

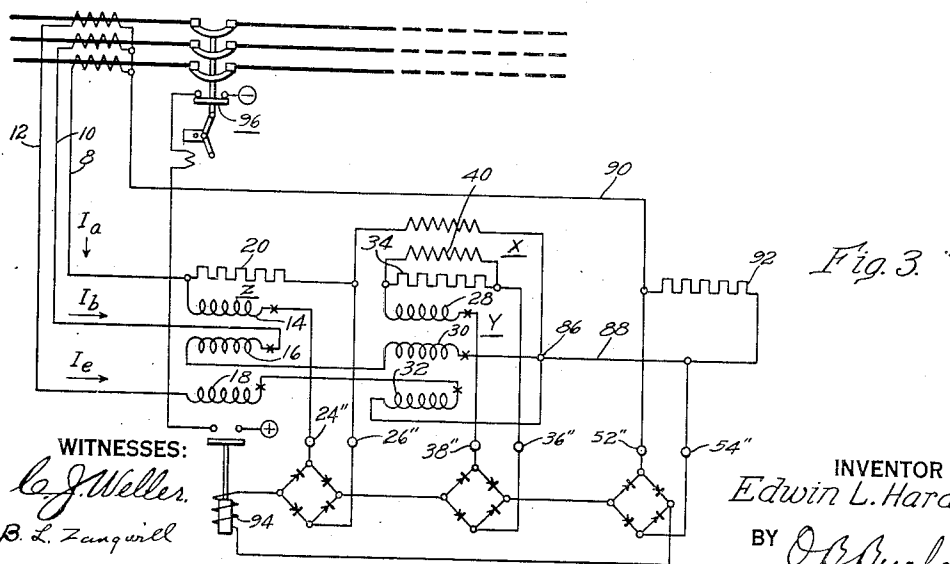
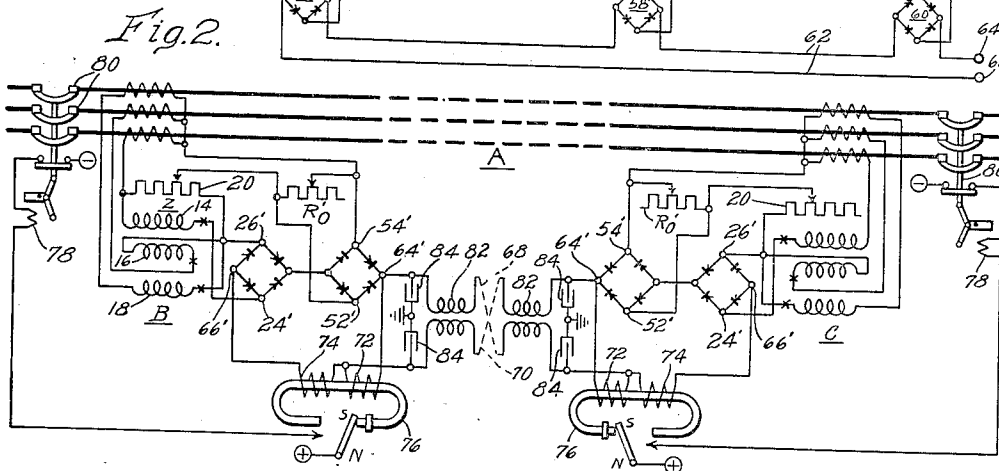
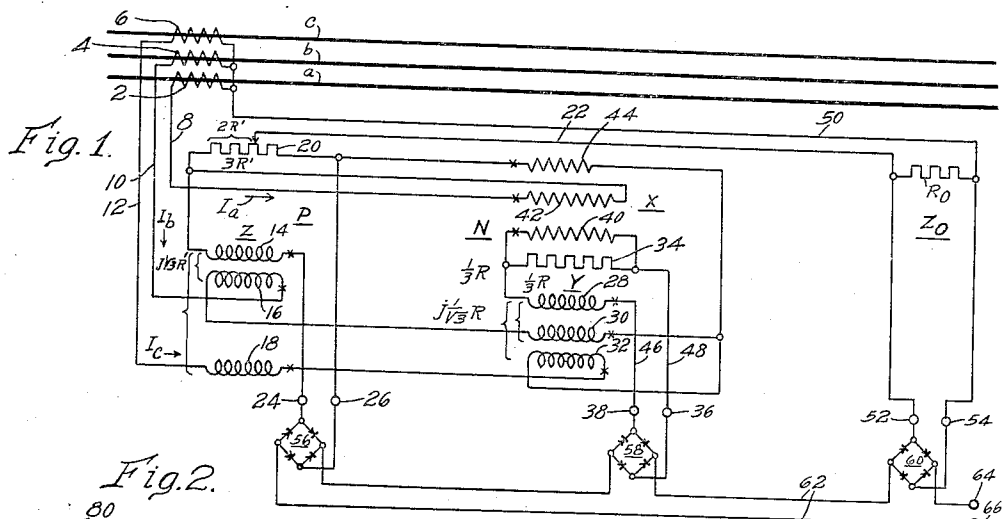
Sept. 22, 1942.

E. L. HARDER

2,296,784

PHASE-SEQUENCE RELAYING

Filed May 31, 1940



WITNESSES:

W. J. Weller.
B. L. Zangwill

INVENTOR

Edwin L. Harder.

BY

O. B. Buchanan
ATTORNEY

UNITED STATES PATENT OFFICE

2,296,784

PHASE-SEQUENCE RELAYING

Edwin L. Harder, Forest Hills, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application May 31, 1940, Serial No. 338,093

14 Claims. (Cl. 175—294)

My invention relates to relays for the protection of transmission lines and other electrical devices in the event of the occurrence of overcurrent or a fault.

In my Patent No. 2,183,646, issued December 19, 1939, and assigned to the Westinghouse Electric & Manufacturing Company, a system is shown whereby a single discriminating function may be obtained by the vector addition of quantities derived from the positive- and zero-sequence current-components of the line-currents, the negative-sequence current-component being excluded, which quantities are suitably weighted so that the discriminating function will be maintained within controllable and adjustable limits for the different kinds of faults. The weighting is so chosen that the limits of the discriminating function are kept within a relatively narrow range so that a single-element relay will register, no matter which of the ten different types of faults might occur.

In the instant invention I disclose another relaying apparatus which, however, utilizes the scalar addition of quantities, derived from the sequence-components of the line-currents, for obtaining the single discriminating function. The quantities may also be suitably weighted, depending primarily on how well the protected line is grounded, so that the discriminating function will also be within a narrow range for the different types of expectable faults.

In one specific embodiment of the instant invention the weighting is such as to build up the discriminating function due to line-to-line faults, to a value close to the discriminating function expectable from a three-phase fault.

In accordance with my invention I do this by introducing an electrical quantity which is representative of the negative-sequence component of the line-currents. However, the introduction of this component does not decrease the sensitivity of the apparatus, that is, the value of the discriminating function, to double line-to-ground faults.

It is an object of my invention to provide a protective means in which the quantities representative of the different sequence-components of the line-currents are numerically combined for controlling a single-element relay by a responsive registration, or discriminating function, whose sensitivity to the different types of expectable faults on the line can be controlled by selecting the sequence-components to be combined, suitably weighted if necessary, and converted to scalar quantities before their combination. The resulting discriminating function is unidirectional so that the relative phase angle relationships of the phase-sequence quantities, which are vectorial, are of small consequence in the registered response.

By suitably selecting which of the scalar quantities, derived from the different phase sequence-components, are to be combined, a discriminating function obtains which will be close to a predetermined magnitude as faults rotate from phase to phase, which will be within a small range of this magnitude whatever the phase relationships of the phase sequence-components, and which will vary only slightly between the different possible types of faults; that is to say, if the level of the discriminating function obtained from a three-phase fault is the base value for comparison, the level of the discriminating function obtained from any combination of line-to-line faults, and any combination of line-to-ground faults, especially double line-to-ground faults, can readily be made to approximate the base value.

My invention has many of the advantages described in my aforesaid patent, and it is also particularly useful for protective purposes within a station where pilot wires are not involved, or for overcurrent protection, or for pilot wire protective systems where the magnitude of current-flow to or from one end of the protected section having an internal fault will be different from that of the current-flow to or from the other end, as for example, in a radial distribution system, or a loop distribution system where the protected section has one terminal close to an energy supply but the other end relatively far from the energy supply.

Where my invention is utilized in pilot wire systems, the unidirectional character of the discriminating function prevents the use of insulating transformers but the terminal equipment can be adequately protected against extraneously induced voltages in the pilot wires by means of self-excited neutralizing transformers, such as described and claimed in my copending application, Serial No. 212,451, filed June 8, 1938, and assigned to the Westinghouse Electric & Manufacturing Company.

Additional objects and features of my invention will become apparent from the following description thereof, taken in conjunction with the accompanying drawing in which like numerals generally indicate like parts, and in which:

Figure 1 is a diagrammatic view of circuits illustrating a network for obtaining scalar quantities representative, respectively, of the zero-, positive- and negative-sequence-components of the line-currents in an electric device, shown in this figure as a three-phase line;

Fig. 2 is a diagrammatic view of circuits and apparatus embodying my invention, for a protective system for a section of a three-phase line wherein the protective system includes pilot wires. This view illustrates a modified form of my invention in which the discriminating func-

tion is obtained by the scalar combination of quantities due to zero- and positive-sequence current-components; and,

Fig. 3 is a diagrammatic view of a further modification, and particularly showing my invention applied to overcurrent protection.

My invention comprises, generally, the scalar combination of quantities derived from selected phase-sequence current-components of the line-currents in an electric device, and in Fig. 1 I show how a discriminating function may be obtained which may be represented by the equation

$$|Em| = |k_0 I_0| + |k_1 I_1| + |k_2 I_2| \quad (1)$$

in which all quantities between vertical bars are absolute or scalar values. In Equation 1 the subscripts 0, 1 and 2 are respectively indicative of zero-sequence, positive-sequence, and negative-sequence components of the three-phase line-currents flowing in lines *a*, *b* and *c*, the respective currents in which may be represented by *I* with a subscript corresponding to the particular line involved. The general symbols employed in this description follow those described in the book "Symmetrical Components" by C. F. Wagner and R. D. Evans.

The filter network, in which the sequence-components are obtained, is energized from the three-phase line, *a*, *b*, *c*, through a single set of current transformers 2, 4 and 6, which are Y-connected and derive currents *I_a*, *I_b* and *I_c*, respectively, in the output lines 8, 10 and 12, the currents *I_a*, *I_b* and *I_c* having a predetermined relation to the actual line-currents flowing in the line wires *a*, *b* and *c*, and are, therefore, representative of the line-currents. The filter network is such that an electrical quantity representative of only the rotational positive-sequence component of the currents *I_a*, *I_b* and *I_c* may be obtained from one filter section P; an electrical quantity representative of the rotational negative-sequence component may be obtained from another filter section N; and an electrical quantity representative of the zero-sequence component may be obtained from still another filter section Z₀.

The section P is very similar to the positive sequence network section described in Fig. 1 of my aforesaid patent, and comprises an impedance Z having a secondary winding 14 inductively coupled to two primary windings 16 and 18 in two circuits traversed, respectively, by the currents *I_b* and *I_c*. This section further includes a resistor 20, having a value 3*R*', which is traversed at least in part by the line-current *I_a* flowing to a neutral conductor 22. The neutral conductor 22 is connected to the

$$\frac{2}{3}$$

point of the resistance 20 so that the discriminating factor across the terminals 24 and 26 is due solely to the positive-sequence component of the line currents *I_a*, *I_b* and *I_c*. To obtain this the mutual reactances between the windings 14 and 16, and the windings 14 and 18 are made equal to $j\sqrt{3}R'$, and by tapping off the neutral conductor 22 of the

$$\frac{2}{3}$$

point of the resistance 20, the discriminating factor $k_1 I_1$ across the terminals 24 and 26 will be due solely to the positive-sequence current *I₁*, as more fully explained in my aforesaid patent, with the weighing-factor *k*, in that patent, for

the zero-sequence component made equal to zero.

The line currents *I_b*, *I_c* also traverse an impedance Y similar to the impedance Z, but so arranged that the current *I_c* is reversed, while *I_b* flows directly therethrough. This impedance Y comprises a secondary winding 28 and primary windings 30 and 32, each having a mutual reactance with the primary winding of

$$j\frac{1}{\sqrt{3}}R$$

A resistance 34 of a value

$$\frac{1}{3}R$$

has one end connected to an end of the winding 28, and its other end to a terminal 36 which is paired with a terminal 38 connected to the other end of the winding 28. Connected across the resistance 34 is a secondary winding 40 of a transformer X having a primary winding 42 traversed by the current *I_a* and a primary winding 44 traversed by the current *I_b* + *I_c*. The winding 42 has twice the number of turns of the winding 44 which in the preferred form equals the number of turns in the secondary winding 40.

The impedance Y, the transformer X, and the resistance 34 compose the section N of the network, and will produce a discriminating factor across the terminals 36 and 38, which is responsive only to the negative-sequence component of the line-currents.

A mathematical explanation of this section is as follows: With no current flowing through the terminals 36 and 38, a circuit may be traced in which the sum of all the voltage drops through the circuit, including connection 46, the primary winding 28, the resistance 34, and connection 48, must equal the voltage *E_{2m}* across the terminals 36 and 38, as follows:

$$E_{2m} = \frac{2}{3}RI_a - \frac{1}{3}R(I_b + I_c) + j\frac{R}{\sqrt{3}}(-I_b + I_c) = \frac{2}{3}RI_a + \left(-\frac{R}{3} - j\frac{R}{\sqrt{3}}\right)I_b + \left(-\frac{R}{3} + j\frac{R}{\sqrt{3}}\right)I_c \quad (2)$$

By substituting the sequence-components of the line-currents *I_a*, *I_b* and *I_c*, which are represented by

$$\begin{aligned} I_a &= I_0 + I_1 + I_2 \\ I_b &= I_0 + a^2 I_1 + a I_2 \\ I_c &= I_0 + a I_1 + a^2 I_2 \end{aligned}$$

and remembering that

$$a = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$$

and

$$a^2 = -\frac{1}{2} - j\frac{\sqrt{3}}{2}$$

Equation 2 becomes

$$\begin{aligned} E_{2m} &= \frac{2}{3}RI_0 + \left(-\frac{R}{3} - j\frac{R}{\sqrt{3}}\right)I_0 + \left(-\frac{R}{3} + j\frac{R}{\sqrt{3}}\right)I_0 + \\ &\quad \frac{2}{3}RI_2 + \left(-\frac{R}{3} - j\frac{R}{\sqrt{3}}\right)\left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right)I_1 + \\ &\quad \left(-\frac{R}{3} + j\frac{R}{\sqrt{3}}\right)\left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right)I_1 + \frac{2}{3}RI_2 + \\ &\quad \left(-\frac{R}{3} - j\frac{R}{\sqrt{3}}\right)\left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right)I_2 + \\ &\quad \left(-\frac{R}{3} + j\frac{R}{\sqrt{3}}\right)\left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right)I_2 \end{aligned} \quad (3)$$

By reducing Equation 3, it will be found that all the I_0 terms, and all the I_1 terms add up to zero, and that

$$E_{2m} = 2RI_2 = k_2 I_2 \quad (4)$$

indicating that the discriminating factor across the terminals 36 and 38 is due solely to the negative-sequence component of the line-currents.

The neutral conductor 22 connects to one end of a resistor R_0 , the other end of which is connected to a further neutral conductor 50 connected to the neutral point of the Y-connected current transformers. Consequently, as is well known in the art, the drop across this resistance R_0 will be due solely to the zero-sequence component flowing in the neutral lines 22 and 50. Terminals 52 and 54 are connected across this resistor R_0 so that an electric voltage-quantity $R_0 I_0 = K_0 I_0$ is manifest across these terminals, which will be representative solely of the zero-sequence component I_0 of the line-currents.

The different discriminating factors across the respective pairs of terminals 24—26, 36—38, and 52—54, are, in this particular instance, converted to scalar quantities by connecting full-wave rectifiers 56, 58, and 60, respectively, across the pairs of terminals. The direct current outputs of the rectifiers are algebraically added by being connected in series. It is evident that by converting the discriminating factors to scalar values, and combining them serially, the summation will produce a single discriminating function which can be manifested in a single measuring circuit, indicated at 62, the circuit being represented as terminating in terminals 64 and 66. Since the discriminating factors across each output of the rectifiers, are derived, respectively, from the individual sequence-components I_1 , I_2 and I_0 , the registration response, or discriminating function, in the measuring circuit 62 will be the sum of the individual scalar quantities derived from these components and is represented by Equation 1.

By varying the value of the resistance R_0 , and each or both of the values of the resistances 20 and 34 (in which case the impedances Z and Y should also be proportionately varied, if necessary), it is possible to control the magnitudes of the constants k_1 , k_2 and k_0 . Or by trebling the magnitude of resistance 34, and correspondingly trebling the mutual impedance of the windings in impedance Y , this impedance will physically duplicate the impedance Z . However, in actual practice of my invention, k_1 and k_2 may be equal, and k_0 can be readily varied by varying the values of the resistance R_0 . In this case the representative relationships of the network shown in Fig. 1 will yield a discriminating function in the measuring circuit which may be represented by

$$|E_m| = |K(I_1 + I_2 + k' I_0)| \quad (5)$$

this equation obviously being the equivalent of Equation (1) under the assumed conditions.

However, for a practical embodiment of the relaying equipment in accordance with my invention, it is desirable to provide taps or other common adjustment features by which the weighting constants of each section of the network can be controlled so that the equipment can be of general application, being adjustable to obtain the relative weightings best suited for the particular alternating-current line or device to which it is applied. Any one, or a combination, of the weighting constants will, in general, be determined by the characteristics of the apparatus

being protected so as to render the equipment best suitable to the particular loads of the protected apparatus, the frequency of expectable fault types, the discriminating difficulties, the force coordination of the responsive devices, or other factors that are usually involved and considered.

The measuring circuit 62 can be utilized with any suitable apparatus. For example, the terminals 64 and 66 might be connected to a suitable relay for operating, in response to a predetermined value of the discriminating function, a tripping coil of a circuit breaker. In such a case, the system of Fig. 1 becomes an overcurrent protective device. Or the terminals 64 and 66 may be connected to suitable apparatus of a pilot wire system, a similar system being provided at the other end of the protected section, and in Fig. 2 I show a modified form of my invention in such a pilot wire protective system wherein the discriminating function is represented by

$$|E_m| = |k(I_1 + k' I_0)|$$

In Fig. 2 the protected line section, represented by A, has end terminals provided with protective equipment B and C, respectively, the protective equipment being joined by pilot wires 68 and 70. In the system shown in Fig. 2, the broken lines are inserted as indicative of extended lengths of wires.

Each of the terminal end protective equipment comprises a network for deriving only scalar quantities representative of the positive-sequence current-component and the zero-sequence current-component. This is done by providing each of the current protective equipments with an impedance Z and a resistance 20 connected as shown in Fig. 1 to yield a discriminating factor across the terminals 24' and 26' which is representative only of the positive sequence component, and a resistance R_0 in the neutral connection of the current transformers which will yield a discriminating factor across the terminals 52' and 54', representative solely of the zero-sequence component, in accordance with the principles outlined in Fig. 1.

The circulating-current protective system shown in Fig. 2 is one similar in its general aspects to that shown in Fig. 11 of my aforesaid patent, and comprises operating coils 72 across the respective measuring circuit terminals 64' and 66', and restraining coils 74 in series in the measuring circuit, a pair of coils 72 and 74 at each terminal operating upon a polarizing relay 76 which, in turn, controls a tripping coil 78 of a circuit breaker 80.

Since the discriminating functions at each of the terminals B and C of the protected section are unidirectional, insulating transformers cannot be used to isolate the terminal equipment from the pilot wires to protect this equipment from voltages-to-ground due to induced voltages in the pilot wires. However, by using several neutralizing transformers 82 at the ends of the pilot wires, and grounding capacitors 84 from each terminal end of each pilot wire to ground, as described in my aforesaid application, the induced voltages can be neutralized and rendered harmless.

Fig. 3 represents a system similar to Fig. 1, but which can be utilized for overcurrent protection of an electric device whose neutral is either ungrounded or not very well grounded so that the proportion of the discriminating factors due to the zero-sequence component flowing through the

different sections P and N will not appreciably affect the actual discriminating factors, and the totalized scalar discriminating function obtained from the series-connected pairs of terminals 24''—26'', 36''—38'', and 52''—54'' does not objectionably depart from its value as represented by Equation 1.

The system of Fig. 3 is also useful for protection where high relative zero-sequence weighting is desirable in systems which might, at times, have fault currents with relatively small zero-sequence components, making desirable an accentuated zero-sequence discriminating factor to take care of conditions of this kind.

In Fig. 3, it may be observed that the line currents I_a , I_b and I_c flow to the neutral point 86 which is connected by wires 88 and 90 to the neutral of the current transformers, a resistance 92 being inserted in series with these conductors for deriving a quantity representative of the zero-sequence current-component. In order to magnify the effect of this zero-sequence component the resistance 92 is made high so that the value of k_0 is high, and will, therefore, make the discriminating factor $k_0 I_0$ of a magnitude approaching or even exceeding the magnitude of the discriminating factors resulting from the positive- and negative-sequence components, although the actual value of the zero-sequence component itself might be considerably less than the expectable value of the other sequence-components. In this modification the outputs of the rectifiers are also serially connected and operate a relay 94 controlling the tripping circuit of a circuit breaker 96, when the discriminating function indicates an excess current in the main lines.

In the system of Fig. 1, the discriminating factors due to the different sequence-components are actually representative of these components whereas in Fig. 3, the discriminating factors across the pairs of terminals 24''—26'' and 36''—38'' are modified somewhat by the zero-sequence component flowing through the connected sections of the network, but the extent of the modifying is negligible in ungrounded systems or poorly grounded systems, or in systems where high relative zero-sequence weighting is to be used, for which this embodiment is useful.

As an example of the application of the fundamental Equation 1, by making k_1 and k_2 the same and k_0 five times either of these, the magnitudes of discriminating functions resulting from the 10 different types of expectable faults on a fairly well grounded three-phase line, will fall within a small range, and may be made to fall within a range of less than two to one between minimum and maximum magnitudes, even with maximum phase-angle displacements between the sequence current-components themselves. Consequently, a particular advantage of my system resides in this fact that the phase-angle between the sequence-components is not a factor in the discriminating function present in the measuring circuit since each component is first rectified so that only scalar values are added or combined. By the introduction of a factor due to the negative-sequence component, the percentage ratio W of the lowest fault-response as compared to the highest fault-response for any of the types of faults which might occur on a given line, can be made to approximate unity and kept even above 50 per cent for all conditions. The values of the different constants k_0 , k_1 and k_2 will depend on the characteristics of the protected device and by suitable adjustments in the phase-

sequence network sections, the constants may be varied to give the desired percentage ratio W.

In some systems where the scalar addition of the discriminating factors due to the positive-sequence current component and the zero-sequence current component is sufficient for protective purposes, the possibility of an excessively low discriminating function which might, for example, occur when the zero-sequence current-component has very large phase displacement as compared to the positive-sequence current-component, is eliminated.

In order to reduce the internal impedance of the different network sections from which the different discriminating factors are obtained, it may be desirable to have the primary windings of the impedances Z and Y of relatively large number of turns as compared to the secondary windings, and for the network section of the negative-sequence component the secondary winding 40 may be a small number of turns as compared to those of the primary windings 42 and 44, the value of the resistance 34 being correspondingly made smaller or a transformer interposed thereat for the purpose. If desired, in some embodiments smoothing filters including capacitors may also be connected across the output ends of some or all the rectifiers where slower relaying is involved, such capacitors further reducing the effects of phase-angle displacement between the different current-components.

Additionally, voltage limiters, such as shown in M. A. Bostwick Patent No. 2,183,537, issued December 19, 1939, and assigned to the Westinghouse Electric & Manufacturing Company, may be utilized, preferably across the alternating-current input terminals of the rectifiers, and so designed as to limit its voltage output only after the responsive relay setting has been exceeded by an adequate margin to secure the desired speed.

In the above description, it is understood that, in general, all alternating current electric quantities in the networks are vectors.

The systems just described have many features and advantages described in my aforesaid patent, and while I have illustrated my invention in a number of different forms, I desire it to be understood that such illustrations are not by way of limitations since it is obvious to those skilled in the art that many modifications of the precise details and networks may be adopted or equivalent substituted without departing from the teachings of my invention. Another embodiment of my invention, more especially for impedance relaying, is shown in my Patent No. 2,242,951 of May 20, 1941, for which a reissue patent application has been filed.

I claim as my invention:

1. A three-phase device having a three-phase line, a single set of current transformers for said line, networks connected to said transformers comprising a plurality of means including impedance devices and circuits having three distinct pairs of connections for obtaining, respectively, across said pairs of connections, unidirectional voltages individually representative of the positive-sequence, negative-sequence, and zero-sequence components of the line-currents, and means for algebraically adding the said obtained voltages for deriving a response to line-conditions, which response is a function of variables dependent solely on said obtained voltages.

2. A three-phase device having a three-phase line, current transformers for said line, networks

connected to said transformers comprising a plurality of means including impedance devices and circuits having three pairs of connections for obtaining, respectively, across each of said pairs of connections, a sequence-voltage representative of the positive-sequence, negative-sequence, and zero-sequence components of the line-currents, and utilization means including rectifiers for rectifying and serially combining said sequence-voltages.

3. Means for utilizing a single relay to respond to any one of a plurality of different kinds of faults in a three-phase electrical device to be protected, comprising the combination, with said relay, of selective phase-sequence filter means and circuit means to said relay for energizing said relay with a current corresponding, in a predetermined manner or manners, to the values of a combination of rectified, weighted sequence-components derived from the phase-currents in the protected device, said filter means including means for applying to said circuit means, in series, individual rectified voltages representative of the zero- and positive-sequence components of the phase-currents in said protected device.

4. Means for utilizing a single relay to respond to any one of a plurality of different kinds of faults in a three-phase electrical device to be protected, comprising the combination, with said relay, of selective phase-sequence filter means and circuit means to said relay for energizing said relay with a current corresponding, in a predetermined manner or manners, to the scalar values of a combination of rectified, weighted sequence-components derived from the phase-currents in the protected device, said filter means including means for applying to said circuit means, in series, individual rectified voltages representative of the zero-, negative-, and positive-sequence components of the phase-currents in said protected device, with the magnitude of said series combination of rectified voltages within a relatively narrow predetermined range for the different kinds of faults.

5. An electrical system responsive to the line-currents in a three-phase device, comprising a plurality of network means for obtaining electrical quantities k_0I_0 , k_1I_1 , and k_2I_2 , where I_0 , I_1 , and I_2 are the zero-, positive-, and negative-sequence components of the line-currents, and k_0 , k_1 , and k_2 are selected constants, and means including a utilization circuit, for rectifying said quantities to obtain scalar values of each, and algebraically adding, in a predetermined manner or manners, only the said scalar values to derive a resulting single unidirectional electrical quantity utilizable as a discriminating function in said utilization circuit.

6. A three-phase device having a three-phase line, network means for deriving individual single-phase electrical quantities representative, respectively, of a rotational- and a zero-sequence-component of the line-currents, said network means having a plurality of pairs of junctions, one for each of said sequence-components, rectifier means connected to said junctions to convert said individual single-phase electrical quantities to individual unidirectional electrical quantities, and a utilization circuit including the outputs of said rectifier means in series whereby said unidirectional quantities are algebraically added.

7. A three-phase device having a three-phase line, network means for deriving an individual electrical quantity k_0I_0 , an individual electrical quantity k_1I_1 , and an individual electrical quan-

tity k_2I_2 , where I_0 , I_1 and I_2 are representative of the zero-, positive-, and negative-sequence components of the line-currents, and k_0 , k_1 and k_2 are weighting constants, means for converting said quantities to scalar quantities, said means including a utilization circuit in which said scalar quantities are algebraically added to provide a single electrical quantity in said circuit represented by $|k_0I_0| + |k_1I_1| + |k_2I_2|$, the bars being indicative of scalar values, and fault-responsive means responding to the last said quantity.

8. A three-phase device having a three-phase line, network means for deriving an individual electrical quantity k_0I_0 and an individual electrical quantity k_1I_1 , where I_0 , and I_1 are representative of the zero-, and positive-sequence components of the line-currents, and k_0 , and k_1 are weighting constants, means for individually converting said quantities to scalar quantities, said means including a utilization circuit in which said scalar quantities are algebraically added to provide a single electrical quantity in said circuit represented by $|k_0I_0| + |k_1I_1|$, the bars being indicative of scalar values, and fault-responsive means responding to the last said quantity.

9. A differential-protective apparatus for an alternating-current electrical device having lines including a plurality of separated terminals where current may enter or may leave, comprising means at each of said terminals for deriving quantities including a plurality of unidirectional quantities, each of which is individually representative, in some manner or manners, of selected sequence-components of the line-currents at the corresponding terminal, said means including means for combining said derived quantities in a predetermined manner or manners, and comparing means including connections between said terminals, having the property of comparing the combined electrical quantities at each of said terminals for the detection of faulty conditions in said electrical device, the last said means including devices operable by said comparing means.

10. An electrical system responsive to the electrical quantities in a multi-phase device, comprising a plurality of means for obtaining electrical quantities k_0O , k_1P , and k_2N , where O , P , and N are the zero-, positive-, and negative-sequence components of the said electrical quantities, and k_0 , k_1 , k_2 are selected constants, and means including a utilization circuit, for rectifying said quantities to obtain scalar values of each, and algebraically additively combining all of said scalar values in a predetermined manner or manners to obtain a single unidirectional electrical quantity utilizable as a discriminating function in said utilization circuit.

11. A three-phase device having a three-phase line, means for deriving individual single-phase electrical quantities representative, respectively, of a rotational- and a zero-sequence-component of the electrical quantities, said means having a plurality of pairs of junctions, one for each of said sequence-components, rectifier means connected to said junctions to convert said individual single-phase electrical quantities to individual unidirectional electrical quantities, and a utilization circuit including the outputs of said rectifier means in series whereby said unidirectional quantities are algebraically added.

12. A three-phase device having a three-phase line, means for deriving an individual electrical quantity k_0O , an individual electrical quantity k_1P , and an individual electrical quantity k_2N ,

where O, P, and N are representative of the zero-, positive-, and negative-sequence components of the electrical quantities k_0 , k_1 and k_2 are weighting constants, means for converting said quantities to scalar quantities, said means including a utilization circuit in which said scalar quantities are algebraically added to provide a single electrical quantity in said circuit represented by $|k_0O|+|k_1P|+|k_2N|$, the bars being indicative of scalar values, and fault-responsive means responding to the last said quantity.

13. A three-phase device having a three-phase line, means for deriving an individual electrical quantity k_0 and an individual electrical quantity k_1P , where O, and P are representative of the zero-, and positive-sequence components of the electrical quantities, and k_0 , and k_1 are weighting constants, means for individually converting said quantities to scalar quantities, said means including a utilization circuit in which said scalar quantities are algebraically added to provide a single electrical quantity in said circuit represented by $|k_0O|+|k_1P|$, the bars being indicative of scalar values, and fault-responsive means responding to the last said quantity.

14. The combination, with a polyphase electrical apparatus, of a plurality of different means for producing a plurality of different single-phase relaying quantities responsive to different phase-sequence components of a predetermined electrical quantity of said polyphase electrical apparatus, at least one of said single-phase relaying quantities being selectively responsive substantially exclusively to a rotational phase-sequence quantity, and at least one other of said single-phase relaying quantities being responsive to a zero phase-sequence quantity, separate means for individually rectifying the several single-phase relaying quantities, and means for combining, only in series-circuit relation, said single-phase relaying quantities for obtaining a joint response dependent upon the rectified quantities.

15. The combination, with a polyphase electrical apparatus, of a plurality of different means for producing a plurality of different single-phase relaying quantities responsive to different phase-sequence components of a predetermined electrical quantity of said polyphase electrical apparatus, at least one of said single-phase relaying quantities being selectively responsive substantially exclusively to a rotational phase-sequence quantity, and at least one other of said single-phase relaying quantities being responsive to a zero phase-sequence quantity, separate means for individually rectifying the several single-phase relaying quantities, and means for combining, only in series-circuit relation, said single-phase relaying quantities for obtaining a joint response dependent upon the rectified quantities.

EDWIN L. HARDER.