

Jan. 7, 1936.

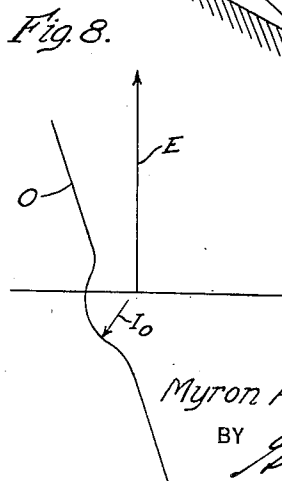
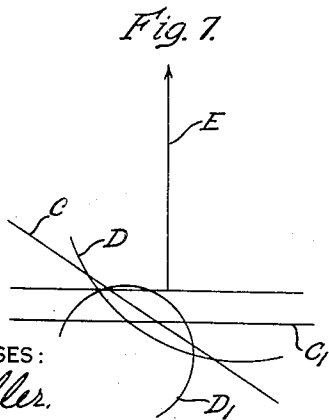
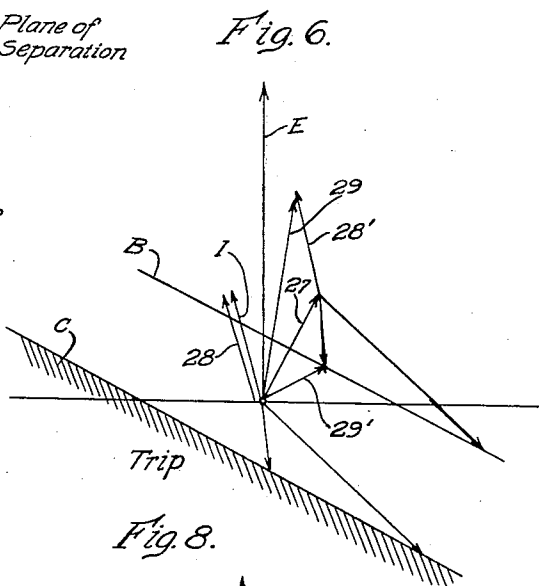
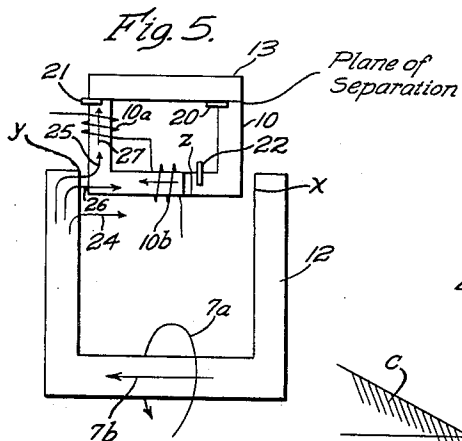
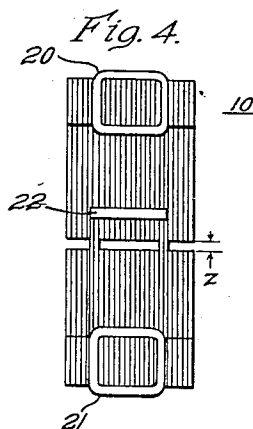
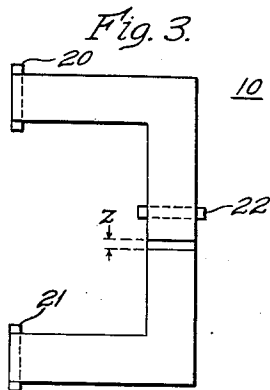
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2,027,221

DIRECT TRIP DEVICE

Filed July 19, 1934

3 Sheets-Sheet 2



WITNESSES:

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Fig. 9.

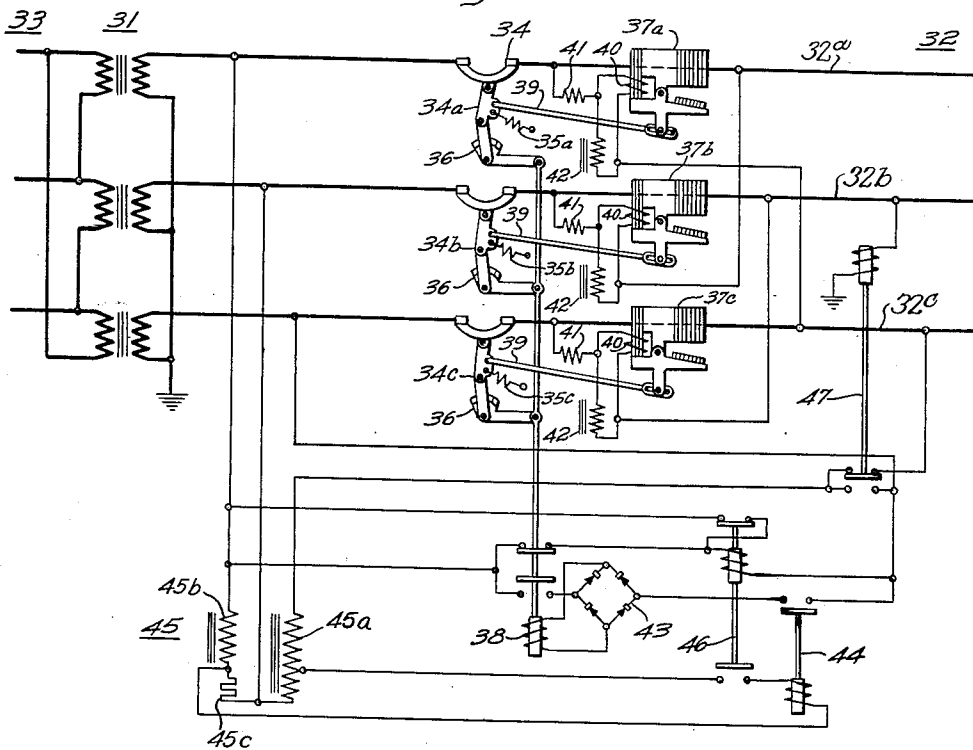
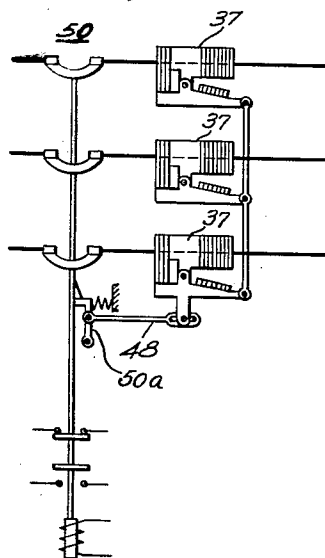


Fig. 10.



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2,027,221

DIRECT TRIP DEVICE

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Application July 19, 1934, Serial No. 736,022

14 Claims. (Cl. 175—294)

My invention relates to directional protective apparatus and particularly to a novel form of direct-trip device suitable for use in connection with circuit breaker apparatus generally and particularly applicable to network protectors.

Various direct-trip devices having power-directional characteristics have heretofore been proposed, but, so far as I am aware, all such devices of the prior art have either had undesirable characteristics, such as a circular tripping curve, or have been unable to deliver a powerful mechanical tripping impulse unless built to an undesirably large scale.

It is accordingly an object of my invention to provide a novel direct-trip device which shall have substantially straight-line or other desirable tripping characteristics, and which shall operate to deliver a powerful mechanical tripping impulse for a given size or weight of the device.

Other objects of my invention will become evident from the following detailed description, taken in conjunction with the accompanying drawings, in which

Figure 1 is an elevational view of a direct-trip device embodying my invention.

Fig. 2 is a sectional view taken upon the line II—II of Fig. 1.

Figs. 3 and 4 are elevational views of a detail of the device shown in Figs. 1 and 2.

Fig. 5 is a diagrammatic view of a magnetic circuit of my improved direct trip device.

Figs. 6, 7 and 8 are vector diagrams illustrating the operation of my improved direct-trip device; and,

Figs. 9 and 10 are diagrammatic views of circuit breaker apparatus embodying my invention.

In accordance with my invention, I utilize the principle of a pair of magnetic elements arranged to exert opposing forces upon a movable member, as disclosed in the United States patent to Edgar A. Hester, No. 1,948,711, issued Feb. 27, 1934, and assigned to the Westinghouse Electric & Manufacturing Company. As explained in the above-mentioned patent, the mechanical tripping energy delivered by such a device may be increased by causing the movable member to operate from a normally stable position through a mechanically unstable range to a tripping position. However, in accordance with my invention, a straight line tripping characteristic may be produced, whereas that of the Hester device is necessarily a circle.

Referring to Fig. 1, the direct trip device of my invention comprises a movable member 1 arranged to be acted upon by opposing forces pro-

duced by an actuating element 2 and a restraining element 3. In the preferred form of my invention, the movable member 1 is rotatably supported upon a shaft 4 in such a manner that the elements 2 and 3 normally exert opposing moments or torques thereupon. It will be obvious, however, that there are numerous other mechanical arrangements suitable for obtaining the balance of forces involved in my invention, and that the invention may be practiced with such other arrangements.

The actuating element 2 comprises a stationary magnetic structure 5 consisting of a U-shaped assembly of laminations arranged to form an open magnetic circuit, the laminations being secured together by any suitable means such as bolts 5a. The magnetic structure 5 is fastened to a suitable base plate 6 of non-magnetic material, by any suitable fastening means (not shown), in a position to partially surround a bus bar 7 which carries the alternating-current to which the direct-trip device is to respond. The shaft 4 is mounted upon a pair of brackets 8, only one of which appears in Fig. 1, secured to the base plate 6 by means of machine screws 8a. The ends of the shaft 4 are threaded to receive suitable fastening nuts 4a.

An armature 9 for the actuating element 2 is mounted in the air gap of the open magnetic structure 5, in such a manner as to close the magnetic circuit upon rotation of the member 1 in the counter-clockwise direction.

The structure of the restraining element 3 is best shown in Fig. 2. Referring to Fig. 2, a laminated C-shaped pole-piece assembly 10 is secured by means of suitable non-magnetic spacers 11 to a U-shaped assembly of laminations 12 in such a manner as to provide air gaps at points x and y. The U-shaped laminations of the assembly 12 are preferably of the same size and shape as those of the assembly 5, in order to provide similar magnetic characteristics, for a purpose as will be hereinafter more fully explained.

The restraining element 3 is provided with an armature 13, fastened to a metallic block 14 (see Fig. 2) which constitutes part of the movable member 1. In the preferred form of my invention, the armature 13 is mounted upon a bolt 13a and is spaced from the block by means of a compression spring 13b. A lock-nut 13c, threaded upon the bolt 13a, provides a means for adjusting the relative torques exerted on the movable member 1 by the actuating element 2 and the restraining element 3. A pair of voltage windings 10a and

10b are provided upon the pole-piece assembly 10, for a purpose which will hereinafter appear. The terminals of the windings 10a and 10b are brought out to a suitable terminal block 10c (see Fig. 1).

5 The movable member 1 is preferably mechanically balanced about the shaft 4 as an axis, and comprises a pair of plates 15 and 16, separated by means of the block 14 and a lug 9a (see Fig. 1) which constitutes part of the armature 9. Suitable machine screws 17 and a bolt 18 are provided for fastening the block 14 and lug 9a to the plates 15 and 16. A tripping pin 19 is provided for mechanically operating the toggle mechanism or latch of a circuit breaker (not shown) in response to operation of the direct-trip device.

10 The structure of the C-shaped pole-piece assembly 10 is best shown in Figs. 3 and 4. Referring to the latter figures, the laminations are of such size and shape as to provide an effective air gap z across the entire cross-section of the magnetic circuit. A pair of lag loops 20 and 21 are set in the pole faces of the assembly 10, to provide an out-of-phase component of flux to prevent chattering of the armature (not shown in Figs. 3 and 4). The lag loops 20 and 21 interlink a predetermined proportion of the cross-section of the magnetic circuit, such as 50%, and a third lag loop 22 is provided in connection with the air-gap z , which interlinks the same percentage of the magnetic cross-section of the inner magnetic branch of the assembly 10. The cross-sectional areas of magnetic material are the same at the points where the lag loops 20, 21 and 22 are located, and the lag loop 22 is designed to absorb twice as much power, during normal operating conditions, as either lag loop 20 or 21.

15 Referring to Fig. 5, which shows diagrammatically the entire magnetic circuit of the restraining element 3, the magnetic structure 12 is inductively interlinked with the equivalent single-turn circuit of the bus bar 7, as indicated diagrammatically at 7a. However, because of the air gaps x and y , the magnetic circuit divides into a leakage path 24, an armature path 25 and a balancing path 26.

20 The purpose of this divided magnetic circuit is to make the mutual inductance of the voltage winding 10a and the main circuit 7a, equal to that of the potential winding 10b and the main circuit 7a, so that by connection of the windings 10a and 10b in opposition, mutual inductance effects between the potential circuit and the main circuit 7a may be eliminated.

25 Although the desired end may be accomplished in several ways, I prefer to make the air-gap z of such length that the total reluctance through the path 25 equals the total reluctance through the path 26. With this relationship of reluctances, the windings 10a and 10b must have the same number of turns. As the power absorbed by the lag loop 22 is equal to that absorbed by both lag loops 20 and 21, the fluxes produced in the paths 25 and 26 in response to given value of alternating current in the voltage windings 10a and 10b are equal in magnitude and phase position.

30 The effect of the flux which traverses the air-gap path 24 is to introduce series reactance in the bus circuit 7a. Such reactance is not ordinarily objectionable, and in network systems is, in fact, desirable.

35 The operation of the direct-trip device may be explained as follows, with reference to Fig. 5: The voltage windings 10a and 10b are preferably connected in series and energized in accordance with

a main circuit voltage through a circuit which will be hereinafter pointed out. Assuming the normal direction of flux produced by the winding 10a to be as indicated by the arrow 27, and the normal direction of flux produced by the main circuit 7a to be as indicated by the arrows 7b and 25, the fluxes 27 and 25 normally add, and the vector resultant of fluxes 25 and 26 produces a restraining force on the armature 13.

40 If the phase position of the current in the main circuit 7a becomes such that the resultant of fluxes 25 and 27 is reduced, the restraining torque produced by the element 3 may become less than the actuating torque of element 2, (Fig. 1) and the movable member 1 operates in counter-clockwise direction. It will be noted that as the movable member 1 leaves its normal position, the restraining force produced by the restraining element 3 becomes smaller and smaller because of the increasing air gap in the restraining element 3, and the actuating force produced by the element 2 becomes greater and greater because of the reduction of its air gap. In this way, the force exerted by the movable member 1 rapidly increases as it leaves its normal position.

45 The vector relationship of variables in the trip device is indicated in Fig. 6, in which the effects of magnetic saturation are, for convenience, not considered. Denoting the line voltage by E , the voltage flux produced by the winding 10a may be represented by a vector 27 having magnitude and phase position determined by the impedance and phase angle of the potential circuit. An arbitrary value of line current is indicated by the vector I . Such a vector produces a proportional flux 28 in the actuating element 2, which for convenience is shown to the same scale. In the restraining element 3, however, the flux component 28' corresponding to the current I , adds vectorially to the voltage flux 27, to produce a resultant flux 29.

50 Assuming that the lock-nut 13c (shown in Fig. 1) is adjusted so that the torque produced by the actuating element 2 exactly equals the torque produced by the restraining element 3, for a given value of line current, the magnitudes of actuating and restraining forces are proportional to the flux vectors 28 and 29, respectively. As long as the resultant vector 29 remains greater in scalar value than the vector 28, the restraining force exceeds the actuating force and the device does not operate.

55 However, if the resultant vector 29 attains a value such as 29', terminating on a perpendicular bisector B of the voltage flux vector 27, the actuating force exactly equals the restraining force, as may be seen from the geometry of the arrangement. To produce this condition, the corresponding current vector must terminate on a line C parallel to line B. The line C accordingly represents the critical tripping condition or tripping characteristic of the direct-trip device. For any current vector which terminates in the shaded area below the characteristic C, the device operates to trip open the associated circuit breaker.

60 Referring to Fig. 7, the tripping characteristic C may be rotated to other positions such as C₁, by changing the impedance phase angle of the potential circuit through the coils 10a and 10b, as by adding impedances of various types, as is well understood in the relay art. By changing the adjustment of the lock-nut 13c, the straight-line tripping characteristic C may be converted into circular characteristics such as D or D₁.

65 Returning to Figs. 1 and 2, as the magnetic

laminations of the assembly 5 are of the same size and shape as those of the assembly 12, they become saturated to substantially the same degree in response to high values of line current.

The effect of magnetic saturation is accordingly minimized. However, if the lock-nut 13c is adjusted so that the actuating and restraining torques for a given value of line current are not equal, magnetic saturation tends to reduce the excess of torque produced by the predominant element at high current values. This has the effect of straightening out the portions of the tripping circle which correspond to high current values. Referring to Fig. 8, the power directional characteristic of the trip device may be changed to the characteristic O for example, which results from the effect of magnetic saturation upon a tripping circle such as D of Fig. 7. The curve O of Fig. 8 is substantially a directional over-current characteristic. That is, to produce a tripping operation, the current must be of at least a predetermined minimum value I_0 , and must have a predetermined phase relationship as compared to the voltage E.

Referring to Fig. 9 in detail, a transformer bank 31, which may be one or a number of similar banks for supplying power to a distribution network 32, is connected between a feeder 33 and one side of a protector circuit breaker 34. I have illustrated the primary windings of the transformer bank 31 connected in delta to the feeder 33 and the secondary windings connected in star with neutral grounded, but it will be understood that my invention may be practiced with other connections known in the art. The circuit breaker 34 is connected between the secondary windings of the transformer bank 31 and the distribution network 32.

The circuit breaker 34 is preferably of specialized construction having individual poles 34a, 34b and 34c for the three phases. The poles 34a, 34b and 34c are provided with separate springs 35a, 35b and 35c effective to operate the corresponding pole to fully open position whenever it is moved past dead center. A mechanical lost-motion connection 36 is provided for tripping open the two remaining poles, when any of the poles 34a, 34b or 34c has been moved beyond its dead center position. In this way, the tripping of all the poles is brought about when any pole is tripped, although the initial latch load to trip the entire breaker corresponds to that of a single pole only. The circuit breaker 34 is provided with a closing solenoid 38, operable to close all the poles 34a, 34b and 34c as a unit.

Individual direct trip devices 37a, 37b and 37c, of the type described above, are provided for initiating the tripping of the individual poles in response to a reverse power condition, or vector product of current and voltage, above a predetermined value in the corresponding phase. A set of lost motion trip rods 39 are provided for transmitting the mechanical tripping impulses of the direct trip devices 37a, 37b and 37c to the corresponding poles 34a, 34b and 34c.

The direct trip devices 37a, 37b and 37c are provided with the pairs of potential windings 10a and 10b described above in connection with Figs. 1 and 2. However, for simplicity, the pairs of windings 10a and 10b are represented together as the single winding 40 in Fig. 9. The windings 40 are connected in delta circuits which include series impedances 41, and preferably also, saturable shunt reactors 42. The saturable reactors 42 have the usual flattened volt-ampere

characteristic, and tend to carry a disproportionately large share of the current through the series impedance 41 at high voltages. In this way, a great reduction of voltage applied to the windings 40 is prevented in the event of low line voltage during fault conditions. At the same time adequate voltage energy is obtained at low line voltages without excessive heating of the potential coils during normal voltage conditions.

To obtain the desired characteristics the reactors 42 are designed to saturate at a voltage considerably below normal line voltage, such as 50% of normal.

The closing solenoid 38 is connected in a closing circuit which includes a set of rectifiers 43, preferably of the dry or copper oxide type, and front contact members of a voltage responsive relay 44. The voltage responsive relay 44 is connected to the output terminals of a phase-sequence filter 45, preferably of the type described 20 in the United States patent to B. E. Lenehan, No. 1,936,797, issued Nov. 28, 1933, and assigned to the Westinghouse Electric & Manufacturing Company. The relay 44 is designed to close when the positive symmetrical components of the polyphase voltage applied to the filter 45 exceed a comparatively high value such as 95% of normal, and to drop out at some lower value, such as 90% of normal.

The phase-sequence filter 45 comprises an auto-transformer 45a, having a tap to provide a voltage less than half of the total voltage impressed on the auto-transformer, for example, a 40% tap, and an impedance consisting of a reactor 45b and a resistor 45c having a combined lagging phase angle of 60°. Assuming that the phase rotation of the secondary voltages of the transformer bank 31 is as indicated by the subscripts a, b, and c of the network conductors 32a, 32b and 32c, the coil of the voltage responsive relay 44 is subject to a voltage equal to the vector sum of 40% of the voltage between the b phase transformer secondary terminal and the a phase transformer secondary terminal, and 40% of the voltage between the b phase transformer secondary terminal and the c phase network conductor 32c, but lagging the latter voltage by 60°. As explained in the above mentioned patent of B. E. Lenehan, the translating device corresponding to the voltage relay 44 is energized in accordance with a positive symmetrical component of the polyphase voltage applied to the terminals of the filter 45 under similar conditions.

A lockout relay 46 is provided for preventing the closure of the circuit breaker 34, after an opening thereof, until the feeder 33 has been completely deenergized by the opening of all other network protectors supplied from the feeder and the opening of the feeder circuit breaker (not shown). The lock-out relay 46 is designed to drop out at a low voltage such as 10% of normal line voltage and to reclose at a considerably higher voltage such as 60% of normal line voltage.

A transfer relay 47 is provided for transferring the c-phase connection of the phase sequence filter 45 from the network side of the protector to the transformer secondary side when the network 32 is deenergized.

The operation of the apparatus shown in Fig. 9 may be set forth as follows: The various relays and switches are shown in the positions which they assume when the network 32 and the feeder 33 are both energized, and power is flowing in the

normal direction from the feeder 33 to the network 32.

If a fault occurs on the network 32, the direction of power flow remains normal, and the fault is burned off in the usual manner.

If a fault occurs on the feeder 33, the direction of power flow reverses in one or more phase conductors, and one or more of the direct trip devices 37a, 37b or 37c operate to open the corresponding poles 34a, 34b or 34c of the network circuit breaker 34. Because of the lost motion provided in the trip rods 39, the direct trip device 37a, 37b or 37c which operates is permitted an initial movement before the tripping impulse is transmitted to the corresponding pole of the circuit breaker 34. The tripping force is, accordingly, greatly increased above that which would be available if the direct-trip device acted upon the circuit breaker pole from its normal position. As soon as any of the individual poles 34a, 34b or 34c is moved beyond its dead center position, the corresponding spring 35a, 35b or 35c completes its opening operation, and the lost motion device 36 operates to trip out the two remaining poles of the circuit breaker 34.

When the feeder 33 has been completely deenergized by the opening of all network protectors supplied therefrom and by the opening of the feeder breaker (not shown) the lock-out relay 46 drops out to connect the voltage responsive relay 44 to the phase sequence filter 45. Assuming that the network 32 remains energized, the transfer relay 47 remains closed, and the phase sequence filter 45 is energized in accordance with the polyphase system of voltages consisting of two phases of transformer secondary voltage and one phase of network voltage. When the positive symmetrical components of this system of polyphase voltages exceed a predetermined value, such as 95% of normal, the voltage responsive relay 44 closes to complete an energizing circuit for the closing solenoid 38 of the circuit breaker 34. The circuit breaker 34, accordingly, recloses.

If, however, upon the opening of the circuit breaker 34, the distribution network 32 is deenergized, the transfer relay 47 drops out and the phase sequence filter 45 is energized in accordance with the polyphase secondary voltage of the transformer bank 31. In this way, it is possible for the network circuit breaker 34 to be reclosed when the network 32 is deenergized, if the transformer secondary phase voltages are of substantially normal value and correct phase sequence.

Although I have described my invention as applied to a specialized circuit breaker construction having individual pole tripping, the invention is equally applicable to single phase circuit breakers or to polyphase circuit breakers in which the poles are operated as a unit.

Fig. 10 shows diagrammatically an application of my invention to a polyphase circuit breaker 50, with individual direct trip devices 37 for separate phases connected mechanically together as a unit. A lost motion connection 48 is provided between the direct trip devices 37 and the latch 50a of the circuit breaker. With this arrangement the direct trip devices 37 totalize the power of all phases, and operation occurs when the polyphase reverse power flow exceeds a predetermined value.

I do not intend that the present invention shall be restricted to the specific details, arrangement of parts, or circuit connections herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of

my invention. I desire, therefore, that only such limitations shall be imposed as are indicated in the appended claims.

I claim as my invention:

1. In an alternating-current direct-trip device, a movable tripping member operable to a tripping position, an electromagnetic actuating element energized solely in accordance with a current condition for moving said member to said position, and a second electromagnetic element energized in accordance with a voltage condition and a current condition for preventing movement of said member to said position except under predetermined conditions of current and voltage.

2. In an alternating-current direct-trip device, a movable tripping member operable from a normal position to a tripping position, an electromagnetic actuating element energized solely in accordance with a current condition for moving said member from said normal position to said tripping position, said actuating element being effective to develop increasing force with increasing displacement of said member from said normal position, and a second electromagnetic element energized in accordance with a voltage condition and a current condition for preventing movement of said member from said normal position except under predetermined conditions of current and voltage.

3. In an alternating-current direct-trip device, a movable tripping member operable from a normal position to a tripping position, an electromagnetic actuating element energized solely in accordance with a current condition for moving said member from said normal position to said tripping position, and an electromagnetic restraining element energized in accordance with a voltage condition and a current condition for exerting a restraining force on said member to prevent movement thereof from said normal position except under predetermined conditions of current and voltage, said restraining element being effective to develop decreasing restraining force with increasing displacement of said member from said normal position.

4. In an alternating-current device responsive to a vector product of a voltage condition and a second electrical condition, a voltage winding, a series impedance, a shunt impedance, a voltage energizing circuit for said winding including said winding and said shunt impedance in parallel relationship and said series impedance in series relationship, said impedances having volt-ampere characteristics so related as to cause the percentage variation of voltage applied to said winding to be less than the percentage variation of voltage applied to said energizing circuit, for a change of the latter voltage between predetermined limits.

5. In an alternating-current device responsive to a vector product of a voltage condition and a second electrical condition, a voltage winding, a series impedance, shunt impedance means having a flattened volt-ampere characteristic within predetermined limits of applied voltage, and a voltage energizing circuit for said winding including said winding and said shunt impedance in parallel relationship and said series impedances in series relationship.

6. In an alternating-current device responsive to a vector product of a voltage condition and a second electrical condition, a voltage winding, a series impedance, a saturable reactor, and a voltage energizing circuit for said winding including said winding and said saturable reactor in par-

allel relationship and said series impedance in series relationship.

7. In an alternating-current direct-trip device, a movable tripping member, an actuating element and a restraining element arranged to exert opposing forces upon said member, each of said elements having a magnetic portion responsive to a common electrical condition, said portions being designed to have similar magnetization characteristics, and means for inductively energizing said portions to the same flux density for each value of said condition to thereby substantially balance the effects of magnetic saturation in said device.

8. In an alternating-current direct-trip device, a movable tripping member, an actuating element and a restraining element arranged to exert opposing forces upon said member, each of said elements having a magnetic portion responsive to a common electrical condition, said portions having the same area and similar configuration in the plane of magnetic flow, and means for inductively energizing said portions to a common flux density for each value of said condition, to thereby substantially balance the effects of magnetic saturation in said device.

9. In an alternating-current direct-trip device, a movable tripping member, an actuating element and a restraining element arranged to exert opposing forces upon said member, each of said elements having an assembly of laminations responsive to a common electrical condition, said laminations being similar in size and design for both of said elements, and means for inductively energizing said laminations to a common flux density for each value of said condition, to thereby substantially balance the effects of magnetic saturation in said device.

10. In an alternating-current direct-trip device, a magnetic structure arranged to provide a magnetic circuit having a pair of parallel branches and a common portion, a first means for inductively energizing said common portion in accordance with a first electrical condition, a second means for inductively energizing one of said parallel branches in accordance with a second electrical condition, a third means for oppositely energizing the remaining one of said parallel branches in accordance with said second electrical condition, and a common energizing circuit for said second and third means, the mutual reactance of said first and second means being equal to the mutual reactance of said first and third means, whereby inductive interference between said first means and said common energizing circuit is eliminated.

11. In an alternating-current direct-trip device, magnetic structure arranged to provide a magnetic circuit having a pair of parallel

branches and a common portion, means for inductively energizing said common portion in accordance with a current condition, a pair of windings for inductively energizing said parallel branches in opposite directions in accordance with a voltage condition, and a common energizing circuit for said windings, the mutual reactances of said windings to said means being equal, whereby inductive interference between said means and said common energizing circuit is eliminated.

12. In an alternating-current direct-trip device, magnetic structure arranged to provide a magnetic circuit having a pair of parallel branches of equal reluctance and a common portion, a first means for inductively energizing said common portion in accordance with a first electrical condition, a second means for inductively energizing one of said parallel branches in accordance with a second electrical condition, a third means for oppositely energizing the remaining one of said parallel branches in accordance with said second electrical condition, and a common energizing circuit for said second and third means, said second and third means being of equal number of effective turns whereby inductive interference between said first means and said common energizing circuit is eliminated.

13. In an alternating-current direct trip device, magnetic structure arranged to provide a magnetic circuit having a pair of parallel branches of equal reluctance and a common portion, means for energizing said common portion in accordance with a current condition, a pair of windings of equal number of turns for inductively energizing said parallel branches in opposite directions in accordance with a voltage condition, and a common energizing circuit for said windings, whereby inductive interference between said means and said common energizing circuit is avoided.

14. In an alternating-current direct-trip device, a magnetic structure arranged to provide a first branch having a movable armature therein, a second branch in parallel to said first branch, and a common portion in series with both of said branches, means for balancing a magnetic condition of said first branch with a corresponding condition of said second branch comprising means for inductively energizing said branches in opposite directions, a first lag loop means interlinked with part of said first branch adjacent said armature to prevent chattering of said armature, and a second lag loop means interlinked with a corresponding part of said second branch to balance the effect of said first lag loop means.

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