May 3, 1949. J. M. WALLACE 2,468,851

RECLOSING CIRCUIT INTERRUPTER

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Fig. 1.

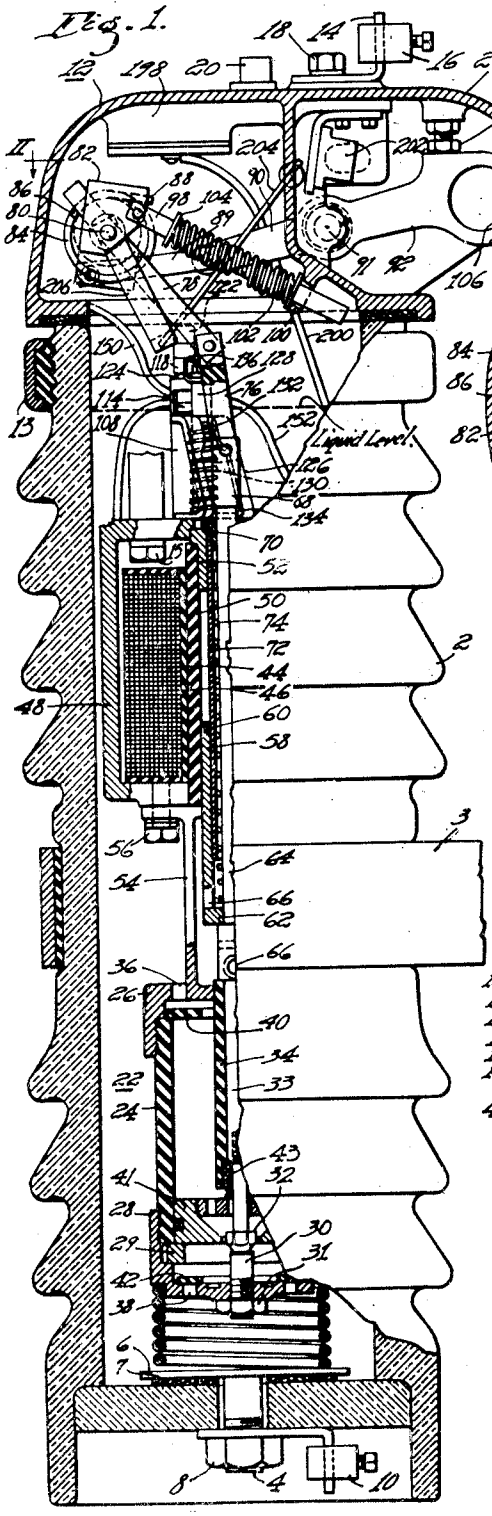


Fig. 2.

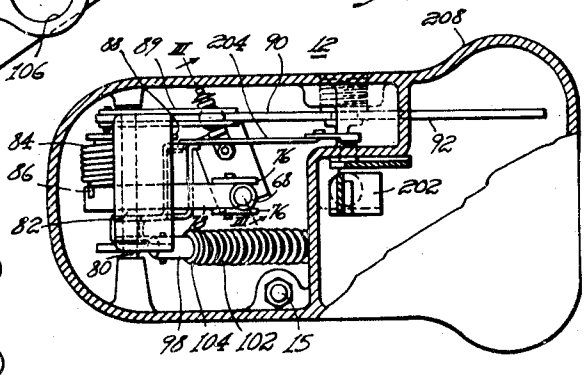
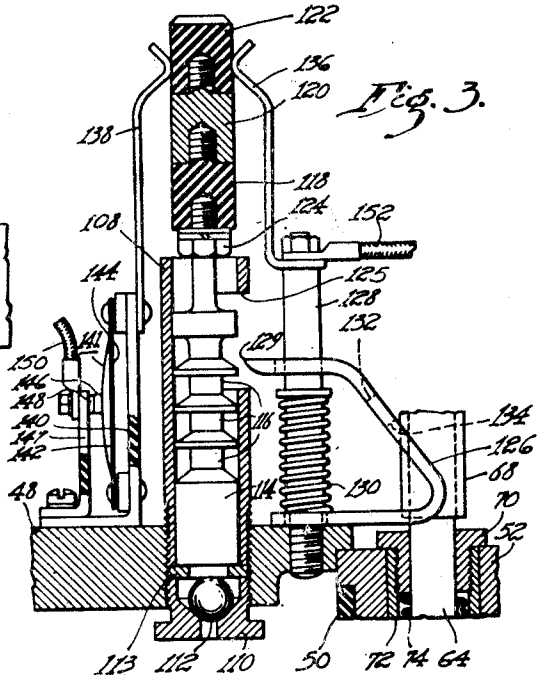


Fig. 3.



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Fig. 4.

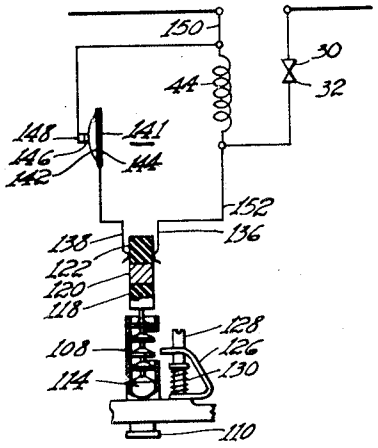


Fig. 6.

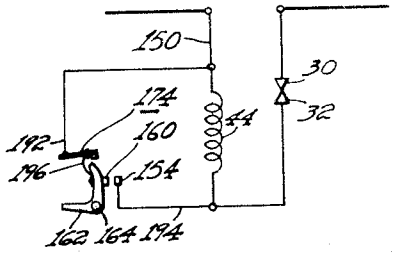
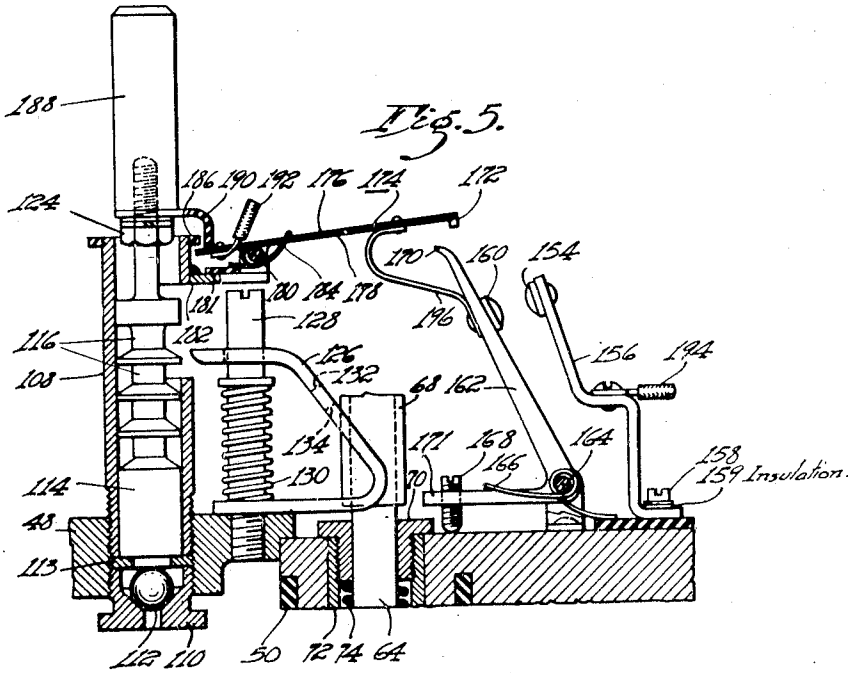


Fig. 5.



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RECLOSING CIRCUIT INTERRUPTER

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Application January 7, 1944, Serial No. 517,327

19 Claims. (Cl. 175—294)

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This invention relates to reclosing circuit interrupters in general, and more particularly to means for providing closely successive circuit interrupting operations of an automatic reclosing circuit breaker with different time characteristics.

Although of general application, this invention is disclosed herein as applied to so-called pole-top breakers which have all of the parts thereof enclosed in a relatively small casing suitable for mounting on a pole or cross arm, wherein it has certain particular novel features of cooperation. Although breakers of this type are made with some time delay on each circuit interrupting operation, it is highly desirable that they operate to interrupt the circuit with different time delay periods on continuing faults where the breaker automatically goes through a plurality of closely successive circuit opening and reclosing operations, and after a predetermined number of such operations is automatically locked in open circuit condition. Use of a relatively great time delay, preferably on the second circuit opening, will permit self-clearing faults to burn clear prior to lockout of the breaker. Furthermore, it is desirable that at least one opening of the breaker have thermal inverse time-current characteristics to properly coordinate with fuses and other apparatus having like characteristics.

Accordingly, one object of this invention is to provide novel means for causing an automatic reclosing circuit breaker to open the circuit with time delay on a selected one or ones of a plurality of closely successive circuit interrupting operations.

Another object of this invention is to provide novel means for causing an automatic reclosing circuit breaker to delay opening the circuit with thermal characteristics on at least one selected circuit opening operation in a series of closely successive circuit interrupting operations, with at least one other circuit opening operation of said series being substantially instantaneous.

A more specific object of this invention is to provide in an automatic reclosing circuit breaker having integrating means to lock the breaker contacts open in response to a predetermined number of closely successive circuit interrupting operations, novel means controlled by said integrating means for determining the time characteristics of such closely successive circuit interrupting operations.

Another object of this invention is to provide an automatic reclosing circuit breaker which is adapted to lock at open circuit position in response to a predetermined number of closely successive

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circuit interrupting operations, with means for causing a selected one of such predetermined number of operations to always occur with a relatively large time delay, irrespective of whether or not said breaker completes said predetermined number of closely successive circuit interrupting operations.

These and other objects of this invention will become more apparent upon consideration of the following detailed description of preferred embodiments thereof, when taken in connection with the attached drawings, in which:

Figure 1 is an elevation of a reclosing interrupter embodying this invention, illustrated partially in section;

Fig. 2 is a cross-section of the interrupter shown in Fig. 1, taken substantially on the line II—II thereof;

Fig. 3 is an enlarged elevation view of a portion of the control mechanism with certain of the parts shown in section, and with the view taken substantially on the line III—III of Fig. 2;

Fig. 4 is a line diagram illustrating the method of connection of applicant's novel circuit interrupter and its control means in a circuit;

Fig. 5 is an elevation view of a modified form of control means, with certain of the parts shown in section; and

Fig. 6 is a line diagram illustrating the circuit connections for the control means shown in Fig. 5.

This invention is illustrated as embodied in a reclosing circuit breaker which is similar to that disclosed in applicant's copending application Serial No. 399,453, filed June 24, 1941, now Patent No. 2,333,604, and assigned to the same assignee of this invention. Such a breaker is provided in a tubular casing **2** of insulating material such, for example, as porcelain or the like. Casing **2** preferably has an open top and a closed lower end, as illustrated, and may be supported from an intermediate portion thereof, for example, as by a supporting bracket **3**, or the like. A terminal bolt **4** is provided through an aperture in the closed lower end of casing **3**, and the bolt is provided with an enlarged head **6** within the casing, and is held in position by a nut **8** which also secures a line terminal **10** in conducting relation to the bolt. Packing material **7** is preferably provided beneath the head **6** of terminal bolt **4** to seal the opening in the lower end of casing **2**. A hollow terminal cover assembly **12** is adapted to be seated on the open upper end of casing **2** and be secured thereto in any desired manner such, for example, as by bolts (not shown) joining the cover assembly and

an anchoring ring 13 suitably secured to the upper end of casing 2. Cover assembly 12 is provided with a terminal strap 14 suitably secured to the cover as by a bolt 18, and the terminal strap 14 carries a line terminal clamp 16. A filler plug 20 may be provided for the cover assembly, to permit filling container 2 with liquid when required.

Within casing 2 at the lower end thereof there is provided an arc chamber 22 comprising a tube 24 of insulating material such, for example, as fiber or the like, having end caps 26 and 28 threadedly engaged with the respective ends of tube 24. The lower end cap 28 is provided with a central threaded aperture for receiving a fixed contact 30 which is threaded into the opening, and secured in adjusted position by a lock nut 31. A movable contact 32 is also provided within the arc chamber for cooperation with fixed contact 30, with contact 32 being provided on the lower end of a contact rod 33 which extends through a central opening in the upper cap 26. Movable contact rod 33 is provided with a sleeve 34 of insulating material such, for example, as fiber or the like; and this sleeve closely fits the opening in cap 26 and is secured on contact rod 33 in any desired manner such, for example, as by a tight friction fit. Interrupter chamber end caps 26 and 28 are each provided with apertures 36 and 38, respectively, to permit the flow of fluid into and out of the chamber, with openings 36 being controlled by valve plate 40 movable between the upper end of tube 24 and cap 26. Openings 38 in cap 28 are controlled by a valve plate 42 freely movable between end cap 28 and a stop ring 29 secured in position by the end cap. A liquid directing piston 41 is slidably mounted on the outer reduced end of contact rod 33 for limited movement between sleeve 34 and contact 32. Piston 41 is biased toward contact 32 by a spring 43 and in the closed circuit position, the piston normally engages stop ring 29.

When contact 32 is moved away from fixed contact 30, an arc will be struck, and since the arc chamber is filled with an arc-extinguishing liquid such as oil, the arc will decompose some of the oil and create a pressure within the arc chamber. The rise in pressure within arc chamber 22 will cause both valve plate 40 and valve plate 42 to seat against openings 36 and 38 to effectively close the arc chamber. The pressure generated within arc chamber 22 is thus confined to the chamber and is available to act on the moving contact assembly, comprising rod 33 and sleeve 34, to move it outwardly relative to the chamber and away from fixed contact 30 in a piston-like manner, to draw out the arc and thus aid in extinguishing it. As soon as the arc is extinguished, the pressure in chamber 22 will decrease and this will allow valve plates 40 and 42 to uncover openings 36 and 38. By uncovering openings 36, gases generated by decomposition of the arc-extinguishing fluid will be permitted to escape from chamber 22, and fresh fluid from casing 2 will flow in through openings 38 to replace the used liquid and gases, due to the head of liquid above openings 38. A flushing of the arc chamber 22 will thus occur after each circuit interrupting operation, prior to or during the reclosing operation of the breaker contacts. In a circuit opening operation, piston 41 is not moved until engaged by contact 32, thereafter continued movement causes piston 41 to move into the contact to cause a stream of arc extinguishing liquid to flow through the arc.

Movable contact 32 of the breaker may be separated from fixed contact 30 by a solenoid coil 44 connected in series in the circuit. The solenoid coil is preferably formed on an insulating supporting collar 46, and is supported in a hollow supporting frame 48 of a magnetic material, such as soft iron or the like. Hollow supporting frame 48 is secured to the top cover structure by bolts 15 and has at least one open side to permit insertion and removal of the solenoid coil, and removal of the solenoid coil from the hollow supporting frame is normally prevented by a cylindrical sleeve 50 of insulating material, such as fiber or the like, which maintains a flanged collar 52 into engagement with a flange about a central opening in the upper side of frame 48. Sleeve 50 may be inserted in frame 48 through an opening in the lower side of the frame, and is maintained in this position by a substantially rectangular supporting frame 54 which is bolted to solenoid frame 48 by bolts 56. Supporting frame 54 may be integral with top cap 26 of the arc chamber, so as to support the arc chamber from the solenoid frame, and the latter is secured to cap assembly 12 as by bolts 56. A cylindrical dashpot piston 58 is slidably mounted within sleeve 50, and this piston is of magnetic material to form a core for solenoid 44 which will be attracted upwardly into the coil upon energization thereof. Piston 58 may be provided with a non-magnetic spacer ring 60, of brass or the like, to prevent residual magnetism from impeding downward movement of piston 58. Piston 58 is provided with a flange 62 defining an opening at the lower end thereof which closely fits an actuating rod 64 extending centrally upwardly through the solenoid and dashpot cylinder and piston structure. Actuating rod 64 is secured to movable contact rod 33 as at 66, so as to actuate contact 32 by movement thereof. The upper end of actuating rod 64 above solenoid supporting frame 48 has a sleeve 68 secured thereto which is adapted to be engaged by a collar 70 slidably mounted on the actuating rod. Collar 70 is threadedly engaged in the upper end of cylindrical tube 72, and a light coil compression spring 74 is positioned within tube 72 and reacts between collar 70 and piston 58, to bias the piston to its lower limit of movement.

Actuating rod 64 is connected by a pair of links 76 of insulating material such, for example, as fiber or the like, to a reclosing crank 78 rotatably mounted on a shaft 80 extending across the hollow space within cover assembly 12. A generally U-shaped spring control member 82 has the leg portions thereof rotatably mounted on shaft 80, and a coil spring 84 has one end 86 thereof engaging crank 78, and the other end 88 engages spring control member 82 so as to bias crank 78 in a clockwise direction such that movable contact 32 is biased into engagement with fixed contact 30. The contacts are biased into engagement by coil spring 84 only provided that spring control member 82 is maintained against movement. The spring control member 82 is normally held against movement about shaft 80 by an over-center toggle comprising toggle levers 89 and 90 secured to control member 82 and a fixed pivot 91 in the cover, respectively. Toggle levers 89 and 90 are pivoted together and normally maintained, as shown in Fig. 1, below center by the fact that toggle lever 90 has an operating handle 92 which engages an adjustable stop screw 94 mounted in a hood structure 208 integral with cover structure 12.

It will now be apparent that upon energization of solenoid 44, dashpot piston 58 will be attracted upwardly into the coil while compressing spring 74. This movement of piston 58 upwardly will be delayed by the necessity of displacing liquid entrapped between the piston and collar 52 through the relatively small clearance with sleeves 50 and 72. Moreover, since spring 74 is relatively weak, this initial movement of piston 58 will not actuate movable contact 32 because it is held in closed circuit position by the relatively strong closing spring 84. Since flange 62 on piston 58 engages the lower end of sleeve 72 during its upward movement and moves the sleeve upwardly until collar 70 engages sleeve 68 on actuating rod 64, a positive drive connection with actuating rod 64 is effected to thereby positively separate movable contact 32 from fixed contact 30. Separation of the contacts produces pressure within arc chamber 22 as previously described, and this pressure acting on the movable contact assembly in a piston-like manner may further separate the contacts a greater distance than that due to solenoid 44, because the movable contact assembly has lost motion relative to piston member 58. After the movable contact 32 has separated from contact 30 a distance sufficient to extinguish the arc, spring 84 may then move contact 32 in a reverse direction back toward fixed contact 30, because of the reduction in pressure in the arc chamber, and because solenoid 44, being in series in the circuit, will deenergize. However, closing movement of contact 32 will be impeded by the dashpot action of piston 58. If desired, a latch may be provided for maintaining contact 32 at an open circuit position, with the latch arranged to be tripped by piston 58 after predetermined downward movement thereof. Such a latch is fully disclosed in the above-mentioned copending application.

In order to maintain the breaker contacts separated when toggle 89, 90 is moved upwardly overcenter, a rod 98 is pivoted to spring control member 82, and is slidably received in an apertured ear 100 integral with cover structure 12. Coil compression spring 102 surrounds rod 98, and reacts between ear 100 and a collar 104 fixed to the rod to bias the rod longitudinally to the left, as viewed in Fig. 1 and consequently bias spring control member 82 for rotation in counterclockwise direction about its supporting shaft 80. Toggle levers 89 and 90, when below center in the position shown in Fig. 1, normally prevent movement of spring control member 82 by spring 102, but when the toggle is moved upwardly overcenter, for example as by manually pulling downwardly on operating handle 92, spring 102 will then be free to expand and to maintain the breaker contacts in open circuit position. Operating handle 92 may be provided with an enlarged hook-eye aperture 106 for the reception of a hookstick operating member or the like.

Integrating means is provided for counting the number of closely successive circuit interrupting operations of the breaker to automatically move toggle levers 89 and 90 upwardly overcenter in response to a predetermined number of closely successive circuit interrupting operations to automatically move the breaker contacts to open circuit condition, and to maintain them in such condition until manually reset. The integrating means as well as the novel control for determining the time characteristic of successive circuit interrupting operations is mounted on top of solenoid supporting frame 48 below the normal

liquid level in container 2, and is more particularly shown in Fig. 3. As shown in this figure, a cylindrical dashpot sleeve 108 is threadedly mounted in an aperture provided in the top of solenoid supporting frame 48, with an apertured collar 110 threaded into the lower end of this aperture to secure a stop washer 113 between the collar and dashpot cylinder 108. A ball check valve 112 is adapted to close the opening in collar 110, but the ball is freely movable between the collar 110 and stop washer 113, all for a purpose to be described. An integrator piston 114 is slidably mounted within dashpot cylinder 108 and is provided above the lower end thereof with a plurality of reduced areas 116 forming in effect a ratchet formation, which is accessible through opening 125 in cylinder 108. The upper end of ratchet piston 114 is threaded for threadedly receiving a control section 118. As shown in Fig. 3, the section 118 is of an insulating material, having a reduced threaded extension for receiving a control section 120 of conducting material, and the latter in turn has a reduced threaded extension for receiving an outer section 122 of insulating material. Piston 114 is provided at its upper end with a lock nut 124 for securing section 118 at the proper position on the piston. A generally U-shaped pawl 126 is provided at one side of dashpot cylinder 108 for cooperation with the ratchet portion of piston 114. Pawl 126 has the lower leg thereof apertured so as to be slidable on a fixed guide rod 128 also mounted in the top of solenoid supporting frame 48. A coil compression spring 130 reacts between a collar fixed on guide rod 128 and the lower leg of pawl 126, to normally maintain the pawl seated on solenoid supporting frame 48. The upper leg of pawl 126 is slotted as at 132 for receiving the guide rod, and the bight portion of pawl 126 is also slotted as at 134 for receiving sleeve 68 mounted on the upper end of actuating rod 64.

The integrator structure thus far described is actuated upon each circuit interrupting operation of the breaker by upward movement of collar 70. When moved upwardly, collar 70 engages the bight portion of pawl 126 to pivotally move the pawl so that end 129 thereof moves into engagement with a reduced section 116 of piston 114. Further upward movement of collar 70 causes upward movement of the pawl and piston 114 a predetermined amount. Upward movement of piston 114 causes ball valve 112 to be unseated so that liquid is drawn into the lower end of dashpot cylinder 108. Upon reclosure of the circuit breaker, pawl 126 is moved downwardly and withdrawn from engagement with a reduced section of piston 114 by compression spring 130. If the condition causing opening of the breaker has disappeared upon reclosure thereof, piston 114 will slowly return to the position shown in Fig. 3 under the influence of gravity. This return movement is very slow because of the dashpot action requiring liquid drawn into cylinder 108 beneath piston 114 to be displaced through the relatively small clearance between the piston and cylinder. If the overload which caused the first circuit interrupting operation has not cleared upon the first reclosure of the breaker, the breaker will immediately reopen, and this time pawl end 129 will engage the next lower reduced section 116 of piston 114, because the piston will not as yet have had time to return to its original position. Accordingly, a second closely successive circuit interrupting operation will cause piston 114 to be advanced up-

wardly beyond the position to which it is moved on the first circuit interrupting operation. Now upon the second reclosure of the breaker, dashpot piston 114 will reset to its original position if the contacts do not immediately open. However, if the fault is still present on the circuit, the breaker will again immediately reopen, and this time pawl end 129 will engage the next lower reduced section 116 of piston 114, and this time the piston will be raised far enough so that end section 122 will engage the knee of toggle levers 89 and 90 to move them overcenter and release spring 102, and permit it to maintain the breaker contacts at open circuit position. With the integrator structure described above, it will be apparent that the breaker contacts will be locked or maintained in open circuit position by spring 102 only in response to a predetermined number (three or four in the embodiment illustrated) of closely successive circuit interrupting operations. If the overload or fault clears before the breaker has time to complete this predetermined number of closely successive circuit interrupting operations, then the integrator structure will reset so that the next time a fault appears upon the circuit the breaker will go through the same predetermined number of closely successive circuit interrupting operations before the contacts are maintained open by spring 102.

Solenoid 44 being connected in series in the circuit acts substantially instantaneously in response to an overload or a short circuit to separate the circuit breaker contacts. Since a high percentage of faults are of the self-clearing type, it is desirable that upon the occurrence of a fault at least one of the circuit interrupting operations of the breaker before lockout of the breaker be delayed for a predetermined time to permit the fault to clear itself, if it is of that type. It is generally desirable that this time delay be introduced upon the second successive circuit interrupting operation of the breaker. This will give a first instantaneous circuit opening operation which is fast enough to open the circuit before any branch circuit fuses blow, so that if the fault is merely transient in nature, it will have cleared upon reclosure and service will be fully restored on all circuits. However, if the fault is still on the circuit upon the first reclosure, a time delay introduced at this time permits the fuse protecting the faulted branch circuit to blow before the second opening and subsequent reclosure so that upon the second reclosure the faulted branch will have been isolated and service will be restored to all other branch circuits. If the fault has not then cleared, it may be desirable to make the third successive circuit opening instantaneous, so that lockout will immediately take place. It is also desirable that the time delay interrupting operation of breaker have thermal characteristics to permit better coordination with fuses and with other breakers. One manner of accomplishing the foregoing desirable results is by using the integrator structure described above to control operation of solenoid 44.

As shown in Figs. 3 and 4, a contact finger 136 is supported on the upper end of guide rod 126, and this contact finger is adapted to bear on one side of the upper end of piston 114 made up of control sections 118, 120 and 122. A contact finger 138 is supported in a position to engage the opposite side of the upper section of piston 114, by an angular supporting bracket 140 of insulating material also mounted on solenoid supporting frame 48. Bracket 140 also supports a bimetal element which is preferably of the snap-acting type. The bimetal element illustrated may be of the circular disc type comprising a pair of metallic laminations intimately secured together in a manner well known in the art, with lamination 142 being of a material which has a relatively low coefficient of thermal expansion such as steel, and the lamination 144 being of a material having a relatively high coefficient of thermal expansion such as brass or the like. This composite disc 141 is preferably concavo-convex in section, so that upon reversal of curvature thereof, the disc will change its convexity with a snap action. To take advantage of this action of the disc, it is preferably supported at opposed points adjacent the periphery thereof, and the central part of the disc is provided with a contact 146 normally engageable with a contact 148 mounted on a bracket 147, of insulating material.

Referring to Fig. 4, it will be observed that solenoid 44 is connected in series in the circuit, by a conductor 150 with contacts 30 and 32 of the breaker. Conductor 150 is also connected with contact 148 and bimetal element 141. Conductor 152 associated with contact finger 136 connects this contact finger to the other side of solenoid coil 44, so that the bimetal element 141 and the switching means, comprising contact fingers 136, 138 and the integrator piston, are connected in series in a shunt circuit about solenoid coil 44.

At the position of the parts shown in Figs. 3 and 4, the shunt circuit including bimetal element 141 is open, so that all of the current must pass through solenoid 44. This means that, when a fault appears upon the circuit, the breaker will be relatively instantaneously opened by the solenoid coil 44. This opening operation of the breaker advances integrator piston 114 in the manner described above, so as to bring conducting control section 120 thereof into a position where it bridges contact fingers 136 and 138. Now upon reclosure of the breaker, it will be observed that the shunt circuit about solenoid coil 44 including bimetal element 141 will be closed. Since this shunt circuit has less impedance than the solenoid coil, it will carry substantially all of the current, so that if the fault is still on the circuit upon the first reclosure, solenoid 44 is ineffective to cause a second opening of the breaker because it is bypassed by the shunt circuit including bimetal element 141. The overload current will cause heating of bimetal disc 141 up to the point where it reverses its curvature with a snap action to separate its contact 146 from fixed contact 148, thus opening the shunt circuit for the solenoid coil, whereupon the solenoid coil 44 again carries the overload current and effects an opening of the breaker contacts. Upon this second closely successive circuit opening operation of the breaker, piston control section 118 is elevated to a position between contact fingers 136 and 138 to thereby open the shunt circuit about solenoid coil 44, so that upon the second reclosure the third opening operation will be relatively instantaneously effected by solenoid coil 44, if the fault still remains on the circuit. It will be noted that the provision of switching means for the shunt circuit includes a bimetal element 141 the energization of which is controlled by the position of integrator piston 114, so that a predetermined sequence of instantaneous and time delay circuit interrupting operations is insured, whenever the breaker goes through its predetermined number of circuit interrupting operations and finally locks the circuit open. Moreover, if the fault clears before lockout of the breaker, the inte-

grator resets, as previously described, so that if a fault again comes on the circuit at a later time, the means controlling the time characteristic of the circuit interrupting operations is also reset, and the same sequence of instantaneous and time delay circuit interrupting operations will occur. The integrator structure disclosed, thus not only determines the number of closely successive circuit interrupting operations which occur prior to lockout of the breaker and resets so that the breaker locks out only in response to that number of closely successive circuit interrupting operations, but this integrator also determines the time characteristic of closely successive circuit interrupting operations, and is arranged so that the resetting of the integrator also resets the time characteristic control so that the same sequence of instantaneous and time delay circuit interrupting operations always occurs on closely successive circuit interrupting operations.

In Figs. 5 and 6 of the drawings, there is illustrated a modified form of control means for determining the time characteristic of closely successive circuit interrupting operations. This control means also may be associated with the integrator structure shown in Figs. 1 to 4, and since most of this structure is identical with that previously described, like reference numerals are used to designate such identical parts. In this embodiment of the invention, but a single set of contacts is provided for control of a shunt circuit about solenoid coil 44, and these comprise a fixed contact 154 mounted on a supporting bracket 156 suitably secured to the frame 48 for solenoid 44, for example, as by a screw 158 with washers 159 of insulating material interposed between the bracket, frame and screw to electrically isolate these parts. A contact 160 is provided on a bell crank 162 pivotally mounted on the solenoid supporting frame by an insulating pivot pin 164, and is normally biased in a counterclockwise direction to maintain the contacts separated, by a coil spring 166 wound about pivot axis 164 and reacting between the bell crank lever and solenoid supporting frame 48. An adjustable stop screw 168 is threadedly engaged through the leg of bell crank lever 162 adjacent the supporting frame, so as to be engageable with the frame and limit movement of the bell crank in a direction to separate contact 160 from contact 154. It will be noted that the end 171 of the bell crank lever overlies collar 70 so that upon a circuit interrupting operation of the breaker bell crank 162 will be rotated in a clockwise direction by upward movement of collar 70 to cause contact 60 to engage contact 154, and thus close the shunt circuit about solenoid coil 144. Contact 160 is adapted to be latched in engagement with contact 154 by a catch 172 which is engageable with the curved latching tip 170 of the bell crank under certain conditions which will hereinafter be pointed out. Catch 172 is provided on the outer end of an ordinary strip bimetal element 174. This type of bimetal element is well known in the art, and comprises a pair of laminations 176 and 178 of different materials having relatively low and high coefficients of thermal expansion, respectively. In this instance, the bimetal element 174 is positioned with the low coefficient of expansion lamination 176 at the upper side, and with the high coefficient of expansion lamination 178 at the lower side, so that upon heating, the bimetal element will bend so as to be concave upwardly, from the position shown in Fig. 5. Bimetal element 174 is pivotally mounted on an insulating pivot pin 180 on a supporting bracket 182 which may be welded or otherwise secured on dashpot cylinder 108. A spring 184 is coiled about pivot 180 and reacts between insulating button 181 on bracket 182 and the bimetal element to bias the bimetal element for pivotal movement in a clockwise direction. Dashpot piston 114 in this embodiment of the invention is provided with a solid extension 188 secured to the upper end thereof, and has a resetting lug 190 of insulating material, which normally engages the inner end of bimetal element 174 to maintain the bimetal element at a position wherein catch 172 is out of the path of movement of the latching tip of bell crank 162. Fig. 6 illustrates how this control assembly is connected in the circuit with conductor 192 secured to the inner end of bimetal element 174 being connected to one side of solenoid coil 44. The outer end of bimetal element 174 is connected by flexible conductor 196 to the bell crank lever and its contact 160, and the other contact 154 is connected by a conductor 194 with the other side of solenoid coil 44.

In the normal closed circuit position of the breaker shown in Figs. 5 and 6, the contacts 154 and 160 of the shunt circuit for solenoid coil 44 are at their open circuit position, so that when a fault occurs on the circuit, solenoid 44 is able to effect a first circuit interrupting operation at substantially the same instant the fault occurs. This circuit interrupting operation results in upward movement of collar 70 and consequent movement of contact 160 into engagement with fixed contact 154. Upward movement of collar 70 also actuates pawl 126 to move dashpot piston 114 upwardly, thereby moving resetting lug 190 out of engagement with bimetal element 174, and permitting spring 184 to move bimetal element 174 in a clockwise direction about its pivot 180 until the inner end thereof engages insulating stop collar 186 provided at the upper end of dashpot cylinder 108. At this position of the bimetal element, catch 172 will be positioned behind latching tip 170 of bell crank 162, so that the bimetal element will be effective to maintain contacts 154 and 160 in engagement. Accordingly, when the circuit breaker is reclosed, the shunt circuit including bimetal element 174 about solenoid coil 44 will be closed, and since this circuit has less resistance or impedance than solenoid coil 44, substantially all of the current will pass through the bimetal element when the breaker is reclosed. If the fault clears upon this first reclosure of the breaker, dashpot piston 114 will slowly sink to its original position, as previously explained, until resetting lug 190 engages the bimetal element and rotates it in a counterclockwise direction to remove catch 172 from latching tip 170 of bell crank lever 162, to thereby permit spring 166 to separate the contacts and reset them in open circuit position, as shown in Fig. 5. However, if the fault has not cleared upon the first reclosing operation of the breaker, the breaker will not immediately reopen because it will be necessary to wait until bimetal element 174 has heated sufficiently to deflect enough to remove catch 172 from behind latching tip 170 and permit spring 166 to open contacts 154 and 160. Only after this has occurred will solenoid coil 44 be energized sufficiently to open the circuit breaker contacts. Upon the second reclosure of the circuit breaker, bimetal 174 will not have had time to cool down sufficiently to resume its normal straight condition, so that if the fault remains on the circuit the third and final circuit inter-

rupting operation will occur substantially instantaneously, because the solenoid coil 44 is not shunted by the bimetal element. Accordingly, upon the occurrence of continuing overloads or faults, the control means illustrated in Figs. 5 and 6 provide a first substantially instantaneous circuit interrupting operation, followed by a second time delayed circuit interrupting operation and finally a third substantially instantaneous interrupting operation, prior to lockout of the breaker. Furthermore, if at any time the overload or fault be cleared, the control means for determining the time characteristic of closely successive circuit interrupting operations will be reset to provide the same sequence of instantaneous and time delayed circuit interrupting operations in the event of a plurality of closely successive operations of the breaker occurring in response to a fault which comes on the circuit at a later time.

With the exception of the particular means controlling the time characteristic of closely successive circuit interrupting operations disclosed herein, the remaining features and structures of the breaker are substantially the same as the corresponding features and structures of the breaker disclosed in the above-mentioned copending application; such features including in addition to those already mentioned, the provision of a lightning arrester assembly 198 mounted within the hollow cover structure 12 and adapted to be connected in shunt with solenoid coil 44 as by conductor 200, a counting device 202 may also be provided beneath hood structure 208 integral with the cover structure 12, with the counting device actuated by a link 204 connected to an actuated crank 206 movable with crank 78 so that each interrupting operation will be recorded. Accordingly, for a more detailed description and better understanding of these and other features previously described, reference is hereby made to the above-identified copending application.

From the foregoing, it is apparent that this invention provides a novel electrical control for determining the time characteristics of closely successive circuit interrupting operations of an automatic reclosing circuit breaker, to provide at least a first substantially instantaneous circuit interrupting operation, a second time delayed opening operation, and a third instantaneous opening of the breaker, in any series of closely successive interrupting operations prior to lockout of the circuit breaker. Furthermore, by the association of the control means with integrator structure for causing the lockout operation, the control means is reset if the fault clears prior to lockout, so that when a fault appears upon the circuit at a later time the same sequence of instantaneous and time delayed circuit interrupting operations will occur. Thus, an automatically reclosing circuit breaker is provided which is not only responsive solely to a predetermined number of closely successive circuit interrupting operations to lock the breaker contacts open, and in the event of the occurrence of less than this predetermined number of closely successive interrupting operations the breaker will reset so as to require the same predetermined number of closely successive interrupting operations when a fault appears on a circuit at a later time, but there is also provided means for obtaining different time characteristics of this same predetermined number of closely successive circuit interrupting operations, which means also resets in the event a smaller number of closely successive circuit interrupting operations occurs so that the same sequence of instantaneous and time delayed circuit interrupting operations will occur when a fault appears upon the circuit at a later time.

Having described preferred embodiments of the invention in accordance with the patent statutes, it is desired that the invention be not limited to the particular embodiments illustrated, inasmuch as it will be obvious to persons skilled in the art that many changes and modifications may be made in these particular embodiments without departing from the broad spirit and scope of this invention. Thus, for example, it is apparent that in the modification illustrated in Fig. 3 that instead of providing the first interrupting operation be instantaneous, the second time delayed, and the third instantaneous, any desired sequence of instantaneous and time delayed circuit interrupting operations may be obtained, by merely changing the order in which control sections 118, 120 and 122 are mounted on the outer end of integrator piston 114. Thus, by mounting conductor section 120 above sections 118 and 122, a first time delayed interruption, and second and third instantaneous interruptions will be obtained. Accordingly, it is desired that the invention be interpreted as broadly as possible, and be limited only as required by the prior art.

I claim as my invention:

1. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, electro-responsive means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, second electro-responsive means responsive to said predetermined conditions for causing separation of said contacts a predetermined time after the occurrence of said conditions, a single electrical control means connected in a circuit with both of said electro-responsive means for determining which one of said condition responsive means will be effective to cause separation of said contacts, and means actuated by said interrupter on each circuit opening operation of said contacts, for actuating said control means, whereby successive circuit interrupting operations may have successively different time characteristics.

2. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, electro-responsive means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, second electro-responsive means responsive to said predetermined conditions for causing separation of said contacts a predetermined time after the occurrence of said conditions, electrical control means having a normal position, said control means connected in a circuit with both of said electro-responsive means determining which one of said condition responsive means will be effective to cause separation of said contacts in accordance with the amount said control means is advanced from its normal position, and means actuated by said interrupter on each circuit opening operation thereof for advancing said control means a predetermined amount in response to each circuit opening operation of said interrupter, whereby successive circuit interrupting opera-

tions may have successively different time characteristics.

3. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, means responsive to said predetermined conditions for causing separation of said contacts a predetermined time after the occurrence of said conditions, electrical control means having a normal position, said control means determining which one of said condition responsive means will be effective to cause separation of said contacts in accordance with the amount said control means is advanced from its normal position, means for slowly moving said control means back to its normal position when it has been advanced therefrom, and means actuated by said interrupter for advancing said control means a predetermined amount in response to each circuit opening operation of said interrupter, whereby closely successive circuit interrupting operations of said interrupter may have successively different time characteristics, and each series of closely successive circuit interrupting operations will have the same time pattern of circuit interrupting operations.

4. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, means responsive to said predetermined conditions for causing separation of said contacts a predetermined time after the occurrence of said conditions, electrical control means having a normal position, said control means determining which one of said condition responsive means will be effective to cause separation of said contacts in accordance with the amount said control means is advanced from its normal position, means for slowly moving said control means back to its normal position when it has been advanced therefrom, means actuated by said interrupter for advancing said control means a predetermined amount in response to each circuit opening operation of said interrupter, whereby closely successive circuit interrupting operations of said interrupter may have successively different time characteristics, and each series of closely successive circuit interrupting operations will have the same time pattern of circuit interrupting operations, and means responsive to advancement of said control means an amount greater than a predetermined multiple of said predetermined amount for maintaining said separable contacts in open circuit position.

5. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, normally closed time delay switch means responsive to said predetermined conditions for opening its contacts a predetermined time after the occurrence of said conditions, control switch means for connecting said time delay switch means in shunt circuit with said instantaneous means, and means actuated by said interrupter for actuating said control switch means in response to a circuit opening operation of said interrupter, whereby the next succeeding circuit interrupting operation will have a different time characteristic than the preceding interrupting operation.

6. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, normally closed time delay switch means responsive to said predetermined conditions for opening its contacts a predetermined time after the occurrence of said conditions, control switch means for connecting said time delay switch means in shunt circuit with said instantaneous means, means actuated by said interrupter for actuating said control switch means comprising an integrating member which is advanced a predetermined amount from a normal position in response to each circuit opening operation of said interrupter, and means for slowly moving said integrating member back toward its normal position, whereby closely successive circuit interrupting operations of said interrupter may have successively different time characteristics, and each series of closely successive circuit interrupting operations will have the same time pattern of circuit interrupting operations.

7. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, normally closed time delay switch means responsive to said predetermined conditions for opening its contacts a predetermined time after the occurrence of said conditions, control switch means for connecting said time delay switch means in shunt circuit with said instantaneous means, means for actuating said control switch means comprising an integrating member which is actuated by said interrupter to be advanced a predetermined amount from a normal position in response to each circuit opening operation of said interrupter, means for slowly moving said integrating member back toward its normal position, whereby closely successive circuit interrupting operations of said interrupter may have successively different time characteristics, and each series of closely successive circuit interrupting operations will have the same time pattern of circuit interrupting operations, and means responsive to advancement of said control means an amount greater than a predetermined multiple of said predetermined amount for maintaining said separable contacts in open circuit position.

8. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for separating said contacts, electroresponsive means for preventing said contact separating means from effecting a circuit interrupting operation, switching means actuated by said interrupter in response

to each of a plurality of circuit opening operations of said contacts in any series of closely successive circuit interrupting operations for opening and closing the circuit of said electroresponsive means to render said electroresponsive means ineffective and effective, respectively, to prevent operation of said condition responsive means, and said electroresponsive means when rendered effective being responsive to said predetermined conditions only a predetermined time after the occurrence thereof to render said contact separating means effective to separate said contacts, whereby said contacts are separated substantially instantaneously in at least one operation of said series, and with a time delay in at least one other operation of said series.

9. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for separating said contacts, electroresponsive means for preventing said contact separating means from effecting a circuit interrupting operation, integrating means which is advanced by said interrupter a predetermined amount from a normal position in response to each circuit opening operation of said contacts, means for slowly returning said integrating member to its normal position after advancement, whereby said integrating member will be advanced an amount greater than said predetermined amount in response to a plurality of closely successive circuit interrupting operations, or will reset to its normal position in the event successive circuit interrupting operations do not closely succeed each other, switching means controlled by the position occupied by said integrating member for opening and closing the circuit of said electroresponsive means to render said electroresponsive means effective or ineffective to prevent separation of said contacts, said electroresponsive means when rendered effective responding to said predetermined conditions a predetermined time after the occurrence thereof to render said contact separating means effective to separate said contacts, and means actuated by said integrating means when advanced said greater amount to maintain said contacts separated.

10. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, means responsive to said predetermined conditions for causing separation of said contacts a predetermined time after the occurrence of said conditions, said time delay means being adapted to control separation of said contacts when both of said means are operatively connected to the circuit, switching means for controlling the connection of said time delay means to the circuit, and means actuated by said interrupter for actuating said switching means in response to each circuit opening operation of said interrupter, whereby successive circuit interrupting operations may have successively different time characteristics.

11. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, means responsive to said predetermined conditions for causing separation of said contacts a predetermined time after the occurrence of said conditions, said time delay means adapted to control separation of said contacts when both of said means are operatively connected to the circuit, switching means for controlling the connection of said time delay means to the circuit, means actuated by said interrupter for actuating said switching means in response to each circuit opening operation of said interrupter, whereby successive circuit interrupting operations may have successively different time characteristics, said switch actuating means having a normal position at which said switching means disconnects said time delay means from the circuit, and means biasing said switch actuating means for slow movement back to its normal position in response to an actuation thereof, whereby the first operation of any series of closely successive circuit interrupting operations will occur substantially instantaneously, and the second operation will be delayed a predetermined time.

12. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, electromagnetic means connected in series with said contacts to separate said contacts in response to overloads greater than a predetermined value, a low resistance shunt circuit around said electromagnetic means containing current responsive time delay circuit opening means, means actuated by said interrupter in response to a predetermined circuit opening operation for closing said shunt circuit, whereby at least the next closely succeeding circuit interrupting operation is delayed for the period of time required for operation of said time delay means.

13. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, electromagnetic means connected in series with said contacts to quickly separate said contacts in response to overloads greater than a predetermined value, a low resistance shunt circuit around said electromagnetic means containing current responsive time delay circuit opening means, means actuated by said interrupter in response to a predetermined circuit opening operation for closing said shunt circuit, whereby at least the next closely succeeding circuit interrupting operation is delayed for the period of time required for operation of said time delay means, and means for opening said shunt circuit a greater predetermined time after said predetermined circuit interrupting operation so that a series of circuit interrupting operations occurring at a later time will have the same sequence with respect to time characteristics.

14. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, electromagnetic means connected in series with said contacts to separate said contacts in response to overloads greater

than a predetermined value, a low resistance shunt circuit around said electromagnetic means containing current responsive circuit opening means for controlling at least a predetermined circuit opening operation of a series of successive circuit opening operations by said electromagnetic means, and means actuated by said interrupter for opening said shunt circuit in response to a predetermined circuit opening operation of any such series of operations.

15. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, electromagnetic means connected in series with said contacts to separate said contacts in response to overloads greater than a predetermined value, a low resistance shunt circuit around said electromagnetic means containing current responsive circuit opening means for controlling at least a predetermined circuit opening operation of a series of successive circuit opening operations by said electromagnetic means, means for delaying a circuit opening operation of said current responsive means, and means actuated by said interrupter for opening said shunt circuit in response to a predetermined circuit opening operation of any such series of operations.

16. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, electromagnetic means connected in series with said contacts to separate said contacts in response to overloads greater than a predetermined value, means for delaying a predetermined circuit opening operation of said electromagnetic means including a low resistance circuit connected in shunt relation with said electromagnetic means at least on said predetermined circuit opening, current responsive time delay circuit opening means in said shunt circuit, and means actuated by said interrupter for opening said shunt circuit in response to a predetermined circuit opening operation of any such series of operations.

17. In an automatic reclosing circuit interrupter, separable contacts adapted to separate to open the circuit, means for automatically reclosing said contacts in response to a circuit interrupting operation thereof, means substantially instantaneously responsive to predetermined electrical conditions in the circuit for causing separation of said contacts, means responsive to said predetermined conditions for causing separation of said contacts a predetermined time after the occurrence of said conditions, electrical control means having a normal position, said control means determining which one of said condition responsive means will be effective to cause separation of said contacts in accordance with the amount said control means is advanced from its normal position, means for slowly moving said control means back to its normal position when it has been advanced therefrom, means actuated by said interrupter for advancing said control means a predetermined amount in response to each circuit opening operation of said interrupter, whereby closely successive circuit interrupting operations of said interrupter may have successively different time characteristics, and each series of closely successive circuit interrupting operations will have the same time pattern of circuit interrupting operations, means responsive to advancement of said control means an amount greater than a predetermined multiple of said predetermined amount for maintaining said separable contacts in open circuit position, and means for preventing return of said control means when said contacts are maintained separated.

18. In an automatic reclosing circuit breaker, separable contacts, electroresponsive means having a single movable portion for always causing separation of said contacts in response to a predetermined electrical condition of the circuit, said contacts automatically reclosing in response to a circuit interrupting operation, means responsive to a sequence of a predetermined number of closely successive circuit interrupting operations to cause said contacts to remain separated, normally ineffective electroresponsive time delay means, means electrically connecting said time delay means and said solenoid coil and being responsive to at least one circuit interrupting operation for delaying a closely succeeding circuit opening operation by said electroresponsive means, the movable portion of said electroresponsive means being at all times free from a mechanical restraining interlocking of said time delay means.

19. An automatic reclosing circuit breaker, comprising, separable contacts, a solenoid coil connected in series circuit relation with said contacts for causing separation of said contacts in response to over-currents in the circuit, means for automatically closing said contacts following a circuit opening operation thereof, normally ineffective electroresponsive time delay means, means electrically connecting said time delay means and solenoid coil and operated by said breaker for rendering said time delay means effective to delay the next closely succeeding circuit opening operation of said breaker, and said solenoid having a movable core for always causing contact separation which is at all times free from a mechanical restraint by said time delay means.

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