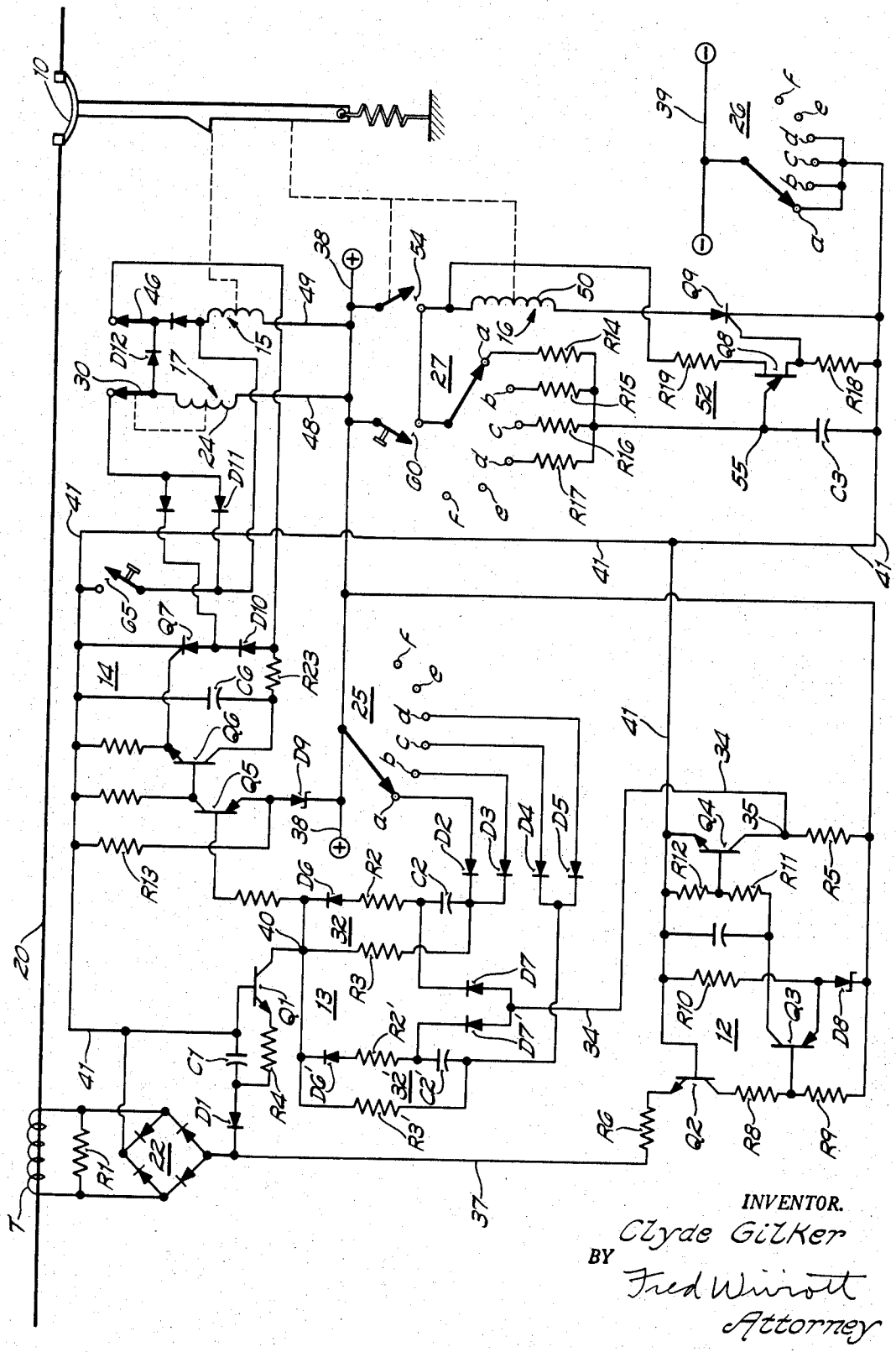
March 12, 1968 C. GILKER 3,373,317

REPEATING CIRCUIT INTERRUPTER WITH IMPROVED STEP ADVANCE CONTROL MEANS

Filed Jan. 17, 1966



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United States Patent Office 3,373,317
Patented Mar. 12, 1968

3,373,317

REPEATING CIRCUIT INTERRUPTER WITH IMPROVED STEP ADVANCE CONTROL MEANS

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Filed Jan. 17, 1966, Ser. No. 521,081
11 Claims. (Cl. 317—22)

This invention relates to repeating circuit interrupters and, more particularly, to means for insuring the proper sequence of operation of a repeating circuit interrupter in response to the occurrence of a predetermined circuit condition.

A repeating circuit interrupter or recloser may be characterized as a circuit protective device having abnormal condition sensing means connected to the system being protected and responsive to an abnormal circuit condition to initiate a switch opening operation. Reclosers also include switch reclosing means operable after each opening operation, opening and reclosing time delay means and sequencing means which is operable to initiate the various functions and to prevent reclosing after a predetermined number of opening operations.

Because the majority of faults in electrical distribution systems are temporary in nature and will clear in a relatively short period of time, it is common to arrange the switch opening means of the repeating circuit interrupter to execute a series of relatively rapid opening operation so that the period during which the system remains energized is shorter than the time required for other system protective devices, such as fuses, to operate. In addition, the circuit interrupter contacts should not be closed immediately in order to allow such fuses to cool. If the fault does not clear during this initial series of rapid operations, opening time delay means is actuated by the sequencing 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 other system protected device to operate. If the fault has not cleared after a predetermined number of such time delayed operations, it is considered permanent and the sequencing means prevents the actuation of reclosing means so that the device is locked open. On the other hand, should the fault clear during any of the relatively rapid or time delayed operations, it is necessary for the operation counting means to be reset in its initial position so that upon the occurrence of a subsequent fault, the recloser will execute the full number of rapid and time delayed operations prior to being locked open. Such resetting means is usually time delayed so that premature resetting will not occur to interfere with normal operations.

Many prior art repeating circuit interrupters comprise a combination of mechanical and electrical components including electronic circuitry for performing various control functions. It is therefore extremely difficult under all conditions to insure the proper sequence of operation of the various electronic and mechanical elements. For example, a common fault of prior art circuit interrupters is that the sequencing means, usually an electromagnetic relay, does not advance properly wherein it will skip a step or advance a plurality of steps.

An object of the invention is to provide a repeating circuit interrupter wherein operation of the sequencing means during each opening operation is insured.

A further object of the invention is to provide a repeating circuit interrupter having sequencing means which is prevented from taking a plurality of steps during any switch opening operation.

These and other objects and advantages of the instant invention will become more apparent from the detailed description thereof taken with the accompanying drawing which schematically illustrates the repeating circuit interrupter according to the instant invention.

In general terms, the invention comprises a repeating circuit interrupter including first circuit means for providing a control signal upon the occurrence of a predetermined condition in the system being protected, second circuit means operable to complete an energizing circuit to the switch opening means upon the occurrence of the control signal, step acting sequencing means operative to a plurality of stages to provide a predetermined sequence of switch opening and closing operations and including an electroresponsive actuating part energizable upon the completion of an energizing circuit to the switch opening means, contact means for open circuiting the electroresponsive actuating part upon the opening of main switch means, and means for interrupting the control signal when a switch opening operation is initiated.

Referring now to the drawing in greater detail, the illustrated repeating circuit interrupter or recloser is shown to have a main interrupting switch **10**, an overload sensing circuit **12**, a timing circuit **13**, an output circuit **14**, switch opening means **15**, switch closing means **16** and sequencing means **17**.

The various portions of the repeating circuit interrupter will be discussed in greater detail hereinbelow, it being sufficient at this point to state that when a predetermined overcurrent is sensed by the overcurrent sensing circuit **12**, a signal is provided to the timing circuit **13** which then initiates a timing operation, and, after a predetermined interval provides a signal to the output circuit **14** which then actuates the switch opening means or trip coil **15** so that interrupting switch **10** will be moved to its open position. Upon this event, the reclosing means **16** is made operable to return the interrupting switch **10** to its closed position. The sequencing means **17**, performs the operation counting and lockout functions and insures the desired sequence of opening and reclosing operations.

For a more complete description of the circuit breaker operating mechanism usable with the illustrated control mechanism, reference is made to copending application Ser. No. 325,215 filed Nov. 21, 1963 and assigned to the assignee of the instant invention.

Before continuing with the discussion of the various circuit portions mentioned above, the operation of the sequencing means **17** will be discussed briefly. The sequencing means is schematically illustrated to include a stepping relay coil **24** and step switches **25**, **26** and **27**. The sequencing means **17** is sequentially operable to a plurality of stages, symbolized by a movable wiper and taps or stages *a–f* for each of the step switches. Each time the coil **24** is energized, it is operable to simultaneously advance each wiper one tap from *a–f* and back to *a*. While it may appear from the schematically illustrated step switches that the circuit through each will be momentarily opened when their respective wipers are between positions, in actual practice the switches are of the type wherein the wiper bridges over to the next contact before moving off to previous ones so that circuit integrity is maintained. For this reason, contacts **30** are provided in the relay **24** energizing circuit and are arranged to open and reclose each time the coil **18** advances the step switches so that coil **24** will be de-energized and drop out in preparation for a succeeding stepping operation.

Referring again to the overcurrent sensing circuit **12**, the timing circuit **13** and the output circuit **14**, these are shown to be coupled to the system **20**, by the current transformer T, a resistor R1 and the full wave rectifier **22** whose output terminals are connected across a capacitor C1 and a diode D1. As a result, a voltage will appear

across capacitor C1 which is proportional to the current flowing in the system 20.

The timing circuit 13 includes a first timing circuit portion 32 connected through isolating diodes D2 and D3 to taps *a* and *b* respectively of stepping switch 25 and a second timing circuit portion 32' connected through isolating diodes D4 and D5 to taps *c* and *d* of said switch. The timing circuit portions 32 and 32' are identical except for the size of their components which determine their time delay characteristics and, accordingly, only timing circuit portion 32 will be discussed in detail for the sake of brevity.

Timing circuit portion 32 is shown to include a timing capacitor C2 connected in series with a timing resistor R2 and a diode D6 and the series combination connected in parallel with a second timing resistor R3. As has been fully discussed in copending application Ser. No. 800,567 filed Mar. 19, 1959 and assigned to the assignee of the instant invention, the impedance values of capacitor C2 and resistors R2 and R3 determine the charging time for any given fault current in the system 20. Under normal operating conditions, the tap switch 25 will be initially connected to tap *a* so that timing circuit 32 will be operable during the first opening operation.

A transistor Q1 couples the time delay circuit 13 to the capacitor C1, wherein its collector is connected to the timing circuits 32 and 32' while its base is connected to one terminal of capacitor C1 and its emitter is connected to the other terminal thereof through resistor R4. As a result, the current flowing to the collector of transistor Q1, which is a function of the voltage across capacitor C1, will split between the parallel paths defined by the resistor R3 and the series combination of timing resistor R2 and capacitor C2.

When there is no fault in the system 20, capacitor C2 is prevented from charging because it is shunted by a leakage resistor R5 located in the overload current sensing portion 12 and to which it is connected by a diode D7 and conductor 34. As a result of this leakage current, the terminal 35 of resistor R5 will have some positive potential.

Turning now to the overcurrent sensing circuit 12, it is shown to include a transistor Q2 whose emitter is connected to one output terminal of full wave rectifier 22 through resistor R6 and conductor 37 such that its emitter current flowing through resistors R8 and R9 to the positive bus 38 will also be proportional to the peak current in the system 20. The base of a second transistor Q3 is connected to the junction between resistors R8 and R9 while its emitter is held at a constant potential by a Zener diode D8 and a resistor R10 connected in series between the positive bus 38 and a conductor 41 which is normally connected to the negative bus 39 through step switch 26. Thus, by a proper selection of components, transistor Q3 can be considered as a level detector which is rendered conductive when the current in the system 20 equals or exceeds the desired minimum actuating current for the device.

Upon the occurrence of an overcurrent in the system 20, the emitter of Q3 will become sufficiently positive relative to its base so that electric current will flow to the negative bus 39 through resistors R11 and R12. This provides a base signal to transistor Q4 which then becomes conductive to connect terminal 35 of resistor R5 to the negative bus 39. This, in turn, causes terminal 35 to assume a negative potential so that leakage current can no longer flow from capacitor C2. As a result, timing capacitor C2 is prevented from discharging through leakage resistor R5 and, therefore, begins charging. In this manner, the timing operation is initiated. Diode D7 performs the function of preventing reverse current flow from terminal 35 to the capacitor C2.

The output circuit portion 14 includes a second level detecting transistor Q5 whose base is connected to the junction between the collector of transistor Q1 and timing circuit 32 and whose emitter is held at a constant potential by a Zener diode D9 and a resistor R13 which are connected in series between the positive bus 38 and conductor 41. The emitter of transistor Q5 is connected to the base of a switching transistor Q6 whose emitter, in turn, is connected to the gate of a silicon controlled rectifier Q7. The anode and cathode of Q7 are connected in series circuit relation with a diode D10 and the trip coil 15 and the series combination is connected between positive bus 38 and conductor 41.

After timing capacitor C2 has charged for a predetermined time, which is the time delay for the first operation of the device, the potential at junction 40 will reach the point where transistor Q5 is rendered conductive which, in turn, makes the base of transistor Q6 more negative than its emitter so that Q6 will also become conductive to provide a gate signal to control rectifier Q7. Upon this event, Q7 will become conductive to complete an energizing circuit to trip coil 15 which then opens the main switch 10 in a manner well known in the art. When the main switch 10 reaches its fully opened position, contacts 46, connected in series therewith, will be opened to de-energize trip coil 15 and render silicon controlled rectifier Q7 nonconductive.

The stepping relay coil 24, which is connected in parallel with trip coil 15 by conductors 48, 49 and isolating diode D12, will also be energized when silicon controlled rectifier Q7 is rendered conductive so that each of the step switches 25, 26 and 27 will be moved to their *b* taps. As a result, the time delay circuit portion 32 will also be effective during the second switch opening operation. Should the fault persist, requiring a third and a fourth opening operation, the switch 25 will be moved to taps *c* and *d* so that time delay circuit portion 32' will be effective whereby the third and fourth opening operations may have a longer time delay than the initial operations.

The reclosing circuit 16 includes a closing coil 50 mechanically coupled to the main switch 10 and a closing time delay circuit 52 which includes four resistors R14, R15, R16 and R17 each of which has one terminal connected to taps *a*, *b*, *c* and *d* respectfully of step switch 27. In addition, the closing time delay circuit 52 also includes a capacitor C3 connected between conductor 41 and the other terminals of resistors R14–R17. The emitter electrode of a unijunction transistor Q8 is connected to the junction 55 between capacitor C3 and resistors R14–R17 while its base-one electrode is connected through resistor R18 to conductor 41 and its base-two-electrode is connected through resistor R19 to contacts 54, the latter of which are coupled to the main switch 10 and which are opened when said main switch is closed and which are closed when the main switch is opened. The closing time delay circuit 52 also includes a silicon controlled rectifier Q9 whose gate electrode is connected to the base-one electrode of unijunction transistor Q8 and whose anode and cathode electrodes are connected in series with the closing coil 50 and the series combination is connected to conductor 41 and the positive bus 38 through contacts 54.

It will be recalled that upon the initial operation of the repeating circuit interrupter, each of the step switches 25–27 will be on tap *a*. When the trip coil 15 is energized in the manner discussed hereinabove, the stepping relay coil 24 will also be energized to advance each of the step switches 25–27 to their *b* taps. When the switch 10 reaches its fully opened position, contacts 54 will close to complete an energizing circuit to capacitor C3 through resistor R15 and step switch 26. After a time delay, determined by the relative sizes of resistor R15 and capacitor C3, the junction 55 therebetween will reach the breakover potential of unijunction transistor Q8. This will cause current flow through the emitter-base-one circuit of Q8 to provide a gate signal to silicon controlled rectifier Q9 which then becomes conductive to energize closing coil 50 whereby the main switch 10 is closed. Upon this event, auxiliary contacts 54 open to de-energize clos-

ing coil 50 and to interrupt the anode current to Q9 which then becomes nonconductive.

Should the fault in system 20 reappear when the main switch 10 is reclosed, this will again be sensed by the overcurrent sensing circuit 12 which initiates a second timing operation by timing circuit portion 32 so that trip coil 15 will be energized to open the main switches 10 and the stepping relay coil 24 will advance each of the step switches 25–27 to their *c* taps. When the main switch 10 opens for a second time, capacitor C3 will be charged through resistor R16 so that controlled rectifier Q9 will become conductive after a second time delay to energize the closing coil 50 and initiate a second closing operation. Similarly, should the fault persist after the second reclosing operation, trip coil 15 will be energized after a relatively long time delay dictated by time delay circuit 32' to again open the main switch 10. In a like manner, after the third opening operation, the stepping relay coil 24 will move each of the step switches 25–27 to their *d* taps whereupon closing coil 50 will be energized as a result of the charging of capacitor C3 through resistor R17. If the fault continues after the third closing operation, trip coil 15 will again be energized to open the main switch 10 and stepping relay coil 24 will advance each of the step switches 25–27 to their *e* taps.

It can be seen that because of the taps *e* of switches 26 and 27 are open-circuited, closing coil 50 will remain de-energized even though contacts 54 are closed when the main switch 10 is open. As a result, the main switch will not reclose. In this manner, the recloser is locked in open position after a predetermined number of opening and closing operations.

Resetting of the recloser after it has been locked open in the manner described above, is accomplished by means which are not shown, but which are well known in the art, such as that shown in copending application Ser. No. 488,371, assigned to the assignee of the instant invention.

If it is desired to initiate a manual switch opening operation, manual contacts 65, which are connected in parallel with control rectifier Q7 of the output circuit 14, are closed to immediately energize the trip coil 42 whereby the main switch 10 is opened. The closing of switch 65 also energizes the stepping relay coil 24 which advances each of the step switches 25–27 to their *b* taps. In addition, contacts 30, in series with stepping relay coil 24, open and close so that coil 24 drops out and is then re-energized to advance step switches 25–27 to their next taps and so on until coil 24 becomes open-circuited by tap *e* of step swtich 26.

Step switch 26 is provided to de-energize each of the portions of the circuit whenever the recloser is in its lockout position wherein switch 26 is on tap *e*.

The foregoing discussion of the repeating circuit interrupter is essential to the understanding of the invention discussed hereinbelow.

One shortcoming of prior art reclosers employing stepping relays is that the stepping relay may fail to advance during a switch opening operation or may advance a plurality of steps during a single opening operation. In order to insure that the relay coil 24 completes the stepping operation, its energizing circuit must be maintained for a sufficient period to allow it to advance each of the step switches 25–27. This is accomplished by means of the contacts 30 in series with the coil 24 and which opens and closes whenever the coil 24 completes a stepping operation. Thus, if the main switch 10 opens prematurely to open contacts 46, contacts 30 insure that current continues to flow to the anode of silicon controlled rectifier Q7 through coil 24 until the stepping operation is completed. Upon the latter event, contacts 30 open to interrupt the flow of anode current so that Q7 becomes nonconductive and so that relay coil 24 drops out. Contacts 30 then reclose in preparation for a subsequent operation.

It will be recalled that anode potential is provided to silicon controlled rectifier Q7 through contacts 46 which are closed whenever the main contacts are closed and which open when the main contacts open. The gate signal for Q7 is provided by transistor Q6. Normally, Q7 becomes nonconductive to de-energize trip coil 42 and stepping relay coil 24 when the main switch 10 opens to open contacts 46. However, should the contacts bounce to provide a second anode signal to the silicon controlled rectifier Q7, a second energization of the stepping relay coil 24 may result which would cause the step switches 25–28 to be advanced a second time. In order to prevent such a double step of relay coil 24, a gate turn-off capacitor C6 is connected between the collector of transistor Q6 and conductor 41. Capacitor C6 is normally charged from positive bus 38 through the coils 24 and 42 and resistor R23. When capacitor C6 is charged, it provides collector potential so that transistor Q6 may become conductive when a tripping operation is indicated in the manner discussed hereinabove. However, when the silicon controlled rectifier Q7 becomes conductive during a tripping operation, capacitor C6 is discharged through resistor R23 and Q7. This results in a loss of collector potential for transistor Q6 which then becomes nonconductive to turn off the gate signal to silicon controlled rectifier Q7. The latter, therefore, remains conductive only until its emitter current is interrupted by the opening of contacts 30 and 46. Thus, should the contacts 46 bounce closed momentarily during a switch opening operation, silicon controlled rectifier Q7 will not become conductive a second time to cause a second stepping operation of the stepping relay 24.

While only a single embodiment of the instant invention has been shown and described, it is not intended to be limited thereby but only by the scope of the appended claims.

I claim:

1. A repeating circuit interrupter including switch means in circuit with an electrical system, electroresponsive switch opening means, first circuit means coupled to said system for providing a control signal upon the occurrence of a predetermined condition in said system, second circuit means coupled to said switch opening means and to said first circuit means and being operable to complete an energizing circuit to said switch opening means upon the occurrence of said control signal, step acting sequencing means operative to a plurality of stages to initiate a switch closing operation after each of a predetermined number of switch opening operations and to prevent further reclosure thereof after the next succeeding switch opening operation after said predetermined number, said step acting means including an electroresponsive actuating part coupled to said second circuit means for being energized upon the completion of an energizing circuit to said switch opening means, contact means coupled to said switch means and in circuit with said electroresponsive actuating part for open circuiting the latter upon the opening of said switch means and for interrupting said control signal, and static means coupled to said first circuit means for disabling the same when a switch opening operation is initiated.

2. The repeating circuit interrupter set forth in claim 1 wherein said electroresponsive actuating part is constructed and arranged to operate upon being energized and to reset in preparation for a succeeding operation upon being de-energized.

3. The repeating circuit interrupter set forth in claim 2 wherein said electroresponsive actuating part is an electromagnetic coil constructed and arranged to pull in upon being energized and to drop out upon being de-energized, said step acting means also including self-interrupting contacts in series with said coil.

4. The repeating circuit interrupter set forth in claim 1 wherein said second circuit means comprises electronic switching circuit means constructed and arranged to be-

come conductive upon the occurrence of said control signal.

5. The repeating circuit interrupter set forth in claim 4 wherein said switching circuit means has an anode-cathode circuit connected to said electroresponsive actuating part and to said switch opening means and a gate connected to said first circuit means for receiving said control signal and being constructed and arranged to become conductive to pass anode and cathode current upon the receipt of said control signal and to continue to conduct current upon the disappearance of said control signal until the interruption of its anode current.

6. The repeating circuit interrupter set forth in claim 4 wherein said first circuit means includes AND logic circuit means coupled to said second circuit means and having an active state wherein it is operative to provide said control signal to said first circuit means and an inactive state, second signal means normally operative to produce a second signal, said AND logic circuit means being connected to said second signal means for assuming its active state upon the occurrence of an overload in said system and upon receiving said second signal, said second circuit means being operable to render said second signal means inoperative upon receiving said signal.

7. The repeating circuit interrupter set forth in claim 4 wherein said first circuit means includes output means coupled to said second circuit means and having a first state wherein it is active to provide said control signal to said first circuit means and a second state, energy storage means coupled to normally receive charge, said output means being connected to said energy storage means for assuming its first state upon the occurrence of an overload in said system and when said energy storage means is charged, said first circuit means being operable to discharge said energy storage means upon receiving said signal to return said output means to its second state.

8. The repeating circuit interrupter set forth in claim 4 wherein said first circuit means includes bi-stable circuit means coupled to said second circuit means and having a conductive state wherein it is active to provide said control signal to said first circuit means and a nonconductive state, capacitance means coupled to normally receive charge, said bi-stable circuit means having a first terminal connected to said capacitance and a second terminal connected to said switching circuit means for assuming its conductive state upon the occurrence of an overload in said system and when said capacitance means is charged, said first circuit means being operable to discharge said capacitance means upon receiving said signal.

9. The repeating circuit interrupter set forth in claim 8 wherein said switching circuit means has an anode-cathode circuit connected to said electromagnetic coil and to said switch opening means and a gate connected to said second terminal means and being constructed and arranged to become conductive to pass anode and cathode current upon the receipt of a gate signal and to continue to conduct current upon the disappearance of said gate signal until the interruption of its anode current.

10. The repeating circuit interrupter set forth in claim 9 wherein said bi-stable circuit means comprises a transistor and said switching circuit means comprises a silicon controlled rectifier.

11. The repeating circuit interrupter set forth in claim 10 wherein said electroresponsive actuating part is an electromagnetic coil constructed and arranged to pull in upon being energized and to drop out upon being de-energized, said step acting means also including self-interrupting contacts in series with said coil.

References Cited

UNITED STATES PATENTS

3,198,989	8/1965	Mohoney	317—22 X
3,246,206	4/1966	Chowdhurt	317—22 X
3,273,018	9/1966	Goldberg	317—22 X
3,328,638	6/1967	Reis	317—22

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