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 synchronous circuit breaker for an electrical circuit comprising a pair of contact means connected in series with said electrical circuit and movable between an engaged and disengaged position with respect to one another; an energizable operating means connected to at least one of said pair of contact means for moving said contact means between said engaged and disengaged positions responsive to energization thereof; first and second current responsive means connected in circuit relation with

said electrical circuit; said first current responsive means connected to said energizable operating means whereby generation of output energy from said first current responsive means energizes said energizable operating means to move said one of said contact means from said engaged position to said disengaged position; said second current responsive means connected to said energizable operating means whereby generation of output energy from said second current responsive means energizes said energizable operating means to move said one of said contact means from said disengaged position to said engaged position; said first current responsive means including phase shift means for causing the output of said first current responsive means to lead the current flow in said electrical circuit and generating a high output energy just prior to the passage of current in said electrical circuit through zero, thereby to energize said energizable operating means prior to the passage of zero current through said pair of contact means; said second current responsive means generating output energy responsive to current flow through said circuit immediately after the occurrence of zero current, thereby to close said pair of contact means if current continues to flow after a current zero; said first and second current responsive means being normally deactivated; and means for activating said first and second current responsive means to synchronously operate said pair of contact means.

2. The device as set forth in claim 1 wherein said energizable operating means includes a fixed electrical winding connected to said first current responsive means; said one of said pair of cooperating contact means defining an axially movable short circuited turn disposed adjacent said electrical winding whereby energization of said electrical winding causes axial movement of said short circuited turn from an engaged position with the other of said contact means to a disengaged position.

3. The device as set forth in claim 2 wherein said pair of contact means includes a main movable contact and an auxiliary movable contact; said energizable operating means including first operating means connected to said main movable contact and second operating means connected to said auxiliary movable contact; said second current responsive means connected to said second operating means for moving said auxiliary movable contact into engagement with the other of said pair of contact means responsive to continued current flow immediately following a current zero.

References Cited

UNITED STATES PATENTS

2,196,868	4/1940	Kramer	200—148
2,672,541	3/1954	Paul	200—148
2,849,659	8/1958	Kesselring	317—11
2,898,421	8/1959	Date	335—32 X
2,904,660	9/1959	Forwald	200—148
2,951,188	8/1960	Diebold	317—11 X

FOREIGN PATENTS

422,775	1/1935	Great Britain.
718,985	11/1954	Great Britain.

MILTON O. HIRSHFIELD, *Primary Examiner.*

J. D. TRAMMELL, *Assistant Examiner.*