Dec. 20, 1932. C. M. LAFFOON 1,891,716

WINDING FOR DYNAMO ELECTRIC MACHINES

Filed April 4, 1930

Fig. 1.

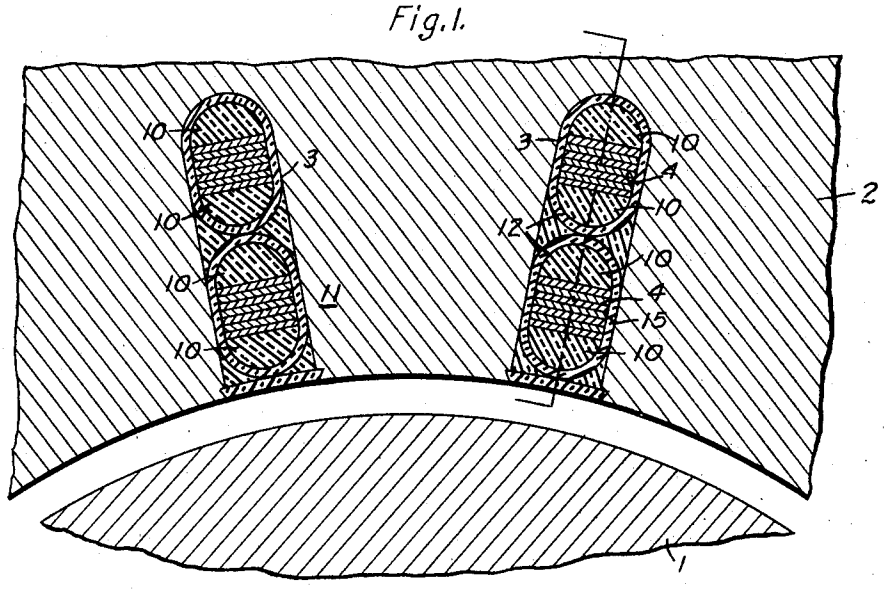
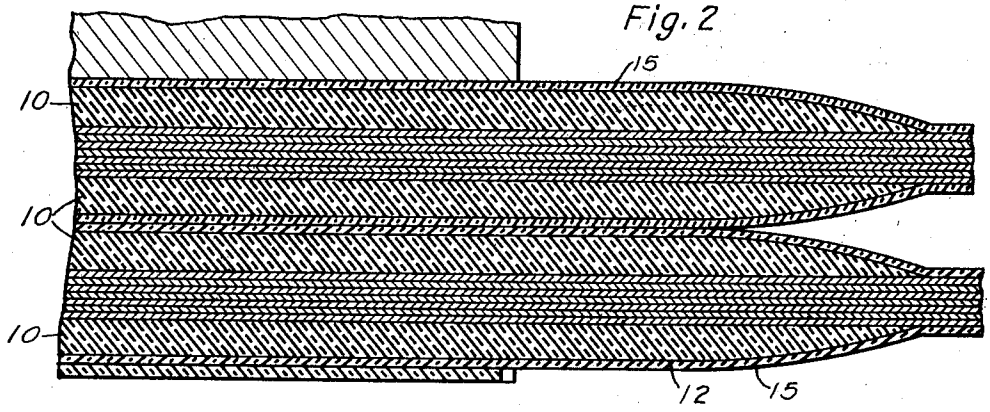


Fig. 2



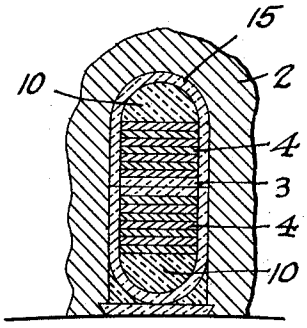
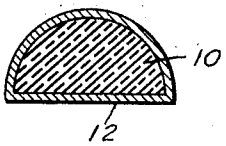


Fig. 4.

Fig. 3.



INVENTOR

Carthrae M. Laffoon

BY

Wesley & Carr

ATTORNEY

Patented Dec. 20, 1932 1,891,716

UNITED STATES PATENT OFFICE

CARTHRAE M. LAFFOON, OF IRWIN, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA

WINDING FOR DYNAMO ELECTRIC MACHINES

Application filed April 4, 1930. Serial No. 441,589.

My invention relates to a high-voltage dynamo-electric machine and particularly to winding elements for such machines.

The need for high-voltage dynamo-electric machines has long been felt, but, while larger and ever larger machines have been built, and increasingly higher transmitting voltages are being employed, the generated voltages and the load voltages have remained practically stationary because of the lack of a satisfactory insulation for the higher-voltage dynamo-electric machines. The result of this has been the use of low voltage (such as 11000 or 18000 volts) and enormous currents in rotary apparatus. Particularly is this true in generators.

These enormous currents have been causing more and ever more annoyance. The heat losses resulting from the heavy currents have become such a problem as to overshadow the whole industry.

Also, these enormous currents have been a great problem in the switching operations. With modern circuit breakers, very high voltages can easily be interrupted without serious arcing or destruction of the switch elements, but the heavy currents delivered by generators are almost impossible to interrupt without serious injury to the apparatus. This has resulted in the direct connection of generators to step-up transformers so that any switching could be done at comparatively high voltages, such as 33000 or 66000. This has made switching possible but has in no way alleviated the heating in the generator and its leads and has, in fact, added greatly to the lengths of the low-tension high-current leads.

I have discovered that, with know insulation and the use of a voltage-gradient equalizer on the windings, I can insulate a dynamo-electric machine for comparatively high voltages such as 33000 volts or 66000 volts and thus reduce the high machine currents and make possible a great reduction in the current losses in the machine, as well as making possible an increase in the power output.

My invention also makes it possible to use direct-connected synchronous condensers on normal distribution voltages.

It is general practice to form the conductors of dynamo-electric machines of a plurality of rectangular copper bars in parallel. To prevent eddy-current losses, the individual bars are provided with insulation of sufficient thickness or strength to prevent cross currents between them. Since the individual bars of a conductor must of necessity, be at different levels in the slot they will have slightly different induced potentials. In order to equalize the potentials and further limit circulating currents in the conductors, the individual bars are transposed in such manner that each bar is at every level in the conductor. These bars are made with substantially square corners to facilitate transposition and to eliminate voids in the slots.

I have found that these square corners are the seat of insulation trouble on high-voltage machines. This seems to be the result of at least two immediate vices. First, the potential-gradient through the insulation is highly concentrated at the sharp corners, so that the voltage stress in the insulation is greatly increased at these points, eventually causing breakdown at the corners and thereby disabling the machine. Second, this breakdown is further aided by the mechanical disruption of the insulation at the point where it makes the short bend to closely follow the contour of the conductor.

Because the bars are of the transposed type, it is not commercially feasible to make them by machine, except with angular corners. Even if they were finished by hand, only the extreme corners could be removed without seriously impairing the efficiency of the bars. This partial rounding of the edges, while a step in the right direction, is both expensive and inefficient.

I have eliminated all of this trouble by inserting in the windings potential-gradient equalizers by the use of which the insulation is protected, both electrically and mechanically.

It is an object of my invention to provide an improved dynamo-electric machine.

It is a further object of my invention to provide an improved winding for a dynamo-electric machine.

A still further object of my invention is to provide a potential-gradient equalizer or protection member for the windings of a dynamo-electric machine.

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

Figure 1 is a fragmentary cross sectional view of a dynamo-electric machine embodying my invention,

Fig. 2 is a fragmentary view of the end of my winding adjacent to the end connections, and,

Fig. 3 is a detailed cross section of one of my equalizing strips.

Fig. 4 shows a modification.

The apparatus disclosed in Fig. 1 comprises a rotor 1 for a dynamo-electric machine and a laminated stator 2 for such machine. The stator is provided with a plurality of winding slots 3 opening to the periphery of the stator member. These slots 3 are provided with arcuate bottom portions to accommodate my improved coil. This coil comprises a conductor section composed of a plurality of superposed conductor elements 4 usually in the form of rectangular conductor bars and provided with a desired thickness of insulation to insulate the individual bars. The conductor sections are preferably of the type known as transposed, that is, individual bars have been off-set and transferred to different levels in the conductor in order to provide a high-resistance path for the circulating or eddy currents in the bar.

The superposed conductor bars form a rectangular conductor section of less width than the width of the slot in which they are to be received. At the top and bottom of each rectangular conductor section is placed my potential equalizer member 10. The potential equalizer member is of a width equal to the width of the conductor section and shaped on one side to conform to the surface of such section, the opposite side being arcuate. Preferably, the equalizer member will be semi-cylindrical in cross section.

To prevent circulating or eddy currents in the equalizer strip, I prefer to make this strip of substantially non-conducting material, such as fibre, micarta, or wood. However, in order to utilize this strip to distribute potential to all parts of its surface, it is necessary to provide its surface with a conducting layer 12 which may be a metal sheath but is preferably a high-resistance material, such as metal paint, treated fabric, carbonized material or graphite. The conducting layer 12 may be applied only to the arcuate surface but, for ease in application, I prefer to coat the entire surface of the strip. I have found that the material of the high-resistance coating should have a resistance of the order of 5 to 200 ohms per cubic inch. If a material of lower resistance is applied, the coating is liable to damage by eddy currents.

In some cases, it may be found desirable to apply the equalizer strip only to that portion of the coil lying in or near the slots of the machine as the equalizer strip permits the maximum use of the insulating material and the consequent improvement of the space factor of the machine. However, I prefer to extend the equalizer strip to a point adjacent to the end connections so that it will be but little shorter than the conductor itself. In either case I prefer to taper the strip gradually from the outer to the inner space to prevent an abrupt change of gradient in the insulation and to prevent the abrupt termination of the strip and the consequent difficulties of applying the insulation at its end.

In those machines which have a plurality of conductors per slot, it will sometimes be possible to eliminate the equalizer strips from the adjacent edges of the conductors and to utilize them only at the top and the bottom of the slot as shown in Fig. 4.

Also, by the use of my invention, it will be possible to increase the reliability of insulation in present low-voltage machines.

The operation of my device is as follows:

Upon energizing the machine, a voltage will be induced in the conductors and this voltage will be communicated to the conducting surface of the equalizer strip in such manner that the coil, as a unit, will have no sharp corners. This elimination of sharp corners will so distribute the potential of the coil that the potential-gradient from the coil through the insulation 15 will be the potential-gradient from a cylindrical surface, and, consequently, constant at all points on the coil. Also, since the major portion of the insulation 15 has to be applied to, or wrapped around the assembled conductor section 4 and equalizer strips 10, there will be no sharp bends in the insulation 15, and, consequently, no mechanical injury to the insulation. The insulation is thereby enabled to withstand much higher voltage than would have been possible if the insulation had been applied directly to the rectangular conductor sections.

While it is true that the use of my equalizer strips has made necessary a deepening of the slots 3 in which the conductors are placed, this has added a secondary advantage to the machine by increasing its reactance to enable it the better to withstand surges or other service phenomena. Other advantages and details of construction are set forth in my paper entitled "Increased voltages for synchronous machines," presented at the Great Lakes district meeting of the American Institute of Electrical Engineers on December 2, 1929.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, there-

fore, is not to be restricted except in so far as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. A dynamo-electric machine comprising a rotor and a stator, the stator having winding slots therein, said winding slots having an arcute bottom portion, windings in said slots, said windings comprising a plurality of superposed conductor bars assembled to form a rectangular conductor section of less size than the slots, half-round potential-equalizer strips applied to the top and bottom of said conductor section, said strips being of less length than the conductor section to provide space at the end of such section for the end connections, said equalizer strips tapering at the ends to facilitate the application of insulating material, conducting surfaces on said potential equalizer strips, insulating material applied to said conductor section and said stress strips as a unit, said insulating material being of such thickness that the complete winding snugly fits the winding slots.

2. A potential-gradient equalizer for a winding of a dynamo-electric machine having a substantially rectangular conductor, which comprises a semi-cylindrical member applied to the conductor, said semi-cylindrical member having a conducting surface.

3. A winding for a dynamo-electric machine comprising a plurality of superposed conductor bars forming a substantially rectangular conductor, insulation on each of the conductor bars, potential-equalizer strips applied to the top and the bottom of the superposed conductor bars, said strips being substantially half round in cross section, a conducting surface on the strips and insulation surrounding the superposed conductor bars and the equalizer strips as a unit.

4. A potential-gradient equalizer for the conductors of a winding of a dynamo-electric machine comprising a substantially non-conducting strip of a width equal to the width of the conductor and having a flat surface to conform to the surface of the conductor, an arcuate surface on the side remote from the conductor, the equalizer being of less length than the conductor to facilitate the application of end connections, the ends of the equalizer tapering from the arcuate side to the flat surface to facilitate the application of insulating material, and a coating of conducting material of high resistance on said equalizer.

5. A winding for a dynamo-electric machine comprising a rectangular conductor composed of a plurality of individual conductor elements, means applied to that portion of the conductor received in the machine core for changing the effective shape of the conductor, insulation surrounding the conductor and the equalizing means having a surface conforming to the shape of the conductor and an arcuate outer surface for the said equalizing means providing substantially the same potential gradient through the insulation as that provided by a cylindrical surface and said equalizer means having a conducting surface.

6. A winding for a dynamo-electric machine having winding slots comprising a rectangular conductor composed of a plurality of individual conductor elements, means for preventing excessive circulating currents in the conductor, potential-equalizing means applied to the portion of the conductor in the winding slot, insulation surrounding the conductor and the equalizing means, the said equalizing means having an arcuate outer surface for providing a potential gradient through the insulation substantially the same as that provided by a cylindrical surface, a conducting surface on said equalizer means, said conducting surface being in electrical contact with a portion of the conductor.

7. A potential-gradient equalizer for the winding conductors of a dynamo-electric machine, comprising an equalizer means having an arcuate outer surface applied to the face of the conductors and extending for the major portion of their length, the body of said equalizer means being substantially non-conducting, and a high resistance conducting coating on the surface of the equalizing means.

8. A dynamo-electric machine comprising a rotor and a stator, the stator having winding slots therein, conductors in said slots, potential-gradient equalizer strips applied to the tops and bottoms of said conductors for changing the effective shape thereof, said equalizer strips being of less length than the conductors, and insulation surrounding the conductor and the equalizing strip as a unit.

9. A dynamo-electric machine comprising a rotor and a stator, the stator being provided with winding slots, a rectangular conductor in each of said slots, a potential-gradient equalizer strip applied to the portion of said conductor adjacent to the stator, said equalizer strip having an arcuate outer surface and a high-resistance conducting surface and insulation enclosing the conductor and the equalizing strip as a unit.

10. A potential-gradient equalizer for the winding of a dynamo-electric machine, said winding having a conductor with substantially angular longitudinal edges, an equalizer strip applied to and extending along said conductor, said strip having a body of high electrical resistance and a conducting surface, the outer surface of said strip being of arcuate cross section for changing the effective shape of the conductor.

11. A winding for a dynamo-electric machine having a core, the winding comprising substantially rectangular conductors extending through slots in the core, substantially

half round strips applied to the top and bottom of the position of the conductors within the core, said strips having a conducting surface for changing the effective shape of the conductor and insulation surrounding the conductor and applied strips as a unit.

In testimony whereof, I have hereunto subscribed my name this 31st day of March, 1930.

CARTHRAE M. LAFFOON.