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(54) CIRCUIT INTERRUPTER

(71) We, TERASAKI DENKI SANGYO KABUSHIKI KAISHA, of No. 3-3, Showa-chonaka 5-chome, Abeno-ku, City of Osaka, Japan, a Body Corporate organized and existing under the laws of Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to improvements in the current-limiting type of circuit interrupter utilizing electromagnetic repulsion developed between a pair of substantially parallel electric conductors due to a flow of greatly excessive current e.g. a short-circuit current therethrough.

The invention provides a circuit interrupter comprising a pair of movable contact arm units disposed in opposed parallel relationship in the closed position of the interrupter, actuating means operatively coupled to one of said movable contact units for driving said one unit from its closed position into its open position and *vice versa*, said one contact arm unit including a pair of movable contact arms each having a contact at one end and being pivotably mounted at the other end while maintaining electrical connection therebetween, said pair of movable contact arms being symmetrically disposed in alignment with each other in the closed position of the interrupter, the other movable contact arm unit including a pair of movable contact arms each having a contact at one end and being pivotably mounted at the other end, said last-mentioned contact arms being connected respectively to source and load terminals and being symmetrically disposed in alignment with each other in the closed position of the interrupter, said contact arms of said one unit bridging those of the other unit in the closed position of the interrupter so that current flow in each arm of one unit is in the same direction as current flow in the other arm

of that unit but in the opposite direction to current flow in each arm of the other unit, each pair of mating contact arms responding to an electromagnetic repulsion therebetween, arising from flow of a very heavy current, to rotate in opposite directions about their other ends thereby to simultaneously separate the two pairs of contacts from each other.

Preferably each pair of mating contact arms is further from the terminal connected to one of those arms than the other pair and a respective stationary electrical conductor connects each terminal to that contact arm remote from the each terminal, the conductor having one portion disposed in parallel relationship with the associated contact arm so that the said portion is identical in direction of current flow to the latter arm. Upon the occurrence of a flow of very heavy current an electromagnetic attraction is developed between the said portion of the conductor and the associated movable contact arm to increase the speed at which the said arm is separated from the mating moving contact arm.

The invention will be further described in conjunction with the accompanying drawings in which:

Figure 1 is an elevational sectional view of a three pole circuit interrupter constructed according to the invention, in its closed position;

Figure 2 is an inverted plan view of the interrupter, a common cover for arc extinguishing chambers being removed, a first movable contact unit for the central pole being removed to illustrate a second contact unit, and a first and a second contact unit and arc extinguishing devices for another pole also being omitted;

Figure 3 is a fragmentary sectional view of the interrupter illustrating its open or reset position into which it is brought through the operation of the associated operating handle;

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Figure 4 is a fragmentary sectional view of the interrupter illustrating its tripped position into which it is brought through the actuation of the associated trip device upon a flow of ordinary overload current there-through;

Figure 5 is a fragmentary sectional view of the interrupter illustrating its interruption position into which it is brought through a flow of short-circuit current therethrough and independently of the operation of the associated switching and trip devices;

Figure 6 is a perspective view of the first and second movable contact units and the associated stationary conductors to form a closed loop circuit; and

Figure 7 is a fragmental exploded perspective view of the essential parts of the interrupter.

While the invention will be illustrated and described in conjunction with a circuit interrupter of three pole type, it is to be understood that the invention is equally applicable to circuit interrupters of single pole type and other multiple pole types. Also it is to be understood that the components common to all the poles will be described in terms of the central pole alone.

The circuit interrupter illustrated comprises a closed enclosure including a main body member 1, a detachable top cover member 2, and a detachable bottom cover member 3. All the members 1, 2 and 3 may be conveniently made of any suitable, electrically insulating plastic by molding. Within the enclosure a pair of movable contact units 4 and 5 respectively are disposed so as to be substantially horizontally positioned in opposed parallel relationship in the closed position of the interrupter.

The first, lower, unit 4 includes a pair of first or lower contact arms 4s and 4l having contacts 6s and 6l attached to the extremities or free ends respectively. The contact arms 4s and 4l may be conveniently made of any suitable electrically conductive material. The contact arms 6s and 6l are of a symmetrical configuration except that arm 4s has a projection 7s of part circular shape at the other end while the other contact arm 4l has a V-shaped groove 7l at the adjacent end. The arms are disposed in alignment with each other in the closed position of the interrupter. The projection 7s is forced always to engage the groove 7l under pressure by the action of two tension springs 8 (see also Figure 2) one on each side of the arms 4s and 4l, stretched between a pair of anchoring pins 9s and 9l rigidly extending through the respective arms. The contact arm 4s is mounted at the centre of the projection 7s on a pivot pin 10 rotatably carried by and between a pair of spaced contact holders 11 and 11¹.

Thus the first contact arm 4s is rotatable about the axis of the pin 10 while the contact arm 4l is rotatable about the axis of the pin 10 with the circular arcuate surface of the projection 7s in contact with the V-shaped groove 7l. In the closed position of the interrupter those sides of the contact arms 4s and 4l facing the upper contact unit 5 and therefore the first contacts 6s and 6l are substantially flush with each other. The contact arm 4s is electrically connected to the contact arm 4l by a flexible shunting lead 12 connected between the adjacent end portions thereof as shown in Figure 1.

The second or upper contact unit 5 includes a pair of second or upper contact arms 5s and 5l of bilaterally symmetrical configuration spaced from each other and having a pair of contacts 13s and 13l attached to their free ends or extremities respectively. The upper contact arms may be conveniently made of the same metallic material as the lower contact arms. In the closed position of the interrupter, those sides of the second contact arms 5s and 5l facing the first contact arms are substantially flush with each other and bridged by the first contact unit 4 by the contacts 13s and 13l engaging the respective contacts 6s and 6l. The upper contact arms 5s and 5l are pivotably mounted at their other ends on pivot pins 14s and 14l respectively.

As best shown in Figure 2, the pivot pins 14s and 14l are rigidly secured to a pair of opposed holding frames 15s and 15l which are, in turn, mounted to the main enclosure body 1 through respective screws 16s and 16l. Stretched between an anchoring pin 17s rigidly extending through substantially the middle portion of the contact arm 5s and a stop pin 18s fixed on the holding frame 15s on both sides of the contact arm is a tension spring 19s for imparting to the contact 13s the pressure under which it is in engagement with the mating contact 6s. For the same purpose the contact arm 5l is operatively associated with corresponding components 17l, 18l and 19l. The tension springs 8 operatively coupled to the lower contact arms 4s and 4l also provide contact pressures for the contacts 6s and 6l.

As shown in Figures 1 and 6, the upper contact arm 5s is electrically connected through a flexible lead 20s to a connecting element 21s welded to one end of a stationary electric conductor 22s. The conductor 22s is embedded in an electrically insulating partition 1a physically separating the contact units 4 and 5 from a switching mechanism to be described hereinafter, and is connected to a supply terminal 23s disposed at one end of the main enclosure body 1. Similarly the upper contact arm 130

5/ is electrically connected through a flexible lead 20/, a connecting element 21/ and another stationary electric conductor 22/ to a load terminal 23/ disposed in opposite relationship with the source terminal 23s and at the opposite end of the main body 1. Thus, each pair of first and second movable contact arms 4s and 5s, or 4/ and 5/, is disposed further from the terminal 23s or 23/ connected thereto than from the other terminal. As shown in Figure 6, both conductors 22s and 22/ are of a symmetrical configuration and each of them includes one portion 22's or 22'/ located substantially parallel to and overlying the contact arms in closed position of the interrupter.

As shown in Figure 1, the circuit interrupter further includes a pair of opposed arc extinguishing chambers 24s and 24/ of conventional construction adjacent to the free end portions of the upper and lower contact arms. The bottom cover member 3 also serves as a common cover for the chambers.

In order to manually open and close the circuit interrupter, that is to say, to manually move the lower contact unit 4 away from and toward, the upper contact unit 5, there is an actuating mechanism 25 which comprises a pivoted operating handle 26 having one end portion freely projecting beyond the top cover member 2, and a switching lever 27 of inverted U-shape secured to the operating handle 26 at the other end. The lever 27 is pivotably mounted at its free ends on a pivot pin 28 mounted on support plates 29 suitably disposed on the main enclosure body 1. Thus, the operating handle 26 and the switching lever 27 as a whole are turnable about the axis of the pin 28. The mechanism further comprises a pair of toggle elements 30 and 31 articulated at a pin 32 to each other with the free end of the toggle element 31 pivotably mounted on a pivot pin 33 secured to one end of a lever 34. A pair of tension springs 35 on each side of the switching lever 27 are anchored at one end to the switching lever 27 and at the other end to the toggle pin 32. The lever 34 is pivotably mounted on the pivot pin 28 and has extending through the other end a shaft 36.

Fitted onto the shaft 36 are the upper ends of three pairs of spaced contact holders 11 and 11' in spaced parallel relationship, one pair for each pole as shown in Figure 7. The contact holders are made preferably of any suitable reinforced synthetic plastic of high mechanical strength, each loosely extends through a vertical complementary opening 1c or 1c' through a central post 1b formed integrally with the main enclosure body 1 (see Figure 2 and 7).

The lower portion of each contact holder 11

or 11' projecting beyond the opening 1c or 1c' is enlarged in width and has centrally extending at the lower ends a retaining pin 37 provided at each end with a guide roller 38, 38' adapted to roll along a guide groove 3a formed in each of the common side walls of the arc extinguishing chambers 24s and 24/. The two lower movable contact arms 4s and 4/ are sandwiched between the lower wider portions of the mating contact holders 11 and 11' and above the retaining pin 37 for rotational movement about the axis of the pivot pin 10. As best shown in Figure 7, each contact holder is provided on both sides of the lower end portion with a pair of recesses 39s and 39/ along which are guided the anchoring pins 9s and 9/ on the respective lower contact arms 4s and 4/.

For a tripping operation, there is provided a trip mechanism 40 which may be of conventional construction and in the embodiment illustrated comprises a trip lever 41 pivotably mounted at one end on a pivot pin 42 bridging the two parallel support plates 29 and provided on the central portion with a toggle pin 43 on which the free end of the toggle element 30 is pivotably mounted. The trip lever 41 is normally engaged at the other end by a latch 44 pivotably mounted on a pin 44c supported by the support plates 29. The latch 44 has one end portion 44a shaped into a grooved edge normally engaging the trip lever 41 and the other end 44b engaging a second latch plate 45 secured on a common trip shaft 46. The trip shaft 46 is pivotably supported by the support plates 29 and further includes a latch plate similar to the plate 45 for each of the remaining poles as well as shoulder 45a disposed on the piece for the central pole to normally engage the latch 44.

Further the circuit interrupter comprises a thermally responsive mechanism 50 and an electromagnetically responsive mechanism 56 each of which may be of conventional construction.

The thermally responsive mechanism 50 comprises a bimetallic element 51 and an electric resistance type heater 52. The bimetallic element 51 and heater 52, and an energizing winding 57b of an electromagnet, are connected at one end in superposed relationship to a supporting bracket 53 rigidly secured to the main enclosure body 1. The bimetallic element 51 has the other or free end facing a trip adjusting screw 54 screwed into the other end of the latch plate 45, while the heater 52 is connected at the other end to a heater terminal 55 which is, in turn, connected to the stationary conductor 22/ on the load side.

The electromagnetically responsive mechanism 56 includes an electromagnet comprising a stationary iron core 57 having a

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cylindrical leg portion 57a, the energizing winding 57b inductively disposed on the leg portion 57a, and a pair of spaced pole pieces 57c secured at both ends of the leg portion. The stationary core 57 is suitably secured to the support plates 29 while the winding 57b is connected at one end to both the heater 51 and bimetallic element 52 and at the other end to the load terminal 23l through an electric conductor 58.

The electromagnetically responsive mechanism 56 further comprises an instantaneously tripping lever 59 pivotably mounted on the central portion to the support plates 29. The lever 59 includes three arms 59a, 59b and 59c of which 59a has a movable iron core 60 attached to the extremity so as to be positioned in slightly spaced, opposite relationship with the pole pieces 57c of the stationary core. The second arm 59b faces a pin 61 disposed at the other end of the latch plate 45 and the third arm 59c extending between the arms 59a and 59b has attached to its extremity an indication plate 62 viewable through an indication window 2a formed in the top cover member 2. The indication plate 62 serves to indicate the operation of the instantaneously responsive mechanism 56. A tripping spring 63 is stretched between the support plate 29 and the third arm 59c and tends to rotate the tripping lever 59 counterclockwise as viewed in Figure 1 until the movable iron core 60 is biased to abut against an eccentric cam 64.

In order to adjust the magnitude of the current that will trip the interrupter, a current controlling screw 65 projects into a through hole 2b formed in the top cover member 2 and has an eccentric cam 64 secured on the lower end. Rotation of the controlling screw 65 causes the movable iron core 60 to pivot to change the gap between the movable and stationary iron cores for adjusting the magnitude of the triggering current.

The circuit interrupter operates as follows: In Figure 1 wherein the interrupter is illustrated in its closed position, the operating handle 26 can be manually turned to the "OFF" position (to the right) to cause the toggle elements 30 and 31 to collapse thereby to rotate the lever 34 about the axis of the pin 28 clockwise as viewed in Figure 1. This rotation of the lever 34 is accompanied by the downward movement of the contact holders 11 and 11¹ to separate the lower contact arms 4s and 4l from the upper contact arms 5s and 5l, the lower arms remaining in a horizontal straight line as in their closed position, until the lower contact arms are brought into the open position illustrated in Figure 3. It will be appreciated that the guide rollers 38 on the holding pin 37 slide down-

wardly along the associated guide grooves 3a to ensure that the lower contacts are smoothly and rapidly separated from the upper contacts.

If it is desired to close the open interrupter, the operating handle 26 can be manually turned to the "ON" position to reverse the process described above until the lower contacts 6s and 6l are put and maintained in engagement with the upper contacts 13s and 13l respectively.

If an ordinary overload current flows through the circuit interrupter in its closed position, the bimetallic element 51 is heated and bends until its free end pushes against the trip adjusting screw 54. This causes both the latch plate 45 and the trip shaft 46 to be rotated counterclockwise as viewed in Figure 1 whereby the latch plate 45 disengages from the latch 44 resulting in rotation of the latch 44 counterclockwise. This causes the trip lever 41 to disengage from the latch 44 whereupon the toggle elements 30 and 31 collapse. Thereafter the contact-opening process described above is repeated until the interrupter is brought into its tripped position as illustrated in Figure 4.

If an excessive current whose magnitude is equal to from five to ten times the rated current of the interrupter flows through the latter in its closed position, the movable iron core 60 is immediately attracted to the stationary iron core 57 to rotate the instantaneously tripping lever 59 until the trip responsive pin 61 on the latch plate 45 is raised. This raising of the plate 45 causes the contact-opening process described above to be repeated until the interrupter is similarly brought into its tripped position.

If a greatly excessive current such as a shortcircuit current flows through the interrupter in its closed position, the current flows in opposite directions through second contact arms 5s and 5l and the first contact arms 4s, 4l to develop an electromagnetic repulsion which serves to rotate immediately the first or lower contact arms 4s and 4l in opposite directions about the axis of the pivot pin 10, the V-shaped groove 7l on the arm 4l sliding along the periphery of the projection 7s on the arm 4s. At the same time the second or upper contact arms 5s and 5l are rotated in opposite directions about the axes of the respective pins 14s and 14l. Thus the contacts 6s and 13s are rapidly separated from each other as are the contacts 6l and 13l whereby the short-circuit current is interrupted.

It is to be noted that the contact arms rotate independently of the operation of the trip mechanism 40 and without any time delay, while the contact holders 11 and 11¹

remain in their original position as illustrated in Figure 1.

The rotation of the contact arms 4s and 4l in opposite directions is accompanied by the displacement of the anchoring pins 9s and 9l thereon leading to reversal of the action of the contact springs 8 to fold the contact arms 4s and 4l. Finally the contact arms 4s and 4l abut against stops 3a and 3a¹ formed on the bottom cover member 3 and are held folded into an inverted V-shape. The upper contact arms 5s and 5l are similarly folded into a V-shape and are maintained in that shape as long as the electromagnetic repulsion exceeds the force of the contact springs 19s and 19l. Figure 5 shows the upper and lower contact arms in their interrupting positions. However as the repulsion decreases after interrupting the upper contact arms return to their original closed position while the lower contact arms remain in their interrupting position.

It is to be understood that the contact springs 19s and 19l may readily be designed and arranged so as to reverse the action thereof during the rotation of the second contact arms.

A little later after the first and second contact units 4 and 5 and therefore the first contacts 6 and 9 have been separated from each other to interrupt the shortcircuit current, the electromagnetically responsive mechanism 56 operates the trip mechanism 40. That is, the toggle elements 30 and 31 are released from their constraint to depress the interlocking switching shaft 36 and hence the contact holders 11 and 11¹ whereby the abutting end portions of the first contact arms 4s and 4l, folded in inverted V-shape, are forced downwardly. Therefore these contact arms are rotated upwardly as viewed in Figure 1 about the axis of the pivot pin 10. During this rotation, the contact springs 8 reverse their direction of action to horizontally align the contact arms 4s and 4l with each other as in their closed position. Then the interrupter is required only to be reset to be ready for the succeeding closing operation as do conventional interrupters.

Due to the fact that, as previously described, a first pair of movable contact arms 4s and 4l and a second pair of movable contact arms 5s and 5l are disposed in opposite parallel relationship in the closed position of the circuit interrupter and that each pair of mating contacts 6s and 13s or 6l and 13l attached to the free ends of directly opposed contact arms are adapted to respond to an electromagnetic repulsion developed between the associated opposed arms through a flow of greatly excessive current therethrough to be moved away from each other simultaneously with the similar movement of the other contact pair,

a distance of separation between the mating contacts can increase easily enough. This leads to the advantage that the present circuit interrupter, having two interruption points, has its current limiting capability increased to such an extent that the interrupter more nearly resembles in operation the four interruption point type of interrupter and the arcing time as well as the entire interruption time are reduced, leading to an increase in interruption capability.

In the conventional current limiting type of low voltage circuit interrupter operative with a low rated current such as 100 amperes, it has been difficult to impart to the interrupter a normal interruption capability as high as 100,000 amperes at 500 volts ac. However, the present circuit interrupter, even though similar in size to the cited interrupters, possesses a high interruption capability such as above specified and can complete an interruption within twenty percent of one cycle of alternating current or less.

Further the present interrupter is not inferior in interruption capability to any current limiting fuse presently used and its arcing voltage is lower and rises less steeply compared with a fuse. This results in a decreased risk of breakdown of associated electric devices.

As previously described, each of the terminals 23s and 23l is electrically connected to the associated upper movable contact arm 5s or 5l further from it through the stationary conductor 22s or 22l which has one portion substantially parallel with the contact arms 5s or 4s or 5l and 4l in their closed positions. The flow of current through each conductor 22s and 22l is the same in the direction as through the corresponding upper contact arm but opposite in direction to that through the lower contact arm. Upon separation of the contacts in response to a greatly excessive current flowing through the contact arms, the upper contact arms 5s and 5l approach the associated conductor 22s or 22l. This rotation of the contact arms is accompanied by the generation of an electromagnetic attraction between each of the upper contact arms and the connector connected thereto resulting from the flow of current therethrough in a common direction as shown by the arrows in Figure 6. This aids in separating the upper contact arms 5s and 5l from the associated lower contact arms 4s and 4l thereby to increase the speed at which the contact arms 5s and 5l are separated from the contact arm 4s and 4l respectively with the result that the current limiting capability additionally increases.

WHAT WE CLAIM IS:—

1. A circuit interrupter comprising a

remain in their original position as illustrated in Figure 1.

The rotation of the contact arms 4s and 4l in opposite directions is accompanied by the displacement of the anchoring pins 9s and 9l thereon leading to reversal of the action of the contact springs 8 to fold the contact arms 4s and 4l. Finally the contact arms 4s and 4l abut against stops 3a and 3a¹ formed on the bottom cover member 3 and are held folded into an inverted V-shape. The upper contact arms 5s and 5l are similarly folded into a V-shape and are maintained in that shape as long as the electromagnetic repulsion exceeds the force of the contact springs 19s and 19l. Figure 5 shows the upper and lower contact arms in their interrupting positions. However as the repulsion decreases after interrupting the upper contact arms return to their original closed position while the lower contact arms remain in their interrupting position.

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Due to the fact that, as previously described, a first pair of movable contact arms 4s and 4l and a second pair of movable contact arms 5s and 5l are disposed in opposite parallel relationship in the closed position of the circuit interrupter and that each pair of mating contacts 6s and 13s or 6l and 13l attached to the free ends of directly opposed contact arms are adapted to respond to an electromagnetic repulsion developed between the associated opposed arms through a flow of greatly excessive current therethrough to be moved away from each other simultaneously with the similar movement of the other contact pair,

a distance of separation between the mating contacts can increase easily enough. This leads to the advantage that the present circuit interrupter, having two interruption points, has its current limiting capability increased to such an extent that the interrupter more nearly resembles in operation the four interruption point type of interrupter and the arcing time as well as the entire interruption time are reduced, leading to an increase in interruption capability.

In the conventional current limiting type of low voltage circuit interrupter operative with a low rated current such as 100 amperes, it has been difficult to impart to the interrupter a normal interruption capability as high as 100,000 amperes at 500 volts ac. However, the present circuit interrupter, even though similar in size to the cited interrupters, possesses a high interruption capability such as above specified and can complete an interruption within twenty percent of one cycle of alternating current or less.

Further the present interrupter is not inferior in interruption capability to any current limiting fuse presently used and its arcing voltage is lower and rises less steeply compared with a fuse. This results in a decreased risk of breakdown of associated electric devices.

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WHAT WE CLAIM IS:—

1. A circuit interrupter comprising a



pair of movable contact arm units disposed in opposed parallel relationship in the closed position of the interrupter, actuating means operatively coupled to one of said
5 movable contact units for driving said one unit from its closed position into its open position and *vice versa*, said one contact arm unit including a pair of movable contact arms each having a contact at one end being
10 pivotally mounted at the other end while maintaining electrical connection therebetween, said pair of movable contact arms being symmetrically disposed in alignment with each other in the closed position of the interrupter, the other movable contact
15 arm unit including a pair of movable contact arms each having a contact at one end and being pivotally mounted at the other end, said last-mentioned contact arms being connected respectively to source and load
20 terminals and being symmetrically disposed in alignment with each other in the closed position of the interrupter said contact arms of said one unit bridging those of the other unit in the closed position
25 of the interrupter so that a current flow in each arm of one unit is in the same direction as current flow in the other arm of that unit but in the opposite direction to current flow in each arm of the other unit,
30

each pair of mating contact arms responding to an electromagnetic repulsion therebetween, arising from flow of a very heavy current, to rotate in opposite directions about their other ends thereby to simultaneously separate the two pairs of contacts from each other.

2. A circuit interrupter as claimed in claim 1, comprising a respective stationary electric conductor for electrically connecting each of said movable contact arms of the said other unit to the associated terminal and having one portion disposed in parallel relationship with the connected contact arm and identical in direction of current flow to that contact arm so that upon the occurrence of very heavy current an electromagnetic attraction will be developed between said portion of each conductor and the associated movable contact arm to increase the speed at which that contact arm is separated from the mating contact arm of the said one unit.

3. A circuit interrupter substantially as herein described and illustrated in the accompanying drawings.

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