Oct. 22, 1929. D. C. WEST 1,732,736

CIRCUIT BREAKER SYSTEM

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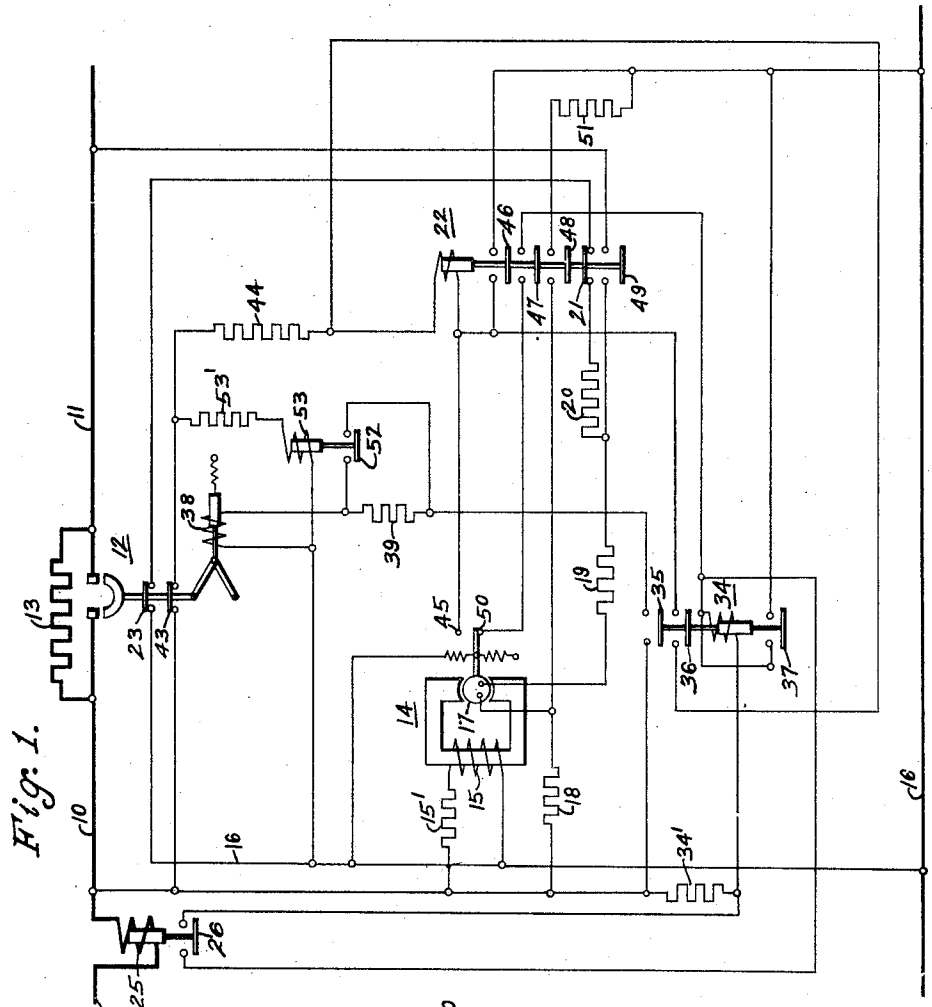

Fig. 1.

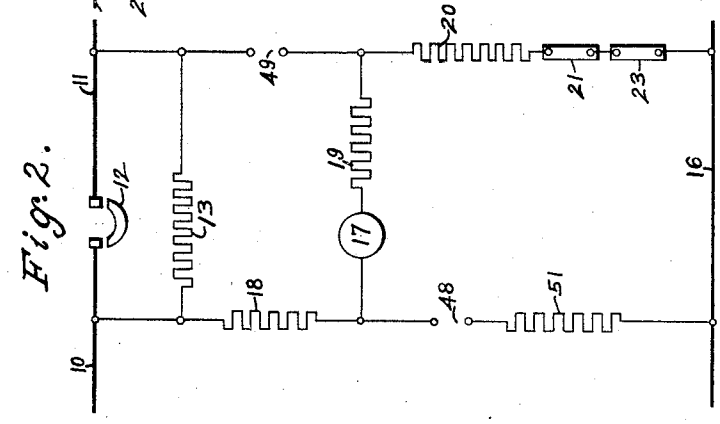

Fig. 2.

INVENTOR
Donald C. West

BY
Wesley J. Barr
ATTORNEY

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Fig. 3.

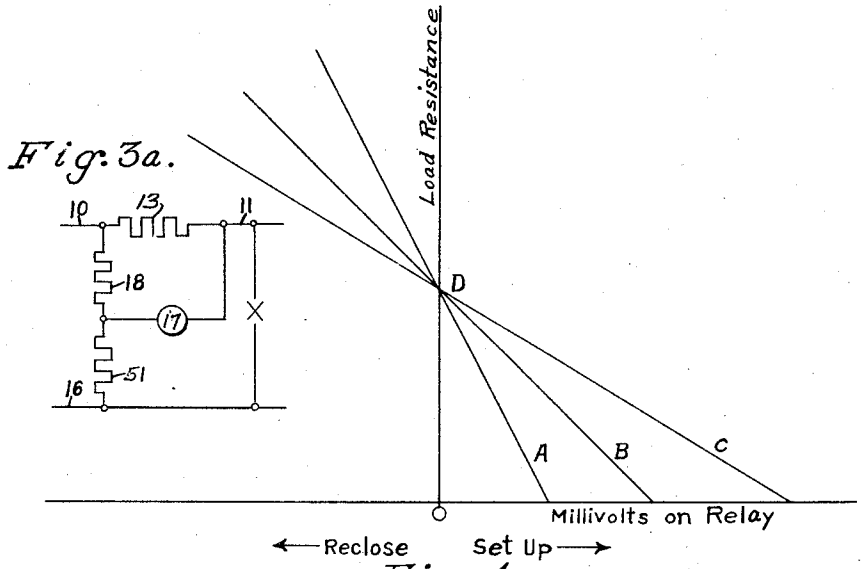

Fig. 3a.

Fig. 4.

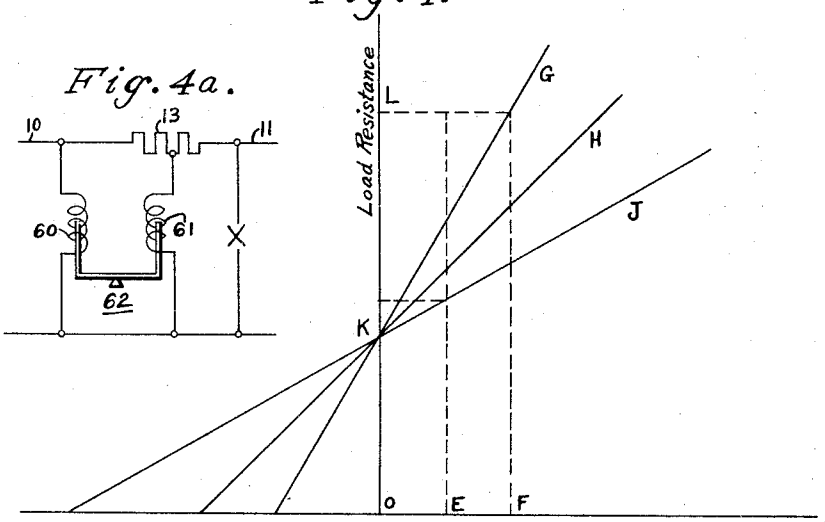

Fig. 4a.

Milamps Difference Between Coils

INVENTOR
Donald C. West

BY
Wesley S. Barr
ATTORNEY

Patented Oct. 22, 1929 1,732,736

UNITED STATES PATENT OFFICE

DONALD C. WEST, OF EAST PITTSBURGH, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA

CIRCUIT-BREAKER SYSTEM

Application filed April 12, 1928. Serial No. 269,492.

This invention pertains to an automatic reclosing-circuit-breaker system, and, more particularly, to a system of the type described, in which the connection between a supply circuit and a load circuit is controlled by a circuit-breaker which is designed to open automatically upon the occurrence of an overload or short-circuit on the load circuit, or in response to a manual operation, and to be automatically reclosed when the resistance of the load circuit increases to a predetermined value.

The principal object of my invention is to provide an automatic reclosing circuit-breaker system whereby the resistance of the load circuit may be accurately measured to determine when the load circuit should be reconnected to the supply circuit.

A further object of the system of my invention is to provide a reclosing circuit-breaker system in which the resistance-measuring circuit is not set up until the lapse of a period of time, following the opening of the circuit-breaker, that is sufficient to permit any transient conditions resulting from the opening of the breaker to disappear. By this means, it is possible to prevent false operation as a result of the transient conditions that follow the interruption of a heavy current in a distribution system.

A further object of my invention is to provide a system of the type described which shall be entirely unaffected by variations in the voltage of the supply circuit.

A still further object of my invention is to utilize a galvanometer relay to cause a resistance-measuring circuit to be connected so as to measure the resistance of the load circuit when the circuit-breaker has been opened in response to any of the above-mentioned conditions, and to employ the same relay, in combination with the resistance-measuring circuit, to determine when the resistance of the load circuit has increased to a definite predetermined value at which it is safe to reconnect the load circuit to the supply circuit.

In accordance with my invention, I utilize an inductively damped galvanometer relay of the D'Arsonval type to cause suitable resistors to be connected in the form of a Wheatstone bridge, of which the load circuit is one arm. By employing an inductively damped galvanometer, I introduce a time delay between the opening of the circuit breaker and the setting up of the Wheatstone bridge circuit. Obviously, it may be desirable to employ an additional relay to obtain the time delay between the opening of the circuit-breaker and the setting up of the resistance-measuring circuit, but in the preferred embodiment of my invention, use is made of the time delay inherent is a galvanometer relay. It is, therefore, impossible for the circuit-breaker in the system of my invention to be reclosed as a result of transient conditions before the resistance of the load circuit has actually increased to a safe value. This relay is so designed that its moving element, when energized by current of a given polarity, magnitude and duration, is actuated first in one direction to set up the resistance-measuring circuit in the nature of a Wheatstone bridge, and after setting up the Wheatstone bridge circuit, is so connected as to be responsive to the potential between two diagonally opposite points of the bridge. The resistors composing the bridge are adjusted so that, when the resistance of the load circuit has increased to a predetermined value, whereby the bridge is balanced, the potential impressed upon the relay is zero. The relay can be so adjusted that it will cause the circuit-breaker to be reclosed, to connect the supply circuit to the load circuit, when the potential impressed on the relay is zero or when it has a definite predetermined value of either polarity.

In a practical embodiment of my invention, the galvanometer relay is set to close its back contact member, to cause the circuit-breaker to reclose, when the moving coil of the relay is entirely de-energized as a result of the exact balancing of the Wheatstone bridge. Thus, I obtain the full benefit of the extreme accuracy of the Wheatstone bridge method of measuring the resistance of the load circuit. Moreover, such a measurement is independent of the applied measuring voltage.

For a full explanation of my invention, reference is made to the accompanying drawings, in which:

Figure 1 is a diagram illustrating the apparatus and circuits involved in a preferred embodiment of my invention,

Fig. 2 is a schematic diagram of a portion of the circuit shown in Fig. 1,

Fig. 3 is a set of curves illustrating the operation of the system of my invention. Fig. 3[a] is a schematic diagram of the circuit, the characteristics of which are shown by the curves in Fig. 3,

Fig. 4 is a similar set of curves illustrating the operation of a system which has been widely used heretofore, Fig. 4[a] shows a different type of resistance-measuring circuit, the characteristics of which are shown in Fig. 4.

Referring to Fig. 1, the system of my invention is designed to control the connection between a supply circuit 10 and a load circuit 11. These circuits are adapted to be connected by a circuit-breaker 12. A bridging resistor 13 is connected across the terminals of the circuit-breaker 12 to form a part of the resistance-measuring circuit to be described later.

A direct-current relay 14 of the D'Arsonval galvanometer type is employed to control the operation of the circuit-breaker 12. The magnetic circuit of the relay 14 may be either that of a permanent magnet or of an electromagnet as shown, the exciting coil 15 of which is connected in series relation with a resistor 15′ across the supply circuit 10 and a common return conductor 16. The moving coil 17 of the galvanometer relay is connected to one terminal of a resistor 18, the other terminal of which is permanently connected to the supply circuit 10, and the coil 17 is further connected through a current-limiting resistor 19 to a resistor 20. The resistor 20 is adapted to be connected to the return circuit 16 through a back contact member 21 on a relay 22 and a back contact member 23 on the main circuit-breaker 12.

An overload relay 25, having its actuating coil connected in supply circuit 10 and having a contact member 26, is provided for opening the main circuit-breaker 12, in a manner to be described later, on the occurrence of a short-circuit or overload.

In addition to the relays 14 and 22, I also make use of a relay 34 to control the operation of the circuit-breaker 12. The remaining details of the apparatus and circuits of the system of my invention will be set forth in the course of the description of the method of operation, which will now be outlined.

Under normal conditions the circuit-breaker 12 is closed and the supply circuit 10 is directly connected to the load circuit 11, the resistor 13 being thus short-circuited. The operating coil of the relay 34 is energized, as a result of certain operations to be described later, and its contact members 35, 36 and 37 are closed, the latter serving to maintain the circuit from the conductor 10 through the resistor 34′, the coil of the relay 34, the contact member 37 and thence to the conductor 16.

The circuit for the operating coil 38 of the main circuit-breaker 12 extends between conductors 10 and 16 and includes the contact member 35 of the relay 34 and a current-limiting resistor 39.

The contact member 36 maintains a short-circuit across the terminals of the operating coil of the relay 22 to prevent actuation of the contact members of the relay until the relay 34 is de-energized in a manner about to be described.

Upon the occurrence of an overload or short-circuit on the load circuit 11, the overload relay 25 is energized sufficiently so that it closes its contact member 26. The closing of the contact member 26 short-circuits the operating coil of the relay 34, which is thereupon de-energized and caused to open its contact members 35, 36 and 37. The opening of the contact member 37 interrupts the previously-traced circuit including the coil 34. The opening of the contact member 35 interrupts the circuit including the closing coil 38 of the circuit-breaker 12 which is thereupon permitted to open, to disconnect the load circuit 11 from the supply circuit 10. Under these conditions the resistor 13 is connected between the circuits 10 and 11 and the auxiliary switches 23 and 43 of the main circuit-breaker are closed.

The opening of the contact member 36 of the relay 34 removes a short-circuit from across the terminals of the operating coil of the relay 22, while the closing of the contact member 43 sets up a circuit from the supply circuit 10 through a current-limiting resistor 44 to the operating coil of relay 22. This circuit is completed by the operation of the relay 14, in a manner to be described hereinafter.

The closing of the contact member 23 on the main circuit-breaker 12 completes a circuit from the supply circuit 10 through the resistor 18, the moving coil 17 of the relay 14, the resistors 19 and 20 and thence through contact member 21 of the relay 22 and the auxiliary switch 23 to the return circuit 16. When the coil 17 of the relay 14 is thus energized, the relay operates to engage its front contact member 45, after a slight time delay effected by inductive damping means integral with the moving element of the galvanometer relay.

This time delay, as previously explained, permits the transient conditions set up in the distribution system by the opening of the circuit-breaker 12 to disappear so that false operation of the relay 14 to reclose the circuit

breaker as a result of such conditions, will not occur.

The closing of the front contact member 45 of the relay 14 completes the circuit from the operating coil of the relay 22 to the return circuit 16, and the relay 22 thereupon operates to close its contact members 46, 47, 48 and 49 and to open its contact member 21. The opening of the contact member 21 interrupts the previously traced circuit including the moving coil 17 of the relay 14.

Simultaneously, the closing of the contact member 46 completes a locking circuit for the relay 22 to the return circuit 16. The closing of the contact member 47 connects the operating coil of the relay 34 to the back contact member 50 of the galvanometer relay 14. This contact member is closed in response to circuit conditions which will be described later. The closing of the contact member 48 connects the resistor 18 to a resistor 51 which is permanently connected to the return circuit 16, and the closing of the contact member 49 connects the resistor 19 to the load circuit 11.

When the operations just described have taken place, it will be found that the resistors 13, 18 and 51 are so connected that they form, with the load circuit, a Wheatstone bridge, to two opposite corners of which the supply-load circuit 10—16 is connected. To the other two corners the moving coil of the galvanometer relay 14 is connected, in series relation with the protective resistor 19. This scheme of connections may be plainly seen in Fig. 2.

It is obvious that, by proper selection of the values of various resistors, it will be possible to cause the moving coil of the galvanometer relay 14 to be de-energized when the resistance of the load circuit attains a predetermined value. When this condition obtains, the back contact member 50 of the relay 14 is closed, and a circuit is completed from the supply circuit 10 through resistor 34′, the operating coil of the relay 34, the contact member 47 of the relay 22, the contact member 50 of the relay 14 and thence to the return conductor 16. The relay 34 is thereupon operated to close its contact members 35, 36 and 37.

The inductive damping means which delays the engagement of the moving contact member of the relay 14 with the front contact member 45, is also effective to delay the engagement of the moving contact member with the back contact member 50. Thus an interval is provided in which the circuit conditions may become stabilized, both immediately after the opening of the breaker and immediately preceding the reclosure thereof.

The closing of the contact member 35 reestablishes the previously traced circuit through the closing coil 38 of the circuit-breaker 12, but the resistor 39 is short circuited by a contactor 52, which is closed by the operation of a relay 53 as a result of the closing of the contact member 43 on the main circuit-breaker 12. The circuit for the relay 53 extends from conductor 10 through contact member 43, the resistor 53′, the coil of relay 53, and thence to the return circuit 16. When the main circuit-breaker 12 is closed in response to the energization of the coil 38, the relay 53 is de-energized and opens its contact member 52 to insert the resistor 39 in series relation with the closing coil 38 of the circuit-breaker 12, in order to reduce the current in coil 38 to a safe continuous value.

The closing of the contact member 36 of relay 34 short-circuits the operating coil of relay 22, as previously described, which is thereupon de-energized to open its contact members 46 to 49 and to close the contact member 21. The closing of the contact member 37 completes a locking circuit for the coil of relay 34, as previously set forth.

It will thus be observed that, in this preferred form, I provide means for automatically causing the opening of a circuit-breaker connecting a supply circuit to a load circuit, upon the occurrence of certain conditions. At the expiration of a predetermined operating period or time after the opening of the circuit-breaker for any reason, the system of my invention sets up a Wheatstone bridge resistance-measuring circuit, whereby the resistance of the load circuit may be measured, and causes the reclosing of the main circuit-breaker only when the resistance of the load circuit increases to a predetermined value at which it is safe to reconnect it to the supply circuit.

I am aware that it has been proposed previously to employ a Wheatstone bridge in connection with an automatic reclosing circuit-breaker, but the system of my invention entails numerous advantages over any such systems known heretofore.

By employing a galvanometer relay which has an inherent time delay in its operation, I am enabled to introduce a time delay between the opening of the circuit-breaker and the setting up of the resistance-measuring circuit. This method of operation prevents the reclosing of the circuit-breaker in response to an operation of the resistance-measuring circuit resulting from transient conditions existing in the distribution circuit as a result of the opening of the breaker. According to my invention, the breaker is opened upon the occurrence of a short-circuit, and a time interval is introduced in which the circuit conditions become stabilized, before the resistance-measuring circuit is connected to measure the resistance of the load circuit.

Another advantage of the system of my invention resides in the fact that a single relay and a single operating coil thereof function to control the setting up of the resistance-meas-

uring circuit, as well as to control the reclosing of the circuit-breaker when the resistance of the load circuit has increased to a predetermined value. It is obvious that, should there be a failure of the relay coil or contact members, the resistance-measuring circuit would not be set up, and reclosing of the circuit-breaker would be thereby prevented. In other words, the operation of the relay to set up the resistance-measuring circuit tests the relay and proves that it is in condition to measure the resistance of the load circiut.

In the systems heretofore known, the accuracy of the resistance measurements depends on the resistance of the resistor bridging the contact member of the circuit-breaker. Because of the inherent accuracy and sensitivity of the galvanometer relay, the system of my invention permits the use of a bridging resistor of higher value than those employed in former systems, so that the transfer of current from the supply circuit to the load circuit is a minimum. This, of course, is a desirable condition from an operating standpoint.

While the Wheatstone-bridge circuit has been suggested heretofore, it has never been applied for practical operation because a relay of proper characteristics for the purpose, namely, a relay of very high sensitivity combined with ruggedness of construction and permanence of calibration, has not previously been employed. The galvanometer relay which is employed in my system meets these requirements and has a sensitivity so great that even though the resistor 19, which is connected in series therewith for protection, is of considerable value, the resistance measurements can be made with very great accuracy.

As already pointed out, in the reclosing system described herein the same relay which, after a time delay following the opening of the circuit-breaker, sets up a resistance-measuring circuit, also functions to control the reclosing of the circuit-breaker when the resistance of the load circuit has increased to a safe value. This system possesses the advantage that reclosing of the circuit-breaker before the resistance of the load circuit has increased to a safe value is positively prevented, and, at the same time, when the resistance of the load circuit has increased to a predetermined value, the circuit-breaker is positively reclosed, and the load circuit is restored to service. The system of my invention, because of its inherent accuracy, is less likely to prevent reclosing when the resistance of the load circuit has reached a safe value than the systems heretofore known. Thus, the system of my invention causes the circuit-breaker to reclose positively at a fixed value of resistance in the load circuit.

A further advantage of the system of my invention is that its operation is entirely independent of variations in the voltage of the supply circuit. This advantage results from the fact that the balancing of the Wheatstone bridge depends only upon the increase in the resistance of the load circuit and is in no way affected by changes in the voltage of the supply circuit.

This characteristic of the system of my invention may, perhaps, be best understood by a consideration of the curves shown in Fig. 3. These curves illustrate the variation of the current through the winding of the relay 17 with variations in the resistance of the load circuit. The curves A, B and C illustrate, respectively, the variation in the relay current as a result of variations in the load resistance for different line voltages, for example, 500, 600 and 700 volts. As already indicated, the relay 14 may be adjusted to close its back contact member at any desired value of current through the moving coil 17. In practice I find it most desirable to adjust the relay so that its back contact member will be closed when the current in the coil 17 is substantially zero.

As shown by the curves in Fig. 3, the current in the coil 17 of the relay is zero at a fixed value of resistance in the load circuit, regardless of the value of the line voltage. If the relay is set to close its back contact member at a current value other than zero, it will be obvious that variations in the line voltage will cause considerable variations in the resistance of the load circuit at which the relay will close its back contact member to cause the reclosing of the main circuit-breaker. This range of variation increases with the value of the current at which the relay is set to close its back contact member. It is desirable, therefore, to adjust the relay to close its back contact member at zero current in the relay winding or as near to that condition as is possible.

Fig. 3ª illustrates schematically the circuit shown in Figs. 1 and 2, the characteristics of which are illustrated by the curves of Fig. 3.

In Figs. 4 and 4ª I have shown the characteristics and the circuit of a reclosing system which has been used heretofore. In this system the reclosing of the circuit-breaker depends upon the existence of a predetermined difference in the currents in the opposing windings 60 and 61 of a balanced relay 62. Because of the inherent inaccuracies in this type of instrument, it is possible to obtain a closure of its contact member (not shown) only when the difference in the currents in the opposing coils is of a value within a fixed range. Thus, referring to Fig. 4, the relay 62 may operate when the difference between the currents in the coils 60 and 61 has a value greater than OE or less than OF. The curves G, H and J illustrate the operation of the relay 62 at various values of line voltage, for example, 500, 600 and 700 volts.

Since the relay 62 may operate at any cur-

rent difference having a value between OE and OF, then, if the voltage of the system varies between 500 and 700 volts, it is obvious that relay 62 may cause the main circuit-breaker to reclose at any value of resistance between OK and OL.

It will be apparent from a comparison of Figs. 3 and 4 that the accuracy of the system of my invention is vastly greater than that of systems heretofore known, an example of which is shown in Fig. 4ª. This increased accuracy results largely from the inherent characteristics of the galvanometer relay and the extreme sensitiveness of the Wheatstone bridge as a resistance-measuring circuit.

As already stated, the accuracy with which the system of my invention measures the resistance of the load circuit is very great over an almost unlimited range, so that by suitable adjustment of the various elements of the circuit, the reclosing of the main circuit-breaker may be prevened until the actual resistance of the load has increased to a safe value, whereupon the reclosing of the circuit-breaker is immediately effected.

Inasmuch as various changes and modifications will appear to those skilled in the art, I do not wish to be limited to the exact embodiment of my invention herein shown and described except as indicated in the appended claims.

I claim as my invention:

1. A reclosing-circuit-breaker system comprising a circuit-breaker controlling the connection of a supply circuit to a load circuit, means for opening said circuit-breaker and means for reclosing the circuit-breaker when the resistance of the load circuit has increased to a predetermined value, said means including a relay for setting up a Wheatstone-bridge circuit when energized by current in one direction as a result of the opening of the circuit-breaker and for causing the breaker to reclose when the Wheatstone-bridge circuit subsequently approaches a balanced condition, whereby the energization of the relay is reduced.

2. In a reclosing-circuit-breaker system, the combination with a circuit-breaker for controlling the connection of a supply circuit and a load circuit, and means for opening the circuit-breaker under predetermined conditions, of a galvanometer relay for controlling the reclosing of the circuit-breaker when the resistance of the load circuit attains a predetermined value, said relay having a contact member adapted to be closed when the relay is energized by current in one direction to set up a Wheatstone-bridge measuring circuit and a second contact member adapted to be closed when the energization of the relay reaches a predetermined value, as a result of the substantial balancing of the bridge, to complete a circuit for causing the reclosing of the circuit-breaker.

3. In a reclosing-circuit-breaker system, a circuit-breaker for connecting a load circuit and a supply circuit, means for opening said circuit-breaker and a Wheatstone-bridge circuit for measuring the resistance of the load circuit, a galvanometer relay adapted to be connected in said bridge circuit, having a contact member adapted to be closed after a time interval when the relay is energized by current in a given direction, and a second contact member adapted to be closed when the energization of the relay reaches a predetermined value as the bridge becomes substantially balanced, means connected to the first-named contact member for setting up the Wheatstone-bridge circuit, and means connected to said second contact member for causing the reclosing of the circuit-breaker.

4. In a reclosing-circuit-breaker system, a circuit-breaker for connecting a load circuit and a supply circuit, an inductively damped galvanometer relay for setting up a Wheatstone-bridge circuit at a definite time after the opening of the breaker from any cause, and for causing the reclosing of the circuit-breaker when the resistance of the load circuit has increased to a predetermined value, whereby the bridge is approximately balanced and the energization of the relay reduced.

5. A circuit-breaker system comprising a supply circuit and a load circuit connected by a resistor, a circuit-breaker for connecting said circuits directly, additional resistors and a galvanometer relay for causing said resistors to be so connected as to form a Wheatstone bridge, one arm of which is constituted by said load circuit at a definite time after the circuit-breaker is opened, and for causing the reclosing of the circuit-breaker when the resistance of the load circuit is increased to a predetermined value, whereby the bridge is balanced and the energization of the relay is changed.

6. A system for controlling the operation of a circuit-breaker adapted to connect a supply circuit to a load circuit comprising a plurality of resistors and a galvanometer relay for causing said resistors to be connected in the form of a Wheatstone bridge of which the load circuit is one arm, at a definite time after the opening of the circuit-breaker, the supply circuit being connected to two opposite corners of the bridge and the relay to the remaining corners, whereby the resistance of the load circuit is measured, and, when it attains a predetermined value, the bridge is balanced and the energization of the relay is changed, and means for causing the circuit-breaker to be reclosed when the energization of the relay reaches a predetermined value.

7. A circuit-breaker system comprising a supply circuit and a load circuit adapted to be connected by a circuit-breaker, means for opening said breaker, a plurality of resistors

adapted to be connected to the circuits to form a Wheatstone bridge of which the load circuit comprises one arm, and a galvanometer relay connected to said resistors for causing them to be so connected at a definite time after the opening of said breaker and for causing the circuit breaker to reclose when the energization of the relay is altered as the resistance of the load circuit increases to a predetermined value, dependent on the values of said resistors, at which the bridge is approximately balanced.

8. In a reclosing-circuit-breaker system, a circuit breaker for controlling the connection of a load circuit to a supply circuit, an overload relay and an auxiliary relay for opening said circuit breaker, the coil of the auxiliary relay being normally connected across the supply circuit and adapted to be short-circuited by the operation of the overload relay, a galvanometer relay having its operating coil connected across the supply circuit by the opening of said circuit breaker, a second auxiliary relay having an operating coil connected to a contact member of said galvanometer relay, for setting up a Wheatstone-bridge circuit and connecting the galvanometer relay thereacross, the coil of said first-mentioned auxiliary relay being also connected to a second contact member of said galvanometer relay, and a closing coil for said circuit breaker, normally connected across the supply circuit and adapted to be disconnected therefrom by the first-mentioned auxiliary relay upon the de-energization of the latter.

In testimony whereof, I have hereunto subscribed my name this 11th day of April 1928.

DONALD C. WEST.