No. 833,194. PATENTED OCT. 16, 1906.

L. ANDREWS.

PROTECTIVE DEVICE FOR ALTERNATING CURRENT CIRCUITS.

APPLICATION FILED SEPT. 18, 1905.

Fig. 1.

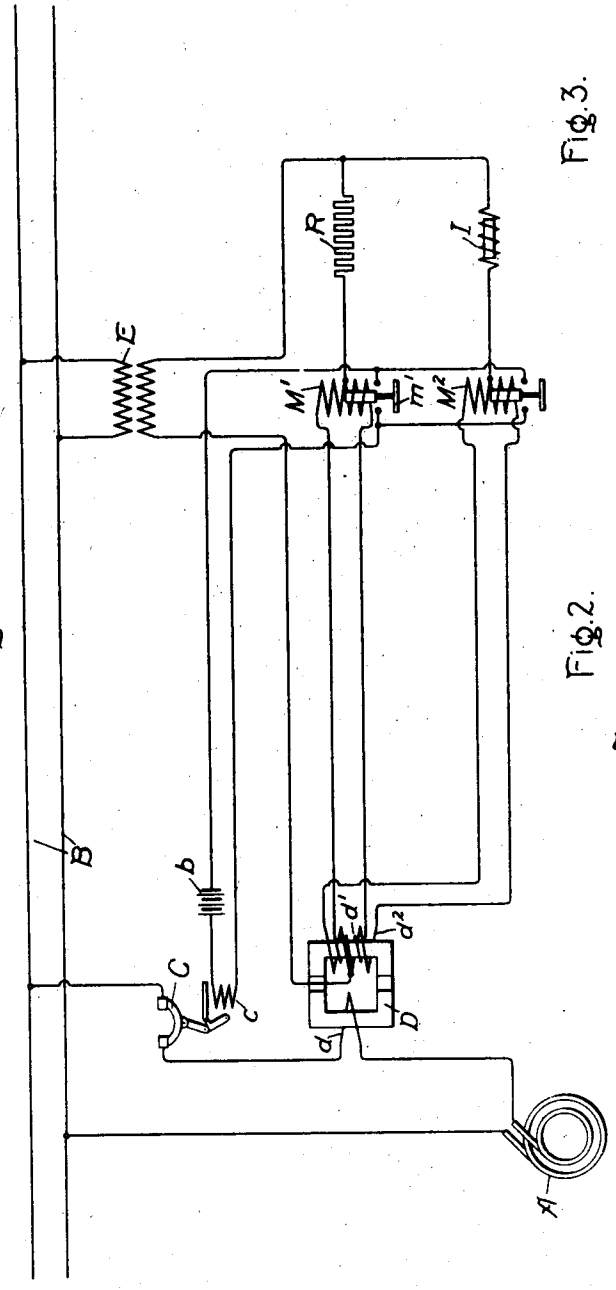


Fig. 3.

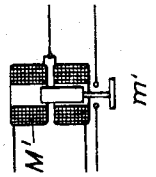
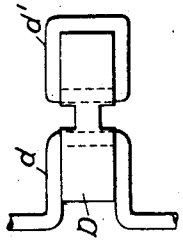


Fig. 2.



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UNITED STATES PATENT OFFICE.

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PROTECTIVE DEVICE FOR ALTERNATING-CURRENT CIRCUITS.

No. 833,194. Specification of Letters Patent. Patented Oct. 16, 1906.

Application filed September 18, 1905. Serial No. 278,863.

To all whom it may concern:

Be it known that I, LEONARD ANDREWS, a subject of the King of Great Britain, residing at Manchester, England, have invented certain new and useful Improvements in Protective Devices for Alternating-Current Circuits, of which the following is a specification.

My invention relates to the protection of alternating-current circuits from a reversal of energy therein; and its object is to provide protecting means which shall be simple and at the same time reliable under all conditions.

It has been proposed heretofore to arrange reverse-current protective devices with two windings, one connected in series with the main circuit to be protected and the other in shunt to that circuit, and to superpose the two windings on each other either in a solenoid or on a transformer-core, the resultant magnetic effect of the two windings being utilized to secure the operation of the device upon a relative reversal of current-flow. When such an arrangement is used with alternating-current circuits, a heavy reverse current in the series coil may completely wipe out the effect of the potential-coil, inducing in the potential-coil by transformer action an electromotive force which renders the device inoperative. Thus such a device may prove unreliable in the case of a short circuit, where its operation is most needed. By combining the effects of the shunt and series windings electrically instead of magnetically this transformer action of the series coil on the shunt-coil is avoided. Such an arrangement is shown in Patent No. 751,441, issued to me February 9, 1904. In that patent I have shown a protective device arranged in a local closed circuit with means for producing in the circuit two voltages dependent in phase on the current and on the voltage, respectively, on the main circuit. Since the series and shunt windings are entirely separate, no transformer action between the two is possible.

My present invention consists in an improvement in the arrangement disclosed in my former patent and renders the apparatus still more reliable for all conditions.

One feature of my invention consists in arranging the series transformer with a core adapted to be saturated by an overload-current, so that the current supplied to the local circuit of the series transformer can never exceed a predetermined amount, and I also connect the series and shunt transformers to the local circuit in such a manner that each current is supplied to the local circuit at points equipotential with respect to the other transformer. By adapting the core of the series transformer for saturation on overload an undue preponderance in the effect of the series current is avoided, and by supplying the two currents at points in the local circuit equipotential with respect to each other they are made entirely independent of each other in their effect upon the protective device.

I have found that under certain conditions protection is required not only against a true reversal of energy in the main circuit, but also against a heavy flow of wattless current. Thus, for instance, in the case of an alternating-current generator connected in parallel with other machines in case of the failure of a prime mover that generator will run as a motor, driving the prime-mover, and a true reversal of energy will occur in the leads connecting the generator to the bus-bars. For such contingency a protective device operating upon a reversal of energy will afford adequate protection; but if the field-circuit of the generator is broken while the prime mover remains undisturbed a different condition exists. Although the generator-armature in one sense acts as a short circuit on the bus-bars, on the other hand the prime mover is still attempting to do work, for as long as the generator remains in synchronism the governor of the prime mover cannot act to cut off the supply of steam or water, so that while, on the one hand, there is a tendency for energy to pass from the bus-bars to the armature, as to a short circuit, on the other hand there is a tendency, due to the power delivered from the prime mover to the generator, for the generator to supply energy to the bus-bars. The result is that a very heavy synchronizing-current passes between the generator and the bus-bars. This current is a leading current with respect to the faulty generator and serves to furnish the magnetization of the machine and to hold it in synchronism, while as regards the other

generators connected to the bus-bars this current is a lagging current. The energy transferred through the leads from the generator to the bus-bars is one instant in one direction and the other instant in the other direction. Consequently there is no true reversal of energy, and a device operative only upon a reversal of energy will not serve to cut the generator out of circuit. In order to meet this contingency, as well as that of a true reversal of energy, I provide two magnet-windings each arranged in a local closed circuit and supply to each circuit two currents dependent in phase on the current and on the voltage, respectively, on the main circuit, but displace the phase of one of these currents in one circuit relative to the same current in the other circuit, and provide means controlled by either magnet-winding for opening the main circuit. With this arrangement one of the magnet-windings may be caused to operate upon a true reversal of energy and the other upon the flow of a heavy wattless current, and since the operation of either device opens the circuit adequate protection is given for all conditions.

My invention will best be understood by reference to the accompanying drawings, in which—

Figure 1 shows diagrammatically an arrangement of protective devices embodying my invention. Fig. 2 shows a view of the series transformer, and Fig. 3 shows a cross-sectional view of one of the relays.

In the drawings, A represents an alternating-current generator connected to the bus-bars B. It is assumed that it is desired to protect the generator against a reverse flow of energy from the bus-bars and also against a heavy flow of wattless current.

C represents a circuit-breaker inserted in the generator-leads and provided with a tripping-coil *c*.

D represents a transformer the primary winding of which, *d*, is inserted in series with the generator-leads. The transformer is shown provided with two secondary windings d' and d^2. The core of the transformer is arranged to be saturated by an overload-current. This may be accomplished by arranging a portion of the core with a reduced cross-section, as clearly shown in Fig. 2, or the whole core may be given a cross-section adapted to be saturated on overload. If preferred, the core may be arranged to be saturated on less than a full load. It is only essential, however, that it should become saturated on an overload, so as to prevent the secondary current from rising a great amount above its normal value in case of a short circuit.

M' M^2 represent two magnet-windings, the terminals of which are connected to the terminals of the secondary windings d' and d^2. While I have shown two independent secondary windings on the transformer D, it is obvious that a single secondary winding may be employed and both magnet-windings connected to the single transformer-winding, if preferred.

E represents a shunt-transformer having its primary connected to the bus-bars. One terminal of the secondary is connected to the middle points of both magnet-windings M' and M^2, while the other terminal of the secondary is connected to the middle points of the series-transformer windings d' and d^2. It will be seen that this connection from the shunt-transformer to each local circuit is at points that are equipotential with respect to the series-transformer secondary, so that the total amount of each of the two currents is wholly unaffected by the other. Furthermore, it will be seen that while the current from the series transformer passes through each winding from one terminal to the other the current from the shunt-transformer passes from the middle of the winding outward to both terminals. The secondary windings d' and d^2, through which these currents pass, serve as differential choke-coils to maintain the currents from the shunt-transformer balanced in the two parts of the magnet-winding. Consequently the two currents assist each other in one half the winding and oppose each other in the other half. Thus, for instance, if normally the two currents in the magnet-winding M' are in phase and assist each other in the lower half of the winding and oppose each other in the upper half there will be no tendency for the magnet to raise its core, but, on the contrary, to hold it in the position shown in Figs. 1 and 3. Now if the relative phase of the current from the series transformer should be shifted one hundred and eighty degrees the two currents would assist each other in the upper half of the winding and oppose each other in the lower half. The magnet-winding would consequently raise its core, raising the switch-contact m' and closing a circuit through trip-coil *c* and battery *b*. The circuit of the generator A would thus be opened by the circuit-breaker C, and protection would consequently be afforded against a reversal of energy. If, however, the two currents in the magnet M' were normally in phase with a non-inductive load upon the generator A, a difference in phase of only ninety degrees in the current from the series transformer would be produced by a flow of wattless current in the generator-leads. The two currents in the magnet-winding would then be ninety degrees out of phase with each other and would merely assist each other to a slight extent in both parts of the winding. The device consequently would be inoperative. If, on the other hand, the two currents in the winding M' were ninety degrees out of phase with each other on a non-inductive load on

the generator, it is evident that a flow of wattless current in the generator-leads, which would shift the current from the series transformer ninety degrees, would bring the two currents in the winding M into opposition in one half of the winding and into the same phase in the other half, so that the devices if properly connected would operate to open the generator-circuit. In order to secure this operation on either a true reversal of energy or a flow of wattless current, I provide two windings M′ and M² and relatively displace the phases of the currents supplied to these windings from the potential-transformer E. This is readily accomplished by inserting a non-inductive resistance R in the connection between the transformer E and one of the windings and an inductive resistance I in connection to the other winding adapted to lag the current by an angle between forty-five and ninety degrees. With this arrangement the winding M′ will operate to open the generator-circuit upon a true reversal of energy, while the magnet M² will operate upon the flow of wattless current. Consequently the generator is protected against all contingencies that can arise.

I do not desire to limit myself to the particular construction and arrangement of parts here shown, but aim in the appended claims to cover all modifications which are within the scope of my invention.

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

1. In a protective device, in combination with a main alternating-current circuit, a transformer having its primary in series with said circuit and having a core adapted to be saturated by an overload-current in said circuit, an electroresponsive device connected in a local closed circuit with the secondary of said transformer, and connections from equipotential points in said circuit to a source of voltage dependent in phase upon the voltage of the main circuit.

2. In a protective device, in combination with a main alternating-current circuit, a shunt-transformer, a series transformer having a core adapted to be saturated by an overload-current in said circuit, and an electroresponsive device connected in a local closed circuit with the secondaries of both transformers, one transformer being connected to equipotential points with respect to the other transformer.

3. In a protective device, in combination with a main alternating-current circuit, a transformer having its primary in series with said circuit and having a core adapted to be saturated by an overload-current in said circuit, a magnet-winding connected in a local closed circuit with the secondary of said transformer, connections from equipotential points in said circuit to a source of voltage dependent in phase upon the voltage of the main circuit, and a switch controlled by said magnet-winding and adapted to open the main circuit.

4. In a protective device, in combination with an alternating-current circuit, a shunt-transformer, a series transformer having a core adapted to be saturated by an overload-current in said circuit, a magnet-winding connected in a local closed circuit with the secondaries of both transformers, one transformer being connected to equipotential points with respect to the other transformer, and a switch controlled by said magnet-winding adapted to open the main circuit.

5. In a protective device, in combination with a main alternating-current circuit, a transformer having its primary in series with said circuit and having a core adapted to be saturated by an overload-current in said circuit, a magnet-winding having its terminals connected to the secondary terminals of said transformer, connections from an intermediate point on said winding to one terminal of a source of voltage dependent in phase upon the voltage of the main circuit and from both terminals of said winding to the other terminal of said source, and means controlled by said winding for opening the main circuit.

6. In a protective device, in combination with a main alternating-current circuit, a shunt-transformer, a series transformer having a core adapted to be saturated by an overload-current in said circuit, a magnet-winding connected in a local closed circuit with the secondaries of both transformers, one of said secondaries being connected to the terminals of said winding and the other to intermediate points on said winding and on the first secondary respectively, and means controlled by said winding for opening the main circuit.

7. In a protective device, in combination with a main alternating-current circuit, a transformer having its primary in series with said circuit, two magnet-windings connected in local closed circuits with the transformer secondary, means for impressing on said local circuits respectively two voltages both dependent in phase on the voltage of the main circuit but differing in phase from each other, and means controlled by either magnet-winding for opening the main circuit.

8. In a protective device, in combination with a main alternating-current circuit, two magnet-windings each connected in a local closed circuit, means for producing in each local circuit two currents dependent in phase on the current and voltage respectively of the main circuit, one of said currents being of different phase in the two local circuits, and means controlled by either magnet-winding for opening the main circuit.

9. In a protective device, in combination with a main alternating-current circuit, a shunt-transformer, a series transformer, two

magnet-windings each connected in a local closed circuit with the secondaries of both transformers, one of said secondaries being connected to points in each local circuit equipotential with respect to the other secondary, means for displacing the relative phases of the currents in said local circuits from one transformer, and means controlled by either magnet-winding for opening the main circuit.

10. In a protective device, in combination with a main alternating-current circuit, a transformer having its primary in series with said circuit, two magnet-windings having their terminals connected to the secondary terminals of said transformer, connections from intermediate points of both windings to one terminal of a source of voltage dependent in phase upon the voltage of the main circuit, a connection from an intermediate point on said transformer secondary to the other terminal of said source, means for relatively displacing the currents supplied to said two windings from said source, and means controlled by either winding for opening the main circuit.

11. In a protective device, in combination with a main alternating-current circuit, a transformer having its primary in series with said circuit and having a core adapted to be saturated by an overload-current in said circuit, two magnet-windings connected in local closed circuits with the transformer secondary, means for impressing on said local circuits respectively two voltages both dependent in phase on the voltage of the main circuit but different in phase from each other, and means controlled by either magnet-winding for opening the main circuit.

12. In a protective device, in combination with a main alternating-current circuit, a transformer having its primary in series with said circuit and having a core adapted to be saturated by an overload-current in said circuit, two magnet-windings connected in local closed circuits with the transformer-secondary, means for impressing on each of said local circuits at points equipotential with respect to said transformer-secondary a voltage dependent in phase upon the voltage of the main circuit, the voltages impressed on the two local circuits being of different phase, and means controlled by either magnet-winding for opening the main circuit.

13. In a protective device, the combination with a main alternating-current circuit, a shunt-transformer, a series transformer, two magnet-windings each connected in a local closed circuit to the secondaries of both transformers, one of said secondaries being connected to points in each local circuit equipotential with respect to the other secondary, a non-inductive resistance inserted in the connection between one of said secondaries and one of the local circuits, an inductive resistance inserted in the connection between said secondary and the other local circuit, and means controlled by either magnet-winding for opening the main circuit.

14. In a protective device, the combination with a main alternating-current circuit, a transformer having its primary in series with said circuit, two magnet-windings having their terminals connected to the secondary terminals of said transformer, a transformer having its primary in shunt to said main circuit, connections from one secondary terminal of said shunt-transformer to intermediate points on both magnet-windings, inductive and non-inductive resistances inserted respectively in said connections, a connection from the other secondary terminal of the shunt-transformer to an intermediate point on the series-transformer secondary, and means controlled by either magnet-winding for opening the main circuit.

In witness whereof I have hereunto set my hand this 16th day of August, 1905.

LEONARD ANDREWS.

Witnesses:

GEORGE H. FAWCUS,

JOSEPH DRUMMOND.