Dec. 15, 1936. S. C. LEYLAND 2,064,018

PROTECTIVE APPARATUS

Filed Sept. 13, 1934

Fig. 1.

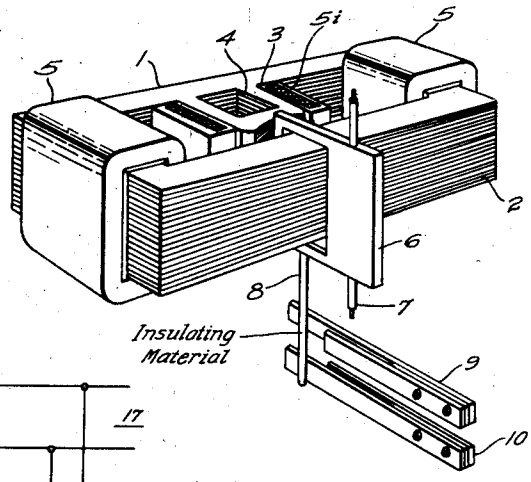


Fig. 3.

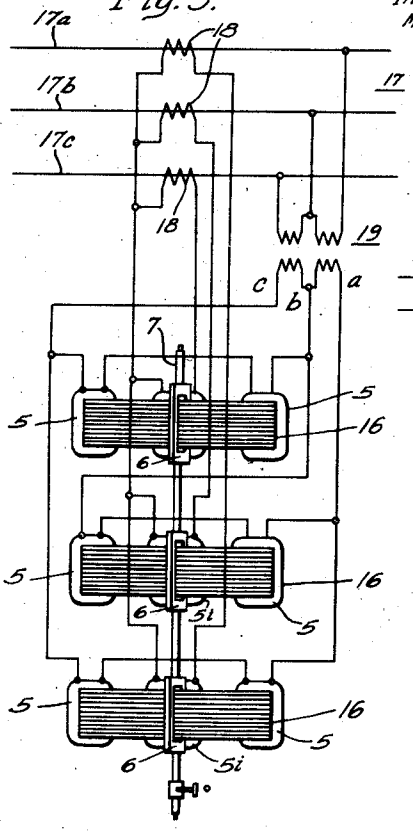
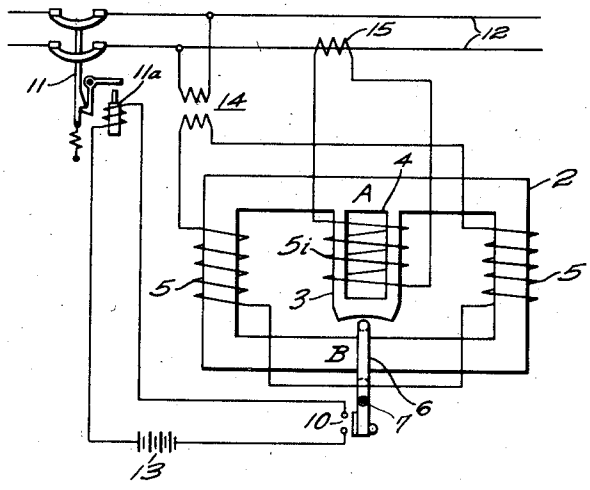


Fig. 2.



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PROTECTIVE APPARATUS

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7 Claims. (Cl. 175—294)

My invention relates to protective apparatus for alternating-current circuits, and particularly to high-speed relay elements of the inductor loop type for use in connection with high-speed protective apparatus.

It is the present practice in connection with the relaying of transmission systems, to clear faults in a time interval of the order of several cycles of a 60-cycle supply. In order to obtain such high-speed operation, it is necessary for the fault responsive elements and the power directional elements of the relay to operate positively in a time interval of the order of 1 cycle or less. The most satisfactory form of directional element at present in use in such high-speed applications consists of an inductor loop of aluminum or copper, mechanically balanced for rotation about a central axis, which is operated upon by two magnetic cores. The first of these cores is interlinked with the inductor loop and is energized in accordance with a line voltage condition. The second core is energized in accordance with a line current condition and provides a magnetic flux which traverses the loop in its plane.

With this arrangement, the loop develops a torque which is proportional to the product of the voltage condition and the current condition times the cosine of the phase angle between them, or in other words, to true power. However, when the loop is rotated slightly from the plane of the current flux, it interlinks part of the current flux and produces a second torque which tends to return the loop to its initial position. The latter torque, termed "straightening torque", as in similar inductive effects, is proportional to the square of the current.

In the event of a fault close to the relay station, the line voltage may fall to a very low value, whereas the line current will be many times normal. Under these circumstances, the product of line voltage and line current may be quite small, whereas the square of the current itself may be quite large. As a result, the straightening torque in the inductor loop element may be quite large as compared to the operating torque, and operation of the element itself will not be certain.

It is accordingly an object of my invention to provide a novel power directional relay element of the inductor loop type, in which the straightening torque shall be minimized.

A further object of my invention is to provide a relay element of the inductor loop type, in which the magnetic system shall be re-arranged and simplified.

Other objects of my invention will become evident from the following detailed description taken in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic view in perspective of a relay element embodying my invention;

Fig. 2 is a diagrammatic view showing the energizing connections for the relay element shown in Fig. 1; and

Fig. 3 is a diagrammatic view showing a polyphase relay element constructed in accordance with my invention and energized from a three-phase alternating-current circuit.

Referring to Fig. 1 in detail, the relay core 1 comprises a symmetrical rectangular outer magnetic loop 2, partially traversed by a magnetic bridge member 3. The bridge member 3 is cut away at 4 to provide a portion of restricted cross-sectional area. A pair of similar potential coils 5 are mounted upon the outer legs of the magnetic loop 2, and are arranged to produce equal magnetomotive forces acting around the magnetic loop 2 in the same direction. The current coil 5*i*, of the directional element is mounted on the bridge member 3.

The armature of the relay element comprises a light aluminum or copper inductor loop 6 mechanically balanced about a shaft 7 for rotation in the air gap formed between the magnetic loop 2 and the bridge member 3. A contact operating lever 8, preferably of insulating material, is secured to the inductor loop 6 for operating the relay contact members, shown diagrammatically as a set of back contact members 9 and a set of front contact members 10.

Referring to Fig. 2, a circuit breaker 11 having a trip coil 11*a* is arranged to control the flow of power in an alternating-current circuit 12. The trip coil 11*a* is connected in a local circuit with a suitable source of tripping current 13 and the contact members 10 of the relay element. In the arrangement shown, the circuit breaker 11 is, for simplicity, illustrated as operated directly by the power directional element, but it will be understood that in a practical embodiment of the invention, various other relay elements would be provided and arranged in accordance with the usual practice.

The potential coils 5 are connected in series to the secondary winding of a potential transformer 14 to be energized in accordance with line voltage. The current coil 5*i* is connected in series with the secondary winding of the cur-

rent transformer 15 to be energized in accordance with line current.

The operation of the apparatus shown in Fig. 2 may be set forth as follows: Assuming that the circuit 12 is energized by alternating voltage of normal potential and that power is flowing in the normal direction therein, the inductor loop 6 acts as a short-circuited secondary turn for the potential coils 5, and carries a comparatively heavy current which is substantially in phase with the line voltage. As the potential coils 5 produce equal magneto-motive forces which act in the same direction around the symmetrical loop 2, the magnetic potentials at the points A and B are equal, and no flux is developed in the bridge member 3 as a result of the energization of the potential coils 5. However, the current coil 5*i* develops a flux in the bridge member 3 which divides symmetrically in the magnetic loop 2 into two components which interlink the potential coils 5 and induce equal electromotive forces in the potential circuit which cancel. The magnetic circuits of the potential coils 5 and the current coils 5*i* are accordingly independent so far as inductive effects are concerned.

The current flowing in the inductor loop 6 is in phase with the flux produced in the bridge member 3 when the power factor of the circuit 12 is unity, and, under these circumstances, the torque developed by the inductor loop 6 is a maximum and acts in a direction to maintain the contact members 10 open.

If the direction of power flow in the circuit 12 reverses, the inductor loop 6 develops a torque tending to close the contact members 10. This torque is proportional to the vector product of current in the loop 6 and flux in the air gap in which the loop 6 lies. This vector product, in turn, is proportional to the vector product of line current and line voltage times the cosine of the phase angle between them. As soon as the inductor loop 6 rotates slightly from its normal position, however, the loop interlinks part of the air gap flux. A second component of torque accordingly appears as a result of the component of current in the inductor loop 6 induced by the air gap flux alone. The latter component of torque is proportional to the square of the line current and acts in a direction to restore the inductor loop 6 to its initial position. However, as the cross-sectional area of the bridge member 3 is restricted, the maximum value of air gap flux and of straightening torque is limited notwithstanding the magnitude of line current.

With this arrangement, therefore, a ratio of operating torque to straightening torque of a sufficient magnitude may be maintained to insure positive operation under conditions of extremely low voltage. In a practical embodiment of my invention, I have succeeded in obtaining satisfactory operation at a voltage of one-half volt with all current values within the range of 1 ampere up to 40 amperes.

Referring to Fig. 3, which shows an application of my invention to polyphase apparatus, three inductor loop elements 16 of the type described above are mounted with their inductor loops pivotally supported on a single shaft 7. With this arrangement the total torque developed is proportional to the algebraic sum of the vector products of current and voltage in three phases of the polyphase circuit 17 from which the device is energized. The current coils of the directional elements 16 are preferably energized by means of current transformers 18 in accordance with line currents, and the potential coils 5 may be energized, in any suitable manner, as by means of a pair of V-connected potential transformers 19. Assuming that the phase relationship of the polyphase circuit is as indicated by the subscripts of the conductors 17*a*, 17*b* and 17*c*, the arrangement is preferably such that with 100% power factor in the circuit 17, each relay element is energized in accordance with the current leading the voltage applied to the element by a phase angle of 30°. This arrangement produces maximum relay torque when current lags the voltage by a phase angle of 60°, as is well known in the art.

Although I have shown a single polyphase element in Fig. 3, it will be understood that the three individual single-phase elements may be operated separately in accordance with the usual practice, where individual phase operation is desired.

I do not intend that the present invention shall be restricted to the specific structural details, arrangement of parts, or circuit connections herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of my invention. I desire, therefore, that only such limitations shall be imposed as are indicated in the appended claims.

I claim as my invention:

1. In a relay element of the inductor loop type, a conducting loop mounted for rotation about an axis, said conducting loop having an inductor portion substantially parallel to said axis and eccentrically displaced therefrom, and energizing means including means for inducing alternating currents in said loop, a magnetic pole portion adjacent to said inductor portion and substantially perpendicular thereto, and coil means for energizing said pole portion in accordance with an electrical quantity, said pole portion being so designed with reference to said coil means as to become magnetically saturated at a comparatively small fraction of the maximum value of said quantity, to thereby limit the torque dependent upon said quantity tending to align said loop with said pole portion.

2. In a relay element of the inductor loop type, a magnetic core having a magnetic loop and a branch extending across said loop, said branch having a portion of restricted cross-sectional area as compared to said magnetic loop and having an air gap, and an inductor loop interlinked with said magnetic loop and having an inductor portion arranged to traverse said air gap.

3. In a relay element of the inductor loop type, a magnetic core having a symmetrical magnetic loop and a branch extending across said loop along an axis of symmetry, said branch having a portion of reduced cross-sectional area and an air gap, and an inductor loop interlinked with said magnetic loop and having an inductor portion arranged to traverse said air gap.

4. In an alternating-current relay element, a pair of relatively movable members one of said relatively movable members having a closed electrical circuit and the other of said relatively movable members having magnetic core means including a first path and a second path having a portion of restricted cross-sectional area as compared to said first path and an air gap, a movable armature having a closed electrical circuit interlinked with said first path, said circuit including an inductor portion arranged to traverse said air gap, means for inductively ener-

gizing said first path in accordance with an alternating electrical condition, and means for inductively energizing said second path in accordance with an alternating electrical condition.

5. In an alternating-current relay element, a stationary magnetic core having a divided magnetic circuit including a first path and a second path having a portion of reduced cross-sectional area and an air gap, a movable armature having a closed electrical circuit interlinked with said first path, said circuit including an inductor portion arranged to traverse said air gap, means for inductively energizing said first path in accordance with an alternating electrical condition, and means for inductively energizing said second path in accordance with an alternating electrical condition.

6. In a relay element responsive to a vector product of a current condition and a voltage condition, a magnetic core having a divided magnetic circuit comprising a closed path and an open path having a portion of restricted cross-sectional area as compared to said closed path and having an air gap, a movable armature having an inductor loop interlinked with said closed path, said inductor loop including an inductor portion arranged to traverse said air gap, means for inductively energizing said closed path in accordance with said voltage condition, and means for inductively energizing said open path in accordance with said current condition, whereby the force on said inductor loop produced by said current condition alone is limited as compared to the force produced by said voltage condition and said current condition.

7. In a power directional relay element of the inductor loop type, a magnetic core having a divided magnetic circuit comprising a closed symmetrical magnetic loop and a branch traversing said magnetic loop along an axis of symmetry, said branch having a portion of restricted cross-sectional area as compared to said loop and having an air gap, a movable armature having an inductor loop interlinked with said magnetic loop, said inductor loop including an inductor portion arranged to traverse said air gap, a pair of potential coils mounted on said magnetic loop at opposite points for producing equal magnetomotive forces acting in the same direction around said magnetic loop, and a current coil mounted on said branch.

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