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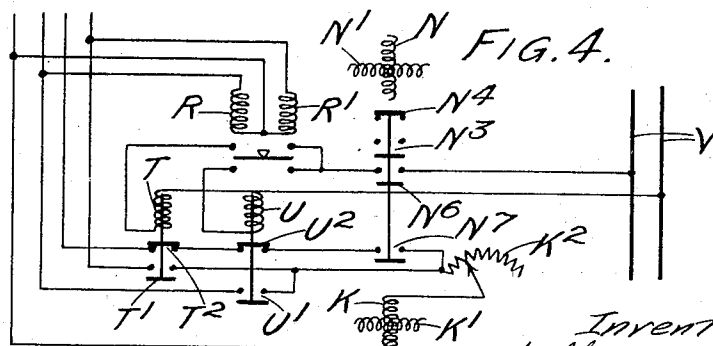
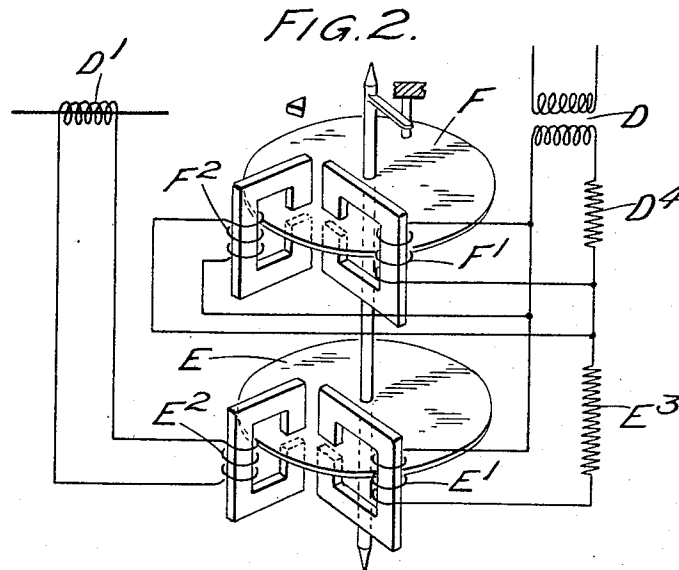
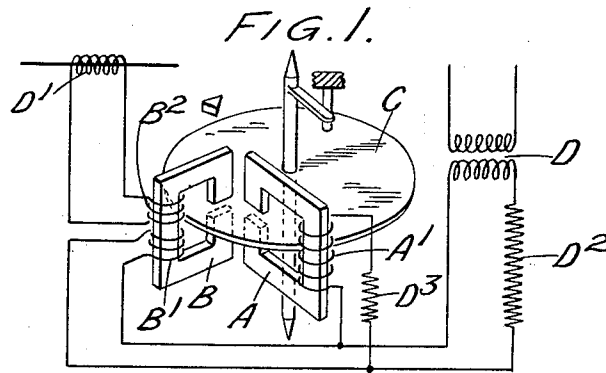
H. LEBEN ET AL

1,870,518

ELECTRIC PROTECTIVE SYSTEM

Filed July 11, 1929

2 Sheets-Sheet 1



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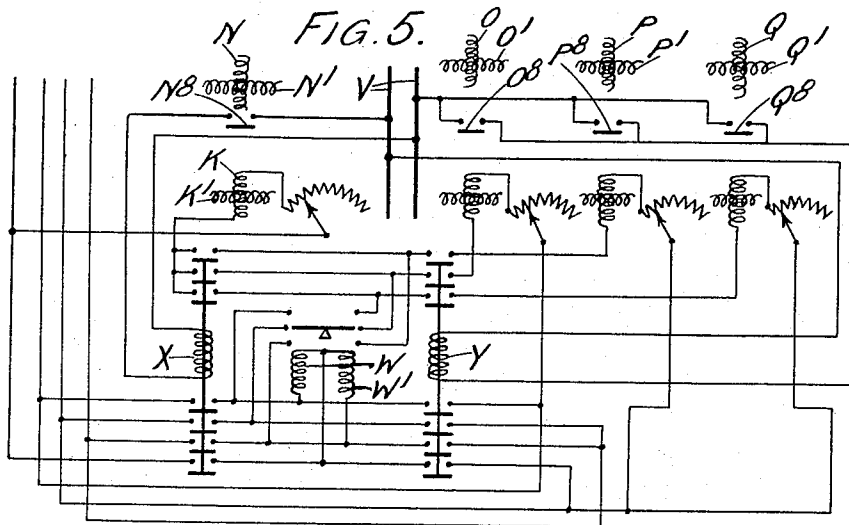
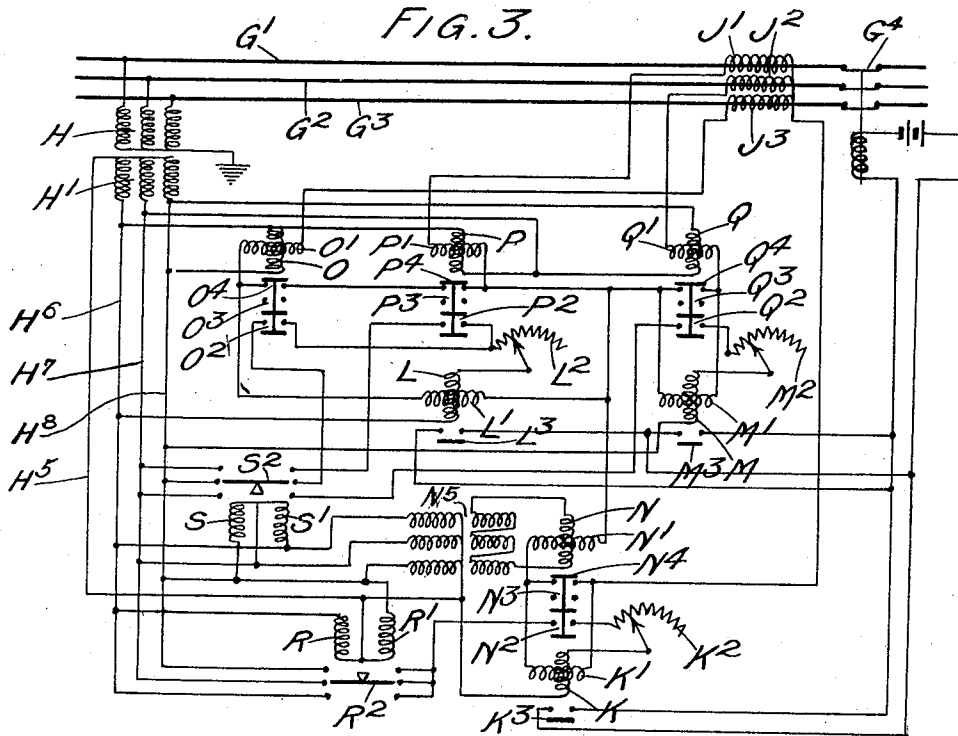
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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ELECTRIC PROTECTIVE SYSTEM

Application filed July 11, 1929, Serial No. 377,563, and in Great Britain July 31, 1928.

This invention relates to electric protective systems of the kind generally known as impedance or like protective systems, which depend for their operation on the fact that the impedance or reactance or resistance of the portion of the protected line between the fault and the protective relay is proportional to the distance of the fault from the relay. In such systems a number of "time-discriminating" relays are disposed at the ends of sections of the protected line, such relays being employed to give discriminative protection for the sections of the line by so arranging them that the time of operation of each relay is proportional to the impedance or other ratio of the line. In such systems it has been proposed that the time-discriminating relays should normally be disconnected and should be brought into circuit on the occurrence of a fault by means of initiating relays operative when the voltage of the line falls to an abnormally low value or when the current therein rises to an excessive value or when the impedance or like characteristic of the line falls below a predetermined value.

The primary object of the present invention is to provide an improved arrangement for controlling the energizing circuits of the time-discriminating relay coils.

In systems of this kind it is necessary to introduce a directional feature, whereby each of the time-discriminating relays, which are provided at both ends of the protected section, is prevented from operating unless the current is entering the section at the adjacent end. With some types of time-discriminating relay a directional feature is present in the relay itself, but in such a case (unless the relay has unduly high power consumption) it is difficult to ensure operation of the relay at low voltages unless compensating means are provided which would interfere with the accuracy of the time discrimination. On the other hand the employment of separate directional relays is undesirable since it increases the already large number of relays necessary to give adequate protection for earth and interphase faults and thus complicates the system.

A further object of the invention is there-

fore to provide a system wherein a directional feature satisfactorily operative at low voltages can be incorporated into the system without interfering with the accuracy of the time-discriminating relays and without increasing the number of relays employed.

It is usually necessary in such systems to employ separate initiating relays for earth faults and for interphase faults, but with the minimum number of initiating relays in three-phase systems (namely one for earth faults and three for interphase faults) there is risk of inadvertent relay operation owing to the connection of the time-discriminating relay coils to healthy phases instead of to the faulty phase or phases.

Yet another object of the invention is therefore to provide simple and efficient means for ensuring correct energization of the time-discriminating relay coils when a fault occurs.

Still further objects of the invention will be apparent from the appended claims and from the following description of the accompanying drawings, which illustrate by way of example some convenient arrangements according to the invention. In these drawings

Figures 1 and 2 respectively illustrate somewhat diagrammatically two convenient practical constructions of initiating relay,

Figure 3 is a circuit diagram of the whole protective system, and

Figures 4 and 5 show modifications of the system of Figure 3.

In the arrangement of Figure 1, the initiating relay has a single wattmetrical movement, which is illustrated as of the induction type although it will be clear that analogous arrangements can be employed with other types of wattmetrical movement. Thus the relay comprises two field cores A B co-operating with a disc or like contact member C. One of the field cores A carries a single coil A¹ energized from a potential transformer D in accordance with the voltage, whilst the second B carries two coils B¹ B² respectively energized from the potential transformer D and from a current transformer D¹ in accordance with the voltage

and with the current, the two voltage coils $A^1 B^1$ being connected in parallel with one another. The two coils $B^1 B^2$ on the second field core B respectively constitute a restraining coil and an operating coil and are arranged to produce opposing fluxes in the core B, the resultant of which interacts with the flux in the core A to exert a torque on the contact disc C. This torque is proportional to $V(I \cos X^1 - kV)$, where V and I are respectively the voltage and the current in the protected line, k is a constant and X^1 is an angle dependent upon the power factor of the line. In actual practice it is preferable to arrange the angle X^1 to be such that $\cos \Phi^1$ is never much less than unity, however severe the fault may be. This may be effected by giving a phase lag θ to the current flowing in the voltage coils $A^1 B^1$ with respect to that flowing in the current coil B^2 (or alternately giving a lead θ to the current flowing in the current coil B^2 with respect to that in the voltage coils $A^1 B^1$), the angle θ being chosen so that for all types of fault $\cos \Phi^1$ (which is equal to $\cos(\Phi - \theta)$ where $\cos \Phi$ is the power factor of the line) has a value greater than, say, 0.75. In the example illustrated a non-inductive resistance D^2 of suitable magnitude is connected in series with the voltage coil circuit to give the desired phase lag, a further resistance D^3 being inserted in the circuit of the coil A^1 in order to prevent current from the current transformer D^1 being fed to the coil A^1 by transformer action between the coils B^1 and B^2 .

With this arrangement it will be clear that the relay will operate as soon as the flux operating component $I \cos \Phi^1$ exceeds the restraining component kV , i. e. when the ratio $V/I \cos \Phi^1$ falls below a predetermined value. This arrangement is also directional in operation since a current reversal will reverse the operating flux component but not the restraining component.

It will be appreciated also that, quite apart from its function in producing the desired ratio characteristic of the relay, the provision of an additional voltage coil B^1 on the wattmetrical movement ensures the satisfactory operation of the relay even when the voltage falls to a very low value.

In the arrangement of Figure 2 operating and restraining torques are produced in two separate elements mechanically coupled together. The operating element consists of a simple wattmetrical movement having a voltage coil E^1 and a current coil E^2 so arranged as to produce a torque proportional to $VI \cos \Phi^1$ on the contact disc E, the currents flowing in the two coils being displaced relatively in phase in the manner above referred to (for instance by means of the resistances D^1 and E^3) in order to ensure a relatively large operating torque for all types

of fault. The contact disc E is mechanically coupled to the contact member F of the restraining element, which can be arranged in various ways to produce a torque proportional to V^2 opposing the operating torque. Thus for instance the restraining element may consist of a simple electromagnet energized in accordance with the voltage, the square law being obtained by not saturating the iron circuit. Alternatively (as shown), a second wattmetrical movement may be employed, the two coils $F^1 F^2$ of which are both energized in accordance with the voltage. The desired directional effect is obtained owing to the fact that the operating torque reverses and assists the restraining torque in the event of a current reversal.

Figure 3 illustrates a complete protective arrangement at one end of a section of a three-phase protected circuit employing initiating relays of either of the above kinds. In this arrangement the protected circuit $G^1 G^2 G^3$ is provided with a potential transformer having star-connected primary and secondary windings $H^1 H^2$ (the latter being connected to busbars H^0, H^1, H^2 and a neutral busbar H^3) and with a group of current transformers having star-connected secondaries $J^1 J^2 J^3$. Three time-discriminating relays $K K^1, L L^1, M M^1$ are employed, one of the relays $K K^1$ being operative for earth faults and the other two $L L^1$ and $M M^1$ for interphase faults. These relays are preferably of the kind described in the present applicants' copending U. S. patent application Serial No. 371,484, dated 17th June 1929 having voltage and current coils (of which one voltage coil K or L or M and one current coil K^1 or L^1 or M^1 only are shown in the drawings for simplicity) and a variable resistance K^2 or L^2 or M^2 operated by independent timing mechanism (not shown) in the circuit of, say, the voltage coil K or L or M. The contacts $K^3 L^3 M^3$ of the time-discriminating relays control a tripping circuit for a circuit-breaker G^4 in the protected circuit $G^1 G^2 G^3$ in the usual manner. These relays are normally disconnected, but their coils are brought into circuit by the operation of initiating relays of the kind above described. Four initiating relays $N N^1, O O^1, P P^1, Q Q^1$ are provided (each being shown for simplicity as having a single voltage coil N or O or P or Q and a single current coil N^1 or O^1 or P^1 or Q^1), of which the first $N N^1$ is associated with earth faults, whilst the other three are associated with interphase faults. The normally open contacts N^2 of the relay $N N^1$ control the energizing circuit of the voltage coil K of the relay $K K^1$, whilst contacts N^4 on the relay $N N^1$ normally short-circuit the current coil K^1 . In a similar manner the contacts $Q^2 Q^4$ of the relay $Q Q^1$ control the relay $M M^1$, and the contacts $O^2 O^4$ and $P^2 P^4$ of the relays $P P^1$ and

Q Q¹ together control the relay L L¹. The current coils of the initiating and time-discriminating relays derive their current from the current transformer secondaries J¹ J² J³. Thus the star-point of the current transformer secondaries J¹ J² J³ is connected through contacts N⁴ to the current coil N¹, the other side of which is connected either through contacts Q⁴ and the current coil Q¹ to the secondary J² or through the current coil P¹ to the secondary J¹ or through contacts P⁴ O⁴ and the current coil O¹ to the secondary J³, whilst the current coils of the time-discriminating relays are connected to the same circuits, the coil K¹ being normally short-circuited by contacts N⁴, the coil M¹ by contacts Q⁴ and the coil L¹ by contacts O⁴ P⁴. The voltage coils of the interphase fault initiating relays are energized from the potential transformer secondary busbars H⁶ H⁷ H⁸, the coil O from H⁶ H⁸, the coil P from H⁶ H⁷ and the coil Q from H⁷ H⁸. The voltage coil N of the earth-fault initiating relay derives its current from a small auxiliary potential transformer N⁵, although other means may be employed for this purpose such for example as the energization of the voltage coil from the current in an earthing connection to the neutral point of a power transformer in the protected circuit, if available. The contacts N³ O³ P³ Q³ of the initiating relays control a starting circuit (not shown) for the timing mechanism which drives the contact arms of the resistances K² L² M². The voltage coils of the time-discriminating relays also derive their current from the busbars H⁶ H⁷ H⁸, energizing circuits.

In order to ensure that the time-discriminating relays are correctly energized from the faulty phases, two phase-selecting relays R R¹ S S¹ are provided, these relays being respectively operative for earth faults and for interphase faults and acting to control the energizing circuits of the voltage coils of the time-discriminating relays.

The earth-fault phase-selecting relay R R¹ comprises a contact-making system (which may be in the form of a pivoted beam R² as shown or of a rotatable spindle) operated differentially by two coils R R¹ which are connected respectively between the busbars H⁶ H⁶ and H⁵ H⁸ i. e. are energized respectively in accordance with the earth voltages of two of the phases G¹ G³. In the event of an earth fault on the phase G², the earth voltage on that phase will drop, as will also those on the other phases. The earth voltage on the phase G² will however be considerably lower than those on the phases G¹ G³ which will be equal to one another. Thus for such a fault the contact beam R² will remain in its normal balanced position, and will allow the voltage coil K to be energized from the phase G², the

initiating relay N N¹ having operated. The energizing circuit for the coil K may be traced from potential transformer busbar H⁷ through contact beam R² in its central position, contacts N², variable resistance K², and coil K to neutral busbar H⁵. For an earth fault on phase G¹, the coil R will exert a greater force than the coil S¹ and will consequently move the beam R² in one direction to energize the coil K from the faulty phase G¹ i. e. from busbar H⁶ instead of busbar H⁷ in the above traced circuit. A fault on phase G³ will similarly move the beam R² in the other direction to energize the coil K from the phase G³ i. e. from busbar H⁸.

The interphase fault phase-selecting relay is arranged in a similar manner with a contact beam S² or spindle operated differentially from two coils S S¹, which however in this case are energized respectively from the interphase voltages G² G³ and G¹ G², i. e. from busbars H⁷ H⁸ and H⁶ H⁷. Thus for an interphase fault between the phases G¹, G³, the beam S² will remain in its central position, and owing to the operation of the initiating relay O O¹, the time-discriminating relay L L¹ will be operative with its voltage coil L energized from the phases G¹ G³. The energizing circuit for the coil L may be traced from busbar H⁶ through coil L, variable resistance L², contacts O², and contact beam S² in its central position to busbar H⁸. For a fault between the phases G¹, G², the initiating relay P P¹ will operate and the beam S² will move over in a direction to energize the voltage coil L from the phases G¹ G², the force of the coil S exceeding that of coil S¹ and pulling down the left-hand end of the beam so that the energizing circuit for the coil L in this case runs from busbar H⁶ through coil L, resistance L², contacts P² and contact beam S² to busbar H⁷. Similarly for a fault between the phases G² G³ the initiating relay Q Q¹ will operate and the beam S² will move to a position in which the voltage coil M of the relay M M¹ is energized from the phases G² G³. The circuit for coil M runs from busbar H⁸ through coil M, resistance M², contacts Q² and contact beam S² in its other operated position to busbar H⁷.

Instead of providing each phase-selecting relay with contacts in all its three operating positions, it may have two sets of contacts only, these contacts being completed respectively in the two unbalanced positions of the relay. Such an arrangement is shown in Figure 4 for the earth fault phase-selecting relay R R¹, a similar arrangement being equally applicable also to the interphase fault relay S S¹. In this case two auxiliary contactors T U are provided, whose energizing circuits (preferably from a D. C. source indicated at V) are controlled respec-

tively by the two sets of contacts on the phase-selecting relay R R¹ and by normally open contacts N⁶ on the earth fault initiating relay N N¹. One of these contactors T has normally open contacts T¹ controlling the energizing circuit from the phase G³ to the voltage coil K of the time-discriminating relay, and the other has normally open contacts U¹ controlling the corresponding circuit from the phase G¹. The circuit from the phase G² is taken through normally closed contacts T² U² on the two auxiliary contactors and through normally open contacts N⁷ on the initiating relay N N¹.

Figure 5 shows a modification in which a single phase-selecting relay is employed both for earth faults and for interphase faults, the energizing circuits for the two coils W W¹ of this relay being controlled by two D. C. contactors X Y. The contactor X is energized whenever the earth fault initiating relay N N¹ operates its contacts N⁸ which replace the contacts N² of Figure 3, and acts to supply the correct earth voltages to the coils W W¹ and to the voltage coil K of the earth fault time-discriminating relay, the latter circuit also being controlled by the phase-selecting relay contacts. The contactor Y is likewise operated whenever one or other of the interphase fault relays O O¹, P P¹, Q Q¹, operate their contacts O^s P^s Q^s, and acts to supply the correct phase voltages to the coils W W¹ and to the voltage coils of the interphase fault time-discriminating relays (this figure showing a symmetrical arrangement in which three time-discriminating relays are used instead of the two in Figure 3).

The above arrangements have been described by way of example only and may be modified in various ways within the scope of the invention. Thus for instance the phase-selecting relays may if desired control the energizing circuits to the current coils of the time-discriminating relays as well as the voltage circuits, and again may be employed for the control of time-discriminating relays of other kinds.

What we claim as our invention and desire to secure by Letters Patent is:—

1. In an electric protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay, means whereby the time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval which depends on a ratio dependent on the voltage and current characteristics of the line and representative of the fault distance, an instantaneously acting initiating relay having a contact-making system and coils acting wattmetrically thereon, means whereby the initiating relay acts when operated to

render the time-discriminating relay operative, and means for energizing the initiating relay coils in accordance with the voltage and current characteristics of the line whereby the relay is caused to operate only when the flow of power in the line is in a predetermined direction and a ratio dependent on the voltage and current characteristics of the line and representative of the fault distance is less than a predetermined value.

2. In an electric protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay, means whereby the time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval which depends on a ratio dependent on the voltage and current characteristics of the line and representative of the fault distance, and an instantaneously acting initiating relay comprising a contact member, a wattmetrical operating element including coils and a movable member, a restraining element including at least one coil and a movable member, means for mechanically coupling the contact member and the two movable members together, and means for energizing the coils of the relay elements in accordance with the voltage and current characteristics of the line whereby the relay is operative only when the flow of power in the protected line is in a predetermined direction and when a ratio dependent on the voltage and current characteristics and representative of the fault distance is less than a predetermined value.

3. In an electric protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay, means whereby the time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval which depends on a ratio dependent on the voltage and current characteristics of the line and representative of the fault distance, and an instantaneously acting initiating relay comprising a contact member, a single wattmetrical element having operating and restraining coils and a movable member, means whereby in such element a single torque due to the interaction of two magnetic fluxes produced by the coils is exerted on the movable member, means whereby such movable member operates the contact member, and means for energizing the coils of the wattmetrical element in accordance with the voltage and current characteristics of the protected line whereby the torque is rendered dependent on the direction of power flow in the line and on a ratio dependent on the voltage and cur-

rent characteristics and representative of the fault distance.

4. In an electric protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay, means whereby the time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval which depends on a ratio dependent on the voltage and current characteristics of the line and representative of the fault distance, and an instantaneously acting initiating relay comprising a contact member, a wattmetrical operating element having voltage and current coils and a movable member, means for so energizing such coils that they will exert on the movable member an operating torque proportional to $VI \cos X^1$ (where V and I are respectively the voltage and the current in the protected line and X^1 is an angle dependent on the power factor of the line), a restraining element having at least one coil and a movable member, means for so energizing such coil that a restraining torque proportional to V^2 is exerted on the movable member, and means for mechanically coupling the two movable members to the contact member, the arrangement of the operating element being such that in the event of a reversal of power flow in the protected line the operating torque will reverse and assist the restraining torque.

5. In an electric protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay, means whereby the time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval which depends on a ratio dependent on the voltage and current characteristics of the line and representative of the fault distance, and an instantaneously acting initiating relay comprising a contact member, a wattmetrical operating element having voltage and current coils and a movable member, means for so energizing such coils that they will exert on the movable member an operating torque proportional to $VI \cos X^1$ (where V and I are respectively the voltage and the current in the protected line and X^1 is an angle dependent on the power factor of the line), means whereby the currents flowing in the current coil and the voltage coil of the operating element are displaced in phase relative to one another by such an angle as to ensure a relatively large operating torque for all types of fault, a restraining element having at least one coil and a movable member, means for so energizing such coil that a restraining torque proportional to V^2 is exerted on the movable member, and means for mechanically cou-

pling the movable members to the contact member, the arrangement of the operating element being such that in the event of a reversal of power flow in the protected line the operating torque will reverse and assist the restraining torque.

6. In an electric protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay, means whereby the time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval which depends on a ratio dependent on the voltage and current characteristics of the line and representative of the fault distance, and an instantaneously acting initiating relay comprising a contact member, a movable member mechanically coupled to the contact member, two magnetic circuits the fluxes in which interact to exert a single torque on the movable member, a single coil on one magnetic circuit, means whereby such coil is energized in accordance with the voltage in the protected line, an operating coil on the second magnetic circuit, means whereby such coil is energized in accordance with the current in the protected line, a restraining coil on the second magnetic circuit, and means whereby such coil is energized in accordance with the voltage in the protected line, the arrangement of the coils on the second magnetic circuit being such that in the event of a reversal of power flow in the protected line the action of the operating coil will reverse and assist that of the restraining coil.

7. In an electric protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay, means whereby the time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval which depends on a ratio dependent on the voltage and current characteristics of the line and representative of the fault distance, and an instantaneously acting initiating relay comprising a contact member, a movable member mechanically coupled to the contact member, two magnetic circuits the fluxes in which interact to exert a single torque on the movable member, a single coil on one magnetic circuit, means whereby such coil is energized in accordance with the voltage in the protected line, an operating coil on the second magnetic circuit, means whereby such coil is energized in accordance with the current in the protected line, a restraining coil on the second magnetic circuit, means whereby such coil is energized in accordance with the voltage in the protected line, and means whereby the currents flowing in the operating current coil and in the voltage coil on the first mag-

netic circuit are displaced in phase relative to one another by such an angle as to ensure satisfactory operation of the contact member for all types of fault, the arrangement of the coils on the second magnetic circuit being such that in the event of a reversal of power flow in the line the action of the operating coil will reverse and assist that of the restraining coil.

8. In a three-phase protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a group of normally inoperative time-discriminating relays, means whereby each time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval dependent on a ratio which depends on the voltage and current characteristics of the protected line and is representative of the fault distance, a group of initiating relays, means whereby at least one initiating relay is caused to operate on the occurrence of a fault on the line, means whereby each initiating relay on operating causes a selected time-discriminating relay to be rendered operative, at least one phase-selecting relay, means for energizing such phase-selecting relay in accordance with the voltage characteristics of the line whereby it will operate in accordance with the voltage unbalance between the phases of the line set up by the fault, and means whereby the phase-selecting relay acts to ensure that the selected time-discriminating relay is energized from the faulty phase or phases.

9. In a three-phase protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a group of normally inoperative time-discriminating relays, means whereby each time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval dependent on a ratio which depends on the voltage and current characteristics of the protected line and is representative of the fault distance, a group of initiating relays, means whereby at least one initiating relay is caused to operate on the occurrence of a fault on the line, means whereby each initiating relay on operating causes a selected time-discriminating relay to be rendered operative, two phase-selecting relays, means for energizing such phase-selecting relays in accordance respectively with the earth voltages and with the interphase voltages in the protected line whereby each phase-selecting relay will operate in accordance with the voltage unbalance between the phases of the line set up by the fault, means whereby one phase-selecting relay acts in the event of an earth fault to ensure that the selected time-discriminating relay is energized from the faulty phase, and means whereby the other phase-selecting re-

lay acts in the event of an interphase fault to ensure that the selected time-discriminating relay is energized from the faulty phases.

10. In a three-phase protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay, means whereby such relay when rendered operative acts to open the circuit-breaker after a time interval dependent on a ratio which depends on the voltage and current characteristics of the protected line and is representative of the fault distance, an initiating relay, means whereby the initiating relay is caused to operate on the occurrence of an earth fault on the protected line, means whereby the initiating relay on operating acts to render operative the time-discriminating relay, a phase-selecting relay, means for energizing the phase-selecting relay differentially in accordance with the earth voltages on two of the three phases of the line whereby the contact member of the phase-selecting relay takes up one or other of three operative positions in accordance with which of the phases is faulty, and means whereby the position of such contact member determines the phase of the line from which the time-discriminating relay is energized.

11. In a three-phase protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a group of normally inoperative time-discriminating relays, means whereby each time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval dependent on a ratio which depends on the voltage and current characteristics of the protected line and is representative of the fault distance, a group of initiating relays, means whereby at least one initiating relay is caused to operate on the occurrence of an interphase fault on the line, means whereby each initiating relay on operating causes a selected time-discriminating relay to be rendered operative, a phase-selecting relay, means for energizing the phase-selecting relay differentially in accordance with two of the three interphase voltages whereby the contact member of the phase-selecting relay takes up one or other of three operative positions in accordance with which of the pairs of phases is faulty, and means whereby the position of such contact member determines the phases of the line from which the selected time-discriminating relay is energized.

12. In a three-phase protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a group of normally inoperative time-discriminating relays, means whereby each time-discriminating relay when rendered opera-

tive acts to open the circuit-breaker after a time interval dependent on a ratio which depends on the voltage and current characteristics of the protected line and is representative of the fault distance, a group of initiating relays, means whereby at least one initiating relay is caused to operate on the occurrence of a fault on the line, means whereby each initiating relay on operating causes a selected time-discriminating relay to be rendered operative, two phase-selecting relays respectively associated with earth faults and with interphase faults, means for energizing the earth fault phase-selecting relay differentially in accordance with the earth voltages on two of the phases of the line whereby its contact member takes up one or other of three operative positions in accordance with which of the phases is faulty, means for energizing the interphase fault phase-selecting relay differentially in accordance with two of the three interphase voltages whereby its contact member takes up one or other of three operative positions in accordance with which of the pairs of phases is faulty, and means whereby the positions of the contact members of the phase-selecting relays determine the phase or phases of the line from which the selected time-discriminating relay is energized.

13. In a three-phase protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a group of normally inoperative time-discriminating relays, means whereby each time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval dependent on a ratio which depends on the voltage and current characteristics of the protected line and is representative of the fault distance, a group of initiating relays associated with the individual phases or pairs of phases of the line and each having a contact-making system and coils acting wattmetrically thereon, means whereby each initiating relay on operating causes a selected time-discriminating relay to be rendered operative, means for energizing the coils of each initiating relay in accordance with the voltage and current characteristics of the associated phase or phases of the line whereby such relay is caused to operate only when a characteristic of the associated phase or phases representative of the fault distance is less than a predetermined value and when the flow of power in the line is in a predetermined direction, at least one phase-selecting relay, means for energizing such phase-selecting relay in accordance with the voltage characteristics of the line whereby it will operate in accordance with the voltage unbalance between the phases of the line set up by the fault, and means whereby the phase-selecting relay acts to ensure that the selected

time-discriminating relay is energized from the faulty phase or phases.

14. In a three-phase protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a group of normally inoperative time-discriminating relays, means whereby each time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval dependent on a ratio which depends on the voltage and current characteristics of the protected line and is representative of the fault distance, a group of initiating relays associated with the individual phases or pairs of phases of the line and each having a contact-making system and coils acting wattmetrically thereon, means whereby each initiating relay on operating causes a selected time-discriminating relay to be rendered operative, means for energizing the coils of each initiating relay in accordance with the voltage and current characteristics of the associated phase or phases of the line whereby such relay is caused to operate only when a characteristic of the associated phase or phases representative of the fault distance is less than a predetermined value and when the flow of power in the line is in a predetermined direction, two phase-selecting relays respectively associated with earth faults and with interphase faults, means for energizing the earth fault phase-selecting relay differentially in accordance with the earth voltages on two of the phases of the line whereby its contact member takes up one or other of three operative positions in accordance with which of the phases is faulty, means for energizing the interphase fault phase-selecting relay differentially in accordance with two of the three interphase voltages whereby its contact member takes up one or other of three operative positions in accordance with which of the pairs of phases is faulty, and means whereby the positions of the contact members of the phase-selecting relays determine the phase or phases of the line from which the selected time-discriminating relay is energized.

15. In a three-phase protective system having a time-discriminating action dependent on the fault distance, the combination of a circuit-breaker in the protected line, a normally inoperative time-discriminating relay associated with earth faults, a group of normally inoperative time-discriminating relays associated with interphase faults, means whereby each time-discriminating relay when rendered operative acts to open the circuit-breaker after a time interval dependent on a ratio which depends on the voltage and current characteristics of the protected line and is representative of the fault distance, an earth fault initiating relay, means whereby

means such initiating relay is caused to operate on the occurrence of an earth fault, means whereby the earth fault initiating relay on operating renders the earth fault time-discriminating relay operative, three interphase fault initiating relays associated respectively with the three pairs of phases, means whereby the appropriate initiating relay is operated on the occurrence of an interphase fault, means whereby each interphase fault initiating relay on operating renders a selected interphase fault time-discriminating relay operative, two phase-selecting relays respectively associated with earth faults and with interphase faults, means for energizing such phase-selecting relays in accordance respectively with the earth voltages and with the interphase voltages in the protected line whereby each phase-selecting relay will operate in accordance with the voltage unbalance between the phases of the line set up by the fault, means whereby one phase-selecting relay acts in the event of an earth fault to ensure that the earth fault time-discriminating relay is energized from the faulty phase, and means whereby the other phase-selecting relay acts in the event of an interphase fault to ensure that the selected interphase fault time-discriminating relay is energized from the faulty phases.

In testimony whereof we have signed our names to this specification.

HENRY LEBEN.
NORMAN COOKE.

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