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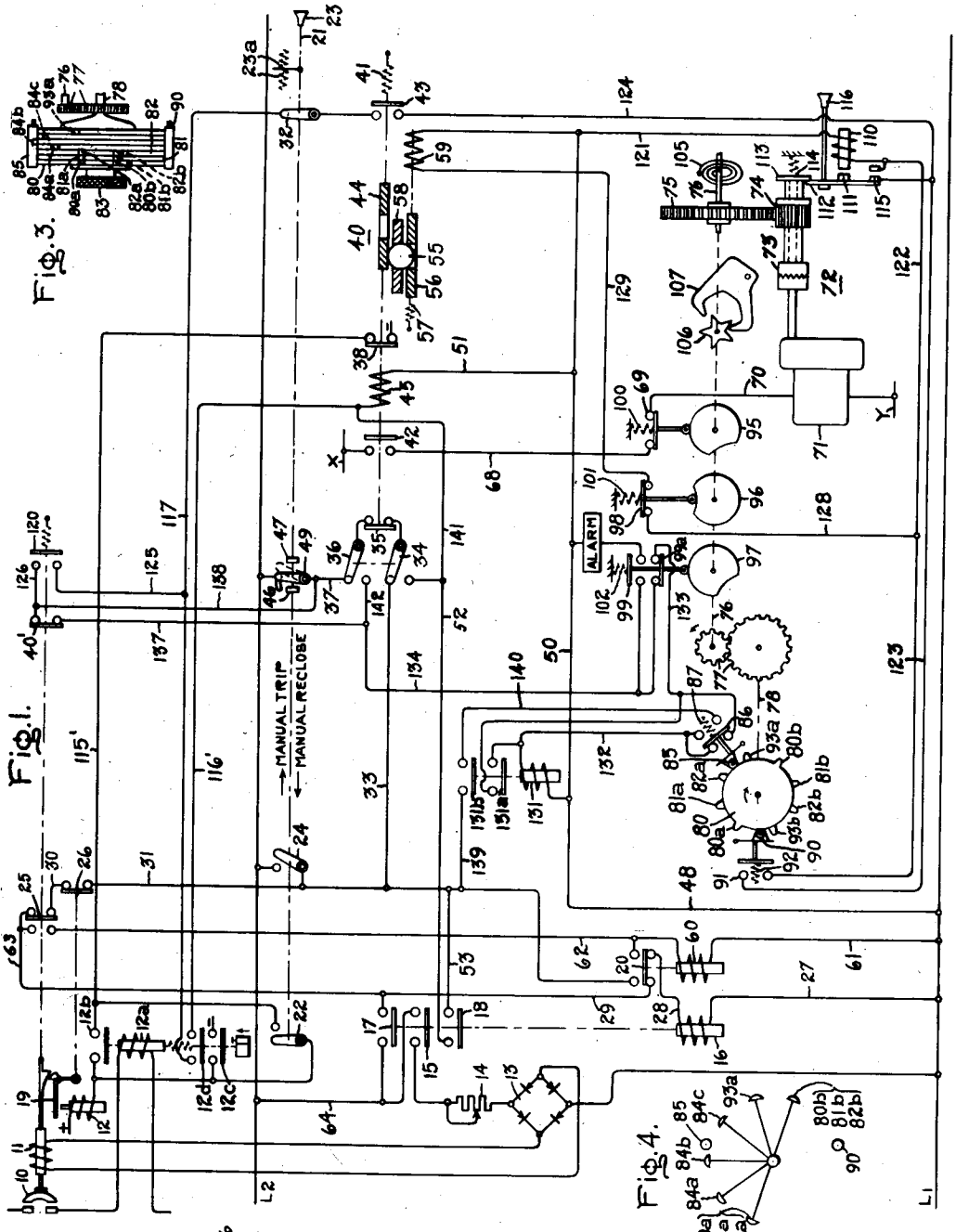


Fig. 1.

Fig. 3.

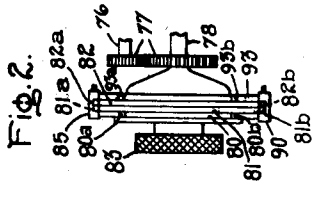


Fig. 2.

Fig. 4.

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AUTOMATIC CIRCUIT BREAKER RECLOSING SYSTEM AND APPARATUS

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The invention relates to automatic circuit breaker reclosing control and the principal object is to provide an improved convertible system and apparatus for automatically reclosing a fault-responsive circuit breaker upon automatic opening thereof and convertible to produce an initial reclosure either instantaneously or time-delayed as selected followed by one or more consecutive time-delayed reclosures in case the circuit breaker fails to remain closed for a limited check interval after each reclosure thereof due to a continuing fault.

Another object is to provide an improved automatic timing cycle interrupting and restarting form of motor-driven cam-operated check interval and time-delay reclosure sequencing switch mechanism for cooperating with an improved two-position interlocking multi-contact switch mechanism and auxiliary switches operated by the circuit breaker to preset an instantaneous reclosure circuit in response to the circuit breaker remaining closed at the end of a check interval and responsive to a subsequent instantaneous reclosure and opening of the breaker during the ensuing check interval to produce a predetermined number of consecutive time-delay reclosures and sequentially timed check intervals with final lockout at the end of the cycle in case all reclosure attempts prove unsuccessful and with the cooperating elements coordinated promptly to interrupt the cycle and return to restart or initial condition whenever the breaker remains closed at the end of any timed check interval due to clearance of the fault.

Another object is to provide for electromagnetically releasing a clutch to interrupt the timing cycle and restore all the reclosing control elements to their initial condition so as to prevent false operation or break in the sequential time check and reclosure cycle of the coordinated electrically operated reclosing control combination in case of loss of operating power at any time before or after a lockout has occurred.

Another object is to provide for continuous selective adjustment of each time-delay interval between successive reclosure attempts over a relatively wide range as may be required to meet varying operating conditions while always insuring the occurrence of the end of a check interval a predetermined time after each time-delay reclosure attempt.

Another object is to combine a manual closing and tripping control for the breaker with the automatic reclosing control so as to eliminate the possibility of an automatic instantaneous reclosure after the breaker has been manually tripped and then manually reclosed on a fault.

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Another object is to prevent automatic cycle restart after lockout when the breaker is manually reclosed and immediately is tripped automatically while the manual closing control is in the closing position.

Further objects and advantages of the present invention will appear in the following description of the accompanying drawing in which the Fig. 1 is a schematic circuit diagram of a circuit breaker reclosing control system embodying the improvements of the present invention, and Fig. 2 is a broken-away side view of a preferred form of coordinated check interval and adjustable time-delay reclosure controlling cam operated sequential timing switch mechanism.

As shown schematically in Fig. 1, the automatic circuit breaker 10 may be of any conventional type provided with a closing coil 11 for operating the circuit breaker 10 from the open position in which it is shown to the closed position and with a trip coil 12 energized under control of a selective time delay and instantaneous tripping relay 12a in a well-known manner in response to moderate overloads or heavy faults in the circuit controlled by the circuit breaker 10 to trip latch 19 and thereby effect the automatic opening of breaker 10. The closing coil 11 may be connected, as shown, to be energized from alternating current supply lines L1, L2 through a full-wave rectifier 13 with a variable impedance 14 included in the circuit for varying the rectified voltage although other forms of closing devices may be used if desired. The closing coil 11 becomes energized when the contact 15 is closed by a temporarily energizable electroresponsive reclosing control relay or device 16 which simultaneously closes the sealing contact 17 to maintain the operating winding of reclosing relay 16 energized from the supply lines L1, L2 for a brief interval until the contact 20 of the follow-up de-energizing relay 60 is operated from the closed position in which it is shown as more fully described hereinafter. Thus, whenever the reclosing relay 16 is temporarily energized, the circuit breaker closing coil 11 is likewise temporarily energized, thereby to close the breaker 10 which normally will remain latched closed until an overload or fault automatically opens the breaker by releasing latch 19.

In order to manually open and close breaker 10, a multiple contact manually two-way oper-

able control switch indicated generally by the reference character 21 is provided with a contact 22 that is connected to energize the trip coil 12 of the circuit breaker 10 when the manual operating handle 23 is pulled to the right so as to open the breaker for servicing or testing purposes and with a contact 24 for energizing the closing relay 16 when the manual operating handle 23 is pushed to the left so as to restore the breaker into automatic reclosing operation. The two-way switch 21 is provided with suitable springs 23a for returning the manually operable switch to its mid position in which it is shown after manual movement either to the right or to the left. The manual control switch 21 also is provided with a contact 49 that is operated as shown schematically by the lost motion stops 46 and 47 in such a manner that contact 49 is opened by stop 46 to render the automatic reclosing ineffective when handle 23 is moved to the right to manually trip the circuit breaker 10 and remains in the open position when the handle 23 is released to return to the mid position. However, stop 47 serves to reclose contact 49 when the manually operating handle 23 is moved to the left to close the reclosing contact 24, and thereby restore the breaker for automatic reclosing operation. Also the manually operable switch 21 is provided with a contact 32 that is closed when the manual switch 21 is in its mid position as shown but is open when the manual switch 21 is moved either to the right to its trip position or to the left to its reclosed position. Consequently, with the circuit breaker 10 open as shown and contact 49 open as indicated by the dotted lines, the circuit breaker 10 would remain indefinitely in the open position until the manually operable switch 21 is operated to the left in order to close contact 24 and thereby effect a manual reclosure of the circuit breaker 10 and at the same time reclose contact 49.

Upon the manual closure of contact 24, a temporary energizing circuit is completed for the reclosing relay 16 extending from supply line L1 through conductor 27, relay 16, conductor 28, contact 20, conductor 29 and contact 25, conductor 30, contact 26, conductor 31, and thence through the manual reclosing control contact 24 to supply line L2.

The improved automatic reclosing control combination of the present invention provides for selective energization of the circuit breaker reclosing means including relay 16 upon an automatic fault-responsive opening thereof. As explained in detail hereinafter a preset instantaneous reclosure control switch 35 serves to produce an initial instantaneous reclosure or a timing reclosure control switch 86 serves to produce a time-delayed initial reclosure as may be selected by operation of suitable manually operable switches 34 and 36, followed by one or more successive operations of the timing reclosure control switch 86 to produce time-delayed reclosure in case the circuit breaker 10 fails to remain closed for a limited check interval after each reclosure thereof sufficient to indicate elimination of the fault in the circuit controlled by the circuit breaker 10.

To cooperate in the control of the instantaneous as well as of the time-delayed reclosures, the circuit breaker 10 is provided with the auxiliary switch contacts 25 and 26 that are closed when the circuit breaker 10 opens and the latter of which may be of the latch check type as indicated. These auxiliary switch contacts serve in conjunction with the instantaneous reclosing control switch 35 to complete the instantaneous energizing circuit for the reclosing relay 16 extending from the conductor L1 through conductor 27, the operating winding of relay 16, conductor 28, contact 20, conductor 29, contact 25 in its righthand closed position, as shown, conductor 30, contact 26, conductor 31, conductor 33, manually operable switch 34, the preset instantaneous reclosure control switch contact 35, the interconnected manually operable switch 36, conductor 37 and manually operable switch 49 in its closed position to the other supply line L2. In this way, as soon as the circuit breaker 10 opens in response to a fault and closes contact 25 and the latch 19 returns to its latching position to close contact 26, the reclosing relay 16 at once is energized to effect automatic reclosure of the circuit breaker through the preset instantaneous contact 35 and the circuit just traced and seals itself in through the contact 17.

The instantaneous reclosing control switch contact 35 is automatically returned to the preset closed position thereof as shown whenever the circuit breaker 10 remains closed at the end of a check interval by means including a cycle interrupting and restart control switch 91 in order to expedite a succeeding instantaneous reclosing action as explained hereinafter. The instantaneous reclosing control switch contact 35 is part of a two-position interlocking multiple contact switch unit or mechanism indicated generally by the reference character 40 and having the contacts 35 and 39 biased closed by a spring 41 that also serves to bias the automatic control contacts 42 and 43 to the open position in which they are shown with all four contacts mechanically connected to be operated as a unit with the interlocking element 44 against the bias of spring 41 upon energization of the trip winding 45. Trip winding 45 is energized simultaneously with each automatic reclosure of the circuit breaker 10 by operation of the contact 18 of the reclosing relay 16 to its closed position, the energizing circuit extending from line L1 through conductor 48, conductor 50, conductor 51, trip winding 45, conductor 141, conductor 52, contact 18, conductor 53, and thence through conductors 31 and 33, switch 34, contact 35, switch 36, conductor 37 and switch 49 in its closed position to supply line L2. As a result, trip winding 45 immediately opens the preset contact 35 and closes contacts 42 and 43 whereupon the interlock ball 55 is operated by movement of interlocking member 56 to the left by spring 57, thus forcing the ball 55 through guide 58 partially into the opening in the interlocking member 44 so as to hold contact 35 open and contacts 42 and 43 closed until the ball 55 becomes released by energization of the reset winding 58 to preset contact 35 in case the reclosure of circuit breaker 10 proves successful. While a ball latch type of interlocking unit 40 has been shown, it will be understood that the same functions could be equally well accomplished by other forms of latching relays.

Upon the instantaneous reclosure of the circuit breaker 10 in the manner just described, the auxiliary switch contact 25 is operated to its left-hand circuit-closing position to energize the follow-up relay 60 through a circuit extending from line L1, conductor 61, operating winding of relay 60, conductor 62, contact 25 in its lefthand closed position, conductor 63, contact 17 of the reclosing relay 16, and conductor 64 to supply line L2. As a result, contact 20 is opened by relay

60 to de-energize the reclosing relay 16 and thereby the closing coil 11 just as soon as circuit breaker 10 closes in response to energization of the reclosing relay 16. The opening of reclosing relay 16 also opens contact 17 and thereby immediately de-energizes the follow-up relay 60 so that these devices are pump free and both returned to their respective positions in which they are shown immediately upon the closure of breaker 10 provided the instantaneous reclosure contact 35 has previously opened. Otherwise a safety interlock holding circuit would be established for maintaining follow-up relay 60 energized, with this circuit extending from supply line L1 through conductor 61, follow-up relay 60, contact 20 in its upper circuit closing position, conductor 31, conductor 33, switch 34, contact 35, switch 36, conductor 37, and contact 49 in its closed position to supply line L2. This interlock circuit serves to prevent repeated instantaneous reclosures of the circuit breaker 10 in case the instantaneous reclosure control contact 35 should, for some reason such as sticking, welding or the like, remain in its normally closed position when the breaker 10 is reclosed and at once opens in response to a fault. Likewise, when the circuit breaker 10 is closed manually by operation of the manual closing contact 24, the seal in contact 20 of relay 60 effectively prevents more than one operation of the closing solenoid 11 for any one closure of contact 24. Thus if the operator holds contact 24 in the closed position there can be no pumping in case the breaker 10 should immediately open in response to a fault.

When the instantaneous reclosing control switch contact 35 is opened by energization of trip winding 45 in response to the operation of the reclosing relay 16 in the manner previously described, contact 42 of the interlock switching device 40 is simultaneously closed to complete an energizing circuit between suitable supply lines X and Y through conductor 68, contact 69 and conductor 70 to start operation of the driving motor 71 of the reclosing cycle timer indicated generally by the reference character 72. As shown schematically, the driving motor 71 is resettably connected through a releasable clutch 73, pinion 74 and gear wheel 75 to drive the auxiliary timing cam shaft 76 that in turn operates through the gears 77 to drive the main cam shaft 78 at a slower angular speed. As shown more clearly in Fig. 2, the main shaft 78 carries a series of juxtaposed separately angularly adjustable coaxial rotatable members of disks 80, 81, 82 each provided with two diametrically opposite cams so as to form the two interrelated adjustable series of successive cam operating elements 80*a*, 81*a*, 82*a*, and 80*b*, 81*b*, 82*b*, as shown in Fig. 1. A common manually operable clamping element 83 is provided for clamping the juxtaposed disks 80, 81, and 82 in the desired angularly adjusted relation on the shaft 78 to be driven thereby. The adjustable series of cams 80*a*, 81*a*, and 82*a* successively engage with the pivotally mounted roller arm 85 to operate the timing reclosure control switch contact 86 from its left-hand circuit-closing position in which it is shown to its right hand circuit-closing position against the bias of spring 87 at predetermined intervals in the cycle. The interrelated series of adjustable cams 80*b*, 81*b*, and 82*b*, successively engage with the pivotally mounted roller arm 90 to operate the reset control switch contact 91 from its open position in which it is shown to its closed position against the bias of spring 92 during each interval. It is important to note that with the diametrically opposite series of cams as shown, the angular relation of the roller arms 85 and 90 is made less than 180° so as to insure that the reset control switch contact 91 is always closed to end a limited check interval a predetermined fixed time after the time reclosure control switch contact 86 is operated to its righthand circuit-closing position to effect reclosure of the breaker irrespective of the angular adjustment of the separately adjustable disks 80, 81, 82 on the auxiliary drive shaft 78 to separately adjust the successive time delay reclosure intervals. Obviously, the same result can be accomplished with other properly coordinated angular relations between the cams and the rollers if desired. The extra cam 93 always remains fixed on shaft 78 at a predetermined angular position for lockout and cycle interrupting and restart control purposes as explained hereinafter and is provided with a special advanced cam finger 93*b* for operating the cycle interrupting and restart control switch contact 91 at the end of a predetermined check time interval indicating a successful instantaneous reclosure, as explained hereinafter.

The auxiliary shaft 76 carries a lockout cam 95, an interlock resetting control cam 96, and an alarm operating cam 97 that respectively control the operating position of the lockout contact 69, the interlock resetting control contact 98 and the alarm contact 99 which are cam-operated as shown and biased respectively by springs 100, 101, and 102. A biasing spring 105 has one end connected with the auxiliary drive shaft 76 and the other end fixed so as to bias both the auxiliary shaft 76 and the main shaft 78 to rotate in a direction opposite that in which they are operated by motor 71 so as to return, along with the operating cams carried thereby, to the initial position in which these parts are shown to restart the cycle whenever the clutch 73 is disengaged. An escapement wheel 106 and oscillating pallet 107 may be provided for preventing too quick return movement of the parts under the bias of spring 105 in order to reduce impact when the initial position is reached. While indicated as on shaft 76, preferably this escapement is mounted on the high speed pinion gear 74 for increased efficiency.

The clutch 73 is released to restart the cycle by means of the releasing electromagnet 110 that attracts an armature 111 to move the releasing arm 112 into engagement with collar 113 and thereby release the clutch 73 against the bias of spring 114. At the same time, the clutch seal-in contacts 115 are closed. A manual clutch release member 116 also is provided to facilitate testing and adjustment of the control parts.

After the circuit breaker 10 is instantaneously reclosed in the manner previously described and the driving motor 71 is energized by the closing of contact 42 as above described, both the auxiliary cam shaft 76 and the main cam shaft 78 start rotating through limited angles in the directions indicated by the arrows to provide a predetermined check interval after the instantaneous reclosure of the circuit breaker 10. This predetermined check interval is measured by the time required for rotation of the cam 93*b* into engagement with the roller 90 to close the cycle interrupting and restart control switch contact 91 and the further operation of the improved control will depend selectively upon whether circuit breaker

10 reopens during the check interval or remains closed at the end of the check interval.

If the circuit breaker 10 remains closed at the end of the check interval following the initial instantaneous reclosure due to a temporary or transient fault in the circuit controlled by the breaker having disappeared, then the auxiliary contact 120 will also remain closed at the end of the check interval. As a result, when the cycle interrupting and restart control switch contact 91 is closed by cam 93b to end the check interval, a cycle interrupting and restart control circuit will be established for energizing the clutch releasing electromagnet 110 so as to disengage clutch 73 and permit the main biasing spring 105 to return the shafts 76 and 78 along with the cams carried thereby to their initial or starting position in which they are shown. This cycle interrupting and restart control circuit extends from line L1 through conductor 48, conductor 50, conductor 121, the operating winding of clutch release magnet 110, conductor 122, contact 91, conductors 123, 124, contact 43 of the interlocking switch mechanism 40 in its closed position, contact 32 in closed position, conductor 125, the auxiliary contact 120, conductor 126, and manual switch 49 to line L2. The seal-in contact 115 shunts the cycle interrupting and restart control contact 91 and maintains the clutch releasing electromagnet 110 energized during the cycle restarting operation.

During the predetermined check interval, cam 96 has been operated to open the interlock reset control contact 98 as indicated in Fig. 1. However, upon return of the cam shaft 76 to its initial position, contact 98 is reclosed, thereby energizing the reset winding 59 of the interlocking device 40 in parallel with the releasing electromagnet 110 through conductors 128 and 129. The energization of winding 59 moves the interlocking plate member 56 against the bias of spring 57 so as to enable the interlocking ball 55 to move downwardly in guide plate 58 into the position in which it is shown, thereby freeing the interlocking plate member 44 for movement to the right by the biasing spring 41 to reclose the instantaneous reclosing circuit control contact 35 as well as contact 38 and open contacts 42 and 43. The opening of contact 42 de-energizes the timer driving motor 71 and the opening of contact 43 de-energizes both the clutch-releasing electromagnet 110 and the reset winding 59. Thus, it will be seen that all parts of the improved automatic cycle interrupting and restart control system are automatically returned to their initial position when the circuit breaker remains closed at the end of the limited check interval after the instantaneous reclosure thereof so as to be ready to respond instantaneously to any subsequent tripping of the fault-responsive circuit breaker 10. The number of time delay reclosures can be made either three, two or one depending on whether the cam projections 80a, 81a and 82a are separated as shown in Fig. 1 or are arranged "back to back" so as to act simultaneously.

If desired so as to meet some unusual line conditions, instantaneous tripping of circuit breaker 10 may be effectively blocked upon automatic reclosure of the breaker 10 by connecting the energizing circuit for the trip coil 12 by means of conductor 115' through the normally closed contact 38 that is opened during the reclosure of circuit breaker 10 by the energization of trip winding 45 and maintained open until a restart operation is obtained in the manner previously described. In this way, the fault responsive relay 12a is rendered ineffective to energize the trip coil 12 by its instantaneous trip contact 12b in case circuit breaker 10 should be reclosed on a fault while contact 38 is open. However, the fault responsive relay 12a is effective to close its time delay tripping contact 12c so as to trip the circuit breaker 10 a limited time interval after the reclosure thereof. During this limited time interval, any sectionalizing fuses in the circuit or circuits controlled by the circuit breaker 10 may blow, thus isolating the faulted sections and thereby preventing subsequent tripping of the main breaker 10 due to faults in such isolated sections.

Furthermore, if desired to meet some other unusual line conditions, instantaneous reclosure of circuit breaker 10 may be effectively blocked after time delay tripping thereof by closure of the time delay trip contact 12c of the fault responsive relay 12a in the following manner. An additional contact 12d that is closed simultaneously with the time delay trip contact 12c is provided for energizing the interlocking trip winding 45. This energizing circuit extends from supply line L1 through conductors 48, 50 and 51, trip winding 45, conductor 116', contact 12d, conductors 117 and 125 and thence through auxiliary contact 120 and conductor 126 and manual switch 49 to the other supply line L2. Thus, at the same instant time delay trip contact 12c becomes effective to energize trip coil 12 to produce a time delay tripping of the circuit breaker 10, the simultaneously closed contact 12d becomes effective to energize the interlock tripping winding 45 and thereby open the instantaneous reclosure control contact 35. Consequently, when the circuit breaker 10 opens, instantaneous reclosure thereof is effectively blocked due to the opening of instantaneous reclosure control switch contact 35. Closure of contact 42 is also effected to start motor 71 so that subsequent time reclosures are obtained as previously described. Thus the normal operating cycle of the improved automatic reclosing system and apparatus of the present invention can be readily varied to meet various unusual line conditions whenever desired.

In case the circuit breaker 10 should automatically reopen during the check interval provided after the initial instantaneous reclosure thereof, the clutch release electromagnet 110 will not be energized upon closure of the reset contact 91 due to the fact that the auxiliary contact 126 will be open at the time the cycle interrupting and restart control contact 91 is closed. Under such conditions, the cam shafts 76 and 78 will continue to rotate and restart control contact 91 will be reopened by disengagement of cam 93b from the roller 90. After a selected time-delay reclosure period that is always longer than the check interval by a time fixed by the angular relation of roller arms 90 and 85, operating cam element 82a will engage with roller 85 to move contact 86 to its righthand circuit-closing position in which the first time-delay reclosure of breaker 10 is effected.

While an antipump control of the reclosing solenoid 11 is provided by operation of the closing relay 16 and the follow-up relay 89 as previously described, additional anti-pump control relay 131 is provided for use where the circuit breaker closing coil 11 may not already be provided with antipump protection. The additional or back-up antipump relay 131 is energized upon the opening of circuit breaker 10 through a circuit

extending from line L1, conductor 48, the operating winding of relay 131, conductor 132, contact 86 in its left hand position to which it is biased as shown, conductor 133, contact 99a, conductors 134 and 137, contact 40' which is closed upon opening of the circuit breaker 10, conductor 138 and manually operated switch 49 in its closed position to line L2.

Thus the movement of the timing reclosure control switch contact 86 to its righthand circuit-closing position establishes an energizing circuit for the reclosing relay 16 that extends from line L1 through conductor 27, the operating winding of reclosing relay 16, conductor 28, contact 20, conductors 29 and 63, auxiliary contact 25, conductor 30, auxiliary contact 26, conductor 31, conductor 139, contact 131b, conductor 140, contact 86 in its righthand circuit-closing position, and conductor 132 and thence through contact 131a and conductor 133 to supply line L2 as just previously traced. Consequently, upon the energization of reclosing relay 16, the circuit breaker closing coil 11 will be energized in the same way as previously described and the follow-up relay 60 will be energized upon the closure of the breaker to interrupt the energizing circuit of the reclosing relay 16 after temporary energization thereof as previously described. Upon closure of breaker 10, contact 40' opens to de-energize the antipump relay 131.

After the first time-delayed reclosure of circuit breaker 10, the timer motor 71 continues to drive shafts 76 and 78 to provide a limited check interval thereafter. In this case, the check interval is determined by the length of time required for cam element 82b to be rotated into engagement with roller 90 to close the reset control switch contact 91. Again the improved reclosing control will respond selectively, dependent upon whether circuit breaker 10 remains closed at the end of the check interval following the first time-delay reclosure thereof or automatically opens during this interval in response to a continuing fault. If the circuit breaker remains closed at the end of the check interval, then a release of clutch 73 and return of the cam shafts 76 and 78 to their start positions will occur together with a resetting of the interlock device 40 to its start position in exactly the same way as previously described. If, however, the circuit breaker 10 again automatically opens during the check interval, a second time-delay reclosure is effected by engagement of cam element 81a with roller 85 to move the time-delay reclosing control contact 86 again to its righthand circuit-closing position to again energize the reclosing relay 16 through contact 131b of antipump relay 131 in the same way as previously described. Upon the resulting second time-delayed reclosure of circuit breaker 10, another limited check interval is provided by the time required for the operating cam 81b to engage with roller 90. As before, if the circuit breaker 10 successfully remains closed at the end of the check interval so that auxiliary contact 120 is closed, then automatic release of the clutch 73 and return of the cam shafts 76 and 78 to the start position will occur. If instead, circuit breaker 10 automatically opens during the check interval, then a third time delay reclosure attempt is made upon engagement of operating cam 80a with roller 85 to successively reestablish the time-delay reclosing circuit by operation of contact 86 to its righthand circuit-closing position to again energize relay 16 through contact 131b of relay 131 and thereby produce a third time delay reclosure attempt.

After this third attempted time-delay reclosure of circuit breaker 10, the improved reclosing control will either return to its initial start condition or lockout depending upon the closed or open condition of the breaker 10 as reflected at the end of the check interval by the closure or opening of auxiliary contact 120. If auxiliary contact 120 is closed at the end of the final check interval provided by the time required for engaging the operating cam 80b with roller 90, then automatic return to the start condition will occur in the manner previously described, but if auxiliary contact 120 is open, then automatic lockout will be effected. Such automatic lockout is produced when the lockout cam 95 is rotated sufficiently to permit the lockout contact 69 to open and thereby deenergized the timer motor 71. In this position contact 91 will be held closed by the angularly fixed cam 93a so that upon a subsequent successful manual reclosure of the breaker 10, core 110 will be energized through 91 to cause resetting of the interlock unit 40 to the start condition.

Just prior to the opening of the lockout contact 69, the alarm cam 97 enables the alarm contact 99 to close and thereby energize a visible or audible alarm device. Thus, both the alarm contact 99 and the lockout contact 69 are operated while the restart control contact 91 remains closed by the fixed angular cam 93a. Whenever final lockout occurs, the circuit controlled by the circuit breaker 10 is first cleared of the persisting faults and then manual reclosure of the breaker is effected by momentary operation of the gang switches 32, 49, and 24. The manual closure of switch 24 completes the energizing circuit for reclosing relay 16 through conductor 31 and the circuit as previously traced. The resulting reclosure of circuit breaker 10 will close auxiliary contact 120 thereby partially completing the energizing circuit for the clutch release electromagnet 110 through the restart control contact 91. Consequently, both the timer cam mechanism 72 and the interlock device 40 will be returned to the start condition when the gang, manually-operated switch 21 is returned to its middle position resulting in return of contact 32 to closed position as shown.

In case an initial instantaneous reclosure of the circuit breaker 10 is not desirable, then a time-delay initial reclosure can be produced merely by moving the manually operable switches 36 and 34 from their upper circuit-closing positions in which they are shown to their lower circuit-closing positions. This will cause energization of the operating winding 45 to operate the interlocking device 40 to open contact 35 and close contacts 42 and 43 as soon as the circuit breaker 10 opens and closes its auxiliary contact 40' with the energizing circuit extending from line L1 through conductor 48, conductors 50 and 51, winding 45, conductor 141, switch 34 in its lower position, contact 35, switch 36 in its lower position, conductors 142 and 137, contact 40', conductor 138, and contact 49 to line L2.

In this way the instantaneous reclosure control switch contact 35 is rendered ineffective to energize the reclosing relay 16 and the only way in which the reclosing relay 16 can now be energized is by engagement of the operating cam elements 82a, 81a, and 80a successively with the roller 85 to operate the time-delay reclosure control contact 86 to its righthand circuit-closing

position. Consequently, an initial time delay reclosure is accomplished due to the fact that contact 42 is closed by energization of operating winding 45 as soon as the circuit breaker opens and closes its auxiliary contact 40', thereby immediately starting operation of the timer motor 71 through the energizing circuit previously traced. After each timed reclosure, restart control contact 91 will be closed after the limited check interval and the subsequent restart or continued time-delay reclosure attempts until lockout is reached will occur in exactly the same way as previously described.

It will thus be seen that the reclosure control embodying the improvements of the present invention enables the first reclosure to be either instantaneous or time-delayed as selected and furthermore enables the instantaneous reclosure to be effected by means of the preset contact 35 since the auxiliary switches 25 and 26 of circuit breaker 10 are closed upon opening of the breaker so that there is no time lost in operating an auxiliary unit. Furthermore, the improved control provides for automatic restart whenever the breaker remains closed at the end of the limited check interval after each reclosure. Moreover, power restart operation for both the cycle timer 72 and the two-position interlock mechanism 40 is provided, since the cycle interrupting and restart circuit must be closed in order to energize the clutch releasing electromagnet 110, as well as the reset winding 59. Consequently, no false resetting or break in the timing sequence can result from loss of power either before or after lockout. In addition, the separate angular adjustment of the double diametrically opposite cam disks 80, 81, and 82 enable the time interval between the timed reclosure attempts to be separately adjusted as desired while always insuring the end of a check interval before each reclosure attempt due to the relative angular positioning of the operating rollers 90 and 85.

When the breaker is reclosed manually, after a manual trip, contact 49 remains closed during the reclosing operation. Thus when the closing relay 16 is picked up by the closure of contact 24, contact 18 energizes the tripping coil 45 of interlocking relay 40 resulting in the opening of contact 35 in the instantaneous reclosing circuit, thus if the breaker 10 trips out again instantaneous reclosing is blocked, and the closure of contact 42 starts the timing motor 71. This will eventually initiate a time reclosure of breaker 10, but the operator has sufficient time to react to the trip-out and return the switch 24 to the open position so that further reclosures are blocked. If the manual reclosure is successful, the interlocking relay 40 automatically returns to the start condition after the first check interval.

If a manual reclosure attempt is made with the automatic control in the lockout position, contact 32 is opened so that restart operation of the automatic control is blocked until switch 21 is released and returns contact 32 to its closed position. Thus if the fault still persists causing reopening of the breaker 10, restart operation of the automatic control with resulting automatic breaker reclosure is prevented.

Figs. 3 and 4 show a modification of the cam operated sequential timing switch mechanism shown in Fig. 2 wherein the fixed cam 93*b* is omitted and three single ended cams 84*a*, 84*b*, and 84*c* are added to enable much greater sequence selectivity as well as shorter time delay intervals to be obtained. Thus the added single ended cams 84*a*—*b*—*c* may be adjusted manually not only to produce identically the same sequential operation as previously described but also to produce various other desired sequences of operation, as for example a series of consecutive time delay reclosures followed by a single restart check interval prior to lockout in case none of the reclosure attempts are successful. In the modified form of cam operating mechanism shown in Figs. 3 and 4, since the cam finger 93*b* has been eliminated from the fixed operating cam that is non-adjustably secured to the shaft 78, the restart check interval after immediate reclosure can readily be omitted whenever desired. Thus much greater sequence selectivity can be obtained since the three double-ended operating cam members 80*a*—*b*, 81*a*—*b*, and 82*a*—*b* are separately adjustable manually into any selected angular position on the shaft 78 or into coincidence and the three added single-ended cam elements 84*a*—*b*—*c* are likewise separately adjustable manually into any selected angular position or into coincidence on the shaft 78. In case all three of the single-ended cam elements 84*a*—*b*—*c* are adjusted into angular coincidence at the same angular position previously occupied by the fixed cam 93*b*, then the sequential operation provided by the modified form of the timing cam mechanism shown in Figs. 3 and 4 will be precisely the same as previously described.

If however, all three double-ended cam elements 80*a*—*b*—*c* are adjusted into angular coincidence in the same angular position, as for example the angular position occupied by the double-ended cam 80*a* and 80*b* and the three single-ended cam elements 84*a*—*b*—*c* are adjustably arranged in displaced angular relation between the cam element 80*a* and the roller 85, then an instantaneous reclosure followed by three time-delayed reclosures will be produced without any check interval following either the instantaneous or the first two time delay reclosures. The coincidental double-ended cams 80*a*—*b*—*c* lying in the position of cam 80*b* necessarily will provide a restart check interval following the last time delay reclosure. Consequently, if the circuit breaker is successfully reclosed upon the instantaneous or any one of the first two time delay reclosures, nevertheless the timing motor will continue the cycle through the restart checking interval after the last time delay reclosure before a restarting operation of the reclosing mechanism is produced upon closure of the cycle restart control switch 91 in the same manner as previously described.

This modified form of the invention enables the time delay reclosure intervals following the instantaneous reclosure to be made shorter than where a reclosure check interval is provided after each reclosure attempt. Thus by the selective adjustment of the added single ended cam operating elements, the automatic cycle interrupting and restart feature can be added or omitted after each or any selected reclosure attempts except for the last reclosure attempt as desired. However, it is impossible to omit the cycle interrupting and restart feature after the final time delay reclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A circuit breaker reclosing control having in combination, a cycle timer having means under control of the circuit breaker for starting the cycle timer into operation, circuit breaker reclosing control means including a switch having a series

of operating cam elements biased in one direction and provided with a releasable clutch connected with the timer for operation in the other direction to become separatively effective to operate the switch at consecutive intervals during the cycle, and electrical means for releasing the clutch to operate the cam elements in accordance with their bias to restart the cycle including a clutch release control switch having a corresponding series of operating cam elements jointly biased in the same direction and operable by the clutch jointly with the first series of elements in the other direction to close the release control switch before the end of each consecutive interval, and means including a switch operated by the circuit breaker to render the clutch releasing means effective only when the circuit breaker remains closed at the time of closure of the release control switch.

2. An automatic circuit breaker reclosing control having in combination, a cycle timer having means under control of the circuit breaker for starting the cycle timer into operation, circuit breaker reclosing control means including a switch having a series of separately adjustable operating elements releasably connected with the timer to become separately effective to operate the switch at adjustable time intervals during the cycle, means for biasing the operating elements to an initial position upon release thereof, and electrical means for releasing the operating elements having a releasing control switch provided with a corresponding series of operating elements, each connected for adjustment, operation, and return to an initial position jointly with the corresponding element of the first series so as to close the releasing control switch a predetermined interval after each corresponding operation of the reclosing control switch, and means including a switch operated by the circuit breaker to render the electrical releasing means effective only when the circuit breaker remains closed at the time of operation of the releasing control switch.

3. An automatic circuit breaker reclosing control having in combination, a cycle timer having means under control of the circuit breaker for starting the cycle timer into operation and provided with a releasably connected series of juxtaposed separately angularly adjustable coaxial rotatable members each having two operating elements in interrelated series, circuit breaker reclosing control means including a switch angularly disposed to be operated by one series of elements at adjustable time intervals during the cycle, means for biasing the elements to return to a start position upon release thereof, and electrical means for releasing the members to restart the cycle including a cycle interrupting and restart control switch angularly disposed to be operated to the circuit closing position by the interrelated series of elements an interval after each operation of the reclosing control switch and a switch connected in series circuit with the restart control switch and operated to the circuit closing position during closure of the circuit breaker to render the releasing means effective only when the circuit breaker remains closed at the time of closure of the restart control switch.

4. An automatic circuit breaker reclosing control having in combination, a cycle timer having means under control of the circuit breaker for starting the cycle timer into operation, a series of jutaposed separately angularly adjustable coaxial rotatable members biased to an initial position and operable therefrom by the cycle timer and each member having two diametrically opposite operating cams in interrelated series, circuit breaker reclosing control means including a switch angularly disposed to be operated by one series of operating cams at adjustable time intervals during the cycle, and electrical means for jointly controlling the return of the rotatable members to the initial position to restart the cycle including an electrically releasable clutch interconnecting the members with the timer and having an energizing circuit including a release control switch angularly disposed to be operated by the interrelated series of operating cams a limited check interval after each operation of the reclosing control switch and a switch in the clutch energizing circuit and operated to the circuit closing position during closure of the circuit breaker to render the release control switch effective only when the circuit breaker remains closed at the end of a check interval.

5. A circuit breaker reclosing control having in combination, a cycle timer motor having an energizing circuit under control of the circuit breaker for starting the cycle timer motor into operation, circuit breaker reclosing control means including a switch having a series of rotatable operating elements biased to one angular position and provided with a clutch for operation by the timer motor to become separately effective to operate the switch at successive intervals during the cycle, electrical means for releasing the clutch to restart the cycle, a resetting control switch biased open and having a corresponding series of operating elements for closing the control switch to energize the clutch releasing means, each carried by the corresponding one of the first series of elements to provide a limited check interval after each corresponding operation of the reclosing control switch, a switch in series with the control switch and operated to the closed position during closure of the circuit breaker to effect energization of the clutch releasing means only when the circuit breaker remains closed during a check interval, and a lockout switch operated by the timer motor to open the energizing circuit of the timer motor when the clutch releasing means remains unenergized at the end of the cycle.

6. A circuit breaker reclosing control having in combination a time sequencing device having a plurality of releasable control elements biased to a start position and operated therefrom for producing successive time delay reclosures of the breaker at predetermined intervals, electrical means effective upon opening of the circuit breaker for producing an immediate reclosure of the breaker and starting the time sequencing device into operation, and electroresponsive means for releasing the control elements having a control switch operated by the circuit breaker and a second control switch provided with a plurality of successive operating elements jointly biased and released with the control elements and jointly operated by the time sequencing device in a predetermined time sequence with the control elements for effecting release of all the jointly releasable elements when the breaker remains closed at any time of operation of the second control switch.

7. A circuit breaker reclosing control having in combination a timer having releasably connected cycling control switch mechanism biased to an initial position and operable therefrom by the timer for successively reclosing the circuit

breaker at predetermined intervals in the cycle and provided with electrical releasing means having a control switch operable during each interval, a two-position interlock switch mechanism having means including a switch closed in one position to effect instantaneous reclosure of the circuit breaker and means including a switch closed in the other position to start operation of the timer and provided with means for operating the interlock switch mechanism to the other position upon the instantaneous reclosure of the breaker, means including a switch operated by the circuit breaker and connected in series with the release control switch for releasing the cycling control switch mechanism to restart the cycle whenever the circuit breaker remains closed at the time of operation of the release control switch, and electrical means for returning the interlock switch mechanism to the one position upon return of the cycling control switch mechanism to the initial position.

8. A circuit breaker reclosing control having in combination a timer motor having an electromagnetically releasable clutch, a rotatable cycling reclosure control switch mechanism biased to an initial position and operated by the clutch against its bias for successively reclosing the circuit breaker at predetermined intervals in the cycle and provided with a clutch release control switch operable during each interval, a two-position interlock switch mechanism having means including a switch closed in one position to effect instantaneous reclosure of the circuit breaker and means including a switch closed in the other position to start operation of the timer motor and provided with means for operating the interlock mechanism to the other position upon the instantaneous reclosure of the breaker, means including a switch operated by the circuit breaker and connected in series with the clutch release control switch for releasing the clutch to free the cycling reclosure control switch gear mechanism to return to the initial position in accordance with its bias whenever the circuit breaker remains closed at the time of operation of the clutch release control switch, and means for returning the interlock switch mechanism to the one position upon return of the cycling reclosure control switchgear mechanism to the initial position.

9. A circuit breaker reclosing control system having in combination a cycle timer motor having a clutch provided with a releasing electromagnet, reclosure control means including a series of operating elements biased to an initial position and operated by the clutch against the bias for successively reclosing the circuit breaker at predetermined intervals in the cycle and provided with a clutch release control switch operable during each interval, a two-position multiple contact switch mechanism having interlock means for holding the mechanism in each position, means including one switch contact closed in one position of the mechanism to effect instantaneous reclosure of the circuit breaker, means including a second switch contact closed in the other position of the mechanism to start operation of the cycle timer motor, means including an electromagnet connected to be energized upon the instantaneous reclosure of the breaker for operating the multiple contact switch mechanism to the other position, circuit means including in series the clutch release control switch, a switch operated by the circuit breaker, and a third switch contact closed in the other position of the mechanism for energizing the clutch releasing electromagnet to free the cycling reclosure control operating elements to return to the initial position in accordance with the bias whenever the circuit breaker remains closed at the time of operation of the clutch release control switch, and means including an electromagnet connected to be energized under control of the third switch contact upon return of the cycling control means to the initial position for returning the multiple contact switch mechanism to the one position.

10. A circuit breaker reclosing system having in combination, instantaneous reclosing means for the circuit breaker including a two-position multiple contact interlock switch mechanism having one position for presetting an instantaneous reclosure circuit effective immediately upon opening of the circuit breaker and provided with means for operating the interlock switch mechanism to another position before completion of the instantaneous reclosure of the circuit breaker, a time-delay reclosing cycle timer having starting control means including the interlock switch mechanism in the other position for starting the cycle timer into operation and time-delay reclosing means including a reclosing control switch having a series of operating elements biased to one position and releasably connected for operation therefrom by the timer to close the reclosing control switch and thereby operate the time delay reclosing means at successive predetermined intervals during the cycle, electrical means for releasing the operating elements and returning the interlock switch mechanism to the one position to restart the cycle including a restart control switch provided with a corresponding series of operating elements releasably connected and biased jointly with the first series of elements to be operated by the timer to close the restart control switch a predetermined time interval after each closure of the reclosing control switch, and an auxiliary switch operated by the circuit breaker and connected in series with the restart control switch to render the releasing means effective only when the circuit breaker remains closed at the time the restart control switch is closed.

11. A circuit breaker reclosing system having in combination an auxiliary switch closed when the breaker is closed, a reclosing device having an energizing circuit including a first switch closed upon each opening of the circuit breaker, and a second switch normally closed to energize the device as soon as the circuit breaker opens and provided with means for opening the second switch upon energization of the reclosing device, a cycle timer having an energizing switch closed upon opening of the second switch and provided with a pair of jointly releasable interrelated timed cycle switching means jointly biased to a start position and, one interconnected with the first switch to energize the reclosing device at successive intervals in the cycle and the other interconnected with the auxiliary switch and having means jointly controlled thereby for releasing both interrelated timed switching means and reclosing the second switch whenever the circuit breaker remains closed at a predetermined time after the end of each interval in the cycle.

12. A circuit breaker reclosing control having in combination, an electroresponsive reclosing device having an energization control switch closed upon opening of the breaker, a cycle timer having a releasably connected series of operating elements biased to a start position and a time-de-

lay reclosure control switch operated thereby at predetermined intervals during the cycle and interconnected with the energization control switch to correspondingly energize the reclosing device, an instantaneous reclosure control switch interconnected with the energization control switch to energize the reclosing device as soon as the circuit breaker opens and provided with an operating winding connected to be energized to open the instantaneous control switch upon the instantaneous operation of the reclosing device, means for energizing the cycle timer upon opening of the instantaneous control switch, and electroresponsive means for releasing the operating elements having an energization control switch operated by the circuit breaker and a series connected control switch provided with a series of operating elements jointly releasable and biased with the first series of elements successively operated by the timer during the cycle for reclosing the instantaneous control switch and resetting the timed reclosure control switch to release the jointly releasable elements to restart the cycle whenever the circuit breaker remains closed at a predetermined time after each operation of the time-delay reclosure control switch in the cycle.

13. A circuit breaker reclosing system having in combination, an auxiliary switch operated upon closure of the circuit breaker, a reclosing device having an energizing circuit including a first switch closed upon opening of the circuit breaker and a second switch normally biased closed to energize the device as soon as the circuit breaker opens and provided with an operating winding temporarily energized to open the biased switch upon energization of the reclosing device, releasable interlocking means for holding the biased switch open, a cycle timing device energized upon opening of the biased switch and having releasably connected switching means biased to an initial position and operable thereby and connected in series with the first switch for successively energizing the reclosing device at successive intervals during the cycle when the circuit breaker opens before a predetermined final part of each interval, and electrical means under joint control of the timing device and the auxiliary switch for releasing the releasably connected switching means for return in accordance with the bias to the initial position whenever the circuit breaker remains closed at the end of the initial part of any interval and thereupon releasing the interlocking means.

14. A circuit breaker reclosing control having in combination an electroresponsive device energizable to effect reclosure of the circuit breaker and having an energization control switch operated on each opening of the circuit breaker, a cycle timer having a first and a second timed circuit-closing means biased to an initial position and releasably connected for operation thereby and interrelated for alternate operation in the cycle, the second timed circuit-closing means having connections for rendering the energization control switch effective to reclose the circuit breaker at successive intervals in the cycle, a two-position interlocking switch unit having one interlocking switch closed in one position and connected to render the energization control switch effective for energizing the reclosing device as soon as the circuit breaker opens and a second interlocking switch closed in the second position for energizing the cycle timer and provided with separately energizable operating windings for closing each switch and opening the other, means including a switch operated upon energization of the reclosure device for energizing one of the operating windings to operate the interlocking switching unit to the second position thereof, electrical releasing means having an energization control switch closed upon each reclosure of the circuit breaker and interconnected with the second of the interrelated time circuit-closing means for effecting the release of the two series of timed circuit-closing means for return to the initial position in accordance with the bias to restart the cycle, and means for energizing the other operating winding of the interlocking unit upon return to the initial position of the timed circuit-closing means only when the circuit breaker remains closed at the time of closure of the second timed circuit closing means.

15. A circuit breaker reclosing control system having in combination, a cycle timer motor having a clutch-connected cam shaft biased to an initial position and provided with a releasing electromagnet having a seal-in switch operated upon energization thereof, a lockout switch operated by the cam shaft at the end of the cycle to deenergize the timer motor, an interlocking restart switch closed in the initial position of the cam shaft, a time delay reclosing control switch having a series of coaxial separately adjustable rotatable operating elements operated by the cam shaft to close the time delay reclosing control switch at successive adjustable time intervals during the cycle, a cycle restart control switch for controlling the energization of the clutch-releasing electromagnet and having a series of coaxial rotatable operating elements, each connected with the corresponding element of the first series for rotation and adjustment jointly therewith and angularly related to close the cycle restart switch during each interval, a two-position multi-contact switch mechanism having interlock means for holding the mechanism in each position and provided with an instantaneous reclosure control contact closed in one position and a second switch contact closed in the other position and interconnected with the lockout switch to start the timer motor into operation and a third switch contact closed in the other position and connected in circuit with the cycle restart switch for effecting energization of the clutch-release electromagnet when the circuit breaker remains closed at the time of closure of the cycle restart switch, an operating electromagnet energizable under control of the circuit breaker for operating the two-position switch mechanism to the other position during instantaneous reclosure of the circuit breaker and an operating electromagnet energized under control of the interlocking restart switch and the seal-in switch for operating the two-position switch mechanism to the one position when the clutch is released and the cam shaft returns to the initial position in accordance with its bias.

16. A circuit breaker reclosing control having in combination a time sequencing device having a plurality of releasable elements biased to an initial position and mounted for manual adjustment to produce time delay reclosures of the breaker at selected intervals, electrical means for producing an immediate reclosure of the breaker and starting the time sequencing device into operation, and electroresponsive releasing means having a control switch operated by the circuit breaker and a second control switch pro-

vided with a plurality of releasable operating elements jointly biased to an initial position and operated by the time sequencing device and mounted for manual adjustment to release all the jointly biased elements when the breaker remains closed at any selected time of operation of the second switch.

17. A circuit breaker reclosing control having in combination a rotatable cycle timer having means under control of the circuit breaker for starting the cycle timer into operation, a cam shaft having a clutch connection with the timer and provided with means including a biasing means and a clutch releasing electromagnet for returning the shaft to an initial position, a plurality of cams mounted on the cam shaft for selective adjustment into different angular positions, circuit breaker reclosing control means including a switch having an operating member mounted to be operated during the cycle by selected cams at selected time intervals dependent upon the adjustment thereof, and means for energizing the clutch releasing electromagnet including a switch under control of the circuit breaker and a switch having an operating member mounted to be operated at least once during the cycle by a selected cam at a time dependent upon the relative angular adjustment thereof.

18. A circuit breaker reclosing control having in combination a rotatable cycle timer having a clutch connected cam shaft provided with biasing means and a clutch releasing electromagnet for returning the shaft to an initial position, a series of single and a series of double ended cams adjustably mounted on the shaft for selective relative angular adjustment of one series into different angular positions and the other series into coincidence, circuit breaker reclosing control means including a switch having an operating member mounted to be operated during the cycle by the one series of cams at selected time intervals dependent upon the relative angular adjustment thereof, and means for energizing the clutch releasing electromagnet including a switch under control of the circuit breaker and a switch having an operating member mounted to be operated at least once during the cycle by the series of cams in coincidence and repeatedly when the double ended cams are selectively adjusted into different angular positions.

19. A selectively adjustable circuit breaker reclosing control having in combination means for effecting an immediate initial reclosure of the breaker including a selective switch selectively operable for rendering said means ineffective, a rotatable cycle timer having means under control of the circuit breaker for starting the cycle timer into operation, a cam shaft biased to an initial position and having a clutch connection with the timer and provided with means including a clutch releasing electromagnet for returning the shaft to the initial position, a series of single and a series of double ended cams adjustably mounted on the shaft for selective relative adjustment of one series into different angular positions and the other series into coincidence, circuit breaker time delay reclosing control means including a switch having an operating member mounted to be operated during the cycle by the one series of cams at time intervals dependent upon the relative angular adjustment thereof, and means for energizing the releasing electromagnet including a switch having an operating member mounted to be operated an interval after the immediate reclosure by the single end cams in coincidence and repeatedly by the double ended cams in different angular positions and at least once by the double ended cams in coincidence when the immediate reclosure means is ineffective and the single ended cams are selectively adjusted into different angular positions.

20. A circuit breaker reclosing control having in combination a time sequencing device having a plurality of releasable reclosing control elements biased to a start position and operated therefrom for producing successive time delay reclosures of the breaker at predetermined intervals, and electroresponsive means for releasing the contol elements having a control switch operated by the circuit breaker and a second control switch provided with a plurality of successive operating elements jointly biased and released with the reclosing control elements and jointly operated by the time sequencing device in a predetermined time sequence with the control elements for effecting release of all the jointly releasable elements when the breaker remains closed at any time of operation of the second control switch.

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