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Datasheet for the decision of 20 March 2013

Case Number: T 2135/11 - 3.5.02

Application Number: 97933177.4

Publication Number: 913023

IPC: H02K 9/00, H02K 15/09, H02K 55/04

Language of the proceedings: EN

Title of invention:
Superconducting Synchronous Motor Construction

Patent Proprietor:
American Superconductor Corporation

Opponent:
Converteam UK Ltd

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - (yes) - non-obvious modification"

Decisions cited:
-

Catchword:
-

Case Number: T 2135/11 - 3.5.02

D E C I S I O N
of the Technical Board of Appeal 3.5.02
of 20 March 2013

Appellant: (Opponent)	Converteam UK Ltd Boughton Road Rugby Warwickshire CV21 1BU (GB)
Representative:	Cadman, Timothy Paul Serjeants LLP 25 The Crescent King Street Leicester LE1 6RX (GB)
Respondent: (Patent Proprietor)	American Superconductor Corporation Two Technology Drive Westborough, MA 01581 (US)
Representative:	Isarpatent Patent- und Rechtsanwälte Friedrichstraße 31 D-80801 München (DE)
Decision under appeal:	**Decision of the Opposition Division of the European Patent Office posted 3 August 2011 rejecting the opposition filed against European patent No. 913023 pursuant to Article 101(2) EPC.**

Composition of the Board:

Chairman: M. Ruggiu
Members: M. Léouffre
P. Mühlens

Summary of Facts and Submissions

I. The opponent appealed against the decision of the opposition division, posted 3 August 2011, to reject the opposition and to maintain the European patent No. 0 913 023 as granted. The statement setting out the grounds of appeal was received on 5 December 2011. The grounds of appeal are based on Article 100(a) together with Articles 52(1) and 56 EPC.

II. The following documents of the state of the art played a role in the appeal proceedings:

D1 = "Application of High Temperature Superconductivity to Electric Motor Design"; J.S. Edmonds & al.; IEEE Transactions on Energy Conversion, Vol. 7, No. 2, June 1992, pages 322 to 328;

D3 = "High Temperature Superconducting Racetrack Coils for Electric Motor Applications"; J.P. Voccio & al.; Advances in Cryogenic Engineering, Vol. 42 pages 945 to 951, 1996 (source: 11th International Cryogenic Materials Conference (ICMC), Columbus, Ohio, United States, 17-21 July 1995);

D7 = "Demonstration of Two Synchronous Motors Using High Temperature Superconducting Field Coils"; C.H. Joshi & al.; IEEE Transactions on Applied Superconductivity, Vol. 5, No. 2, June 1995.

III. Oral proceedings before the board took place on 20 March 2013.

The appellant (opponent) requested that the decision under appeal be set aside and that the European patent be revoked.

The respondent (patent proprietor) requested that the appeal be dismissed (main request), or that the patent be maintained in amended form on the basis of one of the auxiliary requests I and II received on 11 March 2013.

IV. Claim 1 of the patent in suit as granted reads as follows:

"A rotor assembly (10) for use within a superconducting electric motor, said rotor assembly (10) comprising:
(a) at least one superconducting winding (30) formed of high temperature superconductor, the superconducting winding, during operation, generating a flux path within the rotor assembly (10), and
(b) a support member (20) having an inner surface which defines an internal volume and an outer surface; the rotor assembly (10) being characterised in that:
the support member (20) is formed of a non-magnetic, high strength resilient material, whereby the strength must be high enough for supporting the windings when the rotor assembly is in operation, said outer surface having a stepped cross-sectional profile for supporting the superconducting winding; and in that:
a high permeability magnetic material (50), is positioned within the internal volume of the support member (20) and at least a portion of the flux path, thereby to decrease the overall reluctance of the flux path generated by the superconducting winding (30)."

Claims 2 to 16 are dependent on claim 1.

V. The appellant essentially argued as follows:

During the course of the opposition proceedings it was agreed that claim 1 of the main request comprised two novel features, namely
F1: "a high permeability magnetic material (50), is positioned within the internal volume of the support member (10) and at least a portion of the flux path, thereby to decrease the overall reluctance of the flux path generated by the superconducting winding (30)", and
F2: "said outer surface (of the support member) having a stepped cross-sectional profile for supporting the superconducting winding".

The opposition division accepted that F1 and F2 had to be considered as two separate features for the assessment of inventive step.

D1 was considered as the closest prior art. D1 comprised two parts, one disclosing a 10 000 hp motor and a second part disclosing a test motor for testing features of the future 10 000 hp motor.
The two parts of document D1 were parts of a same research project, which started in 1992.

The first part of D1, and in particular figure 1, disclosed a 10 000 hp motor from which claim 1 differed only by features F1 and F2.

The motor of D1 was clearly an air-core motor. The reason for the air core design was that above a certain

power value the superconducting windings would have generated eddy currents in the magnetic material, detrimental to the operation of a superconducting machine.
However, as the project started, superconducting windings for a 10 000 hp machine did not exist. Less powerful motors had to be developed and there was no reason for a skilled person to stick to the air core design. Following the example given in the second part of D1, which disclosed a superconducting machine with an iron core, the person skilled in the art would have replaced the non-magnetic parts of the motor shown in figure 1 by magnetic elements.

D1 was to be regarded as the first chapter of a research book while D7, which referred to D1 (cf. D7, page 971, right column, paragraph 2), was the second chapter. D7 disclosed a 2 hp test motor which was already known from the second part of D1 (figure 2 of D7 is similar to figure 2 of D1). D7 went on disclosing a further development of the test motor in the form of a rotor for a 5 hp motor (see figure 5). The iron core, which was explicitly shown in D7, was included to raise the performance of the motor. Hence, at the filing date there was no prejudice against, and no reason for not using magnetic material in a superconducting machine. Therefore a person skilled in the art would not have maintained the air core design of the first part of D1 when developing low power superconducting motors. The other features of the test motors shown in D7 were modified purely for convenience e.g. the omission of a support member due to the size of the machine.
D7 reported about the start of the design of a larger 125 hp machine and D7 taught to use magnetic material.

Magnetic material would have therefore been included in the 125 hp machine.

Feature F2, namely a support member with an "outer surface having a stepped cross-sectional profile for supporting the superconducting winding", did not provide per se any technical advantage over the motor of D1. Superconducting windings were fragile and could possibly lead to an operable machine when mounted on a stepped surface. Superconductor windings had to have a profile conforming to the support member. However the inventive activity should be assessed for the whole scope of the claim and claim 1 did not specify the profile of the superconducting windings. Thus, feature F2 alone did not involve an inventive step.

Furthermore, like D7, D3 referred to the development of the 125 hp motor (cf. abstract of D3). D3 should be considered as representing the third chapter of the research book. Rather than a curved profile as in the motor shown in figure 1 of D1, D3 disclosed superconducting coils having a stepped profile (cf. figure 6).
While D1 was silent on, and did not show details about the coils to be used, the person skilled in the art was taught by D3 to use coils with stepped profiles. Stepped superconducting coils were fragile and would not have adequate support on a curved outer surface. The skilled person would have therefore inevitably modified the outer surface of the support member 7 of figure 1 of D1. He would have thus arrived to the rotor of claim 1.

Even if the coils of D3 were to be considered as being supported by a mandrel, claim 1 did not exclude a support member made of two parts, namely a tube together with stepped mandrels fixed onto it. As a consequence the distance between the coils and the core of the motor would have been large and, contrary to the respondent's argument, a support member according to feature F2 did not necessarily contribute to the reduction of the reluctance. Feature F2 was not present in original claim 1 but in a dependent claim. Feature F2 did not originally contribute together with feature F1 to the solution of a common problem.

VI. The arguments of the respondent (proprietor) can be summarised as follows:

Features F1 and F2 were not independent. Superconductors were expensive and difficult to bring to a particular form. To reduce the costs, the amount of superconducting material had to be reduced. The reduction in amount of superconducting material led to a reduction of the flux, which rendered possible the use of a high permeability magnetic material in superconducting motors. To insure a good reluctance, (cf. figure 6 of the application) the superconducting windings were mounted on a support member with a stepped profile to be in direct contact with the support member and thereby close to the magnetic material. Hence feature F2 contributed together with feature F1 to the reduction of the reluctance.

Even when considered separately, features F1 and F2 involved an inventive step.

In the event a person skilled in the art would have used superconductors of reduced power in combination with the 10 000 hp motor proposed in D1, he would have had to think of compensating the loss of performance. He would not have applied the teaching of the second part of D1, i.e. he would not have introduced an iron core in the motor of the first part of D1, because, as recited in section [0004] of the patent, the brittleness of the magnetic material is a concern at cryogenic temperatures. High permeability magnetic materials are fragile. Tests motors may comprise such materials because they are not developed for a longer use but only for tests.
According to an embodiment of the invention and to reduce the cooling level of the magnetic material, cooling ducts were provided in the support member and a vacuum gap was provided between the iron core and the support member (cf. figures 8 and 9). With this arrangement of the present invention the magnetic material is not overcooled. However if a high permeability magnetic material, i.e. an iron core, would be inserted in the middle of the rotor of figure 1 of D1, between the non magnetic field support 7 and the liquid nitrogen 8, it would be cooled more than necessary and would be brittle. Consequently, the person skilled in the art would have had to consider solving the problem of brittleness. Figure 1 of D1 was therefore not suited for developing the solution of claim 1.
D7, which might be considered as comprising an iron core, did not comprise a support member according to the invention and did not overcome the problem of brittleness and overcooling of the iron core.

Regarding feature F2, the stepped profile of the support member replaced a coil mandrel. The superconductors were fragile but nevertheless exhibited a certain elasticity allowing them to be fixed onto the stepped profile of the support member. No mandrel was needed and the reluctance was not worsened.
While D7 did not show a coil with a stepped inner profile, figure 2 of D3 showed a stepped coil within an aluminium support bracket used as a mandrel. It could not be derived from figure 2 of D3 that the inner profile of the coils was a stepped profile.

Reasons for the Decision

1. The appeal is admissible.

2. The Board agrees with the appellant and the respondent that the two following features of granted claim 1 are not disclosed in D1:
(F1) "a high permeability magnetic material (50), is positioned within the internal volume of the support member (20) and at least a portion of the flux path, thereby to decrease the overall reluctance of the flux path generated by the superconducting winding (30)", and
(F2) "said outer surface (of the support member) having a stepped cross-sectional profile for supporting the superconducting winding".
The novelty of the subject-matter of claim 1 of the patent in suit is therefore not in dispute.

3. *Inventive step (Article 56 EPC)*

3.1 Interdependence of the two features F1 and F2:

The costs of a high temperature superconducting machine depends on the amount of superconducting composite material rather than on the cooling as for the low temperature superconducting machines (cf. section [0023] of the contested patent). The invention aims at reducing the costs of a high temperature superconducting machine by reducing the amount of superconducting material required for the winding. Less superconducting material leads to lower ampere-turns, making possible the use of iron cores without saturation: "The iron core rotor assembly design requires 45% less ampere-turns than the air core design to produce the same level of flux" (cf. section [0029]).

However "most ferromagnetic materials, including iron, are brittle" and "the brittleness characteristic of such materials become worse when cooled to cryogenic temperatures" (cf. section [0004] of the contested patent). The original application proposes therefore (cf. page 2, lines 20 to 24) a support member that "effectively captures the core member, so that, in certain applications, the core member can be cryogenically cooled without significant risk of its fracturing due to oscillatory forces generated by the machine during operation". Similarly, the patent in suit mentions a torque tube that "effectively captures the core member, so that, in certain applications, the core member can be cryogenically cooled without significant risk of its fracturing due to oscillatory forces generated by the machine during operation. Thus, the invention provides an internally-supported structure which protects the relative brittle components (i.e. core member)" (cf. section [0009] of the contested patent).

The high permeability magnetic material reduces the reluctance of the high temperature superconducting motor. According to the respondent, the reluctance is further reduced with superconductors positioned on a support member having a stepped cross-sectional profile, close to the iron core.

The protection of the core mentioned above and the reduced reluctance may be considered as achieved with a support member in a rotor according to the first embodiment of the invention (figures 1 to 3). However claim 1 encompasses the embodiment shown in figures 8 and 9 wherein the iron core 80 is spaced from the inner wall of the support member or torque tube 20, by a gap 82 which might be air-filled (cf. section [0030]). Hence, in the light of the second embodiment, it cannot be concluded that the support member as claimed would protect the core against its fracturing while contributing to the reduction of the reluctance. Features F1 and F2 may therefore be considered as not contributing to the solution of a common problem.

3.2 Documents D1, D3 and D7 relate to a common project involving at least the proprietor "American Superconductor Corp." and other firms like "Electric Power Research Institute" and "Reliance Electric" (cf. Abstract of D1, D7, page 971, right column, third paragraph and the abstract of D3).

3.3 The long term goal of the project was to develop a 10 000 hp motor as shown in figure 1 (cf. conclusion of D1 "Design calculations have been used to predict the motor performance of a 10 000 hp HTSC motor"). This motor could however not be built essentially because a length of superconducting wire handling 10^6 amp-turns did not exist (cf. section bridging pages 324 and 325 of D1).
Therefore a more modest goal for the first HTSC (high temperature superconductor) synchronous motor was envisaged like the 2 hp test motor disclosed in D1 (cf. figures 2 and 3). The test motor was designed to confirm air core motor design techniques and to provide a lower HTSC wire performance goal for the first superconducting synchronous motor" (cf. D1, page 325, left column, paragraph 2 and table II).

Compared to the design of the future high power superconducting synchronous motor, the test motor comprises a stationary copper field winding 11 and a rotating armature assembly 7 to 9 (cf. D1, page 325, right column, and figure 3). The field winding cooperates with pole pieces 2. The pole pieces are made of magnetic material which helps improving the performance of the test motor. However the pole pieces do not constitute a core.

According to D1, the 2 hp test motor of figures 2 and 3 "designed for both iron core and air core performance testing with the copper field coil, can be modified to accept a superconducting field winding when one becomes available" (cf. D1, page 326, left column, first paragraph).

Actually, the copper field winding 11 and the liquid nitrogen tank 1 shown in figure 3, lie inside a layer of thermal insulation which is surrounded by an outer, stainless steel warm flux shield (cf. D1, page 325, right column, penultimate paragraph). Hence, the copper field winding could easily be replaced with a superconducting winding when one becomes available. According to the above cited sentence found at page 326, the air core of the test motor shown in figure 3 of D1 could be replaced by an iron core in cooperation with copper field windings. The said sentence does not however imply unambiguously that the air core could be replaced by an iron core while replacing the copper field windings by superconducting windings. There is no hint in D1 for an HTS arrangement wherein the core of the test motor would comprise an iron core together with the necessary nitrogen liquid cooling.

3.4 Document D7 reports about a further development of the project. It discloses a 2 hp synchronous motor with an iron core and a stationary HTS field winding mounted on two salient field poles (cf. page 969, right hand column and figure 2). As far as figure 2 might be understood the iron core would be the iron member linking the two salient poles. Therefore figure 2 of D7 sheds some light on the way the 2 hp test motor of D1 could be modified to accept superconducting windings and an iron core (cf. page 326 of D1).

Another synchronous motor with an HTS field winding is disclosed in D7 (cf. "Five Horsepower Synchronous Motor" on page 970). This 5 hp test motor is shown in figure 5 and discloses a core tube linking four salient

pole bodies. On the salient pole bodies are positioned HTS racetrack field coils.
In none of the synchronous test motors disclosed in D1 and D7 is an iron core positioned within the internal volume of a support member which has an outer surface for supporting the superconducting windings.
Actually D7 does not disclose a support member in the sense of the contested patent (cf. D7, figure 5).
D7 teaches to use an iron core in combination with HTS racetrack field windings for low power motors. However the designs of the 2 and 5 hp test motors disclosed in D1 and D7 are different from the design of the hypothetical future 10 000 hp motor of D1, and it cannot be concluded that the non magnetic field winding support 7 shown in figure 1 of D1 would remain as a support member in the sense of the patent in suit when using an iron core in combination with HTS windings in a future test motor. The subject-matter of claim 1 is therefore regarded as being not obvious in the light of the combination of D1 and D7.

4. D3 reports about the same project as D1 and D7 and discloses high temperature superconducting (HTS) windings having a stepped profile (see figure 6a). It is therefore agreed with the appellant that D3 teaches the person skilled in the art to use coils with stepped profile when developing a motor with superconducting windings.
D3 is concerned with the thermal and mechanical characteristics of the coil sets (cf. page 946, lines 1 and 2) and the centrifugal loading on the coil sets (cf. D3, page 947, "structural design"). The coil sets are positioned inside, and conform with, the external tube shown in figure 1 of D3, which figure is a sketch

of the cryogenic rotor for an 125 hp air core synchronous motor (cf. D3, the introduction at page 945). It should therefore be concluded that D3 teaches to place the stepped coils inside a support member in form of a tube, similar to the cold copper flux shield of D7, and not on the outer surface of a support member.
On figure 2 of D3, the same coil is presented mounted on mandrels placed in an aluminium bracket (cf. D3, last sentence of page 946) which was designed to minimize the bending stresses (cf. page 947, "structural design"). There is no hint in D3 to use the stepped coils independently of a mandrel.

Considering that the inner side of the coils shown in D3 presents a stepped profile too, the person skilled in the art could free the coil from the mandrel to mount it on a cylindrical tube as shown in figure 1 of D1. He could equally mount the coil together with the mandrel onto the outer surface of the cylindrical tube. There is however no evidence that he would develop the test motor in that direction. Actually, according to D3 (cf. page 946, first paragraph) "the design of the final rotor assembly will be modified as necessary based on the results of the subset testing", whereas according to D1, "there is a lot of work to be done in developing and confirming design techniques for air core motors" (cf. D1, page 325, left column, first paragraph). The combined teachings of D3 and D7 (figure 5), and possibly of the test motor of D1, might lead to an HTS motor with an iron core and a stepped coil whereby the coil would be together with the iron core on the inside of a support member or cylindrical tube. Starting from the test motors disclosed in D1, D3

and D7 there is however no hint to position a high permeability magnetic material within the internal volume of a support member, which would have an outer surface with a stepped cross-sectional profile to support the superconducting windings.
An HTS coil supported on the outer surface of a cylindrical support member is a feature of the 10 000 hp coreless motor proposed in figure 1 of D1. There is no evidence that a person skilled in the art would keep that particular feature in combination with an iron core for a low power motor and would modify the outer surface of the cylindrical support member 7 of D1 to create an outer surface with a stepped cross-sectional profile.

A support member according to claim 1 comprises an outer surface with a stepped cross-sectional profile for supporting superconducting windings and defines an internal volume in which a high permeability magnetic material is positioned. Thereby a rotor for an HTS motor is defined wherein the HTS coils are separated from the iron core by a support member. Such a structure is not obvious when starting from document D1 even in the light of documents D7 and D3. Depending on the embodiment of the invention, this structure reduces the reluctance while protecting the iron core from fracturing, or contributes to reduce the cooling level of the iron core.

5. The board concludes therefore that the subject-matter of claim 1 of the patent in suit is not obvious in the sense of Article 56 EPC.

The subject-matter of claims 2 to 16, which depend on claim 1, is thereby also not obvious.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

U. Bultmann M Ruggiu