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2,605,325

BRIDGE-CONNECTED RELAY

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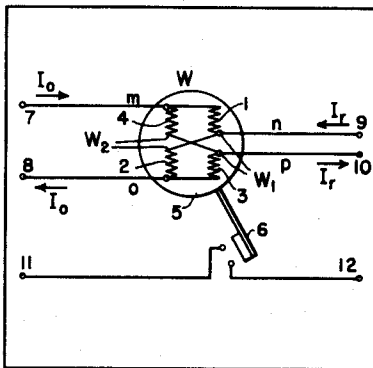


Fig. 1.

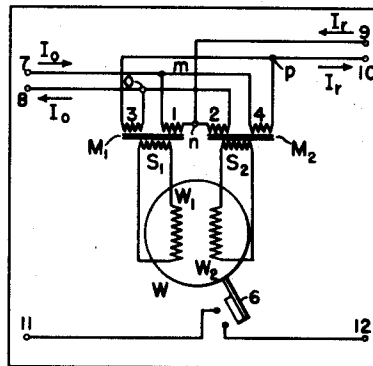


Fig. 2.

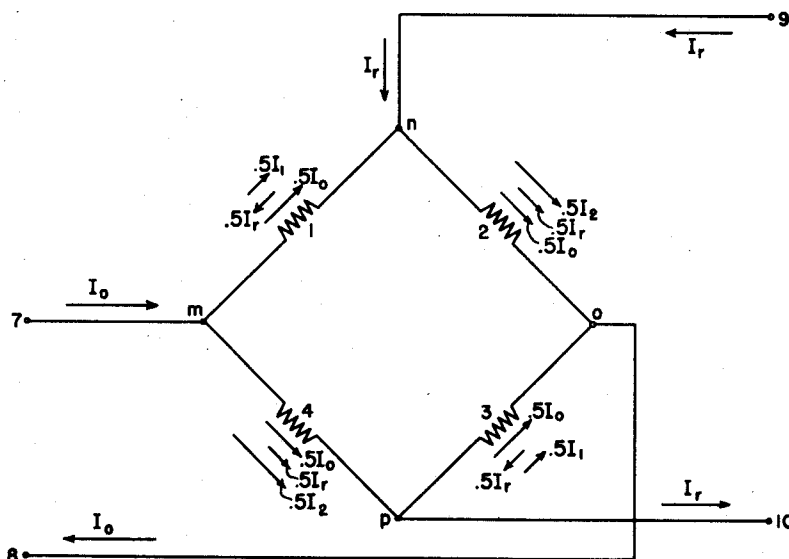


Fig. 3.

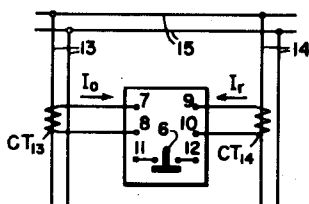


Fig. 4.

WITNESSES:

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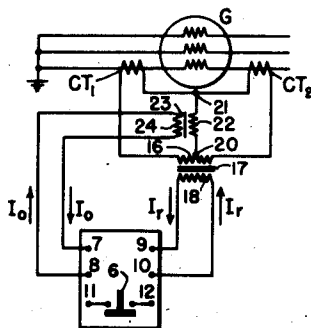


Fig. 5.

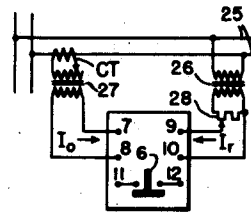


Fig. 6.

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BRIDGE-CONNECTED RELAY

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6 Claims. (Cl. 175—294)

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My invention relates to a wattmetric or product-type relay, and a bridge-network for energizing the windings of the relay from two input-currents of the same frequency. The bridge is preferably so designed that all of its legs have the same impedance. The relay is a product-type relay having two windings, defining a "winding" as an excitation-means for producing one of the two essential excitations or fluxes of the relay. A product-type relay develops a torque which is proportional to the product of the currents traversing the two windings, or excitation-means, multiplied by a function of the phase-angle between said currents. In a preferred embodiment of my invention, each of the windings is divided into the two equal parts, the two parts of each winding being connected in opposite legs of the bridge. The two input-currents are brought into the two diagonals of the bridge, so that the total excitation of one of the relay-windings is equal to the sum of the two input-currents, while the total excitation of the other relay-winding is equal to the difference between the two input-currents.

My relay develops two opposing torques, namely an operating torque tending to operate the relay in response to one of the input-currents, which I designate the operating current, and a restraining torque tending to prevent the relay-operation or to move its rotor-member in the opposite direction, in response to the other input-current, which I designate the restraining current. These torques or responses of the relay are independent of the relative phase-angle between the two input-currents.

My invention is applicable both to high-speed relays and to slow-speed relays in which the speed of response varies significantly with the conditions which produce the relay-operation. My improved relay-assembly may be used either as a differential-current relay, or as a ratio- or percentage-differential relay, or as an impedance relay, or in fact in any relay in which an operating torque and an opposing or restraining torque or force are required.

With the foregoing and other objectives in mind, my invention consists in the systems, circuits, combinations, apparatus, parts, and methods of design and operation, hereinafter described and claimed, and illustrated in the accompanying drawing, wherein

Figure 1 is a diagrammatic view of a wattmetric relay-element in which each of the two relay-windings is split into two parts, the four parts being connected in a bridge-connection, in ac-

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cordance with a preferred form of embodiment of my invention;

Fig. 2 is a similar view showing a modification in which the two relay-windings are not subdivided, but the effect of subdivided windings is obtained through the use of two mixing-transformers, one for each winding;

Fig. 3 is an equivalent circuit diagram of the essential energizing-connections of the relay shown either in Fig. 1 or in Fig. 2; and

Figs. 4, 5 and 6 are application-diagrams showing representative external circuit-connections for using my relay as a differential-current relay, a percentage-differential relay, and an impedance relay, respectively.

In Fig. 1, a wattmetric or product-type element is indicated at W, having two stationary windings or excitation-means W_1 and W_2 . The relay winding W_1 is subdivided into two equal parts 1 and 3, preferably with both of these parts equally distributed in all of the poles or winding-slots of the relay. In like manner, the relay-winding W_2 is subdivided into two parts 2 and 4. The relay-rotor is indicated at 5, and it is shown as carrying a contact-making member 6.

The four winding-parts 1, 2, 3 and 4 are connected in a bridge-circuit having the corners m , n , o , p , with the winding 1 connected in the bridge-leg mn , the winding 2 connected in the next bridge-leg no , etc., as shown in Figs. 1 and 3. An input-circuit, having terminals 7 and 8, is provided, whereby an operating current I_o may be led into the corner m and out of the diagonally opposite corner o of the bridge. A second input-circuit, having terminals 9 and 10, is provided, whereby a restraining current I_r may be led into the corner n , and out of the diagonally opposite corner p of the bridge.

As shown in Fig. 1, a controlled circuit, having terminals 11 and 12, is also provided, in which the relay-contact 6 is connected, as is well understood in the relaying art.

In Fig. 2, an equivalent arrangement is provided, which avoids the necessity for subdividing each of the two relay-windings W_1 and W_2 into two separate winding-parts which are insulated from each other as well as from the frame of the relay, thus saving winding-space in the relay, at the expense of requiring two mixing-transformers M_1 and M_2 . The transformer M_1 has two primary windings 1 and 3 which are connected in the bridge-circuit as in Figs. 1 and 3, and one secondary winding S_1 which is connected to the relay-winding W_1 . The other transformer M_2 has two primary windings 2 and 4 which are

connected in the bridge circuit in the same manner as in Figs. 1 and 3, and a secondary winding S_2 which is connected to the relay-winding W_2 .

The equivalent energizing circuits are shown in Fig. 3, in which I have indicated that each of the two input-currents I_0 and I_r divides equally, in passing through the bridge, because of the symmetry of the bridge-impedances. I have designated the currents which flow through the winding-portions 1 and 3 as each being half of the energizing-current I_1 for the winding W_1 so that the total exciting-current for the winding W_1 may be regarded as the sum of these two part-currents, or I_1 , counting the winding W_1 as having the same number of turns as either of its parts 1 and 3. A like convention is adopted for the currents in the other two winding-parts 2 and 4, as indicated by the designation $.5I_2$, applied to the corresponding arrows in Fig. 3. The subdivided operating-currents $.5I_0$ and the subdivided restraining currents $.5I_r$ are also indicated by suitable arrows in Fig. 3, from which it is apparent that the total energizing-current I_1 for the relay-winding W_1 is equal to the difference between the two input-currents, or $(I_0 - I_r)$, while the total relay-current I_2 for the other relay-winding W_2 is equal to the sum of the two input-currents, or $(I_0 + I_r)$.

I use a dot over a symbol to indicate a complex number, whereas the symbol without the dot represents either the vector generally, without reference to its phase-angle, or the scalar or absolute-magnitude value of the vector, in accordance with a familiar convention.

In explaining the design and operation of my relay, I will assume that the relay is energized by the relay-currents I_1 and I_2 having a phase-angle ϕ between them, and that the relay develops a torque

$$T = I_1 I_2 \cos(\phi - q) \quad (1)$$

where q is an angle which is characteristic of the relay.

If, now, the two energizing-currents are

$$I_1 = I_0 - I_r \angle \theta \quad (2)$$

$$I_2 = I_0 + I_r \angle \theta \quad (3)$$

where θ is the angle by which the restraining current I_r leads the operating current I_0 , the total relay-torque will be the sum of the products of the different pairs of terms, each multiplied by $\cos(\phi_0 - q)$, where ϕ_0 is the angle between the two terms being multiplied. The torque is therefore

$$T = I_0^2 \cos q + I_0 I_r \cos(\theta - q) - I_0 I_r \cos(\theta + q) - I_r^2 \cos q = (I_0^2 - I_r^2) \cos q \quad (4)$$

This proves that the relay-torque has an operative or relay-actuating component, $I_0^2 \cos q$, which is dependent upon the square of the operating current I_0 , and the characteristic response-angle q of the relay; while the relay-torque has a restraining or response-opposing component, $-I_r^2 \cos q$, which is dependent upon the square of the restraining current I_r , and the characteristic response-angle q of the relay. The phase-angle θ of the restraining current relative to the operating current makes no difference in the response of the relay.

Various uses or applications may be made of my novel relay-assembly, three illustrative examples being indicated, in simple forms, in Figs. 4, 5 and 6.

In Fig. 4, external connections are shown,

which make use of my relay as a differential-current relay, which is used to compare the magnitudes of the currents in two feeders 13 and 14 which are connected to a common bus 15 in an alternating-current distribution-system. The input-current I_0 is supplied to the relay from a line-current transformer CT_{13} in the feeder 13, while the other input-current I_r is supplied to the relay from a line-current transformer CT_{14} in the feeder 14. Since my relay develops a torque in one direction in response to the first input-current I_0 , and a torque in the opposite direction in response to the second input-current I_r , my relay can thus be used in the same manner as any other current-differential relay.

Fig. 5 shows illustrative external connections for using my invention in the percentage differential protection of a three-phase generator G. Two line-current transformers CT_1 and CT_2 , on opposite sides of the generator, are connected together through the primary winding 16 of a restraint-transformer 17, this transformer having a secondary winding 18 which produces a restraint-current I_r which is equal to half of the sum of the currents traversing the two current-transformers CT_1 and CT_2 . The primary winding 16 of the restraint-transformer is provided with a midtap 20, which is connected to the common terminal 21 of the current-transformers, through the primary winding 22 of an operating transformer 23. The operating transformer 23 has a secondary winding 24 which energizes my relay with an operating current I_0 which is proportional to the difference between the line-currents flowing in the current-transformers CT_1 and CT_2 . The operating transformer 23 may, or may not, be saturable: if it is saturable it gives the relay the well-known variable percentage characteristic.

Fig. 6 shows the external connections which illustrate the use of my relay as an impedance relay, or a voltage-restraint overcurrent relay, in which the operating current I_0 is derived from a line-current transformer CT in a protected alternating-current line-section 25, while the restraining current I_r is provided by a line-energized potential-transformer 26, so that said restraining current is proportional to the line-voltage. In order to make the design flexible in its use and adjustment for special applications, it is preferable to provide means for adjusting the magnitude of one or both of the input-currents I_0 and I_r , as by means of a variable-ratio auxiliary transformer 27 in the line-current-responsive input-circuit, and a potentiometer 28 in the line-voltage-responsive input-circuit.

The three application-diagrams of Figs. 4, 5 and 6 are intended to be only the simplest sort of diagrams, each illustrative of its particular type of service. It will be understood, of course, that various other external connections may be used. It should be understood, also, that my invention is applicable alike to high-speed relays and slow-speed or time-element relays.

Various modifications and substitutions may be made by those skilled in the art, without departing from the essential spirit of my invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. A product-responsive relaying element having two excitation-means, energizing-means for providing two energizing-circuits for energizing each of said excitation-means, and a bridge-cir-

cuit connection for the four energizing-circuits, the two energizing-circuits for each excitation-means being connected in opposite legs of the bridge, said bridge-circuit including two input-circuits connected to the respective diagonal corners of the bridge, whereby one of said excitation-means is effectively energized responsively to a sum-function of the two input-currents, while the other excitation-means is effectively energized responsively to a difference-function of the two input-currents.

2. A product-responsive relaying element having two excitation-means of substantially identical impedances, energizing-means for providing two substantially equal energizing-circuits for energizing each of said excitation-means, and a bridge-circuit connection for the four energizing-circuits, the two energizing-circuits for each excitation-means being connected in opposite legs of the bridge, said bridge-circuit including two input-circuits connected to the respective diagonal corners of the bridge, whereby one of said excitation-means is effectively energized responsively to the sum of the two input-currents, while the other excitation-means is effectively energized responsively to the difference between the two input-currents.

3. A product-responsive relaying element having two excitation-means, each excitation-means having two winding-parts, and a bridge-circuit connection for the four winding-parts, the two winding-parts of each excitation-means being connected in opposite legs of the bridge, said bridge-circuit including two input-circuits connected to the respective diagonal corners of the bridge, whereby the two parts of one of said excitation-means are energized responsively to a sum-function of the two input-currents, while the two parts of the other excitation-means are energized responsively to a difference-function of the two input-currents.

4. A product-responsive relaying element having two excitation-means of substantially identical impedances, each excitation-means having two substantially identical winding-parts, and a bridge-circuit connection for the four winding-parts, the two winding-parts of each excitation-means being connected in opposite legs of the bridge, said bridge-circuit including two input-circuits connected to the respective diagonal corners of the bridge, whereby each of the two parts of one of said excitation-means is ener-

gized by substantially one-half of the sum of the two input-currents, while each of the two parts of the other excitation-means is energized by substantially one-half of the difference between the two input-currents.

5. A product-responsive relaying element having two windings, a mixing transformer for energizing each of said windings, each mixing transformer having a secondary winding connected to its relay-winding, and having two primary windings, and a bridge-circuit connection for the four primary windings, the two primary windings of each mixing transformer being connected in opposite legs of the bridge, said bridge-circuit including two input-circuits connected to the respective diagonal corners of the bridge, whereby one of said relay-windings is energized responsively to a sum-function of the two input-currents, while the other relay-winding is energized responsively to a difference-function of the two input-currents.

6. A product-responsive relaying element having two windings of substantially identical impedances, two substantially identical mixing transformers for energizing the respective relay-windings, each mixing transformer having a secondary winding connected to its relay-windings, and having two substantially identical primary windings, and a bridge-circuit connection for the four primary windings, the two primary windings of each mixing transformer being connected in opposite legs of the bridge, said bridge-circuit including two input-circuits connected to the respective diagonal corners of the bridge, whereby each of the primary windings of one of said mixing transformers is energized by substantially one-half of the sum of the two input-currents, while each of the two primary windings of the other mixing transformer is energized by substantially one-half of the difference between the two input-currents.

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