E. O. E. KLIPPHAHN.

PROTECTIVE DEVICE.

APPLICATION FILED SEPT. 2, 1909. RENEWED APR. 9, 1917.

1,239,795.

Patented Sept. 11, 1917.

3 SHEETS—SHEET 1.

Fig. 1.

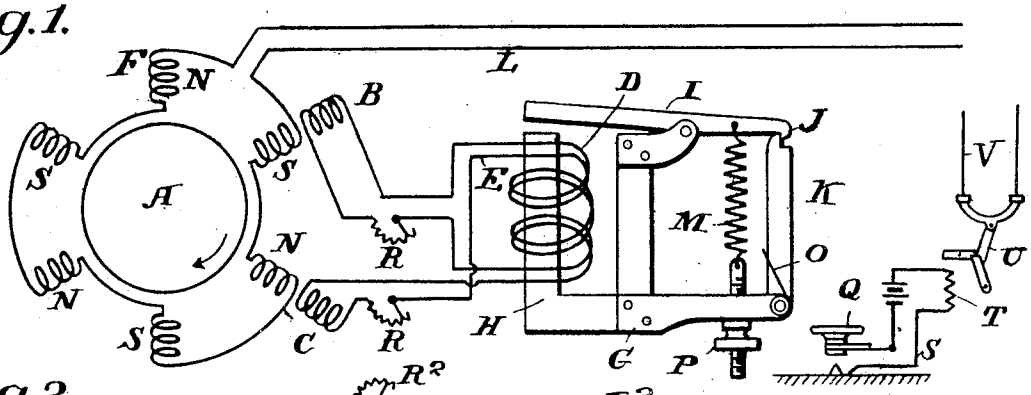


Fig. 2.

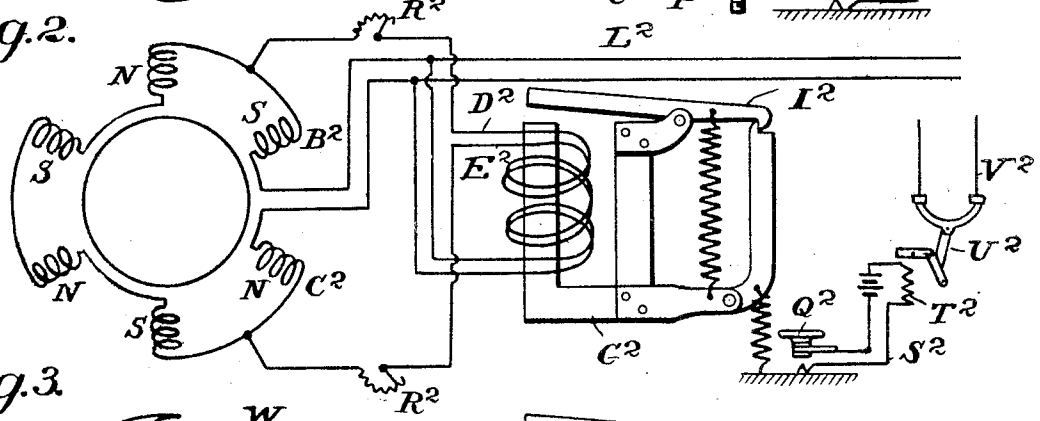


Fig. 3.

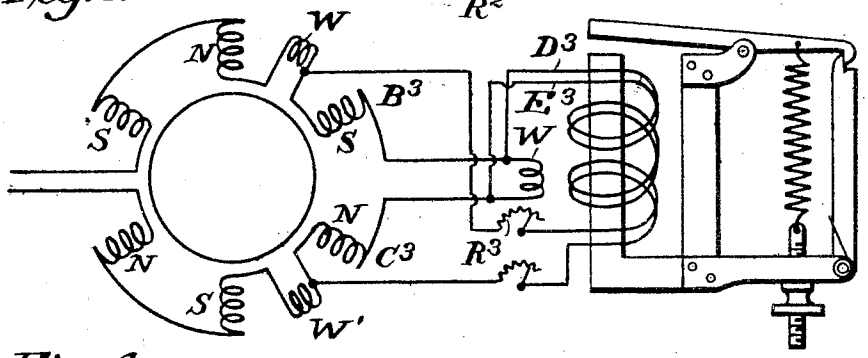


Fig. 4.

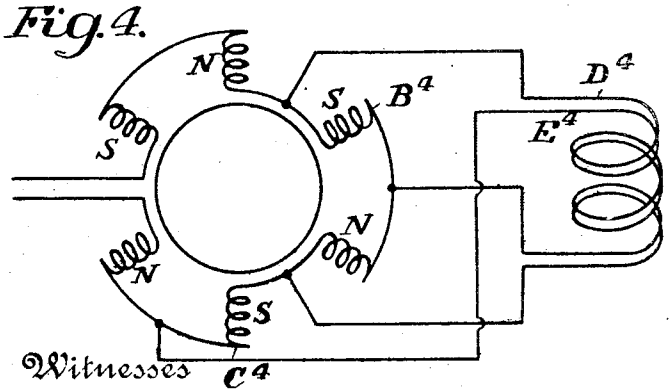
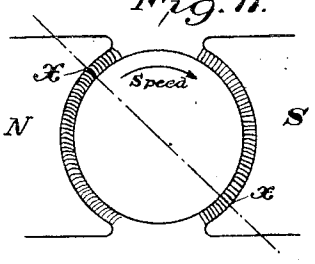


Fig. 11.



Witnesses

J. G. Sinkel

J. H. Bruninga.

Inventor

E. O. E. Klipphahn

by Foster Freeman Watson & Coit

Attorneys

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3 SHEETS—SHEET 2.

Fig. 5.

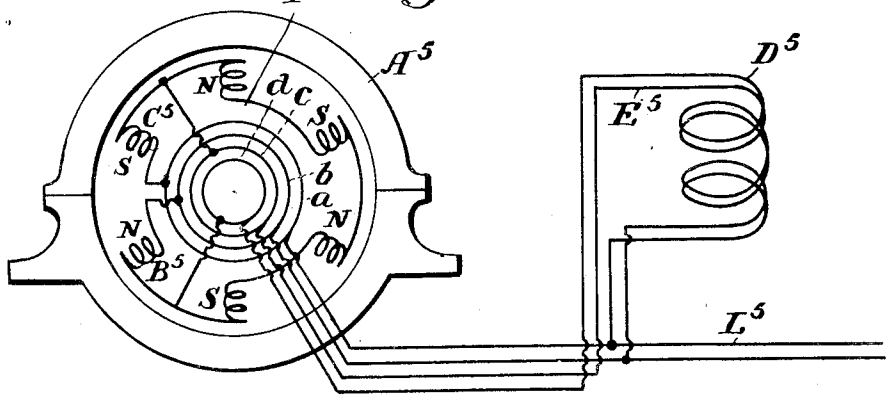


Fig. 6.

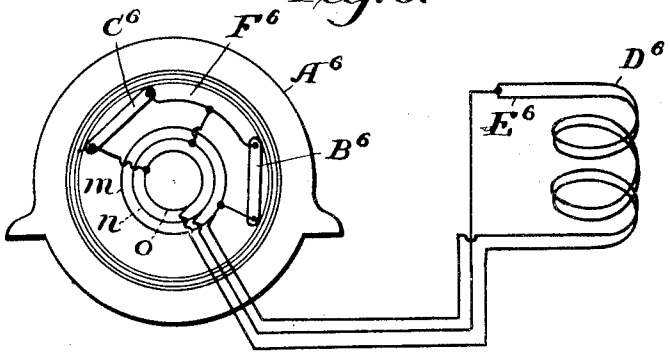
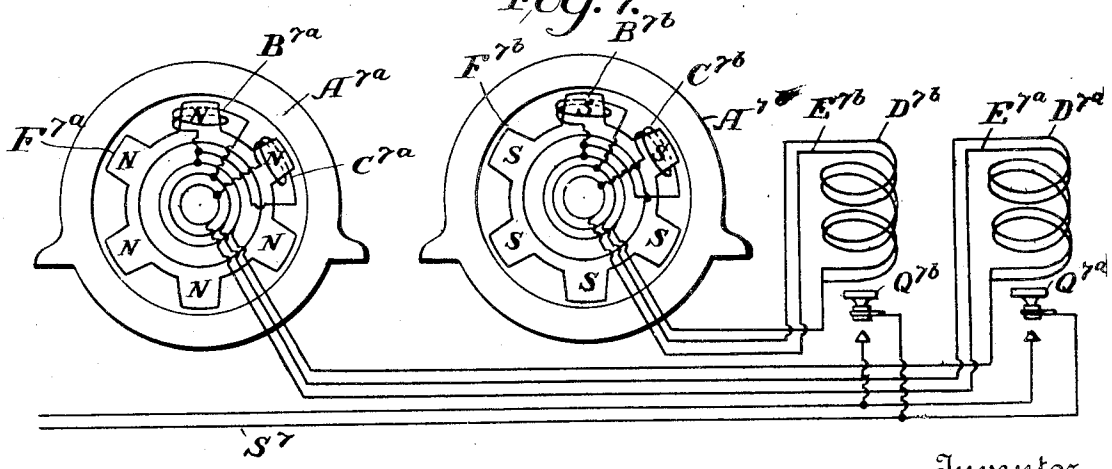


Fig. 7.



Witnesses

J. G. Strukel

J. H. Bruninga.

Inventor

E. O. E. Klipphahn

by Foster Freeman Watson & Coit

Attorneys

E. O. E. KLIPPHAHN.

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3 SHEETS—SHEET 3.

Fig. 8

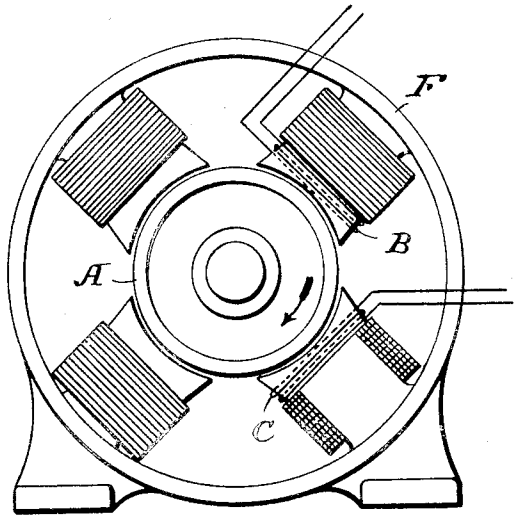


Fig. 10.

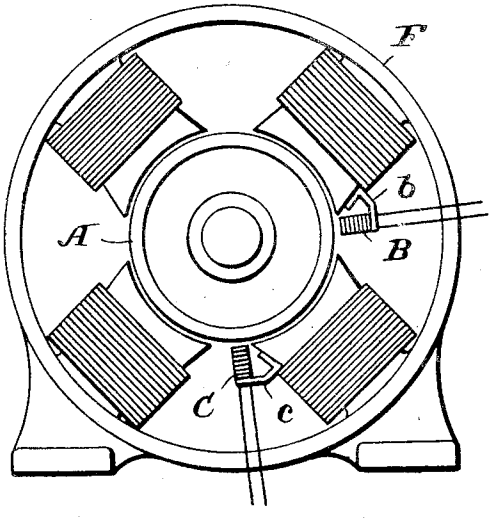
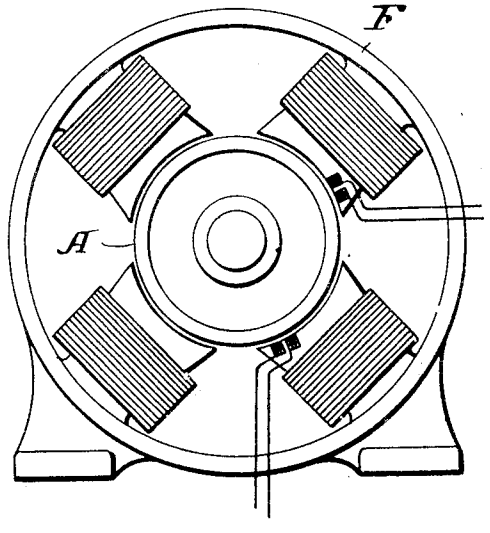


Fig. 9.



Witnesses
J. G. Finkel
J. N. Bruninga.

Inventor
E. O. E. Klipphahn
by Foster Freeman Watson & Coit
Attorneys

UNITED STATES PATENT OFFICE.

ERNEST C. E. KLIPPHAHN, OF DOBBINS, CALIFORNIA.

PROTECTIVE DEVICE.

1,239,795. Specification of Letters Patent. Patented Sept. 11, 1917.

Application filed September 2, 1909, Serial No. 515,835. Renewed April 9, 1917. Serial No. 160,393.

To all whom it may concern:

Be it known that I, ERNEST O. E. KLIPPHAHN, a citizen of the United States, and resident of Dobbins, county of Yuba, State of California, have invented certain new and useful Improvements in Protective Devices, of which the following is a specification.

This invention relates to protective devices for dynamo electric machinery and in particular to protective devices for protecting machines against internal short or open circuits, that is, short or open circuits in the coils of the machine.

The objects of this invention are to provide a device which will notify the attendant by signal or otherwise when a coil in the machine is defective or which will throw a suitable circuit breaker.

The invention generally stated consists in an induced member connected with a suitable indicating device or circuit breaker or both, which is adapted to be placed in inductive relation to the coils of a winding of a dynamo electric machine which is to be protected or tested. A defective coil will act upon this induced member and operate the signal or circuit breaker.

The induced member is preferably placed in one of the pole faces, or forms one of the pole windings. In the induction motor or generator it is placed on the secondary while in an inductor type of alternator it is placed on the rotor or inductor. The induced member may, however, be a separate instrument and may then be placed or held in proper position for the purpose of testing.

The induced member preferably comprises a pair of coils which are connected in circuit with a differential electro responsive device. These coils are symmetrically placed with respect to the windings to be protected or tested; that is, they are placed apart 180 electrical degrees or a multiple thereof. Where the coils form the field pole winding they are placed on separate poles which may be adjacent or not, as desired.

In the drawings,

Figure 1 is a diagram showing one form of this invention in which the winding to be tested or protected is the movable one;

Figs. 2, 3 and 4 are diagrams showing different forms of this invention in which the field coils form a part of the protective device;

Fig. 5 shows the invention applied to a machine of the moving field type;

Fig. 6 shows the invention applied to an induction motor or generator;

Fig. 7 shows the invention applied to a generator or motor of the inductor type;

Figs. 8, 9 and 10 show in detail applications of this invention to direct and alternating current machines, in which the field is stationary while the armature is movable; and Fig. 11 is a diagram showing the theory of operation.

Referring to Fig. 1, A designates the armature of a dynamo electric machine and F the field, the armature being movable while the field is stationary. The field leads are designated by L. A pair of induced members B, C, are connected in circuit with the coils D, E, of the differential device G, which is provided with a core H upon which the differential coils D, E, are wound. The differential device G is provided with an armature I which is pivoted as shown and provided with a hook J which engages a pivotal member K. A spring O normally tends to move the member K to the right, around its pivot, and a spring M normally tends to hold the armature I with hook J into engagement with the member K so as to hold it in the position shown in Fig. 1, an adjustable nut P being provided to adjust the tension of the spring. When the member K is released it drops upon and depresses a circuit closer Q which closes the circuit S containing the coil T of a circuit breaker U. This circuit breaker is connected in circuit V with the armature A or preferably forms the main circuit breaker of the machine, and operates to open the armature or both armature and field. Adjustable resistances R, R, are included in circuit with the induced members B, C, and the coils D, E.

The induced members B and C may be of various forms, and may be applied to the machine in various manners. Figs. 8, 9 and 10 show various arrangements. In Fig. 8, the coils are shown as surrounding the pole pieces. In this case the centers of the coils will be on the center lines of the pole pieces, and will therefore be 180 electrical degrees or a multiple thereof apart. These coils are connected to the relay in the manner shown in Fig. 1.

In Fig. 9, the coils are shown as mounted in slots in the pole pieces. These slots must be so located that the center line of one group of slots is spaced 180 electrical

degrees or a multiple thereof from the center line of the group of slots in another pole piece. The coils are, of course, wound around the tooth between two adjacent slots, as is common when windings are laid in slots. It is not necessary to locate these slots in a definite position since they may be located at any point in the pole pieces, just so the center lines of the groups are spaced a proper distance apart. The number of the windings is, of course, immaterial, since as will be shown later, the effect of one will be neutralized by the other during normal operation, that is, when there is no defective coil in the protected winding.

In Fig. 10, the induced members are separate members which are adapted to be placed in inductive relation to the winding A. The coils of the members B and C are wound upon suitable supports *b* and *c*, whereby they may be secured to or held in engagement with the pole pieces. It will be noted that the side faces of the pole pieces form stops so that the members may be spaced apart 180 electrical degrees or a multiple thereof. The specific construction of these members does not however form a part of this invention.

The operation will now be described: Whenever there is a short circuited coil in an armature, the current in this coil will be increased above normal so that it will act upon an external magnetizable object. This has been taken advantage of for testing purposes. For instance, it has been the practice to hold an iron object, as a screw driver, under one of the pole pieces of a dynamo electric machine, the coil in passing the screw driver pulling or vibrating the same so as to give an indication of the defective coil. In accordance with this invention, the inductive action of such a defective coil is taken advantage of in protecting or testing the machine, by placing an induced member in inductive relation to the armature. There are however complications which necessitate that the induced device be specially constructed.

Referring to Fig. 11, this figure shows an ordinary two pole machine in which an armature rotates between the poles in the direction of the arrow. For convenience, the machine in this case is shown as a generator. The lines of force due to the field will, when the armature circuit is open, pass directly across from N to S. When, however, the armature circuit is closed, there will be set up a field at right angles to the axis of the main exciting field, and this will cause the resultant field to be shifted at an angle. The lines of force will then condense under the trailing pole pieces, if the machine is a generator, while under the leading pole pieces, the field will not be so condensed. This is shown diagrammatically in Fig. 11. The condition of the field as shown in Fig. 11 is the same whether the machine is a direct current generator or an alternating current generator, since in both machines, the armature field will be at right angles to the main field. If the machine is a motor, of course, the field as a whole will not be changed much in form from that shown except that the lines of force are now condensed under the leading pole pieces instead of under the trailing pole pieces.

Under normal operations when the entire or a part of the load is being thrown on and off the generator or motor, the current passing through the armature will vary. Since the armature field will thus vary with the load, the angular position of the resultant field and the strength of this resultant field will also vary. That is, in a generator, as the load is increased the resultant field will shift in a clockwise direction while in a motor it will shift in a counter-clockwise direction.

If, now, a single coil like B were placed at the point *x*, for instance, Fig. 11 the shifting of the magnetic field or its variation in strength due to the load being thrown on the machine, would cause a variation in the number of lines of force threading the coil B, and therefore would cause an electro-responsive device connected in circuit to be actuated. The same would be true if the winding were placed around the pole pieces as in Fig. 8, or if the winding would be the pole winding itself as in Fig. 2. In that case, the total number of lines of force threading the coil would vary, and therefore would cause the actuation of the electro-responsive device if a single coil like B were used.

It is noted however, that in Fig. 11 the field at diametrical opposite points *x* and *x'* will be of the same strength and that the variation in the strength of the field at *x* will be the same as that for *x'*, or in the same proportion. Similarly, any two points located diametrically opposite for a two pole machine, will be symmetrical points, since the strength of the field will vary equally or proportionally. If therefore, two coils like B and C are located at these symmetrical points, the effect on them will be equal and therefore during the normal operation of the machine, that is, when there is no defective coil, the variation of the current in the entire armature, as when a load is thrown off or on, will affect both coils B and C equally, and if these coils are connected to a differential relay they will neutralize each other and there will be no actuation of the armature I.

If the induced members B and C are placed symmetrical, that is, at any two points 180 electrical degrees or a multiple thereof apart, there will be no actuation or indication of the armature I. When, how-

ever, one of the coils of the armature A is short-circuited and the armature rotates in the direction of the arrow, Fig. 1, the short circuited coil will pass underneath B, before it will pass underneath C, and therefore it will act inductively upon B before C. This will cause a current to be set up in D before E, so that coil D will be energized before E, whereby the armature I will be actuated, releasing the member K which will drop down on Q, close the circuit S and open the circuit breaker U, which will open the armature or both the armature and field. A similar action will take place when there is a reversed coil in the armature. Similarly when there is an open circuited coil in the armature, the open circuited coil will pass B before it reaches C and therefore the current will be set up in D before E, and the armature will again be actuated to open the circuit breaker U.

The above discussion applies to both alternating and direct current machines, for in both types of machines the inductive action of the armature coils at symmetrical points will be equal. This has been referred to above. The action of a short or open circuited coil on B and C will also be the same in alternating current as in direct current machines. This discussion applies as well to synchronous as to assynchronous machines, and to machines in which there is a rotating magnetic field. In the latter type of machine, the field instead of being stationary revolves, and the armature generally revolves with it. In view of the fact that the field poles are also spaced 180 electrical degrees apart, the field at any two points spaced 180 electrical degrees apart will be of the same strength, that is, the field will vary in the same proportion if the points are considered as rotating around an armature. If therefore two coils B and C are spaced 180 electrical degrees then these coils will always be equally affected by the rotating field and therefore one will neutralize the other. This is true whether the coils B and C be stationary or movable, since they always cut parts of the field which have the same strength. When, however, there is a defective coil in the primary winding, that is, the winding which sets up the rotating field, then since this defective coil is passed by one of the coils B or C, before the other, one of these coils will be affected; thus causing an actuation of the electro-responsive device in the manner described.

It will thus be seen that this invention provides a protection against defective coils within the machine itself but an external short circuit will have no effect since the external short circuit will be distributed over the entire armature winding and no matter how large the current flowing in the armature, the coils D, E, will neutralize each other. By means of the adjustable resistance R, R, the action of the coils B, C, upon the differential coils D, E, may be closely regulated so that under normal conditions, that is, when there are no defective coils, the coils B and C will exactly neutralize each other. By means of the adjustable nut P, the tension of the spring M may be adjusted so as to correct irregularity of the air gap, etc.

Instead of operating a circuit breaker, the circuit S may include a signal or a bell or a signal may be directly operated by means of the armature I, for instance, it may be directly connected to the shaft upon which the member K is pivoted, in fact the differential device G will operate as a signal if it is placed within the view of the operator. It is not necessary that the induced members or coils B, C, be placed underneath the pole pieces, since they may be placed at any other points around the armature, it being only necessary to space them 180 electrical degrees apart, for as pointed out the inductive action of the armature is equal at symmetrical points. It may therefore be desirable to place them between the pole pieces as shown in Fig. 10. The action in this case would of course be weaker but there are inductive impulses which will effect such coils under certain conditions, especially during certain transitory stages of a short circuit. Armature reaction will also affect such coils and tend to actuate them.

Preferably the induced coils B, C, are placed on the machine and form a permanent attachment; they may, however, form with the differential device G a separate portable instrument which may be used to test out armatures. In Fig. 10, the members B and C and their supports may form with the differential relay and its attached parts a portable instrument which may be used for testing purposes. In testing, the members B and C are placed in the position shown in Fig. 10, the side faces of the pole pieces forming stops whereby the members may be correctly spaced. If there is no short or open circuited coil in the winding A, it will be possible to adjust the rheostats R and R′ (Fig. 1) so that there will be no actuation of the armature I. But if there is such a short or open circuited coil, it will be impossible to adjust these rheostats, so as to obtain a neutralization of the magnetic coils D and E, in view of the fact that they are alternately affected by the defective coil. The machine may therefore be tested to determine the existence of a defective coil. Preferably two induced coils B, C, are provided, it is possible however to use a single coil, especially where the device is in the form of a portable instrument. When using a single coil the resistance R and the ten-

sion of the spring P may be adjusted so that under normal condition the armature I will not be actuated but will be actuated only when there is a large current flowing, that is, when there is a short circuit in the armature coil.

In the arrangement shown in Fig. 1, the induced members B, C, form separate coils. In the form shown in Figs. 2, 3 and 4, the field coils on the separate poles perform the functions of the induced members or coils B, C. In the construction shown in Fig. 2, the field coils B^2, C^2, are connected in circuit with the coils D^2, E^2 of the differential device G^2. The operation of this arrangement is similar to that shown in Fig. 1. The defective coil whether short or open circuited will pass the field coils B^2, C^2, in succession and will cause one of the differential coils D^2, E^2, to be energized before the other and thus actuate the armature I^2 to close Q^2 and open circuit breaker U^2.

The construction shown in Fig. 3 is similar to that shown in Fig. 2, except that reactance coils W, W, W, are connected in circuit with the field coils B^3, C^3, and on each side of the connections which lead to the differential coils D^3, E^3. These reactance coils W will not interfere with the D. C. field current but will confine and intensify the inductive impulses.

In the construction shown in Fig. 4, the differential coils D^4, E^4, are connected to field coils B^4, C^4, and spaced 360 electrical degrees apart.

In the construction shown in Fig. 5, the invention is shown as applied to a dynamo electric machine of the type in which the armature A^5 is stationary while the field F^5 rotates. The slip rings which are connected by the usual brushes to the field leads L^5 are designated by *a*, *b*. In order to reduce the number of slip rings to four, those pole windings B^5, C^5, are utilized which are nearest the connections to the slip rings *a*, *b*. One pair of terminals of the differential coils D^5, E^5, are connected to the field leads L^5, while the other terminals are led to brushes bearing on slip rings *c*, *d*, which are connected on the other side of the field pole windings B^5, C^5, as shown. The action of this form of the invention is similar to that shown in the preceding figures. Instead of using the field windings, separate coils may be mounted in the pole pieces, as in Fig. 1.

Fig. 6 shows the invention as applied to an induction motor or induction generator. The coils B^6, C^6, are in this case mounted in slots in the secondary or rotor of the induction motor or generator. These coils are connected to slip rings *m*, *n*, *o*, which connect by brushes to the differential coils D^6, E^6.

Fig. 7 shows the invention applied to an alternating current generator or motor of the inductor type. The inductor generator or motor consists essentially of two complete independent armatures excited by a common magnetic circuit. The armatures which are stationary are designated by A^{7a} and A^{7b}. The armatures are shown in this case as located side by side in order to illustrate the invention more clearly. In a complete machine, however, they are located coaxially as is well known by those skilled in the art and the rotor or inductors F^{7a} and F^{7b} are located on a common shaft. In this case each armature winding must have its separate protective device, therefore the induced coils B^{7a} and C^{7a} are mounted upon the poles of the inductor F^{7a} and are connected to slip rings which are connected in circuit with the differential coils D^{7a} and E^{7a}. The induced coils B^{7b} and C^{7b} for the armature winding A^{7b} are similarly placed on the inductor F^{7b} and connected in circuit with the differential coils D^{7b} and E^{7b}. The differential coils in this case are mounted upon differential devices of similar construction to that shown in Figs. 1, 2 and 3. For the sake of simplicity, however, these devices have been omitted in Fig. 7, as well as in Figs. 4, 5 and 6. It is to be understood, however, that in each of the constructions each of the differential coils actuates an armature which opens a circuit breaker in the circuit of the winding which it protects, or operates a signal as described in connection with Figs. 1, 2 and 3. In the construction shown in Fig. 7, the circuit S^7 includes a signal for the attendant. A single signal circuit S^7 is provided for both armatures, the two circuit closers Q^{7a} and Q^{7b} being connected in multiple across the line S^7. In this way a single signal circuit is utilized for notifying the attendant of a defect in either of the armature circuits. A circuit breaker for the machine may be connected in circuit the armatures to be actuated by the circuit closers Q^{7a} and Q^{7b}.

The device will not only protect the winding against short circuits or open circuits in the individual coils of the winding but also against short and open circuits of sections of the winding. It will be obvious that a section of a winding which is short or open circuited will act in a similar manner as a short or open circuit in a single coil.

This invention therefore provides a device which will protect a dynamo electric machine against the damage caused by defective coils and also provides means and a method whereby such defects may be discovered or tested out. The invention is applicable to all types of dynamo electric machinery whether generators or motors or whether direct or alternating current and whether the winding to be protected or tested is movable or stationary.

In the claims the terms "induced member," "winding," and "coil" are used. It is to be understood that these terms are to be taken in their broadest sense, so as to include forms in which the induced members B, C, are separate coils as in Figs. 1, 6 and 7, and also forms in which they are the windings on the field poles. Both forms are equivalent constructions. The "inducing member" and "induced member" are respectively the members which induce and have induced in them an electromotive force of current.

It is further obvious that various changes may be made without departing from the spirit of this invention and it is therefore to be understood that this invention is not to be limited to the specific construction shown and described.

Having described my invention what I claim and desire to secure by Letters-Patent is,

1. The combination with a dynamo electric machine having a rotor and a stator and a winding on one of said members, of a symmetrically arranged induced winding on the other of said members, and an electro-responsive device connected to said induced winding and influenced by unsymmetrical conditions in the first mentioned winding.

2. Means for detecting defects in an electric machine having a rotor member and a stator member and a winding on one of said members, said means comprising an induced winding on the other of said members arranged in inductive relation to the first winding, said induced winding comprising a pair of coils symmetrically spaced with respect to the first winding, and an electrical device connected to the coils and responsive to variations in said first winding.

3. In a dynamo-electric machine, the combination with a field frame and an armature having a winding and relatively movable, of an induced winding on the field frame in inductive relation to the armature winding, said induced winding comprising coils symmetrically spaced with respect to the armature winding, and a differential electro-responsive device connected to the coils.

4. Means for detecting defects in an electric machine having a field frame provided with poles and an armature movable relatively thereto, said means comprising an induced winding having coils located on separate field poles and an electro-responsive device connected to the coils and actuated by variations of the current in the armature winding.

5. In a dynamo-electric machine, the combination with a field frame having poles and an armature relatively movable, of an induced winding comprising coils located on separate poles, and a differential electro-responsive device connected to the coils.

6. In a dynamo electric machine, the combination with a field and an armature relatively movable, of a field winding adapted to be inductively affected by variations in the armature field, and an electro-responsive device connected to said field winding and adapted to be actuated and indicate an abnormal condition in the armature winding due to the variations in the armature field.

7. In a dynamo-electric machine, the combination with a field and an armature relatively movable, of an electro-responsive device connected to the windings on the separate field poles and adapted to indicate an abnormal condition in the armature winding.

8. In a dynamo-electric machine, the combination with a field and an armature relatively movable, of a differential electro-responsive device having coils, connections between one coil and the winding on one field pole, and connections between the other coil and the winding on the other field pole.

9. In a dynamo electric machine, the combination with a field and an armature relatively movable, of a field winding adapted to be inductively affected by variations in the armature field, a circuit breaker controlling the external circuit of said machine, and means connected to said field winding and actuated due to the variations in the armature field for operating said circuit breaker.

10. In a dynamo-electric machine, the combination with a field and an armature relatively movable, of a circuit breaker for the machine, operating means for said circuit breaker including a differential electro-magnet, and connections between the electro-magnet and the separate field coil windings.

11. In a dynamo-electric machine, the combination with a field and an armature relatively movable, of an electro-responsive device connected to one of the field pole windings, and reactance coils in the field circuit on each side of the leads which connect the electro-responsive device to the field pole winding.

12. In a dynamo-electric machine, the combination with a field and an armature relatively movable, of a differential electro-responsive device having coils, connections between one of the coils and the winding on one field pole, connections between the other coil and the winding on the other field pole, and reactance coils in the field winding circuit located on each side of the leads which connect the coils of the electro-responsive device to the field windings.

13. The combination with a dynamo-electric machine comprising a rotatable and a stationary element, of two electrical circuits

associated therewith, each circuit comprising a coil carried by one of said elements, a winding, and means for adjusting the resistance of the circuit, the two windings of the circuits being differentially associated so as to normally neutralize one another, and a signal associated with said windings and adapted to be actuated when sufficient current flows in either of said windings to overcome the neutralizing effect of the other winding.

14. In apparatus of the class described, the combination with a rotor and a stator and a winding on one of said members, of a pair of induced members and field coils on the other of said members, and an electro-responsive device connected to said induced members and including means adapted to indicate an abnormal condition in one of said members.

15. Means for detecting the presence of a defect in an electric machine having a rotor member, a stator member, and a winding on one of said members, said means comprising a mechanism having parts symmetrically arranged with respect to normal electrical conditions in said machine and passive under such conditions but rendered active in response to abnormal and unsymmetrical conditions, substantially as set forth.

16. In an electric machine, the combination of a rotor having a winding thereon, a stator having a winding thereon, said rotor and stator windings being inductively related, and means associated with one of said windings and including an electrically operated device having parts symmetrically disposed with respect to the field set up by one of said windings and arranged to operate only when an unsymmetrical condition is established in one of the windings.

17. Means for detecting defective coils in an electric machine having a rotor member, a stator member and a winding on one of said members, said means comprising an electro-responsive device having two parts separated an angular distance of 180 electrical degrees or a multiple thereof, substantially as set forth.

In testimony whereof I affix my signature in presence of two witnesses.

ERNEST O. E. KLIPPHAHN.

Witnesses:
I. B. ADAMS,
C. H. BECKER.