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LAMINATED END-SHIELD FOR TURBINE GENERATORS

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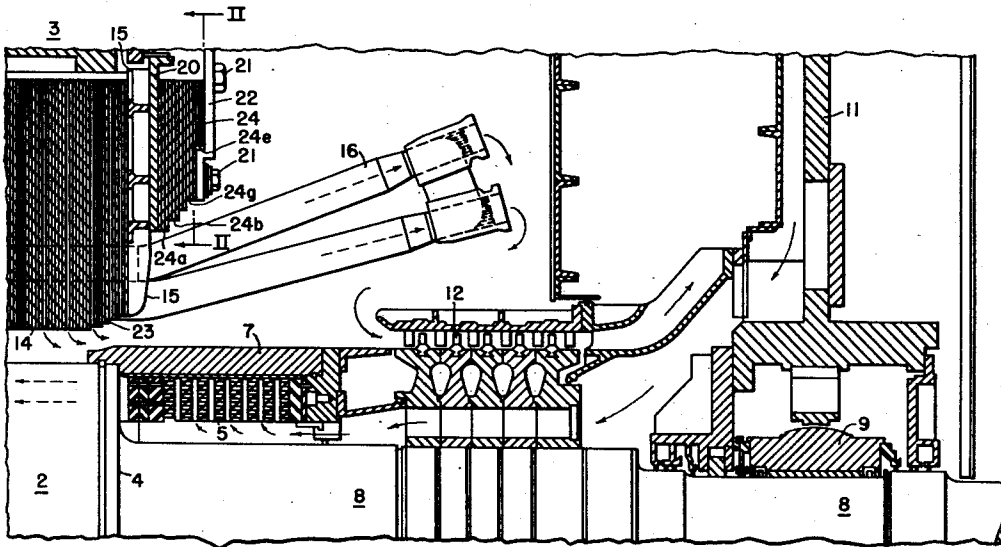


Fig. 1.

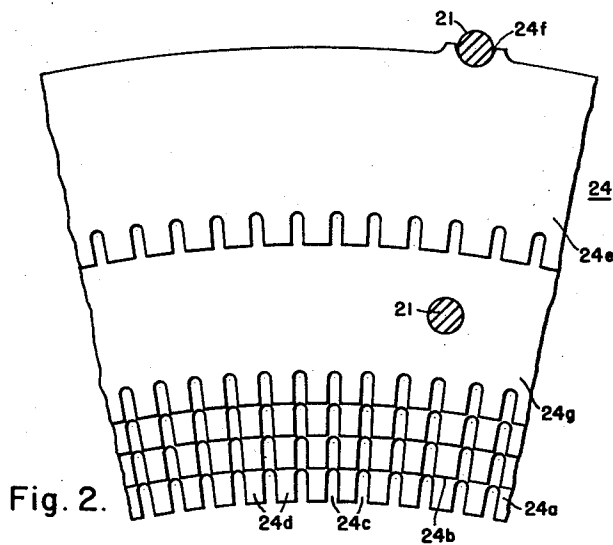


Fig. 2.

WITNESSES

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LAMINATED END-SHIELD FOR TURBINE GENERATORS

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My invention relates to a turbine generator, which is a large, high-speed, two-pole alternating-current generator, having a cylindrical-core rotor-member carrying a field-winding, and a cylindrical-bore stator-member carrying a high-voltage alternating-current winding. Such machines have sometimes heretofore been subject to stray-flux difficulties, necessitating certain special design-features for reducing eddy-current heating as a result of leakage fluxes in the end-winding spaces, causing overheating in certain parts of the ends of the stator-core. With the modern trend toward hydrogen-cooled machines at high gaseous pressures, and direct conductor-cooling, the amounts of current carried by the windings have been considerably increased, so that it is all the more necessary or advantageous to give attention to the amelioration of heating due to the leakage-fluxes.

My present invention relates to a stepped-back construction of a laminated magnetizable end-shield for reducing, to a low value, the eddy-current losses caused in the ends of the stator by the end leakage or stray flux of the machine.

An exemplary form of embodiment of my invention is shown in the accompanying drawing, wherein:

Figure 1 is a somewhat simplified fragmentary longitudinal sectional view of the top half of one end of a machine embodying my invention, and

Figure 2 is a fragmentary end-view of the end-shield on a somewhat larger scale, as seen from the section-plane II—II of Fig. 1.

I have shown my invention embodied in a large hydrogen-cooled two-pole turbine-generator, having a rotor-member 2 and a stator-member 3. The rotor-member has a slotted cylindrical rotor-core 4, carrying a rotor-winding 5 which is a direct-current field-winding having coil-sides disposed in the slots of the rotor-core. The end-turns of the rotor-winding 5 are retained by a retaining ring 7, which may be of either magnetizable or non-magnetizable material, each having advantages. The rotor-member is carried by a shaft 8 which is journaled in suitable bearings 9 carried by the frame 11 of the machine. The rotor-shaft 8 also carries a fan or blower 12 for ventilating purposes.

The stator-member 3 has a laminated stator-core 14 having a cylindrical bore which marks the outer boundary of the air gap between the stator and the rotor cores. Disposed at each end of the stator-core 14 is a slotted finger-ring member 15 which presses against that end of the stator-core. The stator-core 14 carries the high-voltage alternating-current stator-winding 16, having coil-sides which are disposed in the slots of the stator-core and the finger-ring. The finger-ring member 15 may advantageously be made of non-magnetic material, although sometimes it may be possible to make it of magnetizable material without causing too much stray-flux overheating. The finger-ring members 15, at the two ends of the stator-core 14, are pressed against the core by means of end-plates 20, and the end-plates at the two ends of the stator-core are drawn toward each other by means of

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through-bolts 21 which seat against elongated washers 22.

Heretofore, the end-plates 20, or their equivalents, have sometimes been made of non-magnetizable material, and sometimes of magnetizable material. When made of magnetizable material, the end plates 20 of the prior art have served the function of diverting some of the stray flux from the stator-core, so as to prevent the end-laminations of the core from becoming overheated by said stray flux. Heretofore, when the stray flux has been large, the end-plates 20, or their equivalents, have advantageously been made of a high-resistance metal, for reducing the eddy-current loss therein. When these end-plates 20 have been made of magnetizable material, silicon-steel has frequently been used, because of its high resistivity and its resultant low eddy-current losses.

The stray or leakage-fluxes arise in the following manner. The rotor-member 2 is the field-member of the machine, and the rotor-winding 5 is a direct-current field-winding. In a large turbine-generator, the field-member has a two-pole field. Most of the flux which comes out of the north-pole portion of the rotor-core 4 crosses the air gap into the stator-core 14, interlinks with the stator winding 16, passes circumferentially halfway around the stator core, and comes out again at the air gap, returning into the rotor-core 4 at the south-pole portion which is diametrically opposite to the north-pole portion. In a turbine generator, several reasons contribute to the necessity for making the air gap rather large, so that it takes a considerable magnetomotive force to drive this useful flux through the air gap. This results in a considerable amount of flux-leakage or stray flux. This flux fringes out from the ends of the rotor-core 4, passing through the retaining ring 7 if the latter is magnetizable, or passing through the shaft 8 if the retaining ring is not magnetizable. This stray flux then passes through the end-winding space and comes in, in a more or less longitudinal direction, back toward the end of the stator-core 4 at each end of the machine. The currents which are carried by the end-winding portions of the stator-winding 16 also contribute to the magnitude of this stray flux.

The stray-flux problems are so great that it is practically universally customary to step back the inner diameters of the last few laminations of the stator-core 14, as shown at 23, so that more of this stray flux will enter these stepped-back stator-laminations edgewise, instead of impinging against the flat sides of the laminations, where eddy-currents can be produced, which would heat the laminations.

In cases where the end-plates 20, or their equivalents, have hitherto been made of magnetizable material, these end-plates have served as magnetic shields for receiving this stray flux, and intercepting it before it reaches the respective ends of the stator-core 14, so that most or much of the stray flux enters these previously used magnetizable end-plates 20, and then travels halfway around the plates, to come out again and return to the opposite pole of the rotor member.

According to my present invention, I provide a special magnetic end-shield 24 which presses against each finger-ring member 15, or against each end-plate 20 if such an end-plate is used in addition to the finger-ring, as shown. Each end-shield 24 is disposed between its end-plate 20 and the elongated washers 22 which are engaged by the through-bolts 21. Each magnetic end-shield 24, in accordance with my invention, is made of substantially radially disposed laminations, which are preferably punchings made from the same material as the punchings of the laminated stator-core 14.

The inner diameter of the innermost end-shield lamination 24a—the one which is closest to its finger-ring mem-

ber 15—is large enough to fit outside of the coil-sides of the alternating-current winding 16. Successive laminations, or groups of laminations, of the magnetic end-shield 24 have their inner diameters progressively stepped back, or increased in diameter, so as to reduce the broadside areas of said successive laminations or groups of laminations, in a manner suitable for the stray end-flux pattern of the generator.

The object of this stepped-back laminated end-shield construction is to facilitate the edgewise entry (or exit) of the stray flux into (or out of) the end-shield laminations, and to decrease the amount of stray flux which enters (or leaves) said end-shield laminations in a broadside direction. If alternating flux flows into and out of a magnetizable lamination or punching at its broadside face, it produces eddy-currents and heating; whereas, if the flux enters and leaves the punching or lamination at its end or edge, the small thickness of the lamination causes the lamination to have a considerable resistance to the flow of eddy currents, thus reducing the magnitude of the eddy currents and the heating-effects due to eddy currents. This is the reason why laminated magnetic structures are used for carrying alternating-current fluxes, as is well known. But where we are dealing with stray or leakage end-fluxes of the machine, which approach more or less broadside, with respect to the end of the stator-core, it is necessary to provide a stepped-back construction by which the stray end-flux can get into my magnetic end-shield at an edge or end of each lamination, which will be a preferred magnetic path because the edgewise-entering flux will not be bucked by substantial eddy currents in the end-shield laminations.

As is shown more clearly in Fig. 2, I prefer to have at least some of the laminations of the end-shield 24 punched so that their inner edges 24b, which are closest to the rotor-member, or closest to the longitudinal axis of the machine, are serrated so as to increase the effective lengths of these inner edges, and thus to increase the amount of stray flux which enters these end-shield laminations through these serrated inner edges, rather than entering the laminations in a direction which is broadside of the laminations. I am using the term serrated in the sense of being notched or provided with slots 24c and teeth 24d, as shown in Fig. 2, or any similar construction which increases the amount of end-surface of the laminations.

In carrying out my invention, it is necessary to continue this stepped-back end-shield construction over a considerable portion of the ends of the stator-core 14, so as to prevent as much as possible of the flux from entering the magnetic end-shield in a broadside direction, so as to minimize the eddy-current heating of the end-shield. To this end, it is desirable that the radial depth of the last end-shield lamination or group of laminations 24e shall be considerably less than one half of the radial depth of the innermost end-shield lamination 24a, measuring the radial depth from the inner radius to the outer radius of the lamination.

It is quite advantageous that all of the laminations of my magnetic end-shield 24 shall have the same outer diameter as the stator-core 14, so that the end-shield laminations, as well as the stator-core laminations, may be built up, or mounted, on the outermost retaining or through-bolt 21, as by being provided with the usual mounting-notches 24f as shown in Fig. 2.

In a preferred form of construction, which is illustrated in the drawing, each magnetic end-shield 24 comprises a plurality of diverse groups of substantially radially disposed laminations of different sizes, each group comprising one or more laminations. All of these groups, except the very last group, or the group which is furthest away from the finger-ring member 15, as shown at 24e, have their inner diameters progressively stepped back (or enlarged), in relatively short steps; but the very last group

24e of the end-shield laminations contains a considerably larger number of laminations than any of the other groups, and it has its inner diameter stepped back in a relatively large step, so that its inner diameter is considerably larger than the inner diameter of the next adjacent lamination 24g of the end-shield.

This end-shield construction makes possible the use of a bent type of elongated washer 22, which has its outer portion extending radially across the last group of end-shield laminations 24e, while an inner bent portion of the elongated washer 22 extends radially across the exposed surface of the next adjacent end-shield lamination 24g, in the relatively large radial space or step which is provided by the large disparity between the inner diameter of the last group 24e as compared with the inner diameter of the next adjacent group 24g. Since this end group 24e is thicker (comprising more laminations), and since the stray end-flux of the machine becomes somewhat diminished in intensity at points furthest away from the shaft 8, it may not be as necessary to serrate the inner diameters of this last group 24, although a serrated construction is preferred at this point, as shown. Because of the relatively small radial depth of this last group of end-shield laminations 24e, it is possible for the stray flux to divide itself, and enter this group of laminations at both the outer diameter and the inner diameter thereof.

My improved end-plate construction is particularly needed in a modern heavy-duty machine in which the output has been very considerably increased over previous machines, volume for volume. This increased output is obtained by working the winding-conductors harder (by making them carry more current), and also perhaps by working the iron cores harder. This increased current-output is obtained by filling the machine-frame 11 with hydrogen at pressures which may range between 30 and 100 pounds per square inch, gauge, and by using the now-well-established principle of direct conductor-cooling of the stator and rotor windings 16 and 5, wherein the cooling medium, which is shown as being hydrogen, is directly circulated along these conductors in good thermal contact therewith, so as to directly withdraw the conductor-heat from the conductors themselves, as distinguished from withdrawing the conductor-heat from the stator and rotor cores, for example. This direct conductor-heating is indicated, on the accompanying drawing, by the arrows representing the paths of the circulating hydrogen.

While my invention finds its most important application in such a conductor-cooled machine, it will be understood, of course, that the invention is not altogether limited thereto.

I claim as my invention:

1. A two-pole alternating-current generator, having a rotor-member and stator-member; the rotor-member having a slotted rotor-core and a direct-current field-winding having coil-sides disposed in the slots of the rotor-core; and the stator-member having a slotted, cylindrical-bore, laminated stator-core, a slotted finger-ring member pressing against each end of the stator-core, an alternating-current winding having coil-sides disposed in the slots of the stator-core and the finger-ring, and a laminated magnetic end-shield pressing against each finger-ring member; each magnetic end-shield having substantially radially disposed laminations; the inner diameter of the innermost end-shield lamination, which is closest to its finger-ring member, being large enough to fit outside of the coil-sides of the alternating-current winding; and successive laminations, or groups of laminations, of the magnetic end-shield having their inner diameters progressively stepped back so as to reduce the broadside areas of said successive laminations or groups of laminations, in a manner suitable for the stray end-flux pattern of the generator, to facilitate the edgewise entry of the stray flux into the end-shield laminations and to decrease the

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amount of stray flux which enters said end-shield laminations in a broadside direction.

2. The invention as defined in claim 1, characterized by at least some of the end-shield laminations having their inner edges, which are closest to the rotor-member, serrated so as to increase the effective lengths of these inner edges, and thus to increase the amount of stray flux which enters these end-shield laminations through these inner edges, rather than in a direction broadside of the laminations.

3. The invention as defined in claim 1, characterized by the radial depth of the last end-shield lamination being considerably less than one half of the radial depth of the innermost end-shield lamination.

4. The invention as defined in claim 1, characterized by the outer diameters of the end-shield laminations being the same as the outer diameter of the stator-core.

5. A two-pole alternating-current generator, having a rotor-member and a stator-member; the rotor-member having a slotted rotor-core and a direct-current field winding having coil-sides disposed in the slots of the rotor-core; and the stator-member having a slotted, cylindrical-bore, laminated stator-core, a slotted finger-ring member pressing against each end of the stator-core, an alternating-current winding having coil-sides disposed in the slots of the stator-core and the finger-ring, and a laminated magnetic end-shield pressing against each finger-ring member; each magnetic end-shield comprising a plurality of diverse groups of substantially radially disposed laminations of different sizes, each group comprising one

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or more laminations; the inner diameter of the innermost group, which is closest to the finger-ring member, being large enough to fit outside of the coil-sides of the alternating-current winding; the next successive groups, all except the very last group, having their inner diameters progressively stepped back, in relatively small steps; and the very last group of the end-shield laminations containing a considerably larger number of laminations than any of the other groups, and having its inner diameter stepped back in a relatively large step.

6. The invention as defined in claim 5, characterized by at least all except the last of said groups of end-shield laminations having their inner edges, which are closest to the rotor-member, serrated so as to increase the effective lengths of these inner edges, and thus to increase the amount of stray flux which enters these end-shield laminations through these inner edges, rather than in a direction broadside of the laminations.

7. The invention as defined in claim 5, characterized by the radial depth of the last group of end-shield laminations being considerably less than one half of the radial depth of the innermost group.

8. The invention as defined in claim 5, characterized by the outer diameters of the end-shield laminations being the same as the outer diameter of the stator-core.

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