PATENT SPECIFICATION (11) 1 302 549

DRAWINGS ATTACHED

1 302 549

(21) Application No. 41630/69 (22) Filed 20 Aug. 1969 (19)

(23) Complete Specification filed 4 Aug. 1970

(44) Complete Specification published 10 Jan. 1973

(51) International Classification H02K 19/22

(52) Index at acceptance

H2A 11B 1C10A 22 2E11 2E4A 2E4Y 2EX

(72) Inventor AUSTIN HUGHES

(54) SYNCHRONOUS ALTERNATING CURRENT ELECTRICAL MACHINES

(71) We, INTERNATIONAL RESEARCH & DEVELOPMENT COMPANY LIMITED, a British Company of Fossway, Newcastle-upon-Tyne 6, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a synchronous alternating current machine having a D.C. excited rotor field winding of superconducting material and a stator armature winding of non-superconducting material.

The use of a superconducting field winding eliminates the need for a stator core of magnetic material and the stator winding conductors may be supported in air or in a casing of non-magnetic material such as epoxy resin. Because of the high magnetic field intensities produced, however, it is necessary to have a magnetic shield surrounding the rotor but this is usually spaced well away from the rotor so as to lie outside the areas of high flux density.

Large machines of this kind can provide problems under short circuit conditions as the currents flowing under such conditions may be sufficient to damage the windings severely.

Short circuit currents can be reduced by using magnetic material such as iron in the high flux regions, but the need to use such material detracts from one of the main advantages of a superconducting winding in that a magnetic core can be dispensed with.

In accordance with the present invention there is provided a synchronous alternating current electrical machine having a D.C. excited rotor field winding of superconducting material and a stator armature winding of non-superconducting material, the stator winding having active conductors supported in a non-magnetic environment adjacent the rotor, reactance conductors located in a magnetic shield surrounding the active conductors and the rotor, and end connections connecting the active and reactance conductors in series.

The reactance conductors of the winding are associated with the magnetic material of the magnetic shield to provide sufficient reactance to limit short circuit currents without the necessity of providing any additional magnetic material around the active conductors of the winding. The active conductors of the winding can be carried by an annular body of non-magnetic material.

The active and reactance conductors of the winding preferably extend parallel to the axis of the rotor and the end connections extend generally radially with respect to the rotor axis. In a preferred construction the active conductors of the winding form a double layer winding, and the reactance conductors present a number of poles differing from that of the active conductors.

The reactance conductors can be located in slots in a laminated magnetic shield or in an annular gap between two cylinders of laminations forming the shield.

The invention will now be described in more detail with the aid of examples illustrated in the accompanying drawings, in which:—

Fig. 1 is a longitudinal section of a synchronous A.C. machine in accordance with the invention,

Fig. 2 is a partial section on the line II—II of Fig. 1,

Fig. 3 is a section similar to that of Fig. 2 but showing alternative arrangements of the stator winding in the magnetic shield, and

Fig. 4 is a schematic winding diagram of the stator winding of the machine of Fig. 1.

The machine shown in Fig. 1 is a synchronous alternating current generator having a hollow steel rotor 10 within which is supported a direct current field winding 11 of superconducting material. The rotor 10 has stub shafts 12 and 13 at each end which are supported in bearings 14 and 15, respectively, carried by brackets 16 and 17, respectively. The stub shaft 13 has a coupling flange 18 for coupling it to a prime mover such as a turbine for driving the rotor. The stub shaft 12 carries slip rings 19 which are engaged by brushes 20 and connected by leads 21 to the field winding 11 to supply current to the winding. A refrigerating unit 22 is also mounted on the stub shaft 12 to supply coolant at very low temperatures of a few degrees absolute to the winding 11 to maintain it in a superconducting state. The rotor 10 has a radiation shield 23 surrounding its cylindrical surface to reduce the inflow of heat to the winding. The radiation shield 23 is enclosed in a vacuum space within an outer casing 24.

The stator of the machine has end members 25 and 26 and a mild steel outer casing 27. Torque rings 28 of non-magnetic alloy are mounted between the casing 27 and the end members 25 and 26 and an annular main body 29 also of non-magnetic alloy is bolted to the torque rings 28. Active conductors 30 of the stator windings are carried on the inner face of the main body 29. A magnetic shield 31 of laminated construction and of hollow cylindrical form is mounted around the main body 29 between the torque rings 28. Reactance conductors 32 pass through the shield 31 and as shown in Fig. 2 lie in an annular gap 33 between two coaxial cylinders forming the shield. The reactance conductors 32 are connected in series with the active conductors 30 by means of end connections 34 which extend generally radially in a plane transverse to the axis of the rotor. The junctions between the active conductors 30 and the end connections 34 are enclosed in main water boxes 35 and the junctions between the end connections 34 and the reactance conductors 32 in auxiliary water boxes 36. The water boxes 35 and 36, which are annular in form, serve to cool the conductors, which operate at or above room temperature, that is they are not superconducting.

The magnetic shield 31 shown in Fig. 2 is composed of coaxial cylinders each made up of laminations of silicon steel. The reactance conductors 32 which are located in the annular gap between the two cylinders can be embedded in epoxy resin. It is also possible to support the active conductors 30 by means of members of reinforced epoxy resin instead of the body 29 of non-magnetic alloy. These active conductors are located in a non-magnetic environment and are spaced from the magnetic shield 31.

Fig. 3 shows alternative arrangements of the reactance conductors in slots in the magnetic shield 31. Reactance conductors 32A are located in slots in the outer surface of the magnetic shield, or reactance conductors 32B are located in slots in the inner surface. A further alternative is to locate the conductors in drilled holes in the magnetic shield.

Fig. 4 shows the winding diagram of a three-phase winding in which the active conductors form a 2-pole double layer winding and the reactance conductors form an 8-pole winding with only 4 pole-phase groups. The first phase winding is shown by a thick line extending between terminals 40A and 40B, the second phase winding by a thin line extending between terminals 41A and 41B, and the third phase winding by a broken line extending between terminals 42A and 42B. At 43 are shown the active conductors lying in pairs in slots to form the double winding. In each pair one conductor, for example the conductor 44, is shown in the manner specified above and lies over another conductor, for example the conductor 45, which is shown broken (or in the case of the third phase broken line as a chain dotted line). The end connections are shown at 46 and in this case lie at one end of the machine only. The reactance conductors are shown at 47 and it will be seen that they are connected in series with the active conductors by way of the end connections.

It will be noted that the active and reactance conductors of the winding present different numbers of poles. The reactance conductors form is an 8-pole winding but half the pole-phase groups have been omitted, leaving only four. In omitting pole-phase groups the reactance conductors must, of course, remain balanced between phases.

WHAT WE CLAIM IS:—

1. A synchronous alternating current electrical machine having a D.C. excited rotor field winding of superconducting material and a stator armature winding of non-superconducting material, the stator winding having active conductors supported in a non-magnetic environment adjacent the rotor, reactance conductors located in a magnetic shield surrounding the active conductors and the rotor, and end connections connecting the active and reactance conductors in series.

2. A synchronous machine as claimed in claim 1 in which the active conductors are carried by an annular body of non-magnetic material.

3. A synchronous machine as claimed in claim 1 or 2 in which the active and reactance conductors extend parallel to the axis of the rotor and the end connections extend in a plane or planes transverse to the rotor axis.

4. A synchronous machine as claimed in claim 1, 2 or 3 in which the active conductors form a double layer winding.

5. A synchronous machine as claimed in any of the preceding claims in which the magnetic shield comprises two coaxial cylinders of magnetic laminations separated by an annular gap, and the reactance conductors are disposed in the said gap.

6. A synchronous machine as claimed in

any of claims 1 to 4 in which the reactance conductors are located in slots in the magnetic shield.

7. A synchronous machine as claimed in any of the preceding claims in which the portion of the winding formed by the reactance conductors has a number of poles different from that of the portion of the winding formed by the active conductors.

8. A synchronous alternating current electrical machine substantially as described with reference to Figs. 1 and 2 of the accompanying drawings.

REDDIE & GROSE,
Agents for the Applicants,
6, Bream's Buildings,
London, E.C.4.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1973.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY,
from which copies may be obtained.

1302549 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

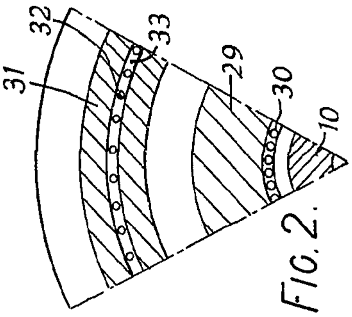

FIG. 2.

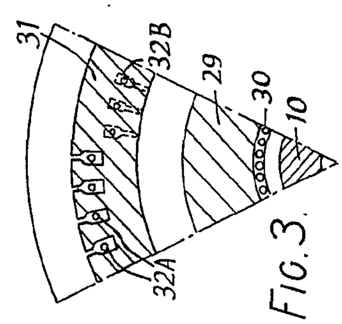

FIG. 3.

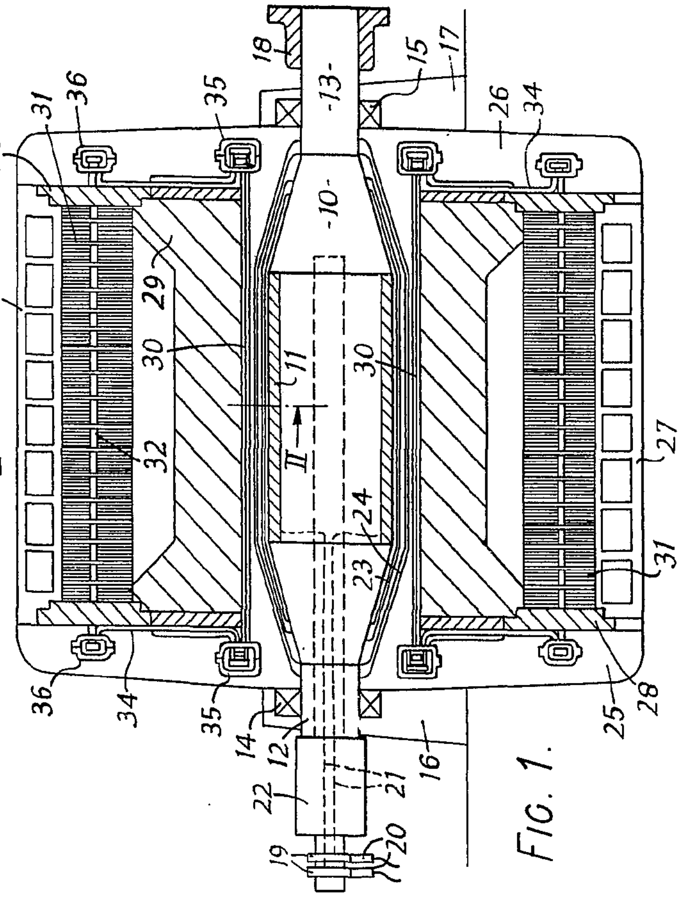

FIG. 1.

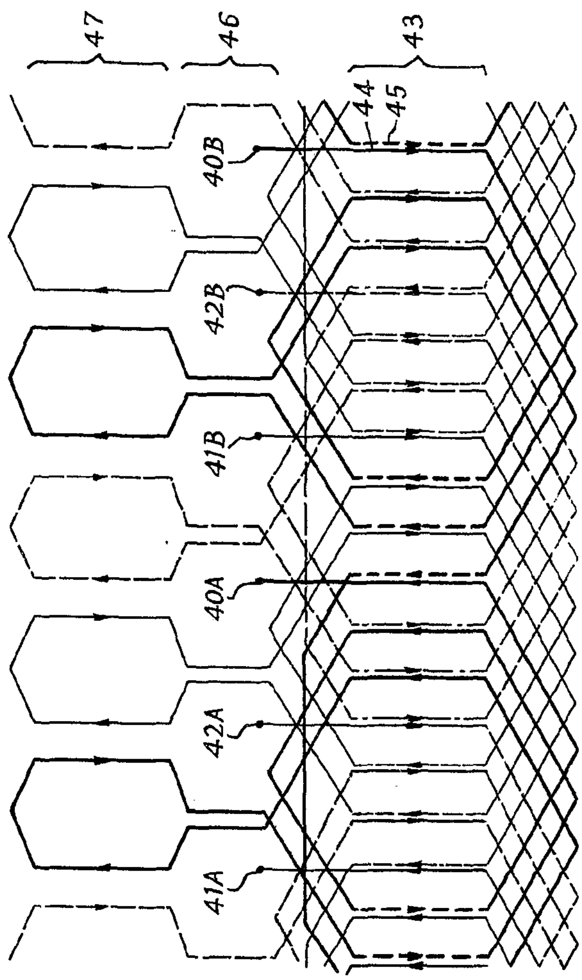

FIG. 4.