Dec. 27, 1966 R. E. RIEBS ET AL 3,295,017

REPEATING CIRCUIT INTERRUPTER

Original Filed Sept. 15, 1960 3 Sheets-Sheet 1

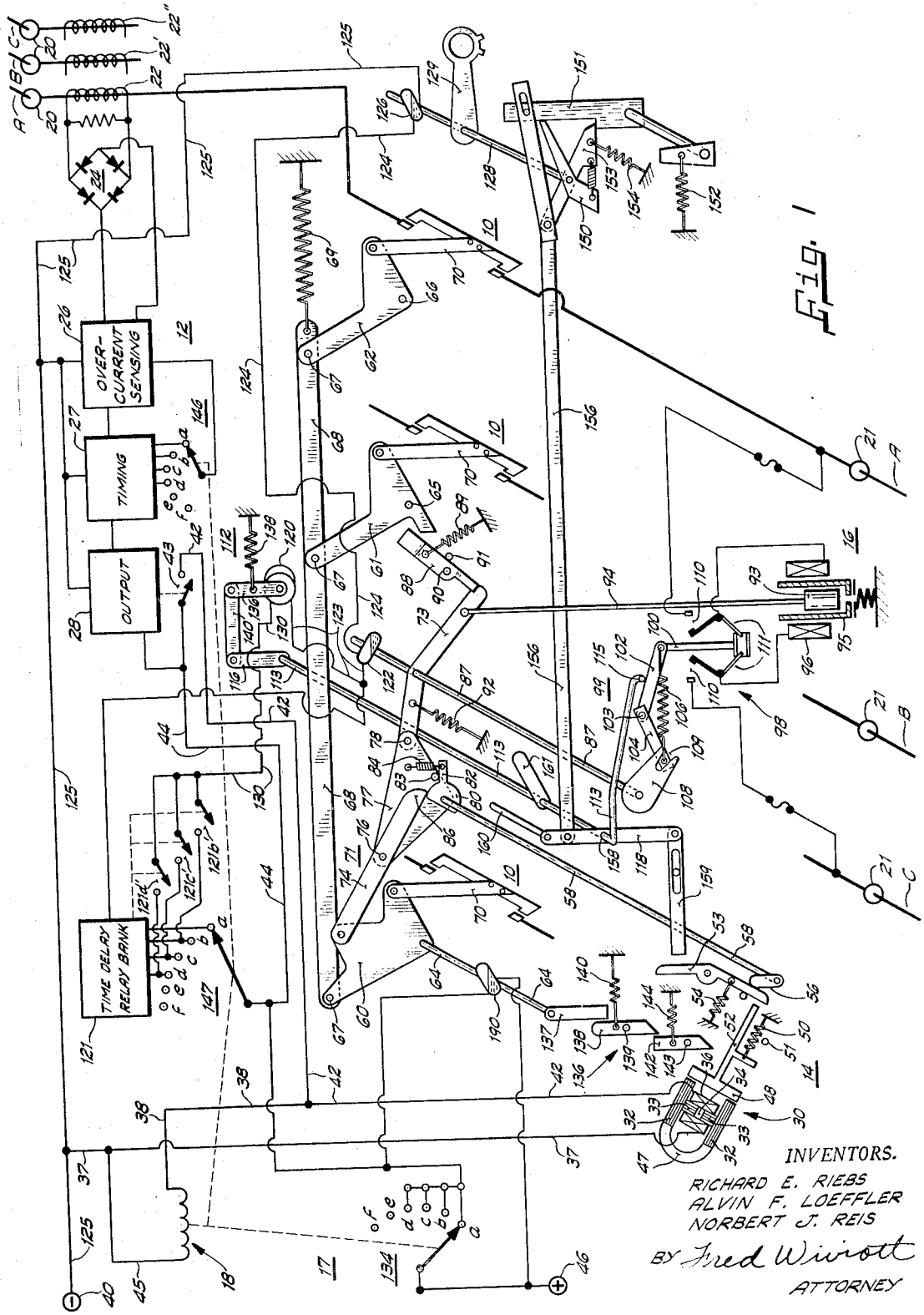


Fig. 1

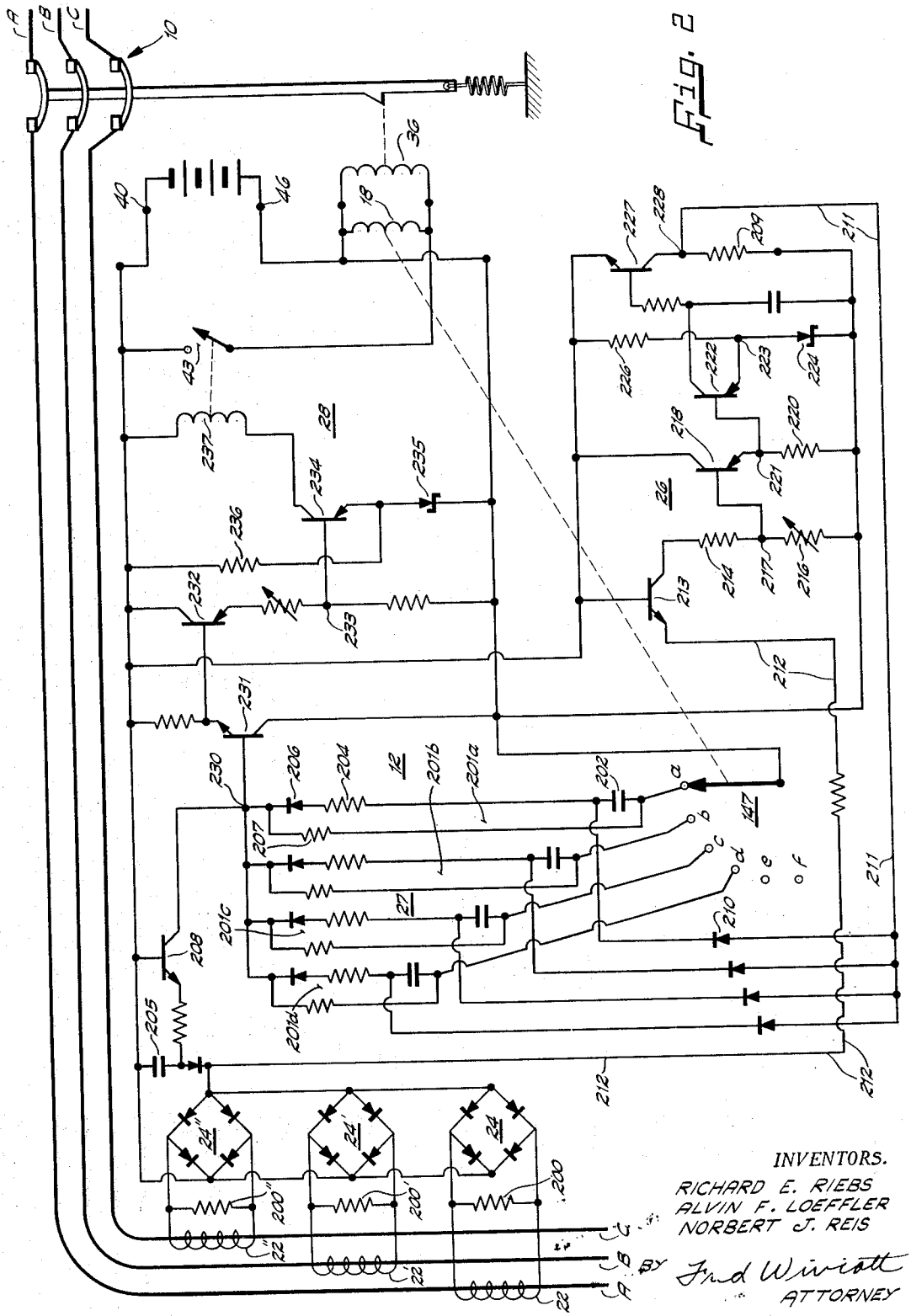
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Original Filed Sept. 15, 1960 3 Sheets-Sheet 2

Fig. 2



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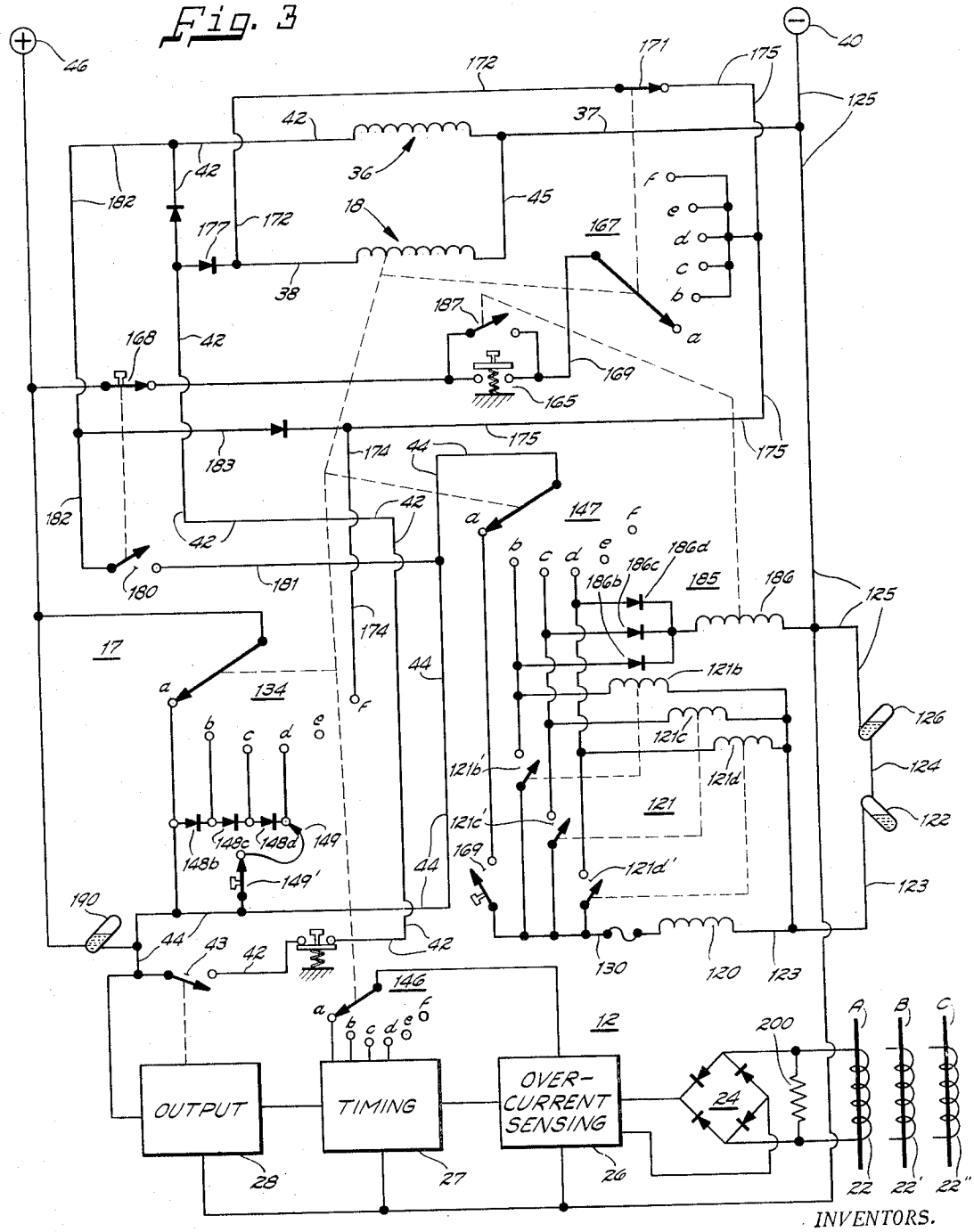
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Original Filed Sept. 15, 1960 3 Sheets-Sheet 3

Fig. 3



United States Patent Office

3,295,017

Patented Dec. 27, 1966

3,295,017

REPEATING CIRCUIT INTERRUPTER

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Continuation of application Ser. No. 56,259, Sept. 15, 1960. This application Nov. 21, 1963, Ser. No. 325,215

25 Claims. (Cl. 317—22)

This invention relates to repeating circuit interrupters and, more particularly, to the class of circuit interrupters commonly known as reclosers. This application is a continuation of application No. 56,259 (filed September 15, 1960) which is now abandoned.

A recloser may be characterized as a circuit protective device having fault sensing means, interrupting switches, switch opening and reclosing means, operation counting and lockout mechanism. More specifically, reclosers are usually provided with means connected in the line being protected and which is responsive to overload currents to initiate a switch opening operation, switch reclosing means operable after each opening operation, normally inactive time delay means, and operation counting and lockout means which is operable to initiate time delayed switch opening after a predetermined number of opening operations.

It is common practice to utilize repeating circuit interrupters of this type in conjunction with other protective devices such as fuses. For example, a distribution system may be provided with a repeating circuit interrupter or recloser connected in series with the main line and located adjacent the source of power and fuses disposed in feeder lines radiating from the main line. Because the majority of faults in such systems are temporary in nature, and will clear in a relatively short time, it is common to arrange the switch opening means to execute a series of rapid opening operations so that the period in which the system remains energized is shorter than the time necessary for the fuse elements to melt. In addition, the circuit breaker contacts must remain open for a sufficient period of time to allow the fuses to cool. If the fault does not clear during this initial series of rapid operations, the time delay means is actuated by the operation counting means so that there follows a second series of operations in which the recloser contacts remain closed for a period of sufficient length to allow the fuse elements to melt. If the fault still has not cleared after a number of such time delayed operations, it is considered permanent and the operation counting means prevents the actuation of the reclosing means so that the device is locked open. In addition, it is desirable for the opening and reclosing times of such reclosers to be sufficiently flexible so that they may be readily coordinated with a plurality of relatively slowly operable circuit breakers.

It is an object of the invention to provide a recloser having electromotive means for effecting reclosure after each opening operation with means for open circuiting said electromotive means after a predetermined number of opening operations to effect lockout thereof.

Another object of the invention is to provide a recloser having electroresponsive switch opening means with a plurality of time delay means and means for successively actuating said time delay means during successive switch opening operations.

A further object of the invention is to provide a recloser having reclosing means and a plurality of time delay means operable to initiate reclosing after each opening operation and means to sequentially initiate successive ones of said time delay means so that the time delay of each reclosing operation can be controlled.

Yet another object of the invention is to provide a recloser with electroresponsive switch closing means and stepping means for completing an energizing circuit thereto after each opening operation wherein said stepping means is operative to open circuit said switch closing means after a predetermined number of closing operations to effect lockout. A still further object is to provide such reclosers with means for recycling said stepping means to its initial position should the fault clear prior to said predetermined number of operations.

These and other objects of the invention will become apparent from the detailed description of the invention taken with the accompanying drawings in which:

FIG. 1 is a schematic illustration of a recloser embodying the instant invention;

FIG. 2 shows the overcurrent responsive portion of the recloser shown in FIG. 1; and

FIG. 3 schematically illustrates the electrical portion of the recloser shown in FIG. 1.

Referring now to FIG. 1, the repeating circuit interrupter according to the preferred embodiment of the instant invention is shown to include interrupting switches 10, overload responsive means 12, switch opening means 14, switch reclosing means 16, and operation counting and lockout means 17. The overcurrent responsive means 12 is operable to actuate the switch opening means 14 upon the occurrence of an overload in the system being protected so that the interrupting switches 10 will each be moved to their open positions. Upon this event, reclosing means 16 is made operable to return the interrupting switches to their closed position. The operation counting and lockout means 17 which includes stepping relay 18 and step switch 134 is operable to initiate time delayed opening and/or reclosing operations if the fault has not cleared after an initial series of rapid operations and finally to prevent reclosure of the main contacts 10 if the fault does not clear after a series of such delayed operations.

The apparatus schematically illustrated in FIG. 1 is generally disposed in a metallic housing (not shown) which supports a set of incoming porcelain bushings 20 for connection to the phase wires A, B and C, and a set of outgoing porcelain bushings 21.

The overcurrent responsive means 12 is shown coupled to phase A by means of a current transformer 22 and a full wave rectifier 24. As will be seen hereinafter, the overcurrent responsive means 12 is similarly connected by means of current transformers and full wave rectifiers to each of the other phases B and C. The overcurrent responsive means 12 includes an overcurrent sensing portion 26, a timing portion 27 and an output portion 28. The overcurrent responsive means 12 will be discussed in greater detail below, it being sufficient at this point to state that the overcurrent sensing portion 26 is operable when the rectified current at the output of rectifier 24 exceeds a minimum value to provide a signal to the timing portion 27. Upon the receipt of this signal the timing portion 27 initiates a timing operation, and after a predetermined interval, provides a signal to the output portion 28 which then initiates a switch opening operation in a manner to be described.

The switch opening means 14 is shown in the preferred embodiment to include a magnetic tripper 30 having a pair of side members 32 and a pair of central pole members 33, one of which is attached to each of the side members 32 intermediate their ends and which are separated from each other by an air gap 34. A coil 36 surrounds the central core members 33 and is connected by a conductor 37 to the negative power supply terminal 40 and by a conductor 42 to contacts 43. Conductor 44 connects the other side of contacts 43 through step switch 134 to the positive power supply terminal 46. The purpose of step switch 134 will be discussed more fully below,

it being sufficient at this point to state that under normal conditions of operation, it is initially on contact A. Contacts 43, which are mechanically connected to the portion 28 of the overcurrent responsive means 12, are normally open so that coil 36 remains de-energized under normal line conditions.

A permanent magnet 47 bridges one pair of ends of the side pole pieces 32 while an armature 48 bridges the other ends thereof. When contacts 43 are open and coil 36 is de-energized, the flux path through the magnetic structure is from the permanent magnet 47 through the pole pieces 32 and the armature 48. This holds armature 48 against the ends of pole pieces 32 in opposition to biasing spring 50.

Upon the occurrence of a fault in one of the phases A, B, or C, output portion 28 will be made operative to close contacts 43, thereby energizing coil 36. Upon this event, the flux through the center of coil 36 will cause the reluctance of the path defined by pole pieces 33 and air gap 34 to be less than that through armature 48 thereby shunting the flux around armature 48 so that it is released for movement by spring 50 to the right as viewed in FIG. 1, until it engages fixed stop 51. This moves a trip rod 52, carried by armature 48, into engagement with the lower end of a trip lever 53 to pivot it in a counterclockwise direction against the influence of spring 54. As a result, the lower end of trip lever 53 is moved into engagement with a rocking lever 56 carried on the end of a trip shaft 58. Trip shaft 58 is thereby rotated in a clockwise direction to effect tripping of the recloser in a manner to be described in the ensuing paragraphs.

The mechanical portion of the recloser to be described next is merely schematically illustrated in the drawings for the sake of brevity. A more complete description of this assembly appears in U.S. Patent 2,804,521 issued to A. Van Ryan et al. and assigned to the assignee of this invention.

The interrupting switch 10 of each phase is carried by an associated bell crank 60, 61 and 62, each of which is shaped somewhat differently so that they may perform their individual functions. Bell crank 60 is affixed to a pivot shaft 64 while bell cranks 61 and 62 are adapted to pivot on fixed pins 65 and 66 respectively. Each bell crank is further pivotally connected at pivots designated 67 to a common power bar 68 to which a switch opening spring 69 is attached. Under normal circuit conditions, when the recloser is closed as shown in FIG. 1, the opening spring 69 tends to shift the power bar 68 to the right and thereby rotate bell cranks 60, 61 and 62 simultaneously in a clockwise direction to open the various switches 10 by a force transmitted from the bell cranks through insulating switch links 70. Such opening action is, however, normally prevented by a collapsible general latch means or toggle linkage assembly 71. When the toggle linkage assembly 71 is in rigid condition, it restrains the power bar 68 and accordingly the switches 10 from being operated by the opening spring 69.

When the recloser is closed, as shown in FIG. 1, the toggle linkage assembly 71 effects a rigid connection between the bell crank 60 and a rocking lever 73, the latter of which is normally latched and participates in a switch resetting operation to be explained. The toggle linkage assembly 71 comprises a long link 74 pivotally connected near its mid-section by a pin 76 to a triangularly shaped link 77 which, in turn, is pivotally connected to the rocking lever 73 at 78. The tendency is for the elongated link 74 to rotate in a clockwise direction under the influence of opening spring 69 acting on the power bar 68, but this is normally prevented by a semicircular latch release member 80 that acts as a stop for link 74. Member 80 is affixed to trip shaft 58 which, in turn, is rotatably mounted on triangular link 77. The semicircular member 80 is also provided with an ear 82 which is normally biased against a stop pin 83 by a small spring 84 that is anchored to the triangular link 77. The tip 86 of the elongated link 74 bears in low frictional relation on the outer periphery of the semicircular member 80 so that clockwise rotation of the trip shaft 58, due to the release of armature 48, as described earlier, will cause clockwise rotation of member 80 against the force of the biasing spring 84 to allow tip 86 to move past its flattened portion so that the toggle links 74 and 77 are free to rotate. Upon this event, bell cranks 60, 61 and 62 rotate clockwise through a limited angle opening the main switches 10. The opening of the main switches 10 in this manner interrupts the current flowing in phases A, B and C so that the output from the overcurrent responsive means ceases. Upon this event, contacts 43 will open to de-energize the circuit to trip coil 36.

The resetting of the trip portion 14 is accomplished by a reset assembly 136 operative to move the magnetic latch 14 to its initial position in a manner now to be described. When the main contacts 10 are moved to their open position, a first lever 137, affixed to shaft 64, rotates clockwise to pivot a second link 138 about a fixed pivot 139 and against a spring 140. This releases a reset lever 142 for movement around its fixed pivot 143 under the influence of a reset spring 144 so that its lower end can pick up the armature 48 and move it into engagement with the ends of pole pieces 32. Because coil 36 is now de-energized, the flux from permanent magnet 47 will again traverse armature 48 and hold it in its reset position shown in FIG. 1. In addition, when the main switches 10 are reclosed, arm 137 will rotate counterclockwise to return levers 138 and 142 to their initial positions as seen in FIG. 1. In this manner, the switch opening means 14 is reset in preparation of another opening operation.

The rocking lever 73, referred to earlier, is carried on a rocking shaft 87 that is journalled in bearings supported by the circuit breaker chassis, neither the chassis nor bearings being shown. The rock shaft 87 and the rocking lever 73 remain inactive, until the interrupting switches 10 are fully open, as a result of the latching of rocking lever 73 by a latch arm 88 that is biased by a spring 89 in a clockwise direction around a fixed pivot pin 90 and against a stop pin 91. The latch arm 88 normally engages and anchors the rocking lever 73, as shown in FIG. 1, when the recloser is closed. When the main switches 10 reach their fully open positions, however, the center bell crank 61 swings clockwise and engages the latch lever 88 freeing the rocking lever 73. The rocking lever 73 then rotates counterclockwise under the influence of a spring 92 and causes the toggle assembly 71 to be reset in a rigid condition in preparation for the power bar 68 being moved to the left so that the various main interrupting switches 10 may again be reclosed simultaneously. During the brief interval immediately following the opening of the main interrupting switches 10 and during the time the toggle assembly 71 is set, the rotation of the rocking lever 73 also elevates a magnetic plunger 93 to which it is attached by an insulating link 94 and which is a portion of the reclosing means 16.

The resetting plunger 93 resides in a dashpot 95 surrounded by a reclosing solenoid coil 96 that is controlled by a switch 98 which is operable upon rotation of the rock shaft 87 through a toggle linkage assembly 99 to which it is connected by a vertical link 100. The toggle linkage 99 includes a first link 102 which is connected at one end to link 100 and at its other to a fixed pin 103. In addition, a second link 104 is also connected at one end to fixed pin 103 while an overcenter spring 106 connects the free ends of each of the toggle links 102 and 104. An arm 108, affixed to the end of rock shaft 87, connects the rock shaft 87 to toggle link 104 by means of a slot and pin 109.

It will be recalled that rocking lever 73 and rock shaft 87 are held inactive by the latch arm 88 until the main interrupting switches 10 reach their fully open po-

sition at which time bell crank **61** strikes the latch arm **88** thereby releasing the rocking lever **73** and the rock shaft **87** for counterclockwise rotation under the influence of spring **95**. As the rock shaft **87** rotates, arm **108** rocks counterclockwise to swing link **104** in a clockwise direction around the fixed pivot point **103**. After link **104** passes a point of coaxiality with link **102**, which initially remains unaffected, spring **106** will be overcentered thereby urging link **102** to snap counterclockwise and thereby draw link **100** upwardly to rotate the bell cranks **111** and to close contacts **110**.

Pivotal movement of link **102** is initially prevented, however, by a reclosing time delay assembly **112** whose angular blocking rod **113** is provided with an offset end **115** that engages the upper edge of link **102**. Blocking rod **113** is affixed to a link **116** and is journalled for rotation about its longitudinal axis in the circuit breaker chassis (not shown).

The reclosing time delay assembly **112** also includes a rotary solenoid **120**, a time delay relay bank **121** and a mercury switch **122**, which is mounted on the rock shaft **87** and which is in open position when said rock shaft is in its unpivoted position shown in FIG. 1. Conductors **123**, **124** and **125** connect the rotary solenoid **120** to the negative supply terminal **40** through the first mercury switch **122** and a second mercury switch **126** which is mounted on the circuit breaker's manual operating handle shaft **128** and which is closed when the operating handle **129** is in its closed position shown in FIG. 1. Conductor **130** connects the other side of the rotary solenoid **120** to the time delay relay bank **121** which in turn is connected to the positive supply terminal **46** through stepping switch **134** and conductor **44**.

Before continuing the discussion of the mechanical portion of the recloser, the operation of the stepping relay **18** will be mentioned briefly. This device accomplishes operation counting and lockout of the recloser in conjunction with step switch **134**. In addition, the stepping relay **18** is also operable to change the time delay for the opening and reclosing operations by operating the tap switches **146** and **147** on the timing portion **27** of overcurrent responsive means **12** and time delay relay bank **121** respectively.

Prior to the first opening operation, step switch **134** and tap switches **146** and **147** are each on position *a*. The stepping relay **18** is connected to conductors **38** and **45** in parallel with coil **36**. When contacts **43** are closed by output portion **28** upon the occurrence of a fault, therefore, the circuit between the negative and positive terminals **40** and **46** will be completed through stepping relay **18** which then operates stepping switch **134** and tap switches **146** and **147** to their positions *b*.

Recall that when the main contacts **10** are in their closed position, mercury switch **122** will be opened so that rotary solenoid **120** and time delay relay bank **121** will be de-energized. It will be remembered, also, however, that when the main switches **10** reach their fully open positions, the rock shaft **87** will be released for rotation in a counterclockwise direction whereupon mercury switch **122** will be tilted to its closed position to complete the circuit through the time delay relay bank **121**. As will be discussed more fully below, the time delay relay in bank **121** that is connected to tap *b* will close after a time delay to complete the circuit through rotary solenoid **120**. Upon this event rotary solenoid **120** will pivot its operating arm **136** counterclockwise against spring **138**. This pivots link **116** through the agency of link **140** so that blocking rod **113** is rotated in a counterclockwise direction to move its offset end **115** out of engagement with link **102** freeing the latter for pivotal movement counterclockwise under the influence of overcenter spring **106** to close contacts **110** and complete the circuit through reclosing solenoid coil **96** between phases A and C.

When the reclosing coil **96** is energized, the resetting magnetic plunger **93** is attracted downwardly whereupon the rocking lever **73** is rotated in a clockwise direction reclosing the main interrupting switches **10**, extending the opening spring **69** to store energy therein for the next opening operation, and tilting mercury switch **122** to its open position thereby de-energizing rotary solenoid **120** and the time delay relay bank **121**. Rocking lever **73** also pivots arm **108** clockwise thereby operating the toggle linkage **99** to its position shown in FIG. 1 to open the contacts **110** and de-energize coil **96**. This completes one opening and reclosing operation of the recloser which is now poised for another operation.

FIG. 2 shows the details of the overcurrent sensing portion **26**, the timing portion **27** and the output portion **28** of the overload responsive means **12**. The circuit **12** is coupled to the phases A, B and C by current transformers **22**, **22'** and **22''** respectively and corresponding full wave rectifiers **24**, **24'** and **24''** whose secondaries are connected in parallel so that the current flowing to circuit **12** is proportional to the highest peak current flowing to any of said rectifiers. In order to limit the current flowing to the circuit **12** resistors **200**, **200'** and **200''** are connected across each of the secondaries of current transformers **22**, **22'** and **22''** respectively.

The timing portion **27** of circuit **12** includes four identical timing circuits which are each connected to one of the taps *a*, *b*, *c* and *d* of switch **147** and correspondingly labeled **201***a*, **201***b*, **201***c*, and **201***d*. Because each of the timing circuits is identical, except of course for the size of its components which determines its time delay, only timing circuit **201***a* will be discussed in detail, for the sake of brevity. This circuit is shown to include a timing capacitor **202** connected in series with a timing resistor **204** and a diode **206**. A second timing resistor **207** is connected in parallel with this series combination. As is more fully discussed in the copending patent application Serial No. 800,567, filed March 19, 1959, and assigned to the assignee of the instant invention, the sizes of capacitor **202** and resistors **204** and **207** determine the charging time for any given fault current in the phases A, B or C.

Under normal operating conditions, switch **147** will be initially connected to tap *a* so that the timing circuit **201***a* will govern the first recloser opening operation. In addition, capacitor **205** will be charged to the peak voltage across the resistors **200**, **200'** or **200''** having the largest IR drop.

In operation, the current flowing in the collector of the charging transistor **208** which is a function of the voltage across capacitor **205** will split between the parallel paths defined by the timing resistor **207** and the series combination of timing resistor **204** and timing capacitor **202**. When there is no fault in any of the phases capacitor **202** is prevented from charging because it is shunted by leakage resistor **207** through diode **210** and conductor **211**.

The current flowing to the overcurrent sensing portion **26** through conductor **212** is also proportional to the highest peak current in any of the phases A, B or C and causes a transistor **213** collector current to flow through resistors **214** and **216** thereby raising the potential of the junction point **217** between them to a value which is also proportional to said peak current. A transistor **218** emitter current, which is controlled by the potential of junction point **217**, flows through a resistor **220** and thereby also raises the potential of junction point **221** to a value proportional to said highest peak current. The base of a signal comparing transistor **222** is connected to junction point **221** while its emitter is connected to junction point **223** which is held at a fixed potential by a Zener diode **224** and a resistor **226**. Thus, by a proper selection of components, when the highest peak current in any of the phases A, B or C equals or exceeds the desired minimum actuating current of the device, the base voltage of transistor **222** can be made to exceed its emit-

ter voltage so that collector current will begin flowing therefrom to the base of an output transistor 227. Upon the latter event, the base potential of transistor 227 will fall below its emitter potential whereupon current will begin flowing to the leakage resistor 209. This, in turn, raises the potential of junction point 228, between the emitter of transistor 227 and conductor 211, above that across timing capacitor 202. As a result, timing capacitor 202 is prevented from discharging through leakage resistor 209 and, therefore, begins charging. In this manner, the timing operation is initiated. Diode 210 performs the function of preventing reverse current flow from junction point 228 to the charging capacitor 202.

As timing capacitor 202 charges up, the voltage at junction point 230 between diode 206 and the base of a coupling transistor 231 of output portion 28 will begin rising so that the emitter currents flowing in transistor 231 and transistor 232, which are proportional to the voltage at junction point 230, will similarly rise. The potential of junction point 233, resulting from the transistor 232 emitter current will, therefore, also follow the potential of junction point 230. The base of a transistor 234, which is connected to junction point 233, will, therefore, always be at a potential proportional to the potential at junction point 230 while its emitter will be held at a constant potential by a Zener diode 235 and a resistor 236 connected across the power supply terminals 40 and 46. After timing capacitor 202 has charged for a predetermined time, which is the time delay for a first operation of the device, the potential of junction point 233 will exceed the potential on the emitter of transistor 234 and said transistor will conduct passing emitter current to a relay 237 which, in turn, closes contacts 43 to open the main contacts 10 in the manner described hereinabove. In addition, stepping relay 18 will also be energized so that tap switch 147 will be moved to contact *b* thereby connecting time delay circuit 201*b* and disconnecting time delay circuit 201*a*. Should the fault reappear the time delay of the second opening operation will be dictated by the components of time delay circuit 201*b*.

Reference is now made to FIG. 3 which shows the electrical control portion of the recloser of FIG. 1 in greater detail. It will be recalled that on the occurrence of a fault in one of the phases, the overcurrent sensing portion 26 will present a signal to the timing portion 27 which, in turn, will actuate the output portion 28 after a time delay determined by the tap to which switch 146 is connected. The output or actuation portion 28 will then close contacts 43 to place the circuit breaker's trip coil 36 and the step switch 18 in circuit between the positive and negative terminals 46 and 40. It will be recalled further that the energization of stepping relay 18 moves step switch 134 and tap switches 146 and 147 to their respective positions *b*. This energizes the time delay relay bank 121 through step switch 134 and conductor 44 so that after a time delay it will complete the circuit to the rotary solenoid coil 120 whereupon the circuit breaker recloses. In addition, each time the main switches 10 open, the current in each of the phases A, B and C will be interrupted so that the signal to the actuation circuit 28 of the overcurrent sensing means 12 will be interrupted and contacts 43 will open to de-energize trip coil 36 and the stepping relay 18.

The time delay relay bank 121 is shown in FIG. 3 to include three distinct time delay relays symbolized by coils 121*b*, 121*c* and 121*d*, although it will be appreciated by those skilled in the art that any type of time delay relay, such as the thermal type may be employed. Each relay coil 121*b*, 121*c* and 121*d* is connected between the corresponding taps *b*, *c* and *d* on switch 147 and the negative supply terminal 40 and each coil is operative upon being energized and after a time delay, to close the appropriate one of contatcs 121*b'*, 121*c'* or 121*d'* to complete the circuit between rotary solenoid coil 120 and taps *b*, *c* and *d*.

Assume, for the sake of illustration, that it is desired to have the recloser execute two rapid and two time delayed opening operations, a single rapid and two time delayed reclosing operations followed by lockout. As a result, rapid or relatively short time delay circuits will be connected to contacts *a* and *b* of the timing portion 27 while long time delay circuits will be connected to taps *c* and *d*. In addition, a relatively fast relay will be connected to tap *b* of switch 147 while relatively slow time delay relays will be connected to taps *c* and *d*. Taps *e* and *f* of switches 134, 146 and 147 are dummy contacts for the purpose of lockout as will be explained in greater detail below.

The first opening operation will be rapid because contact *a* of the timing portion 27 is connected to a short time delay circuit and because stepping relay 18 has not as yet operated. As a result, the output portion 28 will close contact 43 a relatively short time after the fault is sensed by overcurrent sensing portion 26. This energizes trip coil 36 which opens the main switches 10 and also the stepping relay 18 which moves the stepping switch 134 and tap switches 146 and 147 to their *b* positions.

This movement of tap switch 147 to contact *b* completes the energizing circuit through short time delay relay 121*b*, which, after a short time delay, closes contacts 121*b'* to energize the rotary solenoid coil 120 through switches 134 and 147, conductors 44, 123, 124, 125 and mercury switch 122 which is closed when the main switches 10 are open and mercury switch 126 which is closed when operating handle 129 is in closed position. Rotary solenoid 120 then allows contacts 110, as shown in FIG. 1, to close and energize the closing coil 96 whereupon the main switches 10 reclose.

Should the fault persist, the output portion 28 will again be energized after a short time delay to close contacts 43. This will again energize the trip coil 36 and stepping relay 18 so that switches 134, 146 and 147 will each be moved to tap *c* whereupon time delay coil 121*c* will be energized to close contacts 121*c'* after a time delay and thereby energize rotary solenoid coil 120 and institute a second reclosing operation. Similarly, should the fault persist after the second reclosing operation, trip coil 36 will be energized after a relatively long time delay to again open the main switches 10.

In a like manner, after the third opening operation, stepping relay 18 will move each of the tap and step switches to their positions *d*, whereupon rotary solenoid coil 120 will be energized through contacts 121*d'* after a time delay. If the fault continues after the third reclosing operation, switch 43 will be reclosed after a time delay dictated by the time delay circuit connected to tap *d* of timing circuit 27. This will again energize the trip coil 36 and the stepping relay 18 which will then move each of the tap and stepping switches to the dummy contacts *e*.

It can be seen that because contacts *e* of switches 134 and 147 are dummies, rotary solenoid 120 is open circuited even though mercury switch 122 closes when the main contacts 10 open. The offset end 115 of blocking shaft 113, seen in FIG. 1, will therefor remain in engagement with toggle link 102 and the reclosing coil 96 will remain de-energized and the main switches 10 in open position. In this manner, the recloser is locked in open position after a predetermined number of opening and reclosing operations.

It can be seen in FIG. 3 that diodes 148*b*, 148*c* and 148*d* will isolate each of the taps *b*, *c* and *d* respectively of switch 134 from the one immediately preceding it, e.g., diode 148*b* isolates tap *b* from *a*, etc. This allows the number of operations before lockout to be adjusted. In the preceding discussion, with lead 149 connected to tap *d*, there were four opening operations prior to lockout. Assume, however, that only two opening operations be-

fore lockout are desired. Here lead 149 will be connected to tap *b*. After the first opening operation switch 134 will be on tap *b* and reclosure will occur in the above described manner. After the second opening operation, however, switch 134 will be on tap *c* and hence isolated by diode 148*c* from lead 149 and, as a result, from rotary solenoid 120. Thus, the recloser is locked out after two operations. Similarly, by connecting lead 149 to tap *c* there will be three operations to lockout and by opening switch 149' there will be one operation to lockout.

Electrical lockout of the recloser without cycling the main switches 10 is accomplished by closing switch 180 so as to provide a bypass circuit around contacts 43 to the trip coil 36 and the stepping relay coil 18. More specifically, when switch 180 is closed, trip coil 36 is energized through a path defined by step switch 134, which is initially on tap *a*, conductors 44 and 181, switch 180, conductors 182, 42 and 37. This opens the main interrupting contacts 10 of the circuit interrupter. Similarly, stepping relay 18 is energized through a path defined by step switch 134, conductors 44 and 181, switch 180, conductors 182, 183, 175, switch 171 and conductors 172, 38, 45 and 37. The purpose of switch 171, which is connected to stepping relay 18 is to open during each operation of the said stepping relay and then to reclose so that it may be repeatedly operated during electrical lockout or resetting. Because stepping relay 18 is repeatedly energized and de-energized by switch 171 and because it is relatively fast acting compared to the time delay of relay bank 121 and the inertia of rotary solenoid 120 and magnetic plunger 87, each of the tap switches 146 and 147 and stepping switches 134 and 167 will rapidly be advanced to their taps *e* before a reclosing operation can be initiated.

Resetting of the recloser after it has locked out electrically is accomplished by means of a manual reset button 165 and stepping switch 167 which is mechanically coupled to the stepping relay 18. It will be remembered that after lockout each of the step and tap switches 134, 146 and 147 as well as 167 will each be connected to taps *e*. When reset button 165 is depressed stepping relay coil 18 will be energized from the positive terminal 46 to the negative terminal 40 through a path defined by normally closed, manually operable switch 168, conductor 169, tap *e* of step switch 167, conductor 175, switch 171, and conductors 172, 38, 45 and 37. Upon being energized stepping relay 18 will move each of the tap and step switches to their positions *f*. The stepping relay 18 is then energized through the tap *f* on step switch 134, conductors 174, 175, switch 171, conductors 172, 38, 45 and 37. The stepping relay 18 then moves each of the step and tap switches to their positions *a* whereupon they are in position for a switch closing operation to be discussed below. Diode 177 connected between stepping relay 18 and trip coil 36 prevents energization of the latter during the resetting operation just described. Switch 168 in series with reset button 165 is mechanically coupled to lockout switch 180 so that the device cannot be reset while the lockout switch is in closed position.

After the step and tap switches have been cycled to their positions *a* l y reset button 165 the main switches 10 are reclosed by closing switch 169 which completes an energizing circuit to rotary solenoid coil 120 around time delay relay bank 121.

It will be recalled that the recloser will cycle itself to lockout only if the fault current persists after a predetermined number of opening and reclosing operations. In order to reset the device should the fault clear after a lesser number of opening and reclosing operations, the time delay reset assembly 185 is provided. This includes a timed delay relay coil 186 connected through diodes 186*b*, 186*c* and 186*d* to taps *b*, *c* and *d* of step switch 147 and in parallel with the corresponding time delay relay windings 121*b*, 121*c* and 121*d*. Time delay relay winding 186 is operable when energized, to close normally open contacts 187 which shunts reset button 165. Assume that after a single opening and reclosing operation the fault clears so that switch 43 remains open and step switch 18 and trip coil 36 remain de-energized. In addition, mercury switch 122 will be tilted to its open position so that rotary solenoid 120 remains de-energized. As a result, step switch 147 as well as each of the other tap and step switches will reside on their positions *b*. This will energize time delay coil 185 through diode 186*b*. After a time delay, which is longer than the combined time delays of relays 121*b*, 121*c* and 121*d* and of the opening time delay circuits 201*a*, 201*b*, 201*c* and 201*d* (seen in FIG. 2), contacts 187 will close to energize step switch 18 in the same manner as when reset button 165 is closed. Stepping relay 18 will then cycle each of the step and tap switches to position *a* whereupon time delay relay 185 will be de-energized and contacts 187 will open.

In order to provide energy to the fault current sensing portion 12 whenever the main contacts 10 are closed regardless of what position the control circuit of FIG. 2 is in, a third mercury switch 190 is shown in FIG. 1 to be mounted on shaft 64 and in the power supply circuit of the overcurrent sensing means 12. Thus, whenever the main contacts are closed mercury switch 190 will be tilted to its closed position so that should a fault current occur in one of the phases when the control circuit is in lockout condition, switch 43 may be closed to open the main contacts and thereby providing protection to system A.

Referring again to FIG. 1, manual lockout of the recloser may be accomplished by rotating the manual operating handle 129 clockwise through approximately the right angle so as to cause the arm 150 to pry the lockout lever 151 clockwise against a holding spring 152 and thereby release a link 153 for rotation in a clockwise direction by spring 154 to translate a long link 156 to the right. This pivots link 118 in a clockwise direction about rod 113 to move a second link 159, pinned to its lower end, toward the left and into engagement with the upper end of trip lever 53. This pivots rocker arm 56 and trip shaft 58 clockwise to trip the main switches 10 open in the manner previously described. In addition, a pin 160 extending laterally from the upper end of link 118 moves into engagement with an arm 161 affixed to blocking shaft 113 to hold the offset portion 115 in engagement with the toggle link 102 and prevent the energization of reclosing coil 96. In addition, the clockwise movement of operating arm 129 tilts the mercury switch 126 affixed to shaft 128 to open position so that the circuit through the rotary solenoid 120 cannot be completed until the operating handle is returned to its initial position shown in FIG. 1.

While only a single embodiment of the invention is shown and described, it is intended to cover in the appended claims all modifications and embodiments that fall within the scope of the invention.

We claim:

1. A repeating circuit interrupter including main switch means in circuit with an electrical system, switch opening means operable upon the occurrence of an overload in said system, said switch opening means including overload responsive means and a plurality of time delay means for delaying the opening of said main switch means, said time delay means having different delay characteristics, one of said time delay means being in operative association with said overload responsive means during an initial one of the operations of said switch opening means, secondary switching means operable after a susbsequent opening operation of said main switch means to place a different one of said plurality of time delay means in operative association with said overload responsive means so that the time delay of the next succeeding opening operation of said main switch means will have a different

time delay, electromotive means for effecting the reclosure of said main switch means, a plurality of reclosing time delay means each operable to complete an energizing circuit to said electromotive means to reclose said main switch means, said secondary switching means also being sequentially operable after each opening operation of said main switch means to actuate a different one of said reclosing time delay means so that the time delay of each reclosing operation of said main switching means may be controlled, said secondary switch means being operable after a preselected number of reclosing operations to open circuit said electromotive means and prevent the further reclosure of said main switch means.

2. A repeating circuit interrupter including main switch means in circuit with an electrical system, electroresponsive switch opening means, a source of electrical energy, overload responsive means operable upon the occurrence of a fault in said system to place said electroresponsive switch opening means in circuit with said energy source, said overload responsive means including a plurality of time delay circuit means, said time delay means having different delay characteristics, one of said time delay means being in operative association with said overload responsive means during an initial one of the operations of said switch opening means, step switching means operable during a subsequent opening operation of said main switch means to couple a different one of said plurality of time delay circuit means to said overload responsive means so that the time delay of the next succeeding opening operation of said main switch means may be individually controlled, electromotive means for effecting the reclosure of said main switch means, a plurality of time delay relay means each operable to complete an energizing circuit to said electromotive means to reclose said main switch means, said step switching means also being operable during each opening operation of said main switch means to connect a different one of said time delay relay means to said source of electrical energy so that the time delay of each reclosing operation of said main switch means may be controlled, said step switching means also being operable after a preselected number of reclosing operations to prevent the energization of said electromotive means and prevent the further reclosure of said main switch means.

3. A repeating circuit interrupter including main switch means in circuit with an electrical system, electroresponsive switch opening means, electroresponsive switch closing means, a source of electrical energy, overcurrent sensing means coupled to said system, actuating means connected to said overcurrent sensing means and operable upon the receipt of an electrical signal therefrom to complete an energizing circuit to said electroresponsive switch opening means, a plurality of time delay circuit means, said time delay circuit means having different delay characteristics, one of said time delay circuit means being in operative association with said overcurrent sensing means during an initial one of the opening operations of said switch opening means, step switch means operable after a subsequent opening operation of said main switch means to connect a different one of said time delay circuit means between said overcurrent sensing means and said actuating means so that the time delay of the next succeeding opening operation of said main switch means may be controlled, energizing means connected to said main switch means and operable upon the opening thereof to complete an energizing circuit to said switch closing means, normally inactive electromotive means for blocking the operation of said energizing means to prevent the reclosure of said switch means, contact means in circuit with said electromotive means, said contact means also being coupled to said main switch means and operable to close when said main switch means opens, a plurality of time delay relay means each operable to connect said normally inactive electromotive means to said energy source through said contact means so that said energizing means is released and said main switch means may reclose, said step switch means also being sequentially operable after each opening operation of said main switch means to connect a different one of said time delay relay means to said source of electrical energy so that the time delay of the succeeding reclosing operation of said main switch means be controlled, said step switch means also being operable after a preselected number of reclosing operations to open circuit said electromotive means and prevent the further reclosure of said main switch means.

4. A repeating circuit interrupter including main switch means in circuit with an electrical system, electroresponsive switch opening means, electroresponsive means for effecting reclosure of said main switch means after each opening operation, overload responsive means operable upon the occurrence of a fault in said system to complete an energizing circuit to said switch opening means to open said main switch means, said overload responsive means including a plurality of time delay circuit means, said time delay circuit means having different delay characteristics, one of said time delay circuit means being in operative association with said overload responsive means during an initial one of the opening operations of said switch opening means, secondary switch means operable after a subsequent opening operation to place a different one of said time delay circuit means in operative association with said overload responsive means so that the next succeeding opening operation can be individually controlled, said secondary switch means being operative after a predetermined number of opening operations to open circuit said electroresponsive switch closing means to prevent the further reclosure of said main switch means.

5. A repeating circuit interrupter including main switch means in circuit with an electrical system, electroresponsive switch opening means, electroresponsive means for effecting closure of said main switch means, a source of electrical energy, overcurrent sensing means coupled to said system, actuating means connected to said overcurrent sensing means and operable upon the receipt of an electrical signal therefrom for completing an energizing circuit to said electroresponsive switch opening means, a plurality of time delay circuit means, said time delay circuit means having different delay characteristics, one of said time delay circuit means being in operative association with said overcurrent sensing means during an initial one of the operations of said switch opening means, step switching means operable after a subsequent opening operation of said main switch means for connecting a different one of said time delay circuit means between said overcurrent sensing means and said actuating means so that the time delay of the next succeeding opening operation of said main switch means may be controlled, said step switching means also being operable after each opening operation of said main switch means to connect said electroresponsive switch closing means to said source of electrical energy to reclose said main switch means, said step switching means also being operable after a preselected number of reclosing operations to open circuit said electroresponsive switch closing means and prevent the further reclosure of said main switch means.

6. A repeating circuit interrupter including main switch means in circuit with an electrical system, and resettable holding means for maintaining said switch means in closed position, means for opening said main switch means upon the occurrence of a fault in said system and for resetting said holding means, electroresponsive switch closing means, a source of electrical energy, energizing means connected to said holding means and normally operable upon the resetting thereof to complete an energizing circuit to said switch closing means, normally inactive electromotive means for blocking the operation of said energizing means to prevent the reclosure of said switch means, step switching means, a plurality of time delay relay means each operable to connect said normally inactive electromotive means to said energy source so that said

energizing means is released and said main switch means may reclose, said step switching means being operable during each opening operation of said main switch means to connect a different one of said time delay relay means to said source of electrical energy so that the time delay of each reclosing operation of said main switch means may be controlled, said step switching means also being operable after a preselected number of reclosing operations to open circuit said electromotive relative to said source and prevent the further reclosure of said main switch means.

7. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said main switch means upon the occurrence of a fault in said system, electromotive means for effecting reclosure of said switch means, a source of unidirectional energy, secondary switch means having a plurality of successively engageable taps, a unidirectional circuit element electrically connected between successive ones of said taps for electrically isolating each from the preceding one in said succession, circuit means selectively connectable to a predetermined one of said taps, said secondary switch means being sequentially operable to successive taps after each opening operation of said main switch means to complete an energizing circuit to said electromotive means from said energy sources and through said circuit means and to effect reclosure of said main switch means, said unidirectional circuit elements preventing the completion of said energizing circuit upon the operation of said secondary switch means to the next succeeding tap after said predetermined one to prevent further reclosure of said main switch means.

8. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said main switch means upon the occurrence of a fault in said system, a source of electrical energy, electromotive means for effecting reclosure of said main switch means, step relay means having a plurality of taps, a predetermined number of successive taps being in circuit between with said energy source and said electromotive means, the next succeeding tap after said predetermined number being ineffective to couple said energy source to said electromotive means, said step relay means being sequentially operable during each opening operation of said main switch means to connect said electromotive means to said energy source through successive ones of said predetermined number of taps to effect reclosure of said main switch means, the connection of said electromotive means to the next succeeding tap after said predetermined number open circuiting said electromotive means to prevent further reclosure of said main switch means, time delay means connected between said source and each of said predetermined number of taps except the first and operative after a time delay to return said step relay to the first of said successive taps if the number of opening operations is less than said predetermined number.

9. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said main switch means upon the occurrence of a fault in said system, a source of electrical energy, electromagnetic means for effecting reclosure of said main switch means, step relay means having a movable contact and plurality of taps successively engageable thereby, the engagement of a predetermined number of successive taps by said movable contact completing an energizing circuit between said energy source and said electromagnetic means, the next succeeding tap after said predetermined number being ineffective to couple said electromagnetic means to said energy source, said step relay means being sequentially operable during each opening operation of said main switch means to connect said electromagnetic means to said source and thereby effect reclosure of said main switch means, the engagement by said movable contact of said next succeeding tap after said predetermined number open circuiting said electromagnetic means to prevent further reclosure of said main switch means, time delay relay means connected between said source and each of said predetermined number of taps except the first and operative after a time delay to connect said step relay means to said energy source to recycle said step relay to the first of said taps if the number of opening operations is less than said predetermined number.

10. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said switch means upon the occurrence of a fault in said system, a source of electrical energy, electromotive means for effecting reclosure of said switch means, a plurality of time delay means for placing said electromotive means in circuit with said energy source, step relay means having a movable contact and a plurality of taps engageable thereby, a predetermined number of successive taps being in circuit with said energy source and a different one of said time delay means when engaged by said movable contact, the next succeeding tap being ineffective to place any one of said time delay means in circuit with said energy source, said movable contact being operable after each opening operation of said main switch means to contact a different one of said taps and actuate a different one of said time delay means to effect reclosure of said main switch means, the connection of the next succeeding tap after said predetermined one open circuiting said electromotive means to prevent further reclosure of said main switch means, time delay means connected between said source and each of said predetermined taps except the first and operative after a time delay to return said movable contact to the first of said successive taps if the number of opening operations is less than said predetermined number.

11. A repeating circuit interrupter including main switch means in circuit with an electrical system, latch means for holding said main switch means in a closed position, latch release means for opening said main switch means upon the occurrence of a fault in said system, means for resetting said latch means in preparation for a switch reclosing operation, electroresponsive switch closing means for relatching said main switch means in its closed position, a source of electrical energy, energizing means connected to said latch means and normally operable upon the resetting thereof to complete an energizing circuit to said switch closing means, normally inactive electromotive means for blocking the operation of said energizing means to prevent the reclosure of said main switch means, step switching means, a plurality of time delay relay means each operable to connect said normally inactive electromotive means to said energy source so that said energizing means is released and said main switch means may reclose, said step switching means being operable during each opening operation of said main switch means to connect a different one of said time delay relay means to said source of electrical energy so that the time delay relay of each reclosing operation of said main switch means may be controlled, said step switching means also being operable after a preselected number of reclosing operations to open circuit said electromotive means and to prevent the further reclosure of said main switch means.

12. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said main switch means upon the occurrence of a fault in said system, a source of unidirectional electrical energy, electromotive means for effecting the reclosure of said main switch means, step relay means having a first movable contact in circuit with said source and a first group of taps successively engageable by said first contact, a unidirectional circuit element electrically connected between each of the taps in said first group except the last one thereof and electrically isolating each from the preceding one in said succession, said step relay means having a second movable contact and a second group of taps successively engageable by said second movable con-

tact, a plurality of time delay means, each of the taps in said second group being in circuit with a different one of said time delay means, circuit means for selectively connecting said second movable contact to one of said first group of taps, said first and second movable contacts being operable to successive ones of their respective taps upon each opening operation of said main switch means to actuate a different one of said time delay means and effect reclosure of said main switch means, said unidirectional circuit elements preventing the actuation of said time delay means upon the operation of said first contact to the next succeeding tap in said first group after said one tap to provide lockout of said main switch means, time delay means connected between said source and each of the taps in said second group except the first thereof and operative after a time delay to operate said first and second movable contacts to the first of said successive groups in each group if the number of opening operations is less than that required for lockout.

13. A repeating circuit interrupter including main switch means in circuit with an electrical system, electroresponsive switch opening means, electroresponsive switch closing means control means for effecting the reclosure of said main switch means after each opening operation, overload responsive means operable upon the occurrence of an overload in said system to actuate said switch opening means to open said main switch means, a plurality of RC time delay circuit means said time delay circuit means having different delay characteristics, one of said time delay circuit means being in operative association with said overload responsive means during an initial one of said switch opening operations so that said opening operations will have a first time delay characteristic, said control means being operable after a subsequent opening operation to place a different one of said time delay circuit means in operative association with said overload responsive means so that the next succeeding opening operation will have a second time delay characteristic, said control means also being operative after a predetermined number of opening operations to prevent the actuation of said electroresponsive switch closing means to prevent the further reclosure of said main switch means.

14. A repeating circuit interrupter including main switch means in circuit with an electrical system, switch opening means operable upon the occurrence of a predetermined condition in said system, said switch opening means including overload responsive means and a plurality of time delay circuit means for delaying the opening of said main switch means, one of said time delay circuit means being in operative association with said overload responsive means during a predetermined one of the operations of said switch opening means, secondary switching means operable after said predetermined opening operation of said main switch means to place another one of said plurality of time delay means in operative association with said overload responsive means to provide different controlled time delays for at least a pair of successive opening operations, electroresponsive means for effecting the reclosure of said main switch means, a plurality of reclosing time delay means each operable to initiate a delayed reclosing operation by said electroresponsive means, one of said reclosing time delay means being in operative association with said electroresponsive means during a predetermined one of said closing operations, said secondary switching means also being operable after said predetermined closing operation of said main switch means to place a different one of said reclosing time delay means in operative association with said electroresponsive means so that the time delay of at least a pair of successive reclosing operations of said main switch means may be controlled, said secondary switching means being operable after a preselected number of reclosing operations to prevent the actuation of said electroresponsive means so that said main switch means will not be reclosed.

15. A repeating circuit interrupter including main switch means in circuit with an electrical system, electroresponsive switch opening means, a source of electrical energy, abnormal condition responsive means operable upon the occurrence of an abnormal condition in said system to place said electroresponsive switch opening means in circuit with said energy source, said abnormal condition means including a plurality of time delay circuit means, one of said time delay circuit means being in operative association with said switch opening means during a predetermined one of the operations of said switch opening means, stepping means operable after said predetermined opening operation of said main switch means to place another one of said plurality of time delay circuit means in operative association with said switch opening means to provide different controlled time delays for at least a pair of successive opening operations, electromotive means for effecting the reclosure of said main switch means, a plurality of time delay relay means each operable to complete an energizing circuit to said electromotive means to reclose said main switch means, one of said time delay relay means being in operative association with said electromotive means during a predetermined one of said closing operations, said stepping means also being operable after said predetermined closing operation of said main switch means to place a different one of said time delay relay means in operative association with said electromotive means so that the time delay of each reclosing operation of said main switch means may be controlled, said stepping means also being operable after a preselected number of reclosing operations to open circuit said electromotive means and prevent the further reclosure of said main switch means.

16. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said main switch means upon the occurrence of a predetermined condition in said system, said switch opening means including RC time delay circuit means in circuit with said switch opening means to effect the delayed operation thereof, said time delay circuit means having a first effective time constant during a predetermined one of the opening operations of said switch opening means, switching means operable after said predetermined opening operation to modify the effective time constant of said time delay circuit means for the next opening operation to provide different time delays for at least a pair of successive opening operations, electromotive means operative to effect the reclosure of said main switch means, a plurality of reclosing time delay means each operable to initiate a time delayed operation of said electromotive means, one of said reclosing time delay means being in operative association with said electromotive means during a predetermined one of said closing operations, said switching means being operable after said predetermined closing operation means to place a different one of said reclosing time delay means in operative association with said electromotive means so that the time delay of at least a pair of successive reclosing operations of said main switch means may be individually controlled.

17. A repeating circuit interrupter including main switch means in circuit with an electrical system, RC time delay circuit means, input means for deriving a unidirectional current functionally related to the current in said system, overcurrent responsive means coupled to said input means and to said time delay circuit means for initiating the charging thereof when the current in said system exceeds a predetermined value, electroresponsive switch opening means coupled to said time delay circuit means for opening said main switch means when the charge on said time delay circuit means reaches a predetermined value, said time delay circuit means having a first effective capacitance during a predetermined one of the operations of said switch opening means, stepping

means operable after said predetermined operation to modify the effective capacitance of said time delay circuit means to provide different time delays for at least a pair of successive opening operations, electromotive means operative to effect the reclosure of said switch means, a plurality of reclosing time delay means each operable to initiate a time delayed operation of said electromotive means so that said main switch means is closed, one of said reclosing time delay means being in operative association with said electromotive means during a predetermined one of said closing operations, said stepping means being operable after said predetermined closing operation of said main switch means to place a different one of said reclosing time delay means in operative association with said electromotive means, so that the time delay of at least a pair of successive reclosing operations of said main switch means may be controlled, said stepping means being operable after a preselected number of reclosing operations to prevent the actuation of said electromotive means so that said main switch means will not be reclosed.

18. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said main switch means upon the occurrence of a predetermined condition in said system, switch closing means operable after an opening operation, said switch opening means including RC time delay circuit means in circuit with said switch opening means to effect the delayed operation thereof, said RC time delay circuit means having a first effective time constant during a predetermined one of the operations of said switch opening means, switching means operable after said predetermined operation to modify the effective time constant of said RC time delay circuit means to provide different time delays for at least a pair of successive opening operations, reclosing time delay means operable to delay the operation of said switch closing means, said reclosing time delay means having a first effective delay value during a predetermined one of said closing operations, said switching means being operable after said predetermined closing operation of said main switch means to modify the effective delay value of said reclosing time delay means so that the time delay of at least a pair of successive closing operations of said main switch means will have different effective values.

19. A repeating circuit interrupter including main switch means in circuit with an electrical system, switch opening means including overload responsive means operable upon the occurrence of a predetermined condition in said system, switch closing means operable after an opening operation, said switch opening means including a plurality of time delay circuit means for delaying the opening of said main switch means, one of said time delay circuit means being in operative association with said overload responsive means during a predetermined one of the operations of said switch opening means, secondary switching means operable after said predetermined opening operation of said main switch means to place another one of said plurality of time delay means in operative association with said overload responsive means to provide different controlled time delays for at least a pair of successive opening operations, reclosing time delay means operable to delay the operation of said switch closing means, said reclosing time delay means having a first effective time delay during a predetermined one of said closing operations, said secondary switching means being operable after said predetermined closing operation of said main switch means to modify the effective time delay of said reclosing time delay means so that the time delay of at least a pair of successive closing operations of said main switch means may be controlled, said secondary switching means being operable after a preselected number of closing operations to prevent the operation of said switch closing means so that said main switch means will not be closed.

20. A repeating circuit interrupter having switch means for interrupting an electrical system, switch operating means including switch opening means and switch closing means, step-by-step advancing means coupled to said switch operating means and actuable upon the operation thereof, electrical energy storage means coupled to said system for integrating an electrical signal functionally related to said condition, abnormal condition responsive means connected to said system and operable upon the occurrence of an abnormal circuit condition to initiate the integration of said signal by said energy storage means, said switch opening means being connected to said energy storage means and actuable to open said switch means when the energy stored therein reaches a predetermined value, said energy storage means having a first effective time constant during a predetermined one of the operations of said switch opening means, said advancing means being operable after said predetermined operation to modify the effective time constant of said energy storage means to provide different time delays for at least a pair of successive opening operations, reclosing time delay means operable to initiate a time delayed operation of said switch closing means, said reclosing time delay means having a first time delay value during a predetermined one of said closing operations, said advancing means being operable after said predetermined closing operation of said main switch means to modify the time delay value of said reclosing time delay means so that the time delay of at least a pair of successive closing operations of said main switch means may have different time delay values.

21. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said main switch means upon the occurrence of a predetermined circuit condition in said system, a source of electrical energy, electromotive means for effecting reclosure of said switch means, step acting means having a plurality of stages, a predetermined number of successive stages being in circuit between with said energy source and said electromotive means, the next succeeding stage after said predetermined number being ineffective to place said electromotive means in circuit with said energy source, said step acting means being sequentially operable during each opening operation of said main switch means to connect said electromotive means to said energy source through successive ones of said predetermined number of stages to effect the reclosure or said main switch means, the connection of said electromotive means to the next succeeding stage after said predetermined number open circuiting said electromotive means to prevent further reclosure of said main switch means, time delay means connected between said source and each of said predetermined number of stages except the first and operative after a time delay to return said step acting means to the first of said successive stages if the number of opening operations is less than said predetermined number.

22. The device set forth in claim **19** wherein said one of said time delay circuit means includes a first timing capacitor and said another one of said time delay means includes a second timing capacitor and wherein said secondary switching means is operable to place said second timing capacitor in a parallel circuit relation with said first timing capacitor after said predetermined opening operation.

23. The repeating circuit interrupter set forth in claim **15** wherein said stepping means includes electromotive means and a first plurality of stages connected to said time delay circuit means and a second plurality of stages connected to said time delay relay means, and time delay resetting means connected to said second plurality of stages and operative to reset said stepping means to the initial one of its stages if the number of opening operations is less than said preselected number.

24. A repeating circuit interrupter including main switch means in circuit with an electrical system, means for opening said main switch means upon the occurrence of a predetermined circuit condition in said system, electromotive means for effecting the reclosure of said main switch means, step acting sequencing means having a plurality of successive stages, said sequencing means being operable when in a predetermined number of its successive stages after an initial stage for effecting the energization of said electromotive means, said sequencing means being ineffective to cause energization of said electromotive means when said sequencing means is in the next succeeding stage after said predetermined number, said sequencing means being sequentially operable to successive ones of its stages upon each opening operation of said main switch means to effect the reclosure of said main switch means when said sequencing means is in each of its predetermined number of stages, the operation of said sequencing means to the next succeeding stage after said predetermined number being operative to prevent further reclosure of said main switch means, time delay means connected to each of the predetermined number stages of said sequencing means and operable after a time delay to return said sequencing means to said initial stage if the number of opening and closing operations is equal to or less than said predetermined number.

25. A repeating circuit interrupter including main switch means in circuit with an electrical system, abnormal condition responsive means for opening said main switch means upon the occurrence of a predetermined circuit condition in said system, electromotive means for effecting the reclosure of said main switch means, electroresponsive sequencing means having a plurality of successive stages, an energy source, said sequencing means being operable when in a predetermined number of its successive stages after an initial stage to

couple said electromotive means to said energy source, said sequencing means being ineffective to couple said electromotive means to said energy source when said sequencing means is in the next succeeding stage after said predetermined number, said abnormal condition responsive means being operable upon the occurrence of an abnormal circuit condition to complete an energizing circuit to said sequencing means to operate the latter to a successive one of its stages upon each opening operation of said main switch means and to effect the reclosure of said main switch means when said sequencing means is in each of its predetermined number of stages, the operation of said sequencing means to the next succeeding stage after said predetermined number being operative to prevent further reclosure of said main switch means, time delay means connected to each of the predetermined number stages of said sequencing means and operable after a time delay to return said sequencing means to the first of said successive stages if the number of opening and closing operations is equal to or less than said predetermined number.

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