Jan. 13, 1948. W. K. SONNEMANN ET AL 2,434,595

MAGNETIZING-INRUSH TRIPPING-SUPPRESSORS

Filed Nov. 6, 1943

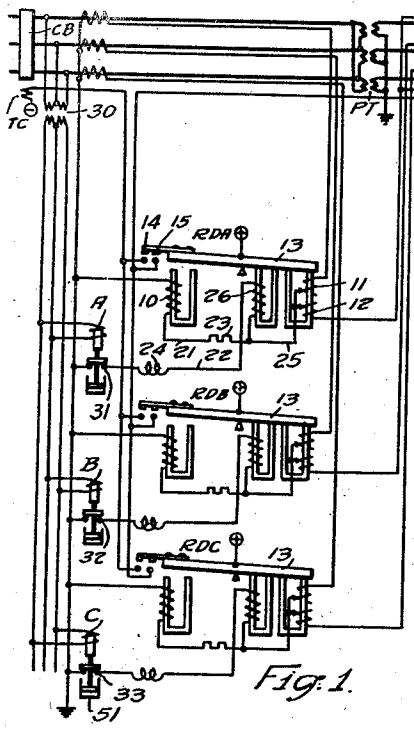


Fig. 1.

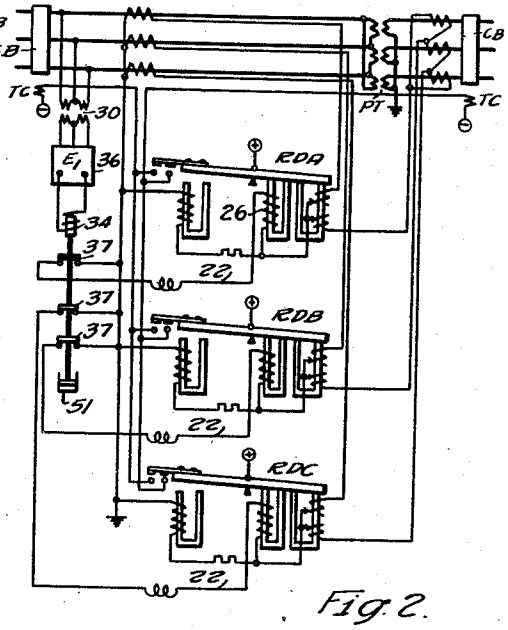


Fig. 2.

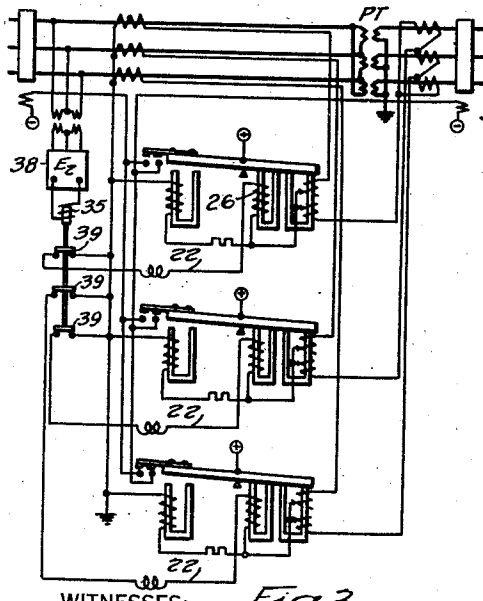


Fig. 3.

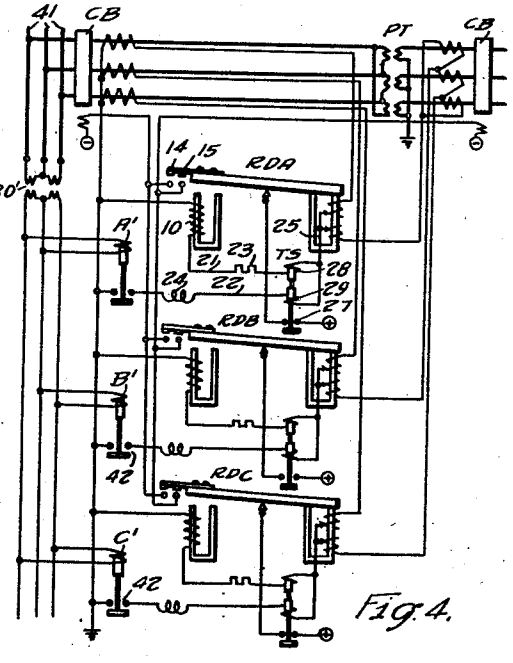


Fig. 4.

WITNESSES:

E. A. McCloskey.

INVENTORS

William K. Sonnemann

and Myron A. Bostwick.

BY O. B. Buchanan

ATTORNEY

Patented Jan. 13, 1948

2,434,595

UNITED STATES PATENT OFFICE

2,434,595

MAGNETIZING-INRUSH TRIPPING SUPPRESSOR

William Knox Sonnemann, Roselle Park, and Myron A. Bostwick, Budd Lake, N. J., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application November 6, 1943, Serial No. 509,242

15 Claims. (Cl. 175—294)

1

Our invention relates to differential relays for the protection of transformer-banks or other alternating-current electrical apparatus of a type which is subject to an inrush of magnetizing current, or other transient fault-simulating conditions, when the apparatus is first energized. More particularly, our invention relates to ratio-differential relays, which respond to the ratio between the difference-current and the through-current, rather than responding simply to a predetermined magnitude of the difference-current alone, the difference-current being the difference between the input and output currents of the protected apparatus, or the sum of all of the currents entering the apparatus, whereas the through-current is the sum of the input and output currents, or any load-current, or combination of load-currents, of the protected apparatus. Our invention is more particularly related to these ratio-differential relays, because such relays can be, and are, set much more sensitively than straight differential relays, thus introducing the danger of faulty tripping, on the magnetizing-current inrush, necessitating some form of magnetizing-inrush tripping-suppressor.

Several different forms of magnetizing-inrush tripping-suppressors have been devised, in the past, but all of these previous devices have involved difficulties in one form or another. Such difficulties may include a race between getting the suppressor-relay contacts open and the differential-relay contacts closed, or the introduction of undesirable delays in the tripping-time in the event of faults, either a permanent retardation of the tripping-time, or a delay which is introduced under certain fault-conditions.

An object of our present invention is to provide a magnetizing-inrush tripping-suppressor which takes advantage of the well-known fact that the magnetizing inrush-current of a transformer always has a pronounced asymmetrical component, or a direct-current component which is superimposed upon the alternating-current component of the current which is first fed into the power-transformer when the latter is first energized, this asymmetrical component being of a transient nature which dies out in a certain length of time, which may be of the order of 1 to 5 seconds, more or less, depending upon the size and characteristics of the power-transformer to be protected and the system connected thereto.

According to our present invention, we sort out this direct-current component, at least partially segregating it from the alternating-current component of the transformer-current, and we provide a device which is selectively responsive to this direct-current component for rendering the differential fault-responsive protective-relay relatively ineffective, or for preventing said protective-relay from producing a tripping-operation while the direct-current component is present in a predetermined degree or magnitude. Thus, we prevent the faulty tripping or opening of the circuit-breakers which are connected in the input and output leads of the protected transformer, during the magnetizing-current inrush.

2

This magnetizing-inrush tripping-suppressor may take the form either of an extra or auxiliary restraining winding or other restraint-torque means which is incorporated in the differential protective-relay itself, or the suppressor may take the form of a separate suppressor-relay having its operating-coil energized selectively responsively to the alternating-current component of a relaying current which is derived from the protected transformer, and having a restraining coil which is energized selectively responsively to any direct-current component which may be present in the same relaying current. When we refer to differential protective-relays, in this connection, we mean to include either straight differential relays or ratio-differential relays.

An asymmetrical-current-responsive suppressor, of the nature just mentioned, will introduce a time-delay during which it is impossible to trip or open the circuit-breakers protecting the protected transformer, throughout the duration of the asymmetrical or direct-current component of the transformer-current. This will introduce a slight delay in the tripping-time in the event of bona fide internal fault in the protected transformer, in all cases except where such faults are symmetrical or substantially symmetrical, the time-delay depending also upon the degree of asymmetry and the time-constant of the direct-current transient. However, the direct-current transient of an internal fault will always have a very much shorter time-constant than the direct-current transient of the inrush-current, in any bank of power-transformers which are large enough to justify the use of a differential protective relay.

A further object of our invention, however, is directed to auxiliary means which may be utilized for distinguishing between asymmetrical components which are obtained during magnetizing-current inrush, and asymmetrical components which are obtained as a result of asymmetrical faults occurring within the protected

transformer while it is in service. To this end, we may provide a relatively slowly responsive "remembrance"-relay means, which is responsive to an energized condition of the protected apparatus, or any suitable fault-detecting means, for rendering said suppressor-means inoperative.

In the case of the "remembrance"-relay means, the slowness of its response is such that the differential protective-relay operates without any suppressor, if an apparent fault-current occurs when the protected transformer has been operating under normal voltage-conditions, and so that the differential protective-relay is under the control of the suppressor whenever a direct-current component appears after a period of deenergization, or substantial deenergization, of the protected transformer. This slowly responsive means may take the form of a fault-responsive fault-detector, or relay-means, energized responsively to a voltage of the protected apparatus. This voltage may either be the several single-phase voltages of the transformer-bank, either delta-voltages or star-voltages, or it may be a phase-sequence component of the transformer-voltage, or any combination of phase-sequence components.

In this way, our tripping-suppressor apparatus becomes effective, only for asymmetrical current-components which appear either during the initial magnetizing-current inrush which occurs when voltage is first applied to a previously unenergized transformer-bank, or the voltage-responsive adjustment may be such that the suppressor also operates during the recovery-voltage period when the transformer-voltage is recovering, or being restored to full value, after the clearing of an external fault somewhere on the electrical system to which the protected transformer is connected.

With the foregoing and other objects in view, our invention consists in the relays, elements, combinations, systems, and methods, hereinafter described and claimed, and illustrated in the accompanying drawing, the four figures of which are diagrammatic views of apparatus and connections which illustrate our invention in four different forms of embodiment.

In the drawings, we have illustrated our invention in connection with ratio-differential relays RDA, RDB and RDC, which are utilized to protect a bank of power-transformers PT in a three-phase line, the power-transformer bank being protected by means of oil circuit-breakers CB which are provided with trip-coils TC. Three differential relays are provided, one for each phase, as indicated at RDA, RDB and RDC, and each relay is provided with a differential-current operating-winding 10, and two through-current restraint-windings 11 and 12, one for each of the terminals or windings of the protected power-transformer PT, so that one of the restraint-windings 11 or 12 responds to the input-currents of the protected transformer, while the other is energized in response to the output-currents of the protected transformer.

We have illustrated our invention in connection with high-speed or instantaneous ratio-differential relays of the balanced-beam type, as indicated at 13, but we wish it to be undnerstood that our invention is also susceptible of application to slow-speed differential relays, and we further wish it to be understood that our invention is also susceptible of application, not only to ratio-type differential relays, having the through-current restraining-means 11—12, but that it is also applicable to straight differential relays which omit the through-current restraining-means 11—12.

The differential relays RDA, RDB and RDC are provided, in a known manner, with tripping-contacts 14 and 15, which are utilized to energize the trip-coils TC of the two circuit-breakers CB which are connected to the primary and secondary terminal-leads of the protected transformer PT.

In accordance with our present invention, we utilize what is known as a transient shunt, for at least partially segregating the alternating-current component and the direct-current component of some relaying electrical quantity which is derived, or obtained in some manner, from the protected transformer. This transient shunt takes the form of two parallel-connected relaying-circuits 21 and 22, the first circuit having a low ratio of inductance to resistance, as obtained by the use of a serially-connected resistor 23, while the second circuit has a high ratio of inductance to resistance, as is obtained by the use of a serially-connected coil 24 having such a high ratio. As a result of this divided-circuit connection, the direct-current component passes freely through the coil 24, and is impeded by the resistance 23 in the other circuit, while the alternating-current component divides between the two circuits in a manner inversely proportional to the respective impedances of the two circuits. The second relaying circuit 22 is thus selectively responsive to the direct-current component, while the first relaying circuit 21 is selectively responsive to the alternating-current component of the current in the common or undivided portion, 25, of the relaying circuit.

We utilize a magnetizing-inrush tripping-suppressor, which is suitably responsive to the direct-current component in the second relaying circuit 22, for suppressing or preventing tripping-operations produced by the differential relays RDA, RDB and RDC. This tripping-suppressor may either take the form of an auxiliary restraint-means or winding 26, which is placed on, or associated with, the differential relay, as shown in Figs. 1, 2 and 3, or the tripping-suppressor may take the form of a separate relay TS, as shown in Fig. 4, having tripping-contacts 27 in series with the tripping-contacts 14 and 15 of the differential relay. This separate tripping-suppressor relay TS has an operating winding 20, which is included in the alternating-current-selective relaying-circuit 21, and a restraining winding 29 which is in the direct-current-responsive relaying-circuit 22.

The tripping-suppressor, in either form of embodiment, may be responsive to the direct-current component of any function of any alternating electrical quantity of the protected apparatus PT, whether it is an apparatus-current or an apparatus-voltage, or any combination of these. For simplicity, however, we have illustrated our invention in the manner in which we at present prefer to utilize it, in which the differential current, which is utilized for operating the differential protective relays RDA, RDB and RDC, is subdivided, by means of the transient-shunt connection, so as to sort out, or partially sort out, the alternating-current component in the relaying-circuit 21, and the asymmetrical or direct-current component in the relaying-circuit 22. The operating coil 10 of the differential relay is included in the alternating-current branch 21 of the relaying-circuit 25, while the inrush-suppressor coil 26 of Figs. 1, 2 and 3, or the coil 29 of

Fig. 4, is connected in the direct-current branch 22 of the common relaying-circuit 25.

In most applications of our invention, we prefer to supplement the suppressor-coil 26 or 29 with additional means for making the suppressor-coil operative only when there is no fault on the system, or for rendering the suppressor-coil inoperative, or relatively ineffectual, when normal voltage-conditions appear on the power-transformer bank PT, and for a short moment of time after the removal or discontinuance of such normal voltage-conditions, while permitting the suppressor-coil to be fully operative when no voltage, or a predeterminedly low voltage, appears on the protected transformer, and for a moment of time after normal voltage is first applied to the protected transformer. This suppressor-controlling apparatus can take a number of different forms of embodiment, several of which are illustrated in Figs. 1, 2, 3 and 4.

In Fig. 1, the suppressor-controlling apparatus takes the form of three delayed-action single-phase under-voltage relays A, B and C, which are energized from potential-transformers 30 which are connected across one of the polyphase terminals of the power-transformer PT which is being protected. These voltage-responsive relays A, B and C have back-contacts 31, 32 and 33, which are connected in series with the respective direct-current branches 22 of the several differential-current relaying-circuits 25. These voltage-relays A, B and C may be connected to respond to different phase-voltages of the polyphase line, these phase-voltages being either delta or star connected. While we have illustrated these voltage-relays A, B and C as having back-contacts 31, 32 and 33 which are connected in series with the several suppressor-windings 26 of Fig. 1, it is obvious that we are not limited to this particular connection, and that we may utilize any form of connection which will make the suppressor-winding ineffective when the corresponding one of the three voltage-relays A, B and C is in its actuated or responsive position, while making all of the suppressor-windings 26 effective, to perform their suppressing-function, whenever all of the voltage-relays A, B and C are in their deenergized positions.

In Figs. 2 and 3, a single polyphase-responsive voltage-relay 34, or 35, is utilized, in place of the three single-phase suppressor-controlling relays A, B and C of Fig. 1. In Fig. 2, the suppressor-controlling relay 34 is a time-delayed undervoltage positive-sequence relay which is energized from the positive phase-sequence component E_1 of the polyphase transformer-voltage, as obtained from a phase-sequence network 36. This under-voltage-relay 34 has three back-contacts 37 which are included in the respective direct-current-segregating branches 22 of the transient shunts.

In Fig. 3, the suppressor-controlling relay 35 is an instantaneously operating undervoltage negative-phase-sequence relay which is energized from the negative-phase-sequence voltage-component E_2, as obtained from a phase-sequence network 38. This undervoltage relay 35 has back-contacts 39 which are connected in series with the several direct-current-segregating relaying-circuits 22.

In Fig. 4, we have shown quick-acting under-voltage fault-detector relays A', B' and C', which are energized, through potential-transformers 30', from one of the busses, 41, to which the protected power-transformer PT is connected through the circuit-breakers CB. Since the bus 41 is normally energized, even when the circuit-breakers CB are open, the undervoltage relays A', B' and C' are normally energized, so as to close their respective make-contacts 42, although the relays are illustrated in their deenergized positions. The relay-contacts 42 are connected in series with the respective direct-current circuits 22 of the transient shunts.

In the forms of embodiment of our invention shown in Figs. 1 and 2, the suppressor-controlling relays A, B, and C and 34 are slower-acting relays than the fault-responsive differential-relays RDA, RDB and RDC, and this greater slowness of response of the suppressor-controlling relays is indicated diagrammatically, in the drawing, by means of dashpots 51, which are associated with the suppressor-controlling relays A, B and C and 34. This representation of dashpots 51 is intended to be symbolic of any means, or arrangements, or types of apparatus, which will make the suppressor-controlling relays slower, in either responding or dropping out, than the fault-responsive or differential relays RDA, RDB and RDC.

In operation, when the protected power-transformer PT is in the non-energized condition, the suppressor-supervisory relays A, B, C, 34 and 35 of Figs. 1, 2 and 3 are in their illustrated deenergized or drop-out positions. When polyphase voltage is first applied to the protected transformer PT by the closure of one of its circuit-breakers CB, voltage will be applied to these voltage-responsive suppressor-controlling relays, and these will begin to pick up, except in the case of the negative-sequence relay 35. However, the pick-up operating-time of the single-phase voltage-relays A, B and C, or of the positive-phase-sequence voltage-relay 34, is longer than the time during which the magnetizing inrush-current of the power-transformer PT will create an artificial difference-current tending to produce a faulty operation of the protective differential relays RDA, RDB and RDC. During this time, the direct-current component of the magnetizing inrush-current of the power-transformer flows selectively through the restraint-winding 26 or 29, and presents a faulty tripping-operation of the circuit-breakers CB.

In the case of the forms of embodiment shown in Figs. 1, 2 and 3, the restraint is placed directly upon the differential or protective relays RDA, RDB and RDC, whereas, in the form of embodiment shown in Fig. 4, the restraint is applied to a separate tripping-suppressor relay TS, which has its make-contacts 27 in the tripping-circuit, in series with the tripping-contacts 14 and 15 of the differential or fault-responsive relay. In this latter case, the restraint-winding 29 is so strong that it prevents a picking up of the auxiliary tripping-suppressor relay TS, under the influence of its operating-coil 28, until the direct-current component of the line-current has subsided to a predetermined fraction of the alternating-current component of the same current, during which time the magnetizing-current inrush will have subsided sufficiently so that the quicker-acting differential relays RDA, RDB and RDC will have reset themselves to their normal, non-actuated positions, with their tripping-contacts 14 and 15 open. In this manner, we effectually avoid a faulty tripping-operation as a result of a differential-relay response during the magnetizing-current inrush-period.

In the event that a bona fide fault should occur within the protected transformer PT while the latter is in operation, if the fault is symmetrical,

there will not be any direct-current component of the fault-current, and hence there will not, in any event, be any effective restraint or inhibition against an immediate tripping-operation. Even though the fault should be asymmetrical (which is the usual case), the duration of its direct-current transient will be, in any event, much shorter than the direct-current transient of the magnetizing inrush-current, and hence the direct-current component would not long delay tripping, even though the operation of the tripping-suppressor means were not restrained by the voltage-responsive supervisory relays A, B, C, **34**, **35**, A', B' or C'. However, as previously pointed out, we prefer to utilize voltage-responsive relays or fault-responsive relays, for locking out the tripping-suppressor means, or rendering it ineffective, in the event of an actual fault within the protected transformer PT, or in the event that such fault occurs when the transformer is in operation, with voltage applied thereto previous to the development of the fault-condition.

Thus, in Fig. 1, any fault which develops within the protected transformer PT at a time when the transformer is already energized will occur at a time when all three of the voltage-responsive relays A, B, and C will be energized, so that their back-contacts **31**, **32** and **33** will be opened. Hence, the direct-current-responsive restraint-winding **26** of each of the differential relays RDA, RDB and RDC will be deenergized. If a fault should occur on the protected transformer PT, one or more of the voltage-relays A, B and C will start to drop out, but their drop-out time will be far longer than the time required for the differential relay RDA, RDB or RDC to effect a tripping operation. Hence the tripping operation will be performed by one or more of the differential relays RDA, RDB or RDC, without any hindrance whatsoever from the auxiliary restraining-winding **26** which is energized selectively responsively to the direct-current component of the differential transformer-current whenever its relaying-circuit **22** is energized.

In Fig. 2, the positive-sequence voltage-relay **34** performs a function similar to that of the three single-phase relays A, B and C in Fig. 1. When the protected transformer PT is first energized, the phase-sequence voltage-relay **34** starts from its deenergized position, with its contact **37** closed, and it starts to open its contact, but it requires so long to accomplish this opening-movement that the magnetizing-current inrush will have subsided sufficiently so that there is no danger of an erroneous response of the differential relays RDA, RDB or RDC, by the time that the voltage-relay contact **37** finally opens. Meanwhile, the direct-current component of the magnetizing inrush-current will have been sufficiently strong to prevent the faulty operation of any of the differential relays while the magnetizing-current inrush lasted. When a fault occurs in the protected transformer PT after it has once been energized, it will likewise be observed that the voltage-relay **34** will start from its energized position, with its back-contact **37** open, so that the restraint-winding **26** will be open-circuited, permitting the appropriate differential relay RDA, RDB or RDC, or any number of them, to respond to the faulty condition within the protected transformer.

In Fig. 3, we have illustrated the general use of any suitable fault-detector, and specifically a negative-phase-sequence voltage-response fault-detector **35**, for supervising the operation of the restraint-winding **26** which is responsive to the direct-current component. In this case, the negative-sequence voltage-relay **35** responds sensitively to any fault except a well-balanced three-phase fault, and it locks out, or prevents the effective operation of, the direct-current-responsive restraining-means **26**, only when there is an actual fault on the system, permitting this restraint to be effective for blocking the operation of the differential relays at all other times whenever there is a direct-current component in the alternating-current wave of the protected transformer. Since the relay **35** responds only to faults, there is no necessity for making it slow in its action, and it will preferably be an instantaneously responsive relay, which responds, without any intentional time-delay, to those fault-conditions to which it is adapted to respond. This will provide instantaneous tripping for all faults within the protected transformer, except a very well-balanced three-phase fault suddenly appearing across all three phases of the protected transformer; and if such a balanced fault should occur, its tripping, by the differential protective relays, will be delayed by any direct-current component which may be present in the current-wave of the transformer.

In Fig. 4, the fault-detectors A', B' and C' replace the "remembrance" relays A, B and C of Fig. 1. These fault-detectors are normally energized, even before the protected power-transformer PT is energized. Hence, our direct-current-responsive magnetizing-inrush circuits **22** are in service at the first moment of energization of the power-transformer PT, thus preventing faulty tripping of the circuit-breakers CB as a result of the magnetizing inrush-current. If a fault should occur within the protected transformer PT while the transformer is in service, the voltage applied to at least one of the undervoltage relays A', B' or C' will be reduced sufficiently to drop out said relay, thus opening the appropriate repressor-circuit **22** and permitting quick tripping by at least one of the differential relays RDA, RDB or DRC. It is desirable for the speed of operation of the fault-detectors A', B' and C' to be faster than that of the differential relays RDA, RDB and RDC, in Fig. 4, so that, when a fault on the line (not in the transformer PT) is cleared, the fault-detector which had dropped out on undervoltage will reclose its contact **42** before a faulty tripping operation is caused by the differential relays in response to the magnetizing inrush due to the recovery-voltage.

In all of the forms of embodiment of our invention, it is to be understood that the direct-current-responsive restraining-means **26** and **29** are interchangeable, in any of the figures of the drawing, in the sense that the restraint **26** or **29** can either be imposed directly on the fault-responsive relays RDA, RDB or RDC which are to be supervised, or a separate supervising-relay may be provided, with said restraint imposed on the separate supervisory-relay, with relay-circuit connections which require a response of both the fault-responsive relay and the supervisory-relay (such as the relay TS in Fig. 4), in order to obtain a tripping-operation. These and many other variations of our invention may be incorporated by those skilled in the art, without in the least departing from the essential principles of our basic invention. We desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

We claim as our invention:

1. Protective relay equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a relay having an operating winding and a restraining winding, means for obtaining a relaying electrical quantity from the protected apparatus, means for at least partially segregating the alternating-current component and the direct-current component of said relaying electrical quantity, means energized from said segregating-means for energizing said operating winding so as to be selectively responsive to said alternating-current component, and means energized from said segregating-means for energizing said restraining winding so as to be selectively responsive to said direct-current component.

2. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, a transient-responsive relay having an operating winding and a restraining winding, means for obtaining a relaying electrical quantity from the protected apparatus, means for at least partially segregating the alternating-current component and the direct-current component of said relaying electrical quantity, means energized from said segregating-means for energizing the operating winding of said transient-responsive relay so as to be selectively responsive to said alternating-current component, means energized from said segregating-means for energizing the restraining winding of said transient-responsive relay so as to be selectively responsive to said direct-current component, and means for obtaining a relaying response to a joint response of said fault-responsive relay and said transient-responsive relay.

3. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a relay having an operating winding and a restraining winding, means for obtaining a relaying current which is responsive to the difference between the input and output currents of the protected apparatus, means for at least partially segregating the alternating-current component and the direct-current component of said relaying current, means energized from said segregrating-means for energizing said operating winding so as to be selectively responsive to said alternating-current component, and means energized from said segregating-means for energizing said restraining winding so as to be selectively responsive to said direct-current component.

4. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a differential relay having operating-means which is responsive to the difference between the input and output currents of the protected apparatus, a transient-responsive relay having an operating winding and a restraining winding, means for obtaining a relaying electrical quantity from the protected apparatus, means for at least partially segregating the alternating-current component and the direct-current component of said relaying electrical quantity, means energized from said segregating-means for energizing the operating winding of said transient-responsive relay so as to be selectively responsive to said alternating-current component, means energized from said segregating-means for energizing the restraining winding of said transient-responsive relay so as to be selectively responsive to said direct-current component, and means for obtaining a relaying response to a joint response of said differential relay and said transient-responsive relay.

5. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a ratio-differential relay comprising operating-means and restraint-means, means for obtaining a differential relaying current which is responsive to the difference between the input and output currents of the protected apparatus, means for at least partially segregating the alternating-current component and the direct-current component of said differential relaying current, means energized from said segregating-means for energizing said operating-means so as to be selectively responsive to said alternating-current component, and means for energizing said restraint-means so as to be responsive to a through-current passing through the protected apparatus.

6. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a ratio-differential relay comprising operating means and restraint-means, transiently operative suppressor-means for rendering said ratio-differential relay relatively ineffective, means for obtaining a differential relaying current which is responsive to the difference between the input and output currents of the protected apparatus, means for at least partially segregating the alternating-current component and the direct-current component of said differential relaying current, means energized from said segregating-means for energizing said operating-means so as to be selectively responsive to said alternating-current component, means energized from said segregating-means for energizing said suppressor-means, and means for energizing said restraint-means so as to be responsive to a through-current passing through the protected apparatus.

7. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a ratio-differential relay comprising differential-current operating means, through-current restraint-means, and asymmetrical-component restraint-means, the operating-means being in a first relaying circuit having a low ratio of inductance to resistance, the asymmetrical-current restraint-means being in a second relaying circuit having a high ratio of inductance to resistance, and circuit-

means for energizing said first and second relaying circuits in parallel to each other in response to the difference between the input and output currents of the protected apparatus.

8. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, transiently operative suppressor-means for rendering said fault-responsive relay relatively ineffective, said suppressor means including means for selectively responding to any direct-current component existing in an alternating electrical quantity of the protected apparatus, and relatively slowly responsive means, responsive to an energized condition of the protected apparatus, for rendering said suppressor-means inoperative.

9. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, transiently operative suppressor-means for rendering said fault-responsive relay relatively ineffective, said suppressor means including means for selectively responding to any direct-current component existing in an alternating electrical quantity of the protected apparatus, and fault-detector-means for rendering said suppressor-means inoperative in response to a fault-condition on the line to which the protected apparatus is connected.

10. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, transiently operative suppressor-means for rendering said fault-responsive relay relatively ineffective, said suppressor means including means for selectively responding to any direct-current component existing in an alternating electrical quantity of the protected apparatus, and fault-responsive voltage-relay means for rendering said suppressor-means inoperative in response to a fault-condition on the line to which the protected apparatus is connected.

11. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, transiently operative suppressor-means for rendering said fault-responsive relay relatively ineffective, said suppressor means including means for selectively responding to any direct-current component existing in an alternating electrical quantity of the protected apparatus, and a relay-means, energized responsively to a voltage of the protected apparatus, for at times rendering said suppressor-means inoperative.

12. Protective relaying equipment for an alternating-current electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, transiently operative suppressor-means for rendering said fault-responsive relay relatively ineffective, said suppressor means including means for selectively responding to any direct-current component existing in an alternating electrical quantity of the protected apparatus, and a relay-means, energized responsively to a voltage of the protected apparatus, for rendering said suppressor-means inoperative when said protected apparatus is in normal service.

13. Protective relaying equipment for a polyphase electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, transiently operative suppressor-means for rendering said fault-responsive relay relatively ineffective, said suppressor-means including means for selectively responding to any direct-current component existing in an alternating electrical quantity of the protected apparatus, and a plurality of relay-means, energized responsively to a plurality of different phases of the protected apparatus, for at times rendering said suppressor-means inoperative.

14. Protective relaying equipment for a polyphase electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, transiently operative suppressor-means for rendering said fault-responsive relay relatively ineffective, said suppressor-means including means for selectively responding to any direct-current component existing in an alternating electrical quantity of the protected apparatus, and a plurality of relay-means, energized responsively to a plurality of different phases of the protected apparatus, for rendering said suppressor-means inoperative when normal voltage appears in all of said plurality of phases.

15. Protective relaying equipment for a polyphase electrical apparatus of a type which is subject to transient fault-simulating conditions when the apparatus is unfaulted, said relaying equipment comprising the combination, with the protected apparatus, of a fault-responsive relay having electrical energizing-means for rendering it responsive to a fault-condition in the protected apparatus, transiently operative suppressor-means for rendering said fault-responsive relay relatively ineffective, said suppressor-means including means for selectively responding to any direct-current component existing in an alternating electrical quantity of the protected apparatus, and a relay-means, energized responsively to a

polyphase voltage of the protected apparatus, for at times rendering said suppressor-means inoperative.

WILLIAM KNOX SONNEMANN.
MYRON A. BOSTWICK.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,877,454	Goldsborough	Sept. 13, 1932
1,924,307	Crichton	Aug. 29, 1933
1,967,093	Lewis	July 17, 1934
1,927,794	Fallou	Sept. 19, 1933
2,290,101	Gutmann	July 14, 1942
1,959,053	Goldsborough	May 15, 1934
2,095,754	Le Vesconte et al.	Oct. 12, 1937
2,376,808	Ratz	May 22, 1945