July 24, 1934. R. WIDERÖE 1,967,850

ELECTRORESPONSIVE APPARATUS

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Fig. 1.

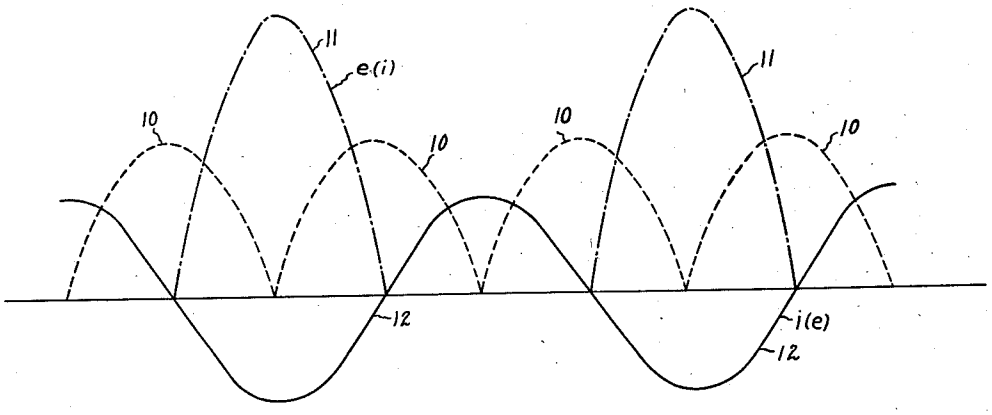


Fig. 2.

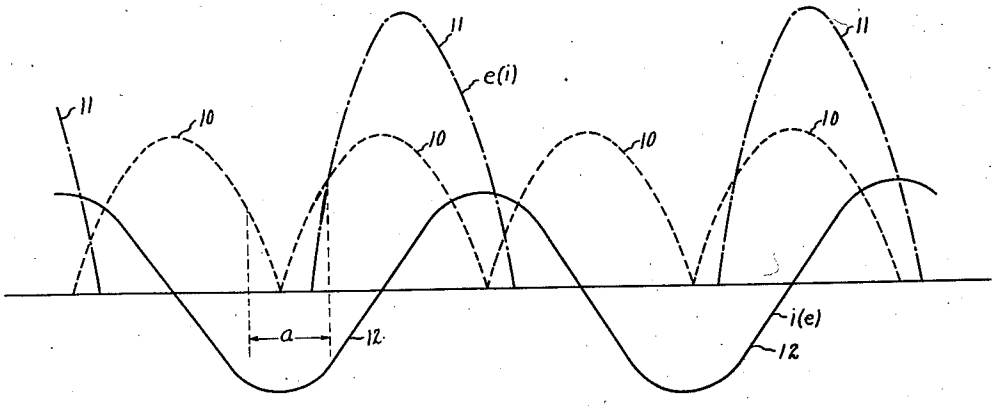
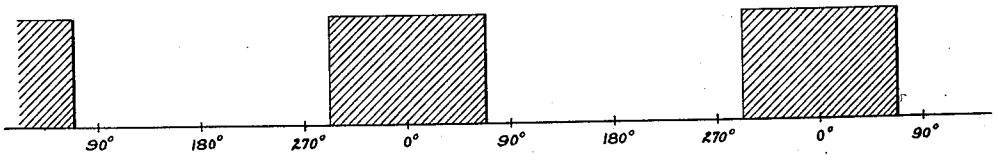


Fig. 3.



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Fig. 4.

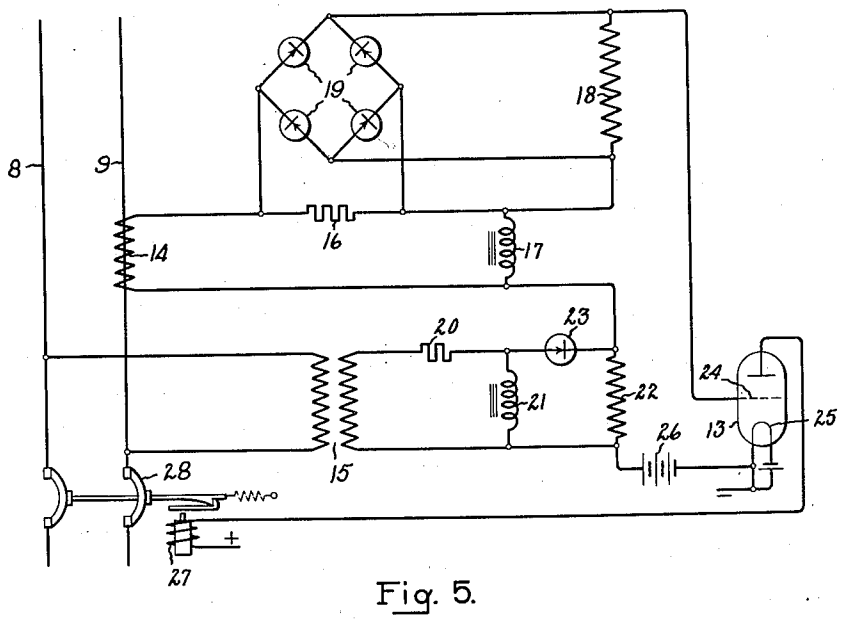


Fig. 5.

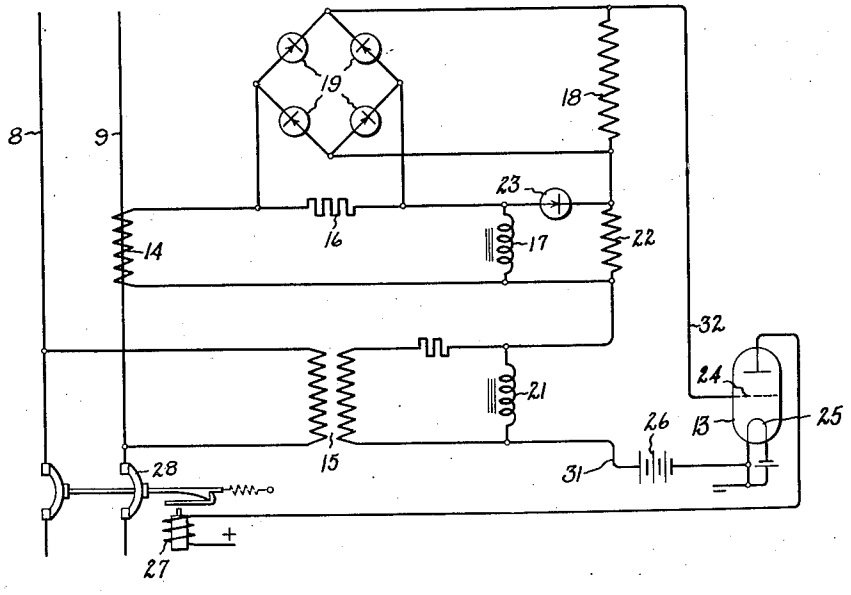
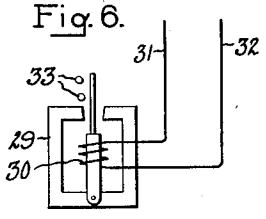


Fig. 6.



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UNITED STATES PATENT OFFICE

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ELECTRORESPONSIVE APPARATUS

Rolf Widerøe, Berlin-Karlshorst, Germany, assignor to General Electric Company, a corporation of New York

Application December 13, 1932, Serial No. 647,041
In Germany December 18, 1931

13 Claims. (Cl. 175—294)

My invention relates to improvements in electro-responsive apparatus and more particularly to improvements in apparatus whose operation is dependent on two coexisting alternating electric quantities, for example the voltage and the current of an alternating current electric circuit or voltages derived therefrom, whereby on the occurrence of a condition, such as a fault, producing a change in the normally existing relation between said quantities, to obtain an action dependent on such change.

The known directional relays dependent on current and voltage are similar to wattmeters in that the current and the voltage energize separate coils which are so arranged that a deflection in one direction or the other is produced in accordance with the relative directions of the current and the voltage. When such relays are to be sensitive, they require a relatively complicated mechanical construction. One object of my invention is to avoid this disadvantage of the known relays.

My invention will be better understood from the following description when considered in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the accompanying drawings, Figs. 1, 2, and 3 are diagrams explanatory of my invention; Fig. 4 illustrates diagrammatically an embodiment of my invention as applied to the protection of an electric circuit; Fig. 5 illustrates diagrammatically another embodiment of my invention and Fig. 6 illustrates diagrammatically a modification of a part of the embodiments of my invention shown in Figs. 4 and 5.

In accordance with my invention, I provide electroresponsive apparatus whose condition of equilibrium depends upon a plurality of voltages. Two of these voltages act in a restraining or holding sense. One of these two is proportional to the circuit current rectified in each half wave and the other is angularly displaced in normal operation by about 90° with respect to the first and is proportional to one-half wave of one of the two circuit quantities, current or voltage. A third voltage which acts in an operating or releasing sense is proportional to the other circuit quantity and is angularly displaced so that it normally acts in opposition to the first circuit quantity.

The operation of such an arrangement will be clear from the diagram of Fig. 1 which shows the voltages acting on the electroresponsive apparatus which may be termed a relay. The voltage proportional to the circuit current rectified in each half wave is represented by the dotted line curve 10. The voltage proportional to the circuit voltage and angularly displaced 90° with respect to the voltage represented by the curve 10 is represented by the dash and dot curve 11. The voltage proportional to the circuit current angularly so displaced that it normally acts in opposition to the first circuit value is represented by the full line curve 12. With conditions as illustrated in Fig. 1, the algebraic sum of the instantaneous values of all the voltages at any instant is such that a voltage tending to cause the operation of the electroresponsive device cannot occur. When the circuit voltage is phase displaced relatively to the circuit current so that the curve 11 takes a position, such as shown in Fig. 2, with respect to the curves 10 and 12, the voltage 12 acting in the operating or releasing sense becomes predominant in the vicinity of the transition of the curve 10 through zero. This resultant voltage thus causes the operation of the electroresponsive apparatus. Thus, the arrangement responds only at a definite phase relation between the two circuit quantities, current and voltage. The circuit quantities corresponding to the voltages may be interchanged so that the curve 11 represents a voltage dependent on the circuit current and the curve 12 a voltage dependent on the circuit voltage, as indicated by the letters in parentheses in Figs. 1 and 2.

By using different angular relations among the voltages derived from the circuit current and voltage, for example by shifting the curve 11 along the horizontal axis, it will be clear, as shown in Fig. 3, that the electroresponsive device is restrained or prevented from operating only within the shaded areas but is released or permitted to operate in all other areas. Thus by giving the various derived voltages suitable positions relatively to each other, it is possible to have the electroresponsive apparatus restrained when energy flows in one direction, for example, in a zone extending from about 270° through 0° to about 90° and to be released within the limits of the flow of energy in the other direction, that is within the zone extending from about 90° to 180° to 270°. These two zones do not, however, meet at exactly 90° or 270° because the holding zone is somewhat smaller than is equivalent to the positive direction of energy flow by reason of the fact that at the zero point the curve 10 rises gradually instead of suddenly. This provides the zone a, as shown in Fig. 2, within which the release is effected. If the releasing and holding zones are of exactly the same length, the release will take place only at the instant the

curve 10 is passing through zero. This zone *a* depends upon the steepness of the curve 10. If the releasing zone is to have an extent of 10°, then the slope of the curve 10 should be of the ratio 1:sin 10° or approximately 5.7. It will then be preferable to select the ratio of the amplitudes of the two curves such that it is greater than 1:6.

The algebraic sum of the instantaneous values of the voltages, shown in Figs. 1 and 2, may be applied either to the operating coil of a highly sensitive polarized relay or to the grid of a discharge valve 13, as shown in the embodiment of the invention illustrated in Fig. 4. A current transformer 14 and a potential transformer 15 are connected to the conductors 8 and 9 of an alternating current circuit shown single-phase for the sake of simplicity. On the secondary side the current transformer 14 is loaded with a resistance 16 and an iron core choke 17. The voltage across the resistance 16 is applied to an impedance 18 through a full-wave rectifier including the rectifying elements 19, suitable examples of which are well-known to the art. The voltage across the impedance 18 is indicated by the curve 10 of Figs. 1 and 2 and the voltage across the inductance device 17 is indicated by the curve 12 and is angularly displaced 90° relatively to the current. A resistance 20 and an inductance coil 21 are connected in the secondary circuit of the potential transformer 15. An impedance 22 is connected across the inductance 21 through a half wave rectifier 23. The voltage across the impedance 22 is indicated by the curve 11 of Figs. 1 and 2. All the voltages across the impedances 18, 17 and 22 are in series relation and are applied between the control electrode 24 and the cathode 25 of the discharge valve 13. A suitable voltage source, such as a battery 26, may be provided for establishing the desired voltage at which the valve 13 is to become conductive. The anode current of the valve may be applied directly or through amplifying means, examples of which are well-known to the art, to energize any suitable control or relay means, such for example as the trip coil 27 of a circuit breaker 28 arranged to control the circuit 8, 9. When the algebraic sum of the instantaneous values of the voltages across the impedance devices 18, 22 and 17 for the curves 10, 11 and 12, as shown in Figs. 1 and 2 reaches a value sufficient to impress on the control electrode 24 a voltage higher than the critical grid voltage of the valve, current flows in the anode circuit whereby to cause the operation of whatever device is connected therein.

In Fig. 5 the current and voltage values are interchanged in accordance with the symbols shown in parentheses in Figs. 1 and 2. For this purpose the rectifier 23 is connected across the choke coil 17 so that the voltage which is applied to this coil and which is proportional to the current is rectified but the voltage at the inductance coil 21 is applied directly to the control electrode as an alternating voltage. This arrangement is otherwise the same as that shown in Fig. 4. The arrangement shown in Fig. 5 may be used in cases in which faults produce relatively large decreases in current whereas the arrangement shown in Fig. 4 is used when, on the occurrence of faults, high voltage drops and large fault currents are expected.

In order to obtain as steep a slope as possible for the curve 10 corresponding to the voltage across the impedance 18 and thereby to decrease the zone *a* without having too high amplitudes of the voltage 12 across the impedance 21 of Fig. 5 or 17 of Fig. 4, it is preferable to have the resistance 16 a voltage dependent resistance, examples of which are well-known to the art, so that a flattening of the crest of the curve 10 is obtained.

Instead of using an electric discharge valve as illustrated in Figs. 4 and 5, I may employ a polarized relay 29 whose operating winding 30 is connected in circuit with the leads 31 and 32 coming from the impedance devices in series, as shown in Fig. 6. In this figure the arrangement for obtaining the different voltages is omitted since it will be obvious from the illustrations of Figs. 4 and 5. The contacts 33 of the relay may be arranged in the control circuit of a trip coil or used for any other purpose desired.

While I have shown and described my invention in considerable detail, I do not desire to be limited to the exact arrangements shown but seek to cover by the appended claims all those changes and modifications that fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. In combination with an alternating current electric circuit, means for deriving from two alternating electric quantities of the circuit a first voltage dependent on the circuit current rectified in each half wave, a second voltage dependent on one of said quantities rectified in one half wave and normally angularly displaced substantially 90° relatively to said first voltage and a third voltage dependent on the other of said quantities and electroresponsive means connected to be energized in accordance with the algebraic sum of the instantaneous values of said voltages.

2. In combination with an alternating current electric circuit, means for deriving from two alternating electric quantities of the circuit a first voltage dependent on the circuit current rectified in each half wave, a second voltage dependent on one of said quantities rectified in one half wave and normally angularly displaced substantially 90° relatively to said first voltage and a third voltage dependent on the other of said quantities and electroresponsive means connected to be controlled by two of said voltages acting in opposition to the remaining one of the voltages for effecting an operation of said electroresponsive means only when a predetermined relation exists between said quantities.

3. In combination with an alternating current electric circuit, electric discharge valve means and means for rendering said valve means conductive when a predetermined relation exists between two alternating electric quantities of the circuit including means for deriving from said quantities a first voltage dependent on the circuit current rectified in each half wave, a second voltage dependent on one of said quantities rectified in one half wave and normally angularly displaced substantially 90° relatively to said first voltage and a third voltage dependent on the other of said quantities.

4. In combination with an alternating current electric circuit, means responsive to the relative directions of the circuit current and voltage including means for deriving from the circuit a voltage dependent on the circuit current rectified in each half wave, a voltage dependent on the circuit voltage rectified in one half wave and normally angularly displaced substantially 90° relatively to said first voltage and a third voltage dependent on the circuit current and electroresponsive means connected to be energized in ac-

cordance with the algebraic sum of the instantaneous values of said voltages.

5. In combination with an alternating current electric circuit, means for deriving from two alternating electric quantities of the circuit a voltage dependent on the circuit current rectified in each half wave and a second voltage dependent on one of said quantities, electroresponsive means connected to be energized in accordance with said voltages and means for effecting an operation of said electroresponsive means only when a predetermined relation exists between said quantities.

6. In combination with an alternating current electric circuit, means for deriving from two alternating electric quantities of the circuit a first voltage dependent on the circuit current rectified in each half wave, a second voltage dependent on one of said quantities rectified in one half wave and normally angularly displaced substantially 90° relatively to said first voltage and a third voltage dependent on the other of said quantities, electroresponsive means connected to be controlled by two of said voltages acting in opposition to the remaining one of the voltages for effecting an operation of said electroresponsive means only when a predetermined relation exists between said quantities and means for flattening the crest of one of said opposition voltages.

7. In combination with an alternating current electric circuit, means for deriving from two alternating electric quantities of the circuit a voltage dependent on the circuit current rectified in each half wave and a second voltage dependent on one of said quantities, electroresponsive circuit controlling means connected to be energized in accordance with said voltages, means for effecting an operation of said electroresponsive means only when a predetermined relation exists between said quantities and means for flattening the crests of the waves of the voltage derived from the rectified current.

8. In combination with an alternating current electric circuit, means for deriving from the circuit a first voltage dependent on the circuit current rectified in each half wave, a second voltage dependent on the circuit voltage rectified in one half wave and a third voltage dependent on the circuit current and means connected to be controlled in dependence on the algebraic sum of said voltages.

9. In combination with an alternating current electric circuit, means for deriving from the circuit a first voltage dependent on the circuit current rectified in each half wave, a second voltage dependent on the circuit current rectified in one half wave and a third voltage dependent on the circuit voltage and means connected to be controlled in dependence on the algebraic sum of said voltages.

10. In combination with an alternating current electric circuit, means for deriving from an alternating electric quantity of the circuit a voltage rectified in each half wave and an alternating voltage, means for obtaining a third voltage and means connected to be controlled in dependence on the algebraic sum of said voltages.

11. In combination with an alternating current electric circuit, means for deriving from an alternating electric quantity of the circuit a voltage rectified in each half wave, means for deriving an alternating voltage dependent on an alternating electric quantity of the circuit, means for obtaining a third voltage and means connected to be controlled in dependence on the algebraic sum of said voltages.

12. In combination with an alternating current electric circuit, means for deriving from an alternating electric quantity of said circuit a voltage rectified in each half wave, means for deriving a second voltage dependent on an alternating electric quantity of the circuit and means connected to be controlled in dependence on the algebraic sum of said voltages.

13. In combination with an alternating current electric circuit, means for deriving from two alternating electric quantities of said circuit varying relatively to each other a voltage rectified in each half wave of one of said quantities, a second voltage rectified in one half wave of one of said quantities and an alternating voltage dependent on one of said quantities and means responsive to a predetermined relation of said quantities including means connected to be operated in accordance with the algebraic sum of the instantaneous values of said voltages.

ROLF WIDERÖE.