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DIRECTIONAL AND OVERCURRENT ELECTRICAL RELAY

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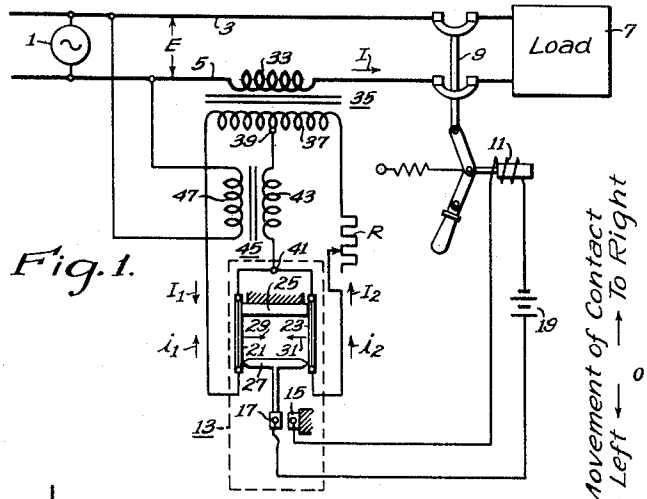


Fig. 1.

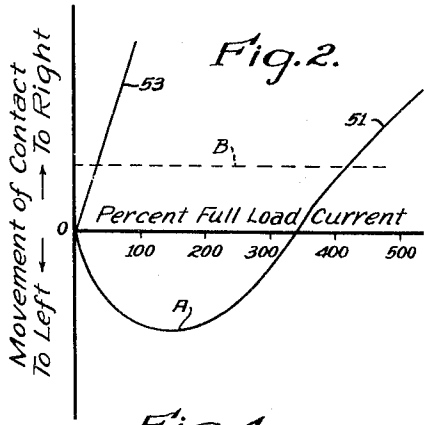


Fig. 2.

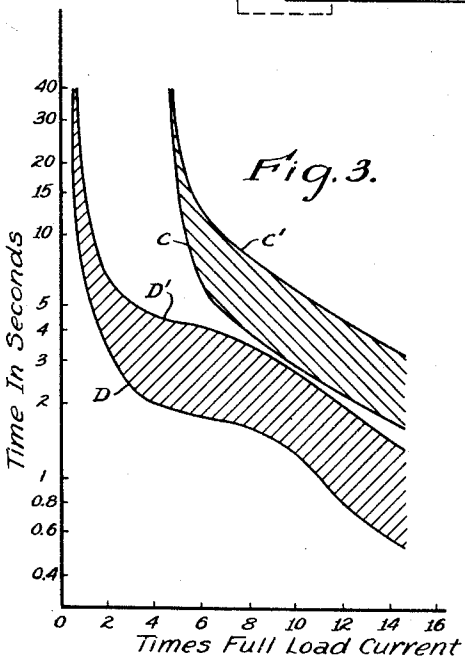


Fig. 3.

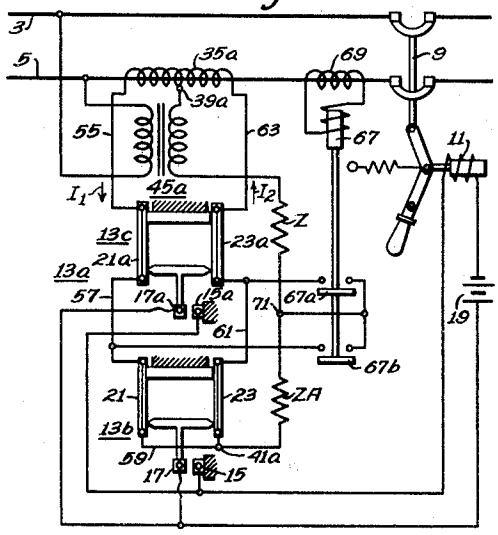


Fig. 4.

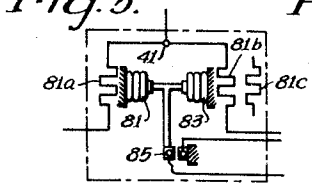


Fig. 5.

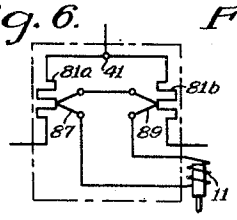


Fig. 6.

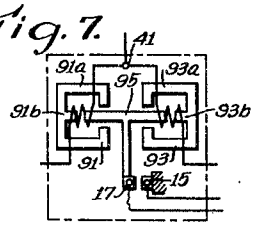


Fig. 7.

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DIRECTIONAL AND OVERCURRENT ELECTRICAL RELAY

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This invention relates to electrical devices which are responsive to a function of voltage and current, and it has particular relation to directional relays which have a response designed to compensate for a drop in the voltage applied thereto. The invention further relates to relays having both directional and overload characteristics.

In Patent 2,323,776, F. D. Johnson discloses a directional relay comprising two electroresponsive units each having an output or a response varying in accordance with the square of the energization thereof. These units are differentially associated to provide a resultant output having a watt or directional characteristic. The units are energized respectively in accordance with the sum and difference of voltage and current in an electrical system with which the relay is associated.

If the voltage applied to the Johnson relay drops excessively, the relay theoretically operates properly in response to severe fault currents. However, if the two units differ slightly in their characteristics, the differential effect resulting from heavy currents flowing therethrough, under fault conditions, may prevent proper operation of the relay. Since the voltage of the system may drop appreciably under severe faults, the watt response of the relay may be less than the response of the relay due to the structural differences in the units.

In such cases, improper operation may be avoided by utilization of a voltage regulator through which the Johnson relay is energized from the system. With such a regulator, a drop in voltage of the system under severe fault conditions does not result in an appreciable drop in the voltage applied to the relay.

In accordance with the invention, an electrical device, such as a relay, is provided which is based on the relay described in the aforesaid Johnson patent. However, the relay is so designed that energizations derived from the current flowing in an electrical system, with which the relay is associated, provides compensation for the drop in voltage of the system under severe fault conditions. To this end, the two arms of the relay which contain the electroresponsive units are energized differently by the currents of the electrical system with which the relay is associated. In a preferred embodiment of the invention, the two arms have different impedances; and, consequently, different currents flow therethrough in response to energization of the arms in accordance with current from

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the associated electrical system. A relay designed in accordance with the invention may respond to small or large reversals in the direction of power flow, and in addition thereto, may respond to excessive current flow in the associated system in a forward direction.

It is, therefore, an object of the invention to provide an improved electroresponsive device which is responsive to a function of the voltage and current of an electrical system.

It is a further object of the invention to provide a directional electroresponsive device having an overload response.

It is also an object of the invention to provide two opposed electroresponsive elements which are energized respectively in accordance with the sum and difference of voltage and current of an associated electrical system, and wherein the energizations of the elements due to the current of the associated electrical system are dissimilar.

It is a still further object of the invention to provide a pair of differentially associated thermo-responsive units which have responses proportional to the square of their energizations and which are energized respectively in accordance with the sum and difference of voltage and current of an associated electrical system, the energizations of the units due to the current of the associated electrical system being dissimilar.

Other objects of the invention will be apparent from the following description, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a schematic view of an electrical system having a relay associated therewith which embodies the invention;

Fig. 2 is a graphical representation of the characteristics of the relay illustrated in Fig. 1;

Fig. 3 is a graphical representation showing further characteristics of the relay illustrated in Fig. 1;

Fig. 4 is a schematic view of an electrical system having a further embodiment of a relay associated therewith which embodies the invention; and

Figs. 5, 6 and 7 are schematic views showing various embodiments of relay units suitable for association with the systems illustrated in Figs. 1 and 4.

Referring to the drawing, Figure 1 shows an electrical system which includes a source 1 of alternating electrical energy. This source may be a polyphase or single-phase source of energy; but, for the purpose of discussion, it will be as-

sumed to be a single-phase source, operating at a frequency of sixty cycles per second. This source is connected through conductors 3 and 5 to a suitable load 7. It will be assumed that the load 7 is capable of returning electrical energy to the source 1 under certain conditions, and that such return of energy is objectionable. A circuit interrupter 9 is provided for controlling the connection of the load 7 to the source 1. The circuit interrupter 9 has a tripping solenoid 11 associated therewith.

In order to control the tripping of the circuit interrupter 9, an electroresponsive control device 13 is provided which may take the form of an electrical relay having a fixed contact 15 and a movable contact 17 which is movable into and out of engagement with the fixed contact 15. These contacts control the connection of the tripping solenoid 11 across a battery 19, or other suitable source of electrical energy.

The movement of the movable contact 17 is controlled by two electroresponsive elements or units 21 and 23. Each of these units has a response proportional to the square of the energization thereof. In Fig. 1, the units 21 and 23 take the form of bimetallic elements each having one end secured to a fixed supporting structure 25. The remaining ends of the bimetallic elements engage a strut 27 which is secured to the movable contact 17. The strut 27 may have a pivotal engagement with the associated bimetallic elements for the purpose of permitting flexure of the elements. The bimetallic element 21 is disposed in response to heating thereof to urge the strut 27 and the contact 17 in the direction of the arrow 29, or to the right, as viewed in Fig. 1, into engagement with the fixed contact 15. The bimetallic element 23 is disposed, in response to heating thereof, to urge the strut 27 and the movable contact 17 in the direction of the arrow 31, or to the left, as viewed in Fig. 1, for the purpose of interrupting or preventing engagement of the contacts 15 and 17.

Suitable connections are provided for energizing the bimetallic elements 21 and 23 from the associated electrical system respectively in accordance with the vectorial difference and sum of voltage E and current I of the electrical system, when power flows from the electrical source 1 toward the load 7. The connections also assure energization of the bimetallic elements 21 and 23 respectively in accordance with the sum of the voltage and current (E+I) of the associated electrical system and the difference of the voltage and current (E—I) of the associated electrical system, when power flows from the load 7 toward the source 1. To this end, a separate voltage transformer and a separate current transformer may be provided for each of the bimetallic elements. However, it is desirable, for most applications, to employ a single voltage transformer and a single current transformer, as shown in Fig. 1.

It should be understood that the aforesaid sum and difference may have other bases. For example, if k is a constant, one element may be energized in accordance with the sum quantity $(E+kI)$ and the other element in accordance with the difference quantity $[E-(1+k)I]$. The elements may be designed to produce equal and opposite forces at predetermined energizations. For present purposes, it will be assumed that the elements are similar.

By reference to Fig. 1, it will be observed that the conductor 5 has the primary winding 33 of a current transformer 35 included in circuit therewith. The bimetallic elements 21 and 23 are connected in series across the secondary winding 37 of the current transformer. It will be noted that the secondary winding 37 is provided with a tap 39 which is disposed between the terminals of the secondary winding. In addition, a terminal 41 is provided between the directly connected ends of the bimetallic elements 21 and 23. The tap and the terminal are connected by the secondary winding 43 of a voltage transformer 45, the primary winding 47 of the voltage transformer being connected across the conductors 3 and 5.

Instantaneous directions of current flow are indicated in Fig. 1 by arrows. It will be noted that the current transformer 35 directs currents I_1 and I_2 respectively through the bimetallic elements 21 and 23; whereas, the voltage transformer 47 directs currents i_1 and i_2 through the bimetallic elements 21 and 23. It might be said that the bimetallic elements in effect are in series across the terminals of the secondary winding of the current transformer 35 and are connected in parallel paths across the secondary winding of the voltage transformer 45. However, it should be noted that with respect to the voltage transformer the secondary winding of the current transformer operates as an auto-transformer to enforce substantially equal division of current from the voltage transformer through the aforesaid parallel paths despite difference between the resistanecs of the paths. As shown by the arrows, when power flows from the source 1 to the load 7, the current components I_1 and i_1 subtract vertorially in the bimetallic element 21, and the current components I_2 and i_2 add vectorially in the bimetallic element 23. Should the direction of power flow in the electrical system of Fig. 1 reverse, the direction of flow of the current components I_1 and I_2 also reverses, the components I_1 and i_1 add vectorially in the bimetallic element 21, and the current components I_2 and i_2 subtract vectorially in the bimetallic element 23. It will be understood that the current components I_1 and I_2 vary in accordance with current flowing in the associated electrical system; whereas, the current components i_1 and i_2 vary in accordance with the voltage of the associated electrical system.

As thus far specifically described, the electroresponsive control device of Fig. 1 is similar to devices illustrated and described in the aforesaid Johnson patent. From a consideration of the Johnson patent, it will be understood that the electroresponsive control device 13 exhibits a directional or watt response and operates to trip the circuit interrupter 9 when the power flow in the electrical system is from the load 7 toward the source 1.

In accordance with the teachings of the Johnson patent, the currents I_1 and I_2 would be equal, and the components i_1 and i_2 would be equal. If a severe fault occurs on the system, the voltage E may drop to an abnormally low value, and the current components i_1 and i_2 consequently would drop to extremely low values. Under these conditions, the current components I_1 and I_2 would rise to abnormally high values. If the bimetallic elements 21 and 23 and their associated components are exactly similar, the relay ordinarily, under such conditions, would operate satisfactorily. However, if slight irregularities are present in the bimetallic elements or their associated components, the current components I_1 and

I_2 alone, in passing through the bimetallic elements, may produce a resultant force acting on the movable contact **17** which is greater than the watt responsive force developed by the relay. Under such circumstances, several relays may not operate uniformly with respect to reversals in the direction of power flow.

In accordance with the invention, the current components I_1 and I_2 are made unequal. This may be effected by displacing the tap **39** from a midposition between the terminals of the secondary winding **37**. Such movement of the tap would result in an unbalance of the components i_1 and i_2, and may result in a no-load force acting on the movable contact **17**. Although the force could be compensated in any suitable way, as by a spring, the desired inequality of the components I_1 and I_2 preferably is obtained by including impedance in the path associated with one of the bimetallic elements. The impedance employed may have a power factor selected to maintain the desired phase relationship between the current components I_2 and i_2. In most cases, the impedance may take the form of the resistor R which is illustrated in Fig. 1 as included in the electrical path associated with the bimetallic element **23**.

The current transformer **35** tends to maintain equal voltages across the two halves of its secondary winding. Consequently, the effect of the resistor R is to reduce the current component I_2 to a value below that of the current component I_1. Despite the presence of the resistor R, the auto-transformer action of the current transformer secondary winding tends to maintain the current components i_1 and i_2 substantially equal.

The effect of the resistor R may be understood from a consideration of the resultant force developed by the bimetallic elements **21** and **23**. It can be shown that the total or resultant force F_T is represented by the following expression:

$$F_T \alpha (I_1^2 - I_2^2) + (i_1^2 - i_2^2) - (2I_1 i_1 \cos\theta + 2I_2 i_2 \cos\theta)$$

In the foregoing expression, the angle θ represents the phase displacement between the voltage and current of the associated electrical system. From a consideration of the expression, it will be observed that the relay has a watt response which, for forward power, urges the movable contacts **17** toward the left, as viewed in Fig. 1. This watt component or force F_W is represented by the following expression:

$$F_W \alpha - (I_1 i_1 \cos\theta + I_2 i_2 \cos\theta)$$

The force component F_W is directed toward the left, as represented by the arrow **31** in Fig 1, when power flows from the source **1** toward the load **7** and is directed toward the right, as shown by the arrow **29** in Fig. 1, when power flows from the load **7** toward the source **1**.

The relay also has a force component F_I which is indicated by the following expression:

$$F_I \alpha (I_1^2 - I_2^2)$$

Since I_1 is always larger than I_2, the force F_I is always directed toward the right or in the direction of the arrow **29** of Fig. 1.

Finally, the resultant force of the relay includes a component F_i which is represented as follows:

$$F_i \alpha (i_1^2 - i_2^2)$$

This force also is always directed toward the right as viewed in Fig. 1. As pointed out above, the components i_1 and i_2 are held substantially equal by the autotransformer action of the current transformer. A slight difference may be present because of the exciting current required for the autotransformer action, but the force component F_i ordinarily is so small compared to the force component F_I, that the force component F_i may be neglected. Although the force component F_i has a negligible value, it is mentioned in the following discussion for completeness.

Further understanding of the operation of the relay of Fig. 1 may be obtained by reference to Fig. 2, wherein abscissae represent per cent of full load current and ordinates represent movement of the movable contact **17**. Movement of the contact **17** toward the contact **15** is represented in Fig. 2 as "movement of contact to right"; whereas, movement of the movable contact **17** away from the fixed contact **15** is indicated in Fig. 2 as "movement of contact to left."

Response of the relay **13** to power flowing from the source **1** to the load **7** is illustrated in Fig. 2 by a curve **51**. It will be noted that, for low values of current flowing from the source to the load, the largest force applied to the movable contact **17** is that due to the force component F_W, and this urges the movable contact **17** away from the fixed contact. At some point A, the curve **51** has zero slope and this indicates that the sum of the force components F_I and F_i has reached equality with the force component F_W. As the current flowing to the load continues to increase, the sum of the force components $F_I + F_i$ exceeds the value of the force component F_W, and the movable contact **17** consequently moves toward the fixed contact **15**. The horizontal axis in Fig. 2 represents a neutral position of the movable contact **17** which is the position illustrated in Fig. 1. The position of the movable contact **17**, when it is in engagement with the fixed contact **15**, is represented in Fig. 2 by a dotted line B. It will be noted that, as the current supplied by the source **1** to the load **7** increases, the curve **51** finally reaches the dotted line B which indicates that the contacts **15** and **17** engage to trip the circuit interrupter **9**. Consequently, the relay operates substantially as an overload-current relay. The intersection of the curve **51** with the line B may take place at a desired value of full load current such as 4.3 times full load current.

Upon reversal of the flow of power, the load **7** supplies current to the source **1**. Such reversal changes the sign or direction of the force component F_W and the total force acting on the contact **17** is the sum of the components $F_I + F_i + F_W$. Under these conditions, the movement of the movable contact **17** is represented, in Fig. 2, by a curve **53**. It will be observed that the utilization of the resistor R does not appreciably alter the shape of the curve **53**. The intersection of the curve **53** with the line B indicates the lowest value of current at which the contacts **15** and **17** engage to trip the circuit interrupter **9**.

The force component F_W is dependent to some extent on the power factor at which the electrical system operates; whereas, the force components F_I and F_i are substantially independent of power factor. If the curve **51** of Fig. 2 represents unity power factor operation of the electrical system, changes in power factor may result in a change in shape of the curve, but the general principles are unchanged and the exact curve can be computed for any desired power factors.

Increase in the resistance value of the re-

sistor R tends to decrease the minimum overload current at which the relay trips the circuit interupter 9 while the source 1 is supplying power to the load 7. Such an increase in resistance results in an increase in the difference between the currents I_1 and I_2 and consequently in the value of the force component F_1. Although the resistor R may be fixed in value in accordance with any desired operating condition, the relay conveniently may be provided with an adjustable resistor to permit adjustment of the performance of the relay.

Since the relay is designed to handle appreciable fault currents, it may be desirable to incorporate some protection for the bimetallic elements. Such protection may be provided by designing the current transformer 35 of Fig. 1 to saturate at a desired value of fault current, or by providing an overcurrent relay for shunting the bimetallic elements 21 and 23. Protection for the relay will be discussed further below.

In Fig. 3, the inverse time charactistics of the relay of Fig. 1 are illustrated. Abscissae represent the current I; whereas, ordinates represent the time in seconds required for the relay to close its contacts 15 and 17.

Curves C and C' show the forward tripping characteristics of the relay. The curve C represents the time required for the relay to close its contacts when the relay starts from a deenergized or no-load condition. A curve C' illustrates the time required for the relay to close its contacts when the relay starts from a full load energized condition. Both of these curves, C and C', are for a forward flow of power from the source 1 to the load 7. If some current intermediate no-load and full-load currents is flowing at the time an excessive current is applied to the load, the resulting curve will be disposed in a shaded area between the two curves C and C'. Since such curves correspond quite closely to the heating characteristics of electrical equipment, they are quite satisfactory for relay operation.

Curve D represents the time required for the relay to close its contacts when the direction of power flow is from the load 7 to the source 1. Curve D represents the relay performance when the relay starts from a deenergized or no-load condition. A curve D' represents the performance of the relay when the relay starts from a normal full-load energization. When the relay starts from intermediate energizations, the corresponding curves fall in a shaded area between the two curves D and D'. The differences between the curves D and D' and between the curves C and C' are due to the thermal lag of the relay. Such differences may be reduced by reducing the thermal lag of the relay.

If desired, the relay may be biased in a desired direction in any suitable manner. For example, load current may be passed through a heater adjacent one of the bimetalic elements for the purpose of biasing this element in accordance with load current. This will be discussed further below.

In order to decrease the spread between the no-load and full-load curves C and C' or D and D', the relay may be designed to permit a slow transfer of heat between the bimetals. This tends to maintain the relay adjacent its neutral position and the relay responds properly to sudden faults. This modification may not be satisfactory for systems wherein fault or overload currents may increase slowly.

In Fig. 4, an electroresponsive control device 13a is associated with the electrical system which again is represented by the conductors 3 and 5. The circuit interrupter 9 and the tripping solenoid 11, together with the battery 19, also are illustrated in Fig. 4. The control device 13a includes, in effect, two relays 13b and 13c. The relay 13b is similar to the corresponding relay of Fig. 1 and includes the bimetallic elements 21 and 23 together with the associated contacts 15 and 17 which are employed for controlling the tripping of the circuit interrupter 9. The relay 13c is similar to the relay 13b, but includes bimetallic elements 21a and 23a which are responsive to values of current larger than those which may be applied safely to the bimetallic elements 21 and 23. The elements 21, 23, 21a and 23a all are connected in series across the secondary terminals of a current transformer 35a which corresponds to the current transformer 35 of Fig. 1. The resulting series circuit may be traced from one terminal of the secondary winding through a conductor 55, the bimetallic element 21a, a conductor 57, the bimetallic element 21, a conductor 59, the bimetallic element 23, a conductor 61, the bimetallic element 23a and a conductor 63 to the remaining terminal of the secondary winding of the current transformer.

In addition, the bimetallic elements are connected in two parallel arms across the secondary winding of a voltage transformer 45a which corresponds to the voltage transformer 45 of Fig. 1. The parallel arms are located between a tap 39a on the secondary winding of the current transformer 35a and a terminal 41a which is connected to the conductor 59. It will be observed that the secondary winding of the voltage transformer 45a has one terminal connected to the tap 39a; whereas, the remaining terminal is connected to the terminal 41a through impedances Z and ZA. By studying Fig. 4, it will be observed that each of the relays 13b and 13c is energized in substantially the same manner discussed with reference to Fig. 1. In order to unbalance the two parallel arms connected between the tap 39a and the terminal 41a, the conductor 63 may have a resistance higher than that of the conductor 55, but it will be assumed that the tap 39a is displaced from the midpoint of the secondary winding of the current transformer. It will be assumed further that the direction of displacement is such that the current I_1 flowing through the bimetallic elements 21a and 21 is greater in magnitude than the current I_2 flowing through the bimetallic elements 23 and 23a. It will be understood that the relay 13b is substantially more sensitive than the relay 13c and may be designed to trip, for example, for a range of load currents up to three times full load. For values of load currents above that for which the relay 13b is designed, shunts are established around the bimetallic elements 21 and 23 by operation of an overcurrent relay 67. The relay 13c thereupon operates over a further overcurrent range which may be, for example, of the order of three to ten times full load current.

The overcurrent relay 67 has an operating winding connected for energization from the secondary winding of a current transformer 69 which is associated with the conductor 5. The relay 67 is designed to pick up and close its contacts 67a and 67b when the current flowing through the conductor 5 is above a desired value, such as three times full load current. Closure of the contacts of the relay 67 shunts the bi-

metallic elements 21 and 23 and only the relay 13c remains energized for further operation. It will be noted that closure of the contacts of relay 67 in effect connects the conductors 57 and 61 to a terminal 71 intermediate the two impedances Z and ZA. This removes the impedance ZA from service and results in an increase in the current supplied to the bimetallic elements 21a and 13a by the voltage transformer 45a. Consequently, operation of the relay 67 tends to compensate, to some extent, for the fall in voltage across the conductors 3 and 5 which results from the flow of excessive current therethrough. Removal of the impedance ZA from service may affect the values of the current components I_1 and I_2 somewhat. The impedances Z and ZA may be of any desired type and may have values selected to provide the desired compensation.

In Figs. 1 and 4, bimetallic elements are shown which are energized or heated by current flowing directly therethrough. If desired, external heaters may be employed, or other electroresponsive units may be employed which have outputs responsive to the squares of their energizations, as discussed in some detail in the aforesaid Johnson patent. For example, in Fig. 5, thermally responsive metallic bellows 81 and 83 each have an end connected to a movable contact 85. The metallic bellows are heated respectively by resistors 81a and 81b. Each of the heating resistors has an end connected to the terminal 41. Consequently, the terminal 41 of Fig. 5 may be connected to the tap 39 through the secondary winding 43 of Fig. 1, and the remaining ends of the resistors 81a and 81b may be connected to the terminals of the secondary winding 37 of Fig. 1 with the resistor R disposed in one of the connections in the manner discussed with reference to Fig. 1. Since the operation of the device shown in Fig. 5 otherwise is similar to that of the device of Fig. 1, and will be understood by reference to the Johnson patent, further discussion thereof is believed to be unnecessary. Thermally responsive metallic bellows are disclosed in Fig. 3 of the Johnson patent. In order to bias the control devices of Fig. 5, an auxiliary heating resistor 81c is provided adjacent the bellows 83. As previously pointed out, this resistor 81c may be energized in accordance with the load current of an associated electrical system, or in any suitable manner, for the purpose of biasing the bellows 83.

If desired, the metallic bellows of Fig. 5, may be replaced by thermocouples 87 and 89 which are differentially connected in series to the solenoid 11. These thermocouples are disposed to be heated respectively by the resistors 81a and 81b. Although no battery need be employed with the thermocouples, it may be desirable to amplify the output of the thermocouples prior to the application thereof to the solenoid 11. Since the modification of Fig. 6 otherwise is similar to that discussed for Fig. 5, and since the operation of the thermocouples is described with reference to Fig. 4 of the aforesaid Johnson patent, further discussion of Fig. 6 is believed to be unnecessary.

In Fig. 7, magnetic devices 91 and 93 are provided in place of the bimetallic elements 21 and 23 of Fig. 1. Each of the magnetic devices includes an E-shaped magnetic structure 91a or 93a which has associated therewith a common magnetic armature 95. This armature carries the movable contact 17 for movement into and out of engagement with the contact 15 in the manner discussed with reference to Fig. 1. Each of the magnetic devices 91 and 93 has a coil 91b and 93b associated therewith for the purpose, when energized, or urging the magnetic armature 95 toward the associated magnetic structure. Since the device of Fig. 7 otherwise operates in a manner similar to that discussed for Fig. 1, and since magnetic devices of this type are discussed in the aforesaid Johnson patent, it is believed that the foregoing description thereof suffices.

Although the invention has been discussed with reference to certain embodiments thereof, numerous modifications are possible. Therefore, the appended claims have been drafted to cover all such additional modifications which fall within the spirit and scope of the invention

We claim as our invention:

1. In an electroresponsive control device, a first electroresponsive unit having an output proportional substantially to the square of the input to the unit, a second electroresponsive unit having an output proportional substantially to the square of the input to the last-named unit, an element differentially connecting the outputs of the electroresponsive units to produce a resultant output substantially equal to the difference between the outputs of said electroresponsive units, and a circuit electrically connecting said units for first energizations in accordance with a first alternating quantity, said units and the circuit having impedances selected to provide a ratio of said energizations other than unity, and circuit elements electrically associated with said circuit for vectorially adding to the first energization of the first electroresponsive unit, a second energization proportional to a second alternating quantity and for vectorially subtracting from the second electroresponsive unit a second energization proportional to the second alternating quantity.

2. In a control device which is responsive to a function of voltage quantity and a current quantity in an alternating electrical circuit, a pair of electroresponsive units responsive to electrical current supplied thereto, electrical circuit elements connecting said electroresponsive units for energizations respectively in accordance with the vector sum and the vector difference of said quantities, the impedances of said units and the circuit elements being selected to provide a ratio of the portions of said energizations which are dependent on a first one of said quantities differing substantially from unity, and translating means differentially responsive to the outputs of the electroresponsive units.

3. In an electroresponsive control device, a pair of electroresponsive units each having a response dependent on the square of electrical current supplied thereto, a circuit connecting said electroresponsive units in parallel for energization from a first source of electrical energy and in series for energization from a second source of electrical energy, the parallel arms of said circuit having different impedances, and translating means differentially responsive to the outputs of said electroresponsive units.

4. In an electroresponsive control device, a transformer having a primary winding and having a secondary winding provided with a tap intermediate the terminals of the secondary winding, a pair of electroresponsive units connected in a series circuit across said secondary winding, each of said electroresponsive units having an output dependent on the square of the energization thereof, said series circuit having a terminal

intermediate the electroresponsive units, whereby the tap and the terminal constitute terminals of a parallel circuit having two arms each containing a separate one of the electroresponsive units, and translating means responsive differentially to the outputs of the electroresponsive units, said arms having different electrical impedances.

5. A device as defined in claim 1 wherein when said alternating quantities correspond to the voltage and current of an alternating current circuit the resultant output has a directional characteristic, said ratio being selected to provide a resultant output having a first directivity for a flow of power in the alternating current circuit in a first direction and for a flow of power above a predetermined value in the alternating current circuit in a second direction, the resultant output for the selected ratio having a second directivity for a flow of power below said predetermined value in the alternating current circuit in the second direction.

6. In an electroresponsive control device, a first electromotive unit having an output proportional substantially to the square of the input to the unit, a second electromotive unit having an output proportional substantially to the square of the input to the last-named unit, an element differentially connecting the outputs of the electromotive units to produce a resultant movement substantially proportional to the difference between the outputs of said electromotive units, and a circuit electrically connecting said units for first energizations in accordance with a first alternating quantity, the units and the circuit having impedances selected to provide a ratio of said energizations other than unity, and circuit elements electrically associated with said circuit for vectorially adding to the fiist energization of the first electroresponsive unit a second energization proportional to a second alternating quantity and for vectorially subtracting from the second electroresponsive unit a second energization proportional to the second alternating quantity, and an electrical switch operable in response to the resultant movement of said electromotive units in a predetermined direction

7. In an electrical relay system, a pair of operating units each having an output proportional to the square of the energization thereof, a pair of electrical relay contacts differentially responsive to the outputs of said operating units, a pair of conductors for carrying an alternating current when an alternating voltage is established thereacross, and means for energizing a first one of the operating units substantially in accordance with the vector sum of the voltage and the current of said conductors and for energizing a second one of the operating units substantially in accordance with the vector difference between the current and the voltage of said conductors, the operating units and the energizing means being proportioned to provide a ratio of the components of said energizations due to the current flowing in said conductors other than unity.

8. A device as claimed in claim 3 wherein said parallel arms have similar components and wherein one of said arms includes in addition to said components a resistor for producing said different impedances.

9. In an electroresponsive control device, a transformer having a primary winding and having a secondary winding provided with a tap intermediate the end turns of the secondary winding, a pair of electroresponsive units connected in a series circuit across said secondary winding, each of said electroresponsive units having an output dependent on the square of the energization thereof, said series circuit having a terminal intermediate the electroresponsive units, whereby the tap and the terminal constitute terminals of a parallel circuit having two arms each containing a separate one of the electroresponsive units, and translating means responsive differentially to the outputs of the electroresponsive units, said tap being substantially displaced from the electrical center of said secondary winding, and from the end turns of the secondary winding.

10. In a relay system for an alternating electrical circuit, a relay unit having a directional element to be actuated in a first direction in response to a first course of alternating power flowing in the circuit and in a second direction in response to a reverse course of alternating power flowing in the circuit, said relay unit having voltage input means and current input means connected for energization in accordance with the alternating voltage and the alternating current respectively of the circuit, and modifying means for modifying said input means to actuate the directional element in a first direction in response to the first course of power flow in the alternating electrical circuit, said modifying means modifying the input means to actuate the directional element in a second direction in response to power flow in the alternating electrical circuit in the reverse course within a predetermined range, and said modifying means modifying the input means to actuate the directional means in the first direction in response to a power flow in the alternating electrical circuit in the reverse course outside of said predetermined range.

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