Nov. 20, 1962 A. L. STREATER 3,065,317

ALTERNATING CURRENT CIRCUIT INTERRUPTER

Filed Sept. 29, 1960 2 Sheets-Sheet 1

Fig. 1.

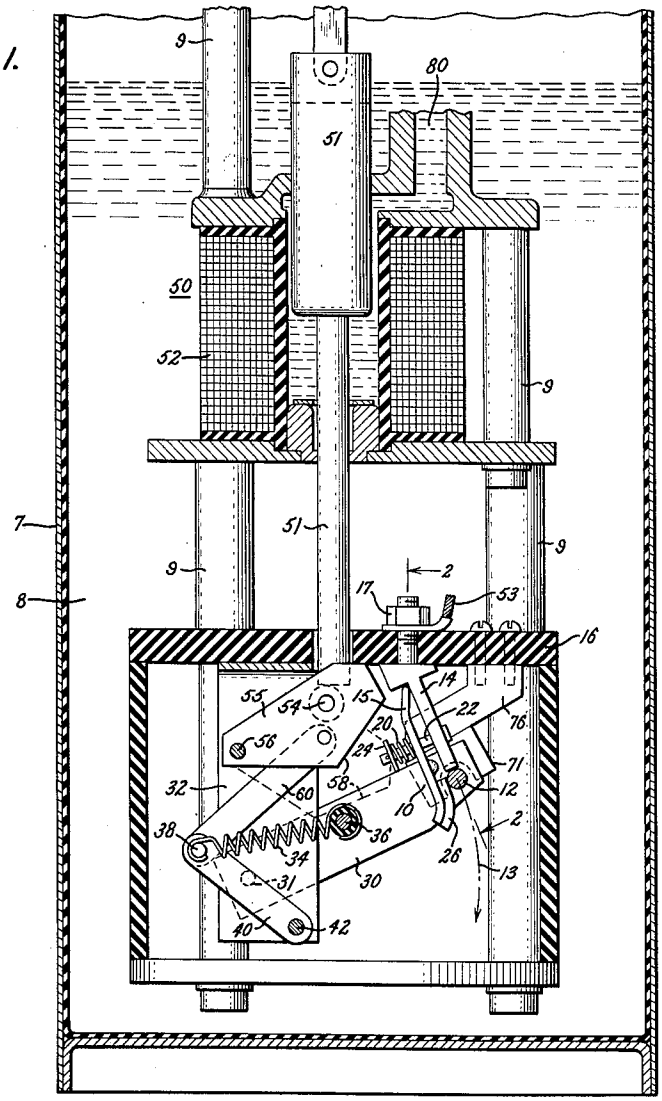
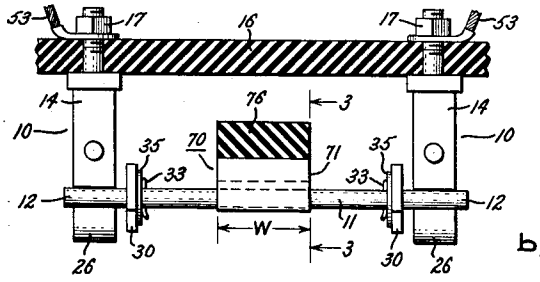


Fig. 2.



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Filed Sept. 29, 1960 2 Sheets-Sheet 2

Fig. 3.

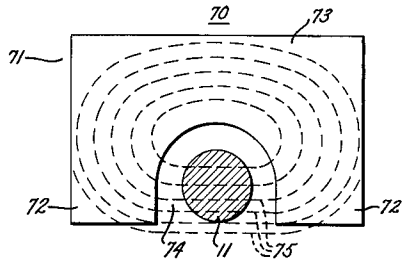


Fig. 4.

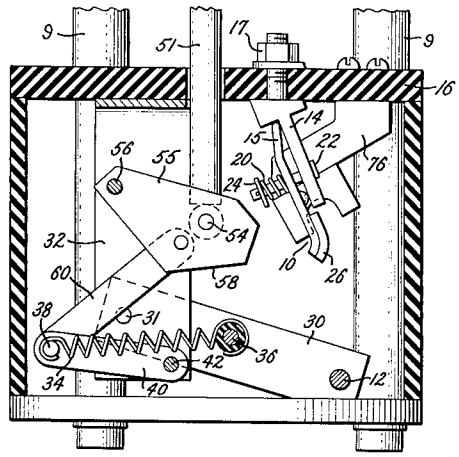


Fig. 6.

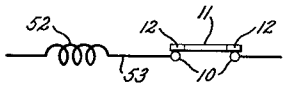
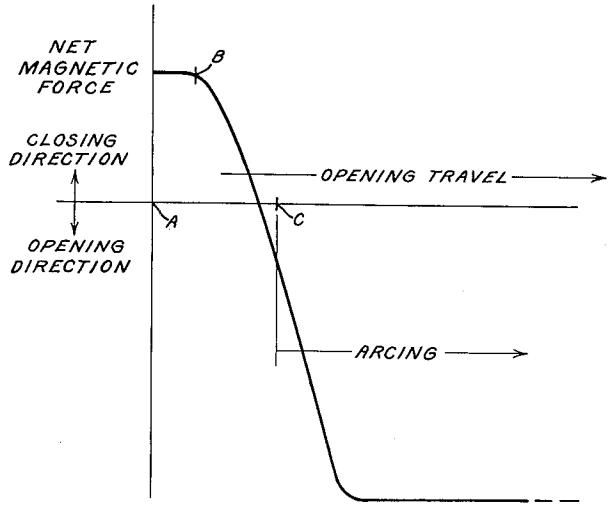


Fig. 5.



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ALTERNATING CURRENT CIRCUIT INTERRUPTER

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9 Claims. (Cl. 200—87)

This invention relates to an alternating current circuit interrupter and, more particularly, to magnetic means for holding the contacts of the interrupter in closed position during the flow of short circuit currents through the interrupter.

In the usual circuit interrupter, the conductive path through the contacts of the interrupter is of a loop-shaped configuration. Current flowing through this loop-shaped path produces magnetic forces tending to lengthen the loop, and these forces are usually in a direction tending to open the contacts of the interrupter. These magnetic opening forces vary in magnitude in accordance with the square of the current flowing through the interrupter, and hence during overcurrent and short circuit current conditions extremely high magnetic opening forces can be developed.

These magnetic opening forces can create some particularly troublesome problems in the type of circuit interrupter where the contacts are maintained in their closed position by a spring. Unless the spring is unduly large, it will be incapable of holding the contacts in their closed position against the magnetic opening forces developed during short circuit current conditions, and the contacts therefore will be forced open against the spring immediately upon the establishment of a short circuit. This can be a serious problem in the type of circuit breaker where it is desired to delay an opening operation until a predetermined time has elapsed after the onset of overcurrent or short circuit currents. For example, in the usual recloser it is necessary, for certain operations, that the contacts be opened only after a predetermined time has elapsed after short circuit currents have been initiated. If the contacts are forced open immediately upon the initiation of a short circuit current, then it will be impossible to provide the desired time delay in opening.

One way of overcoming this problem is to provide a closing spring heavy enough to maintain the contacts closed against the maximum opening forces that will be developed. But this approach is disadvantageous because it requires that the actuator for opening the contacts be unduly large since it must be capable of overcoming the large closing spring to effect contact-opening. In a recloser, it is customary to use a solenoid, series connected with the contacts, as the actuator for opening the contacts. With a solenoid of any reasonable size, it would be virtually impossible at low pick-up currents to develop a large enough opening force to drive the contacts open at high speed against the opposition of a closing spring of the size required to hold the contacts closed against short circuit currents.

Accordingly, an object of my invention is to provide, for an alternating current circuit interrupter, a simple magnetic arrangement that is capable of holding the contacts closed during short-circuit current conditions with little assistance from any closing spring.

Another object is to provide a simple magnetic arrangement capable of holding the contacts closed during short circuit currents and also capable of assisting the closing device in closing the contacts against the high magnetic opposing forces that are abruptly established near the end of a closing stroke when the contacts are closed on a faulted power line.

Another object is to provide a magnetic arrangement that develops during short circuit current conditions a magnetic force exceeding the magnetic loop force tending to open the contacts so that the net magnetic force present acts in a direction to hold the contacts closed.

Another object is to construct the magnetic arrangement in such a manner that this net magnetic force quickly drops to a relatively low value as the contacts are parted during an opening operation so that the moving contact can move toward its open position at the desired high velocity without significant interference from the magnetic arrangement.

In carrying out my invention in one form, I provide an alternating current circuit interrupter that comprises a stationary frame and a first contact mounted on the frame. A second contact is movable along a predetermined path into and out of engagement with said first contact. A rigid conductor electrically connected to the second contact is provided for carrying alternating current to and from the second contact. This rigid conductor is rigidly coupled to the second contact in such a way that the conductor extends transversely to said predetermined path. Fixedly mounted on the stationary frame is a structure of magnetizable material containing a recess into which the conductor is moved upon movement of the second contact into engagement with the first contact. The magnetic circuit for flux generated by current flowing through the conductor while said interrupter is fully closed comprises the magnetizable structure and an air gap in series with the magnetizable structure extending across said recess. The conductor is located within this air gap when the interrupter is fully closed. Due to the tendency of a conductor so located to move into a position where the magnetic circuit will have a minimum reluctance, a magnetic force is developed on the conductor urging it further into the recess, thus tending to hold the contacts engaged.

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 cross-sectional view of a portion of a circuit interrupter embodying one form of my invention. The interrupter is shown in a fully-closed position.

FIG. 2 is a cross-sectional view along the line 2—2 of FIG. 1.

FIG. 3 is a sectional view taken along the lines 3—3 of FIG. 2.

FIG. 4 is a view similar to that of FIG. 1 except showing the parts of the interrupter in their fully-open position.

FIG. 5 is a graphic representation of the manner in which certain magnetic forces vary during an opening operation.

FIG. 6 is a simplified wiring diagram of the circuit interrupter.

Referring now to FIG. 1, the interrupter shown therein comprises a metallic tank 7 filled with a suitable insulating oil 8. A stationary frame 16 of insulating ma-

terial is suspended from a portion of the tank by suitable insulating rods 9.

Mounted on the frame 16 are two stationary contact assemblies 10 disposed in laterally spaced-apart relationship, as best seen in FIG. 2. These stationary contact assemblies 10 are connected together in series-circuit relationship by a conductive cross-bar 11 having terminal portions 12 at its opposite ends constituting the movable contacts of the interrupter. Each of these contacts 12 is movable into and out of engagement with its mating stationary contact assembly 10 along the arcuate path 13 shown in FIG. 1.

As will be apparent from FIGS. 1 and 2, each stationary contact assembly 10 comprises a conductive stud 14 and a contact finger 15 pivotally mounted on the stud 14. The stud extends through a stationary frame 16 of insulating material and is fixedly mounted thereon. Preferably, the mounting comprises a nut 17 threaded onto the upper end of the stud and clamping the frame 16 between the nut and a shoulder provided on the stud. Referring to FIG. 1, the contact finger 15 is pivotally mounted at its upper end on the stud 14 and is biased to the right by a compression spring 20. This compression spring 20 is preferably carried by a guide pin 22 extending freely through a suitable opening in the finger contact 15. The compression spring 20 is disposed between a stop 24 on the pin 22 and the movable contact 15. The lower end of the contact 15 is preferably provided with a facing 26 of arc-resistant material which bears against the movable contact 12 during the early stages of opening movement and the final stages of closing movement.

The conductive cross-bar 11 and the movable contacts 12 at the ends of the cross-bar 11 are carried by laterally-spaced actuating arms 30 of insulating material. As shown in FIG. 1, these arms 30 are pivotally mounted at their left hand end on stationary pivots 31 that are carried on a supporting bracket 32 fixed to the stationary frame 16. The arms 30 are coupled together by a pin 36 that extends between the arms and is fixed to each arm to maintain a fixed lateral spacing between the arms 30. The movable contacts 12 are prevented from shifting laterally with respect to the actuating arms by suitable cotter pins 33 and washers 35 disposed at the inner side of each of the actuating arms 30.

A portion of the force for holding the movable contact 12 in its fully-closed position shown in FIG. 1 is derived from a tension-type overcenter spring 34. This overcenter spring 34 is connected between the pin 36 and another pin 38 carried at the upper end of a guide link 40 that is pivotally mounted on a stationary pivot 42. So long as the longitudinal axis of the spring 34 is above the pivot 31, the spring 34 urges the contact arms 30 in a counterclockwise closing direction, but when the axis of spring 34 is shifted below the axis of pivots 31, the spring 34 urges the contact arm 30 in a clockwise opening direction about its pivot 31.

The force for opening the contacts is derived from a solenoid 50 comprising a vertically movable armature 51 and a stationary coil 52 connected in series with the contacts 10, 12 by suitable conductive means, such as shown at 53 in the wiring diagram of FIG. 6. When current above a predetermined pick-up value flows through the coil 52, sufficient magnetic force is developed to drive the armature 51 in a downward direction from its position of FIG. 1. This downward motion is imparted to a pin 54 carried by a force-transmitting lever 55 pivotally mounted on a stationary pivot 56. The pin 54 responds by moving downwardly, causing the force-transmitting lever 55 to pivot in a clockwise direction about its stationary pivot 56. After a predetermined amount of travel in a clockwise direction, the force-transmitting lever 55 moves into the dotted line position of FIG. 1 and a cam surface 58 on the lever 55 impacts against the pin 36, driving the actuating arms 30 clockwise about their pivots 31. When this clockwise motion of the actuating arms 30 has shifted the longitudinal axis of spring 34 downwardly past the axis of pivots 31, the spring 34 is free to contract and drive the actuating arms 30 further in a clockwise direction to complete their opening stroke.

The position of the parts at the end of an opening stroke is shown in FIG. 4, where the overcenter spring 34 is shown positioned below the axis of the pivot 31 of the actuating arms 30. So long as the armature 51 remains depressed, this spring 34 is maintained in this position of FIG. 4 by a link 60 pivotally connected between the guide link 40 and the force-transmitting lever 55. However, after the circuit through the contacts 10, 12 has been interrupted, the solenoid armature 51 is free to begin returning in an upward direction toward its normal position of FIG. 1 under the influence of a suitable reset spring (not shown). This upward motion of the armature allows the overcenter spring 34 to rotate the guide link 40 in a clockwise direction about its pivot 42. When pin 38 has moved in a clockwise direction sufficiently to carry the longitudinal axis of spring 34 upwardly past the axis of pivots 31, the spring 34 quickly contracts, driving the actuating arms 30 counterclockwise about their pivots 31 through a counterclockwise closing stroke.

It will be apparent from FIG. 2 that the conductive path through the contacts is of a loop-shaped configuration. As is well known, the current flowing through a path of this configuration creates electromagnetic forces tending to lengthen the loop and thus tending to force the cross-bar 11 in a downward, contact-opening direction. These magnetic opening forces vary in magnitude in accordance with the square of the current flowing through the loop-shaped path, and hence, during short circuit currents, extremely high magnetic opening forces can be developed.

The spring 34 can offer some opposition to these magnetic opening forces but not enough to hold the contacts closed under heavy short circuit currents. Providing a spring that is large enough in this respect would require that the solenoid be of an unduly large size in order that it be capable of overcoming the spring, particularly during low current interruptions (when the ampere-turns available from the solenoid might be only two or three percent of those available at maximum rated short circuit current).

In the circuit interrupter of the present invention, I have provided a simple magnetic arrangement 70 that is capable of holding the contacts closed during short circuit currents with little or no assistance from the spring 34. This magnetic arrangement 70 comprises a U-shaped structure 71 of low-retentivity magnetic material such as a soft iron. This U-shaped structure 71 is suitably fixed to a supporting block 76 of insulating material, which, in turn, is suitably fixed to the stationary frame 16. As best shown in FIG. 3, the U-shaped structure 71 comprises a pair of spaced-apart legs 72 and bight portion 73 joining the legs. Between the legs 72 is an open-sided recess 74 into which the cross-bar 11 is driven during a closing operation.

Current flowing through the cross-bar 11 creates magnetic flux around the cross-bar which is depicted by the lines of force 75 in FIG. 3. These lines of force about the conductor 11 follow a magnetic circuit extending through the U-shaped magnetic structure 71 and then across the air gap extending between the legs of the magnetic structure 71. Thus, in this magnetic circuit the air gap is in series with the magnetic structure 71. The conductor 11 is positioned in this air gap when the interrupter is in its fully-closed position of FIGS. 1–3. The flux density in the air gap is essentially zero at the top of the conductor 11 and increases to a maximum at the bottom of the conductor 11, as is depicted in FIG. 3. A conductor located in such an air gap will tend to move into a position wherein the reluctance of the surrounding magnetic

circuit is a minimum, and thus there is a tendency for the cross-bar 11 to move upwardly toward the bight 73 of the U-shaped iron structure 71. The reason that upward movement of the conductor 11 would tend to lower the reluctance of the magnetic circuit is that movement of the conductor 11 toward the bight 73 would make available a greater area for flux lines to cross the air gap between the legs 72, particularly in the region where the flux density is highest, i.e., below the conductor 11. The greater this available area, the lower the reluctance of the magnetic circuit.

The force tending to move the cross-bar 11 in this direction, i.e., toward the bight 73, varies in magnitude as a direct function of the square of the current flowing through the cross-bar. Thus, as the current flowing through the cross-bar increases, increased magnetic force is developed for holding the contacts closed against the electromagnetic loop forces tending to force them open.

The direction of this magnetic force is independent of the polarity of the current flowing through the cross-bar 11 since, irrepective of the direction of the lines of force traversing the air gap, the position of the conductor 11 where the reluctance of the magnetic circuit will be a minimum is still toward the bight 73 of the U-shaped structure 71. The magnitude of this magnetic force depends primarily upon the flux density of the magnetic field in the air gap, and this flux density is substantially independent of the polarity of the current. In this latter regard, the low retentivity of the magnetizable material assures that the flux density will be substantially the same for a given value of current, whether such value is negative or positive.

The magnitude of the force urging the cross-bar toward the bight 73 of the U-shaped structure 71 is dependent upon the width of the structure 71 (depicted at W in FIG. 2) and varies as a direct function of this width W. In a preferred form of my invention, this width W is made sufficiently large that the hold-closed force developed at the magnetic structure 71 for any given current is greater than the electromagnetic loop forces tending to force the contacts open. Thus, for any given current a net force is present tending to hold the contacts closed, and this net force increases as current flowing through the contacts increases. This net hold-closed force will prevent the contacts from being blown open by the magnetic loop forces, and without requiring any assistance from the closing spring 34. This net force simply urges the contacts 12 more firmly against the lower ends of the studs 14 as the current increases.

In a circuit breaker that is designed for time delayed opening, it is particularly important that the contacts not be forced open prematurely by magnetic loop forces immediately upon the initiation of short-circuit currents. Otherwise it would not be possible to provide the desired time delay between the instant that short-circuit current begins to flow and the instant the circuit is interrupted. The disclosed circuit interrupter is a typical one in which it is desired to provide such a time delay in certain of its opening operations. Such a delay is provided by retarding the downward motion of the solenoid armature 51 at least until a predetermined point in its downward opening stroke is reached. Any suitable means (not shown) may be relied upon for providing the desired retardation of the armature, e.g., a metering orifice in passage 80 through which liquid displaced by downward motion of the armature 51 is forced. In the disclosed circuit interrupter initial downward movement of the solenoid armature 51 moves the force-transmitting lever 55 in a clockwise direction but imparts no opening movement to the contacts 12 of the interrupter until the cam 58 is driven into engagement with the pin 36. The desired time delay is obtained by retarding the armature 51 during at least a portion of its downward stroke.

After the cam 58 engages the pin 36, continued downward opening movement of solenoid armature 51 is transmitted to the cross-bar 11 through the parts 58, 36, 30. The opening force developed by the solenoid and transmitted to the cross-bar 11 immediately overcomes the net magnetic hold-closed force and drives the cross-bar 11 toward open position. As the cross-bar 11 emerges from the recess 74 between the legs of the U-shaped magnetic structure 71, the closing force developed at the magnetic structure 71 begins to drop rather sharply. By the time the cross-bar has completely emerged from the gap, this closing force has become negligible. Thus, even before the cross-bar 11 has completely emerged from the gap 74, the net magnetic force on the cross-bar 11 has fallen from a value acting in a closing direction to zero and has begun building up in an opening direction. The cam 58 continues to drive the pin 36 until the contacts 12, 10 have disengaged, and at about this instant the cam 58 becomes ineffective to transmit continued opening force to the pin 36, the pin having passed off the right hand end of the cam surface 58 by this time. Further opening movement continues, however, under the influence of inertia, the above-described net magnetic force on the cross-bar, and the overcenter spring 34, which is now acting in an opening direction. Such motion separates the movable contact 12 from the stationary contact 10 at the desired high velocity, thus interrupting the circuit.

The approximate manner in which the net magnetic force on the cross-bar varies as the opening stroke of cross-bar 11 proceeds is illustrated in FIG. 5, assuming a constant current through the cross-bar. At point 9, the cam 58 first engages the pin 36 coupled to the cross-bar. At point B, the cross-bar begins to emerge from the recess 74 of the magnetic structure 71; and at point C, the cam becomes ineffective and the contacts part. It will be observed that when point C has been reached, the net magnetic force on the cross-bar 11 is no longer acting in a closing direction but is then acting in an opening direction. Since the magnetic structure 71 has become ineffective by the time the contacts part at C, it will be apparent that the movable contact 12 can move toward its open position at the desired high velocity without significant interference from the magnetic structure 71.

Another feature of my magnetic arrangement 70 is that it can assist in closing the contacts 12 against short-circuit produced magnetic forces. In this regard, if the contacts 12 are closed when a fault is present on the line, electromagnetic loop forces are abruptly established at the end of a closing stroke, and these forces tend to oppose the final portion of a closing stroke. However, at about the instant these loop forces are developed, the cross-bar 11 is beginning to enter the gap 74 of the magnetic structure 71, and thus magnetic forces are developed tending to drive the contacts 12 into their fully-closed position. These forces developed at the magnetic structure 71 thus assist the spring 34 in closing the contacts against the electromagnetic loop forces developed when closing on a fault.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend 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. An alternating current circuit interrupter comprising a stationary frame, a first contact mounted on said frame, a second contact movable along a predetermined path into and out of engagement with said first contact, a rigid conductor electrically connected to said second contact for carrying alternating current to and from said second contact, means for rigidly coupling said conductor to said second contact in such relationship that said conductor extends transversely of said predetermined path, structure of low retentivity magnetizable material containing a re-

cess into which said conductor is movable to decrease the reluctance of the magnetic circuit for the flux generated by current flowing through said conductor, means for fixedly mounting said magnetizable structure on said stationary frame in a position wherein said conductor enters said recess upon movement of said second contact into engagement with said first contact during closing of said interupter, said magnetic circuit containing an air gap in series with said magnetizable structure during the time said contacts are engaged and said interrupter is fully closed, said conductor being disposed within said air gap when said interrupter is fully closed, whereby a magnetic force is exerted on said conductor tending to hold said contacts engaged.

2. An alternating current circuit interrupter comprising a stationary frame, a first contact mounted on said frame, a second contact movable along a predetermined path into and out of engagement with said first contact, a rigid conductor electrically connected to said second contact for carrying alternating current to and from said second contact, means for rigidly coupling said conductor to said second contact in such relationship that said conductor extends transversely to said predetermined path, U-shaped structure of low retentivity magnetizable material comprising a pair of spaced-apart legs defining an open-mouth recess therebetween, means for fixedly mounting said U-shaped structure on said stationary frame in a position wherein said conductor enters said recess upon movement of said second contact into engagement with said first contact during closing of said interrupter, the magnetic circuit for flux generated by current flowing through said conductor while said contacts are engaged and said interrupter is fully-closed including the series combination of said U-shaped structure and an air gap extending across said recess, said conductor being disposed within said air gap when said interrupter is fully-closed, whereby a magnetic force is exerted on said conductor tending to hold said contacts engaged.

3. The circuit interrupter of claim 1 in which said structure of magnetizable material extends along a sufficient length of said conductor to develop during overcurrent conditions a magnetic closing force on said conductor in excess of the magnetic force tending to open said contacts due to the configuration of the power circuit through said contacts, whereby the net magnetic force on said conductor is in a contact-closing direction when the contacts are in a fully-closed position.

4. The circuit interrupter of claim 2 in which said U-shaped structure extends along a sufficient length of said conductor to develop during overcurrent conditions occurring while said contacts are fully-closed a magnetic closing force on said conductor in excess of the magnetic force tending to open said contacts due to the configuration of the power circuit through said contacts, whereby the net magnetic force on said conductor while said contacts are fully closed is in a contact-closing direction.

5. An alternating current circuit interrupter comprising a stationary frame, a first pair of spaced-apart contacts mounted on said frame, a second pair of spaced-apart contacts movable into and out of engagement with said first pair of contacts, a rigid cross-bar of conductive material extending between the contacts of said second pair and rigidly coupled thereto for carrying alternating current between said spaced-apart movable contacts, structure of low-retentivity magnetizable material containing a recess into which said cross-bar is movable to decrease the reluctance of the magnetic circuit for the flux generated by current flowing through said cross-bar, means for fixedly mounting said magnetizable stucture on said stationary frame in a position wherein said cross-bar enters said recess upon movement of said second contacts into engagement with said first contacts during closing of said interrupter, said magnetic circuit containing an air gap in series with said magnetizable structure during the time said contacts are engaged and said interrupter is fully closed, said conductor being disposed within said air gap when said interrupter is fully closed, whereby a magnetic force is exerted on said conductor tending to hold said contacts engaged.

6. The electric circuit breaker of claim 5 in which said structure of magnetizable material is of a U-shaped configuration and comprises a pair of spaced-apart legs on opposite sides of said recess.

7. The circuit interrupter of claim 6 in which said U-shaped structure extends along a sufficient length of said cross-bar to develop during overcurrent conditions occurring while said second contacts are fully closed a magnetic closing force on said cross-bar in excess of the magnetic forces tending to open said contacts due to the loop-shaped configuration of the power ciruit through said contacts, whereby the net magnetic force on said cross-bar is in a contact-closing direction while said contacts are fully closed.

8. An alternating current circuit interrupter comprising a stationary frame, a first contact mounted on said frame, a second contact movable along a predetermined path into and out of engagement with said first contact, a rigid conductor electrically connected to said second contact for carrying alternating current to and from said second contact, means for rigidly coupling said conductor to said contact in such relationship that said conductor extends transversely to said predetermined path, structure of low-retentivity magnetizable material containing a recess into which said conductor is movable to decrease the reluctance of the magnetic circuit for the flux generated by current flowing through said conductor, means for fixedly mounting said magnetizable structure on said stationary frame in a position wherein said conductor enters said recess upon movement of said second contact into engagement with said first contact during closing of said interrupter, said magnetic circuit contaning an air gap in series with said magnetizable structure during the time said contacts are engaged and said interrupter is fully closed, said conductor being disposed within said air gap when said interrupter is fully closed, whereby a magnetic force is exerted on said conductor tending to hold said contacts engaged, said magnetizable structure extending along a sufficient length of said conductor to develop during over-current conditions occurring while said interrupter is fully-closed a magnetic closing force on said conductor in excess of the magnetic force tending to open said contacts due to the configuration of the power circuit through said contacts, whereby the net magnetic force on said conductor while said interrupter is fully closed is in a contact-closing direction, actuating means responsive to overcurrents through said contacts for providing an opening force acting in a direction to drive said contacts apart, force-transmitting means for transmitting said opening force to said second contact, means for delaying transmission of said opening force to said contacts for a predetermined interval of time, said net magnetic force holding said contacts in closed position during said overcurrent conditions until said opening force from said actuating means is transmitted to said second contact.

9. The interrupter of claim 1 in which said magnetizable structure extends along a sufficient length of said conductor to develop during overcurrent conditions occurring while said interrupter is fully closed a magnetic closing force on said conductor in excess of the magnetic force tending to open said contacts due to the configuration of the power circuit through said contacts, whereby the net magnetic force on said conductor while said interrupter is fully closed is in a contact-closing direction, actuating means for providing an opening force acting in a direction to drive said contacts apart, force-transmitting means for transmitting said opening force to said second contact, means for rendering said force-transmitting means ineffective after said actuating means has driven said second contact through a portion of an open-

ing stroke, means for greatly reducing said net magnetic force before said force-transmitting means is rendered ineffective comprising means for moving said conductor out of said recess in response to opening movement of said second contact.

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