A large electrically excited synchronous generator

Jensen, Bogi Bech

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(71) Applicant: **DANMARKS TEKNISKE UNIVERSITET** [DK/DK]; Anker Engelundsvej 1, Bygning 101A, DK-2800 Lyngby (DK).

(72) Inventor: **JENSEN, Bogi Bech**; c/o University of the Faroe Islands, J.C. Svabos gøta 14, Tórshavn, 100 (FO).

(74) Agent: **PLOUGMANN & VINGTOFT A/S**; Rued Langgaards Vej 8, DK-2300 Copenhagen S (DK).

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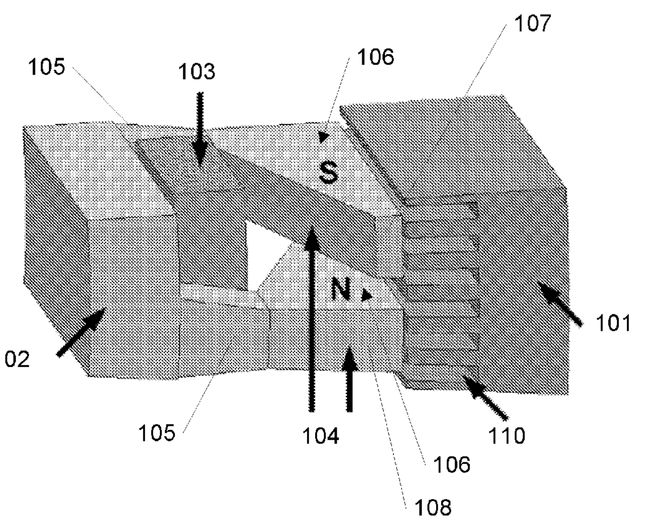

Figure 2

(57) Abstract: This invention relates to a large electrically excited synchronous generator (100), comprising a stator (101), and a rotor or rotor coreback (102) comprising an excitation coil (103) generating a magnetic field during use, wherein the rotor or rotor coreback (102) further comprises a plurality of poles (104), where each pole (104) comprises a pole leg (105) and a pole shoe (106) facing the stator (101), the plurality of poles (104) is arranged spaced apart and radially on the rotor or rotor coreback (102), and the magnetic polarity of a given pole is different than the magnetic polarity of its adjacent neighbouring poles. In this way, a large electrically excited synchronous generator (EESG) is provided that readily enables a relatively large number of poles, compared to a traditional EESG, since the excitation coil in this design provides MMF for all the poles, whereas in a traditional EESG each pole needs its own excitation coil, which limits the number of poles as each coil will take up too much space between the poles.

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A LARGE ELECTRICALLY EXCITED SYNCHRONOUS GENERATOR

FIELD OF THE INVENTION

The present invention relates generally to a large electrically excited synchronous generator, comprising a stator, and a rotor where the rotor comprises an excitation coil, generating a magnetic field during use, and a number of poles.

BACKGROUND OF THE INVENTION

Electrical generators have many applications and some are for use in e.g. wind turbines.

Some types of wind turbines uses e.g. a gear-box between a generally low speed shaft – being driven by the rotor blades – and a high speed shaft connected to the generator.

Other types of wind turbines are e.g. of the so-called direct drive type where a shaft being driven by the rotor blades are connected directly to or a part of the generator. Wind turbines that do not use a gear-box are generally simpler and more reliable, as the gear-box is heavy and potentially unreliable.

A characteristic of direct drive wind turbines is e.g. that its generator requires a relatively large number of magnetic poles (forth only denoted poles) to produce a given electrical output with a lower rotational speed. Furthermore, a relatively large number of poles enable reduction of the weight of the generator, because as the number of poles is increased the flux per pole is reduced thereby enabling the iron coreback that carries the flux from one pole to the next in the generator to be reduced in thickness.

Traditionally, permanent magnet generators (PMGs) are normally used in such generators since the magnetomotive force (MMF) is proportional to the magnet depth and not the magnet width in such designs. Therefore, it is possible to increase the number of poles simply by dividing the magnet circumferentially into however many poles that are desired. As long as the magnet depth (defined as the direction of magnetisation) is maintained then the MMF is also maintained and hence also the flux density in the air gap.

However, use of PMGs involves the use of relatively large quantities of rare-earth magnets for example up to 5000 kg rare-earth metals for a 6 MW generator. Such rare-earth materials are expensive and it is difficult to ensure a reliable supply chain.

Replacing permanent magnets by electromagnets – not requiring scarce and expensive rare-earth materials – are traditionally not straightforward in such designs.

In electrically excited synchronous generators (EESGs), the MMF is delivered by an electromagnet on the rotor and hence the MMF is proportional to the amount of current in the electromagnet. The amount of MMF required per pole is nearly independent of the number of poles whereby approximately the same MMF is required per pole independently of how many poles the machine has. Since the current density (A/mm2) in the electromagnet and the amount of electric current per pole is independent on the number of poles, the radial height of each pole will increase as the number of poles is increased. The reason for this is that the area of the electromagnet coil has to be maintained.

However each magnet must have the same MMF independently of the number of poles, which consumes a large amount of copper in terms of volume and weight if a large number of poles is required. Normally, such weight and volume is not easily accommodated e.g. in wind turbine or other designs.

Therefore, it is traditionally not possible to increase the number of poles in EESGs to the same level as in a PMG, in particular for wind turbine designs, and an EESG will remain significantly heavier than a PMG. For this reason, EESGs for industrial use have not found wide use e.g. in wind turbines.

EESGs have the advantage that the power electronic converter – responsible for converting the variable frequency power output of the generator to a constant frequency power output to the grid – can be simpler, smaller and of lower power rating compared to if a PMG is used since it will be possible to adjust the magnet flux in a simple way to obtain optimum power factor for all loads.

However, since it traditionally is difficult to increase the number of poles in an EESG to the same levels as in a PMG, the advantage of a simpler and smaller converter is normally trumped by the weight savings of the PMG.

Thus, there is a need for an EESG that enables an increase in the number of poles without at least some of the abovementioned drawbacks or at least to a lesser extent.

Patent specification US 7,295,489 discloses a dynamoelectric claw-shaped rotor with magnet retainer aimed at improving a claw pole rotor for an alternator, electric motor, etc.

OBJECT AND SUMMARY OF THE INVENTION

It is an object to provide a large electrically excited synchronous generator (EESG) that readily enables a relatively large number of poles.

Additionally, an objective is to provide a generator that may be used in connection with a simple power electronic converter.

A further object is to provide a generator that avoids the need for rare-earth materials.

According to one aspect, one or more of these objects are achieved at least to an extent by a large electrically excited synchronous generator, comprising a stator, and a rotor or rotor coreback comprising an excitation coil generating a magnetic field during use, wherein the rotor or rotor coreback further comprises a plurality of poles, where each pole comprises a pole leg and a pole shoe facing the stator, the plurality of poles is arranged spaced apart and radially on the rotor or rotor coreback, and the magnetic polarity of a given pole is different than the magnetic polarity of its adjacent neighbouring poles.

In this way, a large electrically excited synchronous generator (EESG) is provided that readily enables a relatively large number of poles, compared to a traditional EESG, since the excitation coil in this design provides MMF for all the poles, whereas in a traditional EESG each pole needs its own excitation coil, which limits the number of poles as each coil will take up too much space between the poles.

Furthermore, a generator is provided that may be used in connection with a power electronic converter being simpler, smaller and of lower power rating (compared to if a PMG would be used) since the generator is an EESG.

By large EESG according to the present invention is to be understood – for all embodiments, variations, and/or combinations thereof – the type of EESG commonly used in connection with relatively large devices or systems, such as – but not limited to – wind turbines, (hydro) power generators, tidal power generators, and/or other low speed high torque applications. What specifically is disclaimed are small generators/small claw-pole generators as commonly used e.g. in automobile applications.

In one embodiment, the pole shoe of each pole has a first side that is narrower than a second opposite side, where one end of the pole leg is secured to or integrated with the rotor or rotor coreback and the other end of the pole leg is secured to or integrated with the pole shoe at or towards the second side of the pole shoe.

In this way, cogging torque may be reduced and thereby the need for skewing of the stator and rotor or rotor coreback.

In one embodiment, the plurality of poles is arranged spaced apart on the rotor or rotor coreback alternatingly at a first radial row and a second radial row so that a given pole is placed on a different radial row than its neighbours, so that the first side of a given pole shoe is facing the first side of the pole shoes of its two neighbours, and so that at least a part of the pole head overlaps with at least a part of the neighbouring pole heads with air gaps between the pole heads, and the magnetic polarity of the poles on the first radial row is the same and different than the magnetic polarity of the poles on the second radial row.

In one embodiment, the pole leg of each pole is centrally secured to or integrated with the pole shoe and is centrally secured to or integrated with the rotor or rotor coreback. This generally provides a T-shape of the poles, which provides a more mechanically stable embodiment, since the pole overhang need not be as long and/or flimsy as otherwise would be the case. This may e.g. enable that no non-magnetic support of the poles are needed. The excitation coil may especially advantageously for this embodiment, and as generally mentioned below, e.g. be wound circumferentially around the rotor or rotor coreback by being on one side of the pole leg of a given pole and being on an opposite side of the pole legs of the given pole’s adjacent neighbouring poles, i.e. more or less wound according a zig-zag pattern or similar.

In one embodiment, the rotor or rotor coreback comprises a recess or groove adapted to accommodate a lower part of the coil. This enables shortening the height of the pole leg and/or having more space available for the coil.

In one embodiment, the excitation coil is wound circumferentially around the rotor or rotor coreback substantially in a straight line between the pole legs of poles of the first radial row and the pole legs of poles of the second radial row and between the pole heads and the rotor or rotor coreback.

In one embodiment, the excitation coil is wound circumferentially around the rotor or rotor coreback by being on one side of the pole leg of a given pole and being on an opposite side of the pole legs of the given pole’s adjacent neighbouring poles.

In this way, the excitation coil is wound according a zig-zag pattern or similar, whereby more or less all the flux coming from the pole leg is accommodated enabling a more compact EESG because the (radial) height of the pole shoe can be lower while still maintaining the same efficiency.

In one embodiment, the excitation coil is wound circumferentially around the rotor or rotor coreback generally in parallel with a first direction of rotation of the rotor or rotor coreback.

In one embodiment, the rotor or rotor coreback is connected to a shaft connected

- directly to a blade rotor or other suitable driving mechanism or force, or

- to a blade rotor or other suitable driving mechanism or force via a gear mechanism.

In one embodiment, the excitation coil comprises aluminium.

Aluminium has the advantages that it is cheaper than copper and also weighs less, which are significant advantages of certain designs/uses of EESGs and in particular in connection with wind turbines, etc. However, since aluminium has a lower conductivity than copper, it requires a larger cross sectional area compared to copper if the same losses are to be achieved.

However, the poles according to the present invention may simply be designed to allow for plenty of room for the rotor excitation coil thereby making it possible to replace copper windings with the more space consuming aluminum to save cost and weight. This is e.g. enabled as the opposite facing poles define a cavity between them where a suitable excitation coil e.g. made of aluminium may readily be located with plenty of room, even given its increased size or e.g. as shown in Figure 7 by having centrally placed poles and letting the excitation coil zig-zag or similar between them.

In one embodiment, the pole shoes comprises a magnetic steel lamination on a side facing the stator (i.e. the pole face) and where the poles consists of a solid soft magnetic material (e.g. like steel).

In this way, iron losses that otherwise can be caused in the pole face from the flux ripple that is caused by the stator teeth may be reduced.

In one embodiment, the end of the pole leg being secured to or integrated with the rotor or rotor coreback of at least some of the poles are tapered.

In this way, leakage flux from pole to pole is reduced.

In one embodiment, the pole head are supported by a non-magnetic material. The support addresses any potential ‘flimsiness’ of the poles (since e.g. a direct drive wind turbine generator can be more than one meter long)

In one embodiment, the non-magnetic material is stainless steel or glass fibre or another composite material.

The invention also relates to a wind-turbine comprising a large electrically excited synchronous generator and embodiments thereof as described throughout the text.

The invention also relates to a hydrogenerator or water turbine comprising a large electrically excited synchronous generator and embodiments thereof as described throughout the text.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects will be apparent from and elucidated with reference to the illustrative embodiments as shown in the drawings, in which:

Figure 1 schematically illustrates one embodiment of a large electrically excited synchronous generator in a direct-drive wind turbine;

Figure 2 schematically illustrates a cut-away part view of one embodiment of a large electrically excited synchronous generator;

Figure 3 schematically illustrates another embodiment of a large electrically excited synchronous generator in a wind turbine comprising a gear-box;

Figure 4 schematically illustrates a cross section and a (radial) top view of an embodiment of a large electrically excited synchronous generator illustrating a different shape of the poles and the orientation and location of the excitation coil;

Figure 5 schematically illustrates a cross section and a (radial) top view of an embodiment of a large electrically excited synchronous generator illustrating a different orientation and location of the excitation coil;

Figure 6 schematically illustrates a cross section of an embodiment of a large electrically excited synchronous generator illustrating a different shape of the poles; and

Figure 7 schematically illustrates a cross section of an embodiment of a large electrically excited synchronous generator illustrating another different shape of the poles.

DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 schematically illustrates a large electrically excited synchronous generator in a direct-drive wind turbine.

Shown is a schematic representation of a wind turbine 200 comprising a wind turbine rotor 202, a shaft 201, a power electronic converter 210, and a large electrically excited synchronous generator (EESG) 100 (such as the one shown and explained in connection with Figures 2, 4, 5, 6, 7 and/or variations thereof), where the EESG comprises a stator 101 and a rotor 102.

The shaft 201 may be omitted if the rotor of the EESG is directly connected to the hub of the wind turbine rotor 202, where the generator stator of the EESG is on the inside and the generator rotor of the EESG is on the outside.

The wind turbine rotor 202 is connected to the shaft 201 that drives the rotor 102 in the EESG 100 or the generator rotor 102 of the EESG 100 is connected directly to the hub of the wind turbine rotor 202 thereby producing power when the wind turbine rotor 202 is rotated. The EESG 100 is connected to the power electronic converter 210 that usually connects to a transformer 203, that transforms the voltage from the generator voltage to the grid voltage, to deliver the generated power to a supply network or similar.

As mentioned, EESGs have the advantage that the power electronic converter – responsible for converting the variable frequency power output of the generator to a constant frequency power output to the grid – can be simpler, smaller and of lower power rating compared to e.g. if a PMG is used since it will be possible to adjust the magnet flux to obtain optimum power factor for all loads.

As mentioned, the EESG comprises a stator 101 and a rotor 102, where the rotor comprises an excitation coil (not shown; see e.g. 103 in Figures 2, 4, 5, 6, and 7) generating a magnetic field during use, i.e. when the excitation coil is powered by an electrical current.

The stator is more or less a standard stator.

The rotor comprises a plurality of (radial) poles (not shown; see e.g. 104 in Figures 2, 4, 5, 6, and 7), where each pole comprises a pole leg (not shown; see e.g. 105 in Figures 2, 4, 5, 6, and 7) and a pole shoe (not shown; see e.g. 106 in Figures 2, 4, 5, 6, and 7) facing the stator. The surface of the pole shoe facing the stator is referred to as pole face (not shown; see e.g. 120 in Figures 4, 5, 6, and 7).

There is a small air gap between the pole shoe and the stator. Purely as examples, the number of poles may e.g. be about 110 for a 3 MW direct drive wind turbine or may e.g. be about 160 for a 6.0 MW direct wind turbine.

The poles may be of the so-called claw-pole type (see e.g. Figures 2, 4, 5, and 6) where each pole has a shape being sort of a bent and pointy 'claw' or 'tooth' or generally an inverted modified L-shape.

The poles may in these embodiments be arranged spaced apart on the rotor in an alternating fashion in two (circumferential) radial rows around the rotor so that the pointy or narrower ends of the claws/poles of one row will face the pointy or narrower ends of the claws/poles on the other row (see e.g. Figures 2, 4, 5, and 6). In this way, the poles are located on the rotor so that if one given pole is placed on a first row, its two immediate neighbour poles are placed on the other row, their next neighbours are placed on the first row again, and so on.

The poles on a given row have the same magnetic polarity, e.g. S, while the poles of the other row all have the opposite magnetic polarity, e.g. N (or the other way around), whereby the magnetic polarity will also alternate between neighbouring poles.

Furthermore, the poles of one row may overlap with the poles of the other row, i.e. the free ends of the poles on one row will be located so it extends past the free ends of the poles on the other row (without touching). See e.g. Figures 2, 4, 5 and 6.

The alternating orientation and/or polarity basically ‘twists’ the magnet field generated by the rotor excitation coil during use to form a series of narrowly spaced poles facing the stator.

This enables a generator design that accommodates a relative large number of poles.

Furthermore, such a described claw-pole design also leaves plenty room for the excitation coil as opposite facing claw-poles will define a cavity between them where the excitation coil readily may be located.

An alternative design, where the pole leg is fixed or integrated at the center of the pole shoe rather than towards one of the sides, is explained e.g. in connection with Figure 7.

This provides an advantageous generator with advantages as will be explained in further detail e.g. in connection with Figures 2, 4, 5, 6, and 7.

While a direct drive wind turbine without a gear-box is shown, the EESG may also be used in connection with low to medium speed (i.e. about 2 – about 400 rpms) wind turbines comprising a gear-box. Such an embodiment is shown in Figure 3.

Figure 2 schematically illustrates a cut-away part view of one embodiment of a large electrically excited synchronous generator (EESG).

Shown in Figure 2 is a part view of a rotor 102 and a stator 101 of one embodiment of an EESG according to the present invention. In the figure, the rotor or rotor coreback 102 (in the following description only denoted rotor) and stator 101 has been cut by two planes more or less perpendicular to the plane of rotation of the rotor to show details of the EESG.

The stator 101 is more or less a common stator of such designs and comprises a number of stator slots 110 for accommodating a number of windings (not shown) that the rotating magnet field of the rotor – when in use – induces electrical voltage in.

The rotor 102 comprises an excitation coil 103 generating a magnetic field during use, i.e. when the excitation coil is powered by an electrical current.

In some embodiments, the excitation coil 103 is wound circumferentially around the rotor 102 generally in parallel with a first direction of rotation of the rotor 102.

The excitation coil 103 may be wound generally in a more or less straight line around the rotor 102, e.g. as shown in Figures 2, and 4, or it may be wound according to another pattern, e.g. in a zig-zag pattern or similar e.g. as shown in Figures 5 and 7. The embodiment of Figure 6 may be wound either in a more or less straight line or in a zig-zag pattern or similar.

Furthermore, the rotor 102 comprises a plurality of poles 104 (where only two are shown in Figure 2) where each pole 104 comprises a pole leg 105 or similar and a pole shoe 106 or similar having a pole face (not shown; see e.g. 120 in Figures 4, 5, 6, and7) facing the stator with a small air gap between the pole shoe 106 and the stator 101 in which a magnetic flux is induced during use of the EESG.

In the shown embodiment (and the ones of Figures 4 and 5), the pole shoe of each pole has a first side, surface, or end 107 that is narrower than an opposite second side, surface, or end 108. In the shown embodiment, the pole shoes have a substantially right-angled triangular shape when viewed (in the picture) from above or below but it is to be understood that variations and/or other shapes may be applicable.

One end of each pole leg 105 is secured to or integrated with the 102 while the other end of the pole leg 105 is secured to or integrated with the pole shoe 106 at or towards the second side 108 of the pole shoe 106, i.e. at or near the thickest part of the pole shoe 106.

The radial length of the pole legs may e.g. be about the same as the diameter or radial length of the excitation coil or longer.

As mentioned, in this particular embodiment, the poles 104 are arranged spaced apart on the rotor 102 in an alternating fashion in substantially two (circumferential) radial ‘rows’ around the rotor so that a given pole 104 is placed on a different radial row than its two immediate neighbours and so that the first (narrower) side 107 of a given pole shoe 106 is facing the first (narrower) side 107 of the pole shoes 106 of its two neighbours, i.e. so that the pointy or smaller end of the pole heads of one row will face the pointy or smaller end of the pole heads on the other row.

Preferably all the poles on a given row have the same magnetic polarity, e.g. S, while preferably all the poles of the other row all have the opposite magnetic polarity, e.g. N (or the other way around), whereby the magnetic polarity also will alternate between neighbouring poles.

Furthermore, the poles may be arranged so that at least a part of a given pole shoe 106 (the free end of it) will overlap with at least a part of the neighbouring pole shoes 106 (the free ends of them) with air gaps between the pole shoes. The reason for this is that laminations are normally used in the stator, which are stacked axially and hence will preferably only accommodate flux in the radial and circumferential plane. All three dimensional flux paths therefore should take place in the rotor, which is predominately constructed from a solid soft magnetic material. The smaller the air gaps are between the poles, the more flux will or may leak from one pole to the next without ever reaching the stator, which will reduce the efficiency of the generator.

An alternative to the described shape of the pole shoes 106 and where they connect to the pole legs 105 is e.g. shown and explained in connection with Figure 7 showing poles having a generally T-shape instead of a generally inverted L-shape.

As e.g. shown in Figure 1, the rotor may be connected to a shaft that is connected directly to a blade rotor or other suitable driving mechanism or force (i.e. a direct drive design) or as, e.g. shown in Figure 3, the rotor may be connected to a shaft that is connected to a blade rotor or other suitable driving mechanism or force via a gear mechanism or similar, especially for medium speed rotations about 2 to about 400 rpms. The generator and variations thereof according to all the embodiments may also be used in many other devices or systems than wind turbines. One example is e.g. to use it in a hydro generator, water turbine or similar where otherwise salient pole rotors often are used. This will enable a higher efficiency and lower losses.

In one embodiment, the excitation coil 103 comprises or is made out of copper or other suitable materials. Copper is a traditional material to use for an excitation coil in an EESG and especially for wind turbines.

In an alternative embodiment, the excitation coil 103 comprises or is made out of aluminium. Aluminium has the advantages that it is cheaper than copper and also weighs less, which are significant advantages of certain designs/uses of EESGs and in particular in connection with wind turbines, etc.

However, since aluminium has a lower conductivity than copper, it requires a larger cross sectional area compared to copper if the same losses are to be achieved.

If the area available to house the coil is not increased when replacing copper with aluminium in traditional EESGs then the efficiency is significantly reduced.

Such additional space is normally not available or prioritised in certain designs/uses for example within wind turbines, as this in traditional designs would make the housing or nacelle bigger and thereby heavier. Keeping the same space available for aluminium as for a corresponding copper winding would reduce the efficiency of the EESG or wind turbine significantly.

However, since the poles according to the present invention may simply be designed to allow for plenty of room for the rotor excitation coil it is possible to replace copper windings with the more space consuming aluminum to save cost and weight. This is enabled as the opposite facing poles define a cavity between them where a suitable excitation coil e.g. made of aluminium may readily be located with plenty of room, even given its increased size. Other designs, e.g. as the one shown in Figure 7, plenty of room for the excitation coil is also obtained (even though it does not have opposite facing poles).

In one embodiment, the top of the pole shoe 106 (normally referred to as the pole face) of at least some poles 104 comprises magnetic steel laminations or similar on the side facing the stator 101 where the rest of the poles 104 are made from a solid soft magnetic material. This has the advantage that the iron losses that otherwise can be caused in the pole face from the flux ripple that is caused by the stator teeth may be reduced.

In some embodiments, at least some of the ends of the pole leg 105 being secured to or integrated with the rotor 102 are tapered. In this way, leakage flux from pole to pole is reduced.

In some embodiments, the tapering can be done on the surface of the poles such that the pole is wider in one end and narrower at the other end. In this way, cogging torque may be reduced thereby reducing the need for skewing of the stator and rotor. This would give the pole head and the pole surface, also of the embodiments shown and explained in connection with Figures 4, 5, 6, and 7, a triangular shape as seen from the stator.

In one embodiment, the poles are supported at the hanging end, i.e. at the first narrow side 107, by a non-magnetic material, which could be stainless steel or glass fibre or other suitable non-magnetic materials. This addresses that the poles may become 'flimsy' since an EESG generator may be more than one meter long.

In this way, a large electrically excited synchronous generator (EESG) is provided that readily enables a relatively large number of poles, compared to a traditional EESG, since the excitation coil in this design provides MMF for all the poles, whereas in a traditional EESG each pole needs its own excitation coil, which limits the number of poles as each coil will take up too much space between the poles.

Figure 3 schematically illustrates another embodiment of a large electrically excited synchronous generator in a wind turbine comprising a gear-box.

Shown is a schematic representation of a wind turbine 200 comprising a wind turbine rotor 202, a first shaft 201, a gear-box or gear-mechanism 215, a second shaft 204, a power electronic converter 210, and a large electrically excited synchronous generator EESG 100 (such as the one shown and explained in connection with Figure 2 and variations thereof) comprising a stator 101 and a rotor 102.

The rotor blade 202 is connected to the first shaft 201 that is connected with the gear-box or gear-mechanism 215 that converts the rpm of the first shaft 201 up at the second shaft 204. The second shaft 204 drives the rotor 102 in the EESG 100 thereby producing power when the rotor 202 is rotated. The EESG 100 is connected to the power electronic converter 210 that normally connects to the transformer 203 to deliver the generated power to a supply network or similar.

This embodiment corresponds to the one in Figure 1 except that the wind turbine comprises a gear-box instead of the direct drive type.

Figure 4 schematically illustrates a cross section and a (radial) top view of an embodiment of a large electrically excited synchronous generator illustrating a different shape of the poles and the orientation and location of the excitation coil. Shown is a cross section of a part of an EESG showing a number of poles, each pole comprising a pole leg 105 and a pole shoe 106 where the pole leg 105 is integrated with or secured to a rotor 102. The pole shoe 106 comprises a pole face 120 being the surface for facing the stator (not shown).

Shown are two poles one ‘pointing’ right and one behind it ‘pointing’ left as indicated by the dashed line. An excitation coil 103 is located in the cavity defined by the poles.

Also shown is a top view of a part of the EESG showing a number of poles.

The pole legs 105 and the parts of the excitation coil 103 that are hidden (seen from the top) by the pole face 120 of the pole shoes are indicated by hashed lines.

This embodiment, more or less corresponds to the embodiment of Figure 2 but with a slightly different design of the poles.

As can readily be seen, the excitation coil 103 is wound generally in a more or less straight line around the rotor 102.

Figure 5 schematically illustrates a cross section and a (radial) top view of an embodiment of a large electrically excited synchronous generator illustrating a different orientation and location of the excitation coil.

Shown is a cross section of a part of an EESG showing a number of poles, each pole comprising a pole leg 105 and a pole shoe 106 having a pole face 120 and where the pole leg 105 is integrated with or secured to a rotor 102. Shown are two poles one ‘pointing’ right and one behind it ‘pointing’ left as indicated by the dashed line.

Also shown is a top view of a part of the EESG showing a number of poles.

The embodiment corresponds to the embodiment of Figure 4 with the exceptions as noted in the following. In the embodiment shown in Figure 5, an excitation coil 103 is wound around the rotor 102 in sort of a zig-zag pattern or similar instead of a more or less straight line as in Figure 4.

As can be seen, the excitation coil 103 is still located in a cavity defined by the poles but the horizontal distance (seen from the side) between the pole legs 105 of two neighbouring poles is less than the diameter or horizontal width (seen from the side) of the excitation coil.

This provides a very compact design of the rotor and/or that the circumference or the width (seen from the side) of the pole legs 105 can be increased and/or that the width (seen from the side) of the pole shoes 106 can be reduced (as they can be located closer together while still accommodating the excitation coil).

Figure 6 schematically illustrates a cross section of an embodiment of a large electrically excited synchronous generator illustrating a different shape of the poles. Shown is a cross section of a part of an EESG showing a pole comprising a pole leg 105 and a pole shoe 106 having a pole face 120 and where the pole leg 105 is integrated with or secured to a rotor 102. Further shown is an excitation coil 103 that may be wound more or less in a straight line around the rotor 102, e.g. as shown in Figures 2, and 4, or it may be wound according to another pattern, e.g. in a zig-zag pattern or similar e.g. as shown in Figures 5 and 7.

The embodiment corresponds to the embodiments of Figures 2, 4, and/or 5 with the exception that the pole legs 105 have been reduced in size, which reduces the weight of the design.

Furthermore, that the pole leg 105 is secured with the pole shoe 106 more towards the middle or center of the pole shoe 106 increases the mechanical stability and the pole shoes becomes less flimsy whereby the need for non-magnetic support of the poles/pole shoes is reduced or avoided.

Figure 7 schematically illustrates a cross section of an embodiment of a large electrically excited synchronous generator illustrating another different shape of the poles. Shown is a cross section of a part of an EESG showing a pole comprising a pole leg 105 and a pole shoe 106 having a pole face 120 and where the pole leg 105 is integrated with or secured to a rotor 102.

In this particular embodiment, and variations thereof, the pole leg 105 is fixed or integrated at the center of the pole shoe 106 rather than towards one of the sides, as otherwise is the case in the embodiments of Figures 2, 4, 5, and 6. Furthermore, the side-ways ends of the pole shoes 106 are also more or less the same as opposed to the embodiments of Figures 2, 4, 5, and 7 where the pole shoes are more claw-like or pointy.

Further shown is an excitation coil 103 that is wound around the rotor 102 in a zig-zag pattern or similar, e.g. like shown in Figure 5.

This design accommodates more or less all the flux coming from the pole leg thereby enabling a more compact EESG, since the (radial) height of the pole shoe 106 can be lower while still maintaining the same efficiency.

Furthermore, that the pole leg 105 is secured with the pole shoe 106 more or less at the middle or center of the pole shoe 106 generally provides further increased mechanical stability and the pole shoes becomes less flimsy whereby the need for non-magnetic support of the poles/pole shoes is reduced or avoided further, even compared e.g. to the embodiment of Figure 6.

As a further alternative, a recess or groove may be located in the rotor 102 to accommodate the lower part of the coil 103. This is particularly advantageous as the flux in the designs according to Figure 7 more or less runs circumferentially around the rotor.

This enables shortening the height of the pole leg 105 and/or having more space available for the coil.

Even though the EESG and variations thereof have primarily been described in connection with wind turbines, it is to be understood that it may readily be used in connection with other devices or systems than wind turbines, as for example tidal power generators, hydro power generators and other low speed high torque applications.

In the claims, any reference signs placed between parentheses shall not be constructed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

It will be apparent to a person skilled in the art that the various embodiments of the invention as disclosed and/or elements thereof can be combined without departing from the scope of the invention.

Claims:

1. A large electrically excited synchronous generator (100), comprising
   - a stator (101), and
   - a rotor or rotor coreback (102) comprising an excitation coil (103) generating a magnetic field during use,

wherein
   - the rotor or rotor coreback (102) further comprises a plurality of poles (104), where each pole (104) comprises a pole leg (105) and a pole shoe (106) facing the stator (101),
   - the plurality of poles (104) is arranged spaced apart and radially on the rotor or rotor coreback (102), and
   - the magnetic polarity of a given pole is different than the magnetic polarity of its adjacent neighbouring poles.

2. The generator according to claim 1, wherein the pole shoe (106) of each pole (104) has a first side (107) that is narrower than a second opposite side (108), where one end of the pole leg (105) is secured to or integrated with the rotor or rotor coreback (102) and the other end of the pole leg (105) is secured to or integrated with the pole shoe (106) at or towards the second side (108) of the pole shoe (106).

3. The generator according to claim 2, wherein the plurality of poles (104) is arranged spaced apart on the rotor or rotor coreback (102) alternatingly at a first radial row and a second radial row so that a given pole (104) is placed on a different radial row than its neighbours, so that the first side (107) of a given pole shoe (106) is facing the first side (107) of the pole shoes (107) of its two neighbours, and so that at least a part of the pole head overlaps with at least a part of the neighbouring pole heads with air gaps between the pole heads, and the magnetic polarity of the poles on the first radial row is the same and different than the magnetic polarity of the poles on the second radial row.

4. The generator according to claim 1, wherein the pole leg (105) of each pole (104) is centrally secured to or integrated with the pole shoe (106) and is centrally secured to or integrated with the rotor or rotor coreback (102).

5. The generator according to any one of claims 1 or 4, wherein the rotor or rotor coreback (102) comprises a recess or groove adapted to accommodate a lower part of the coil 103.

6. The generator according to any one of claims 2 – 3, wherein the excitation coil (103) is wound circumferentially around the rotor or rotor coreback (102) substantially in a straight line between the pole legs (105) of poles (104) of the first radial row and the pole legs (105) of poles (104) of the second radial row and between the pole heads (106) and the rotor or rotor coreback (102).

7. The generator according to any one of claims 1 – 6, wherein the excitation coil (103) is wound circumferentially around the rotor or rotor coreback (102) by being on one side of the pole leg (105) of a given pole (104) and being on an opposite side of the pole legs (105) of the given pole's adjacent neighbouring poles.

8. The generator according to any one of claims 1 – 7, wherein the excitation coil (103) is wound circumferentially around the rotor or rotor coreback (102) generally in parallel with a first direction of rotation of the rotor or rotor coreback (102).

9. The generator according to any one of claims 1 – 8, wherein the rotor or rotor coreback (102) is connected to a shaft (201; 204) connected

- directly to a blade rotor (202) or other suitable driving mechanism or force, or
- to a blade rotor (202) or other suitable driving mechanism or force via a gear mechanism (215).

10. The generator according to any one of claims 1 – 9, wherein the excitation coil (103) comprises aluminium.

11. The generator according to any one of claims 1 – 10, wherein the pole shoes (106) comprises a magnetic steel lamination on a side facing the stator (101) and where the poles (104) consists of a solid soft magnetic material.

12. The generator according to any one of claims 1 – 11, wherein the end of the pole leg (105) being secured to or integrated with the rotor or rotor coreback (102) of at least some of the poles (104) are tapered.

13. The generator according to any one of claims 1 – 12, wherein the pole head (106) are supported by a non-magnetic material.

14. The generator according to claim 13, wherein the non-magnetic material is stainless steel or glass fibre or another composite material.

15. A wind-turbine comprising a large electrically excited synchronous generator (100) according to any one of claims 1 – 14.

16. A hydrogenerator or water turbine comprising a large electrically excited synchronous generator (100) according to any one of claims 1 – 14.

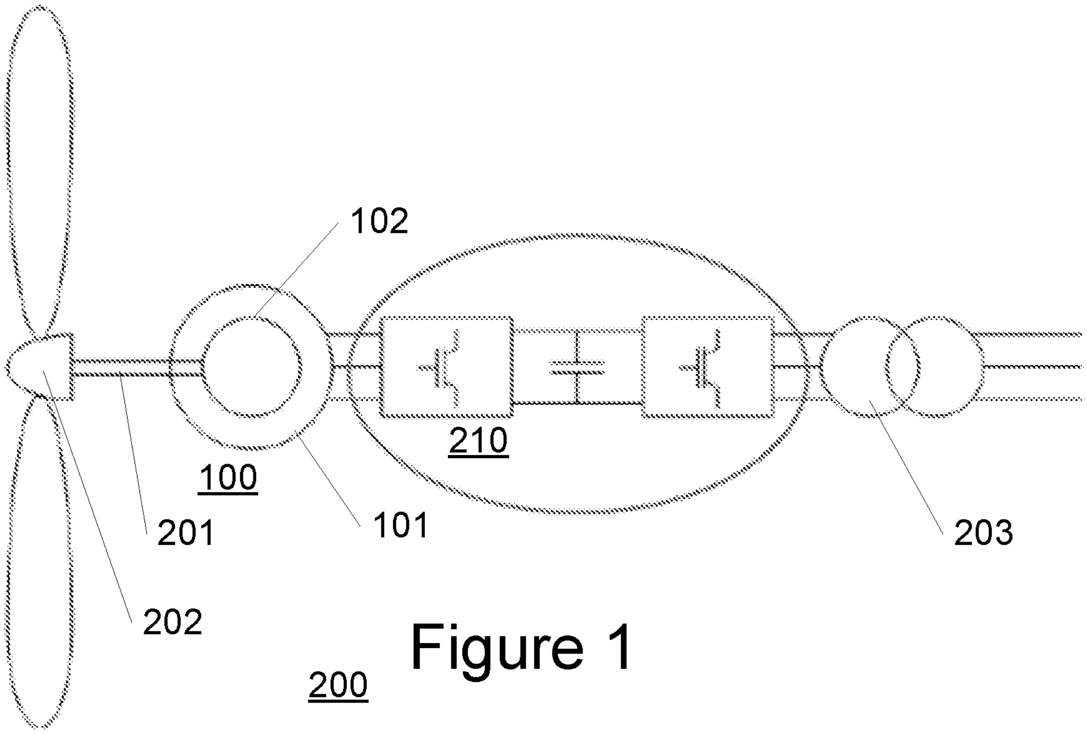

Figure 1

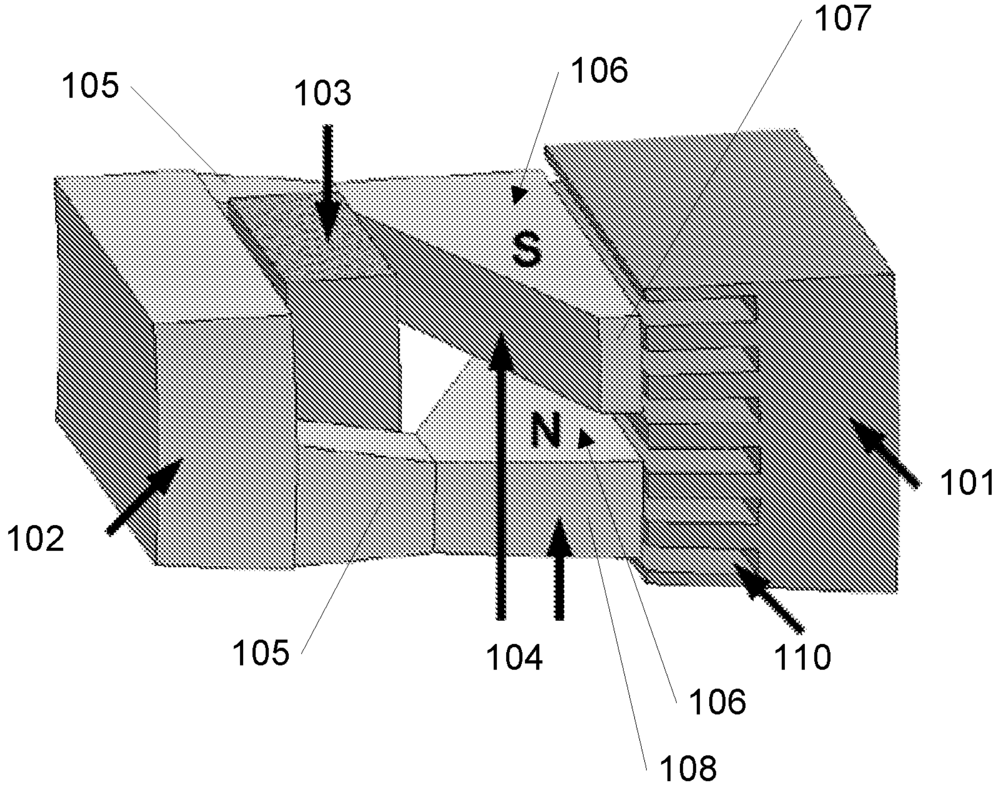

Figure 2

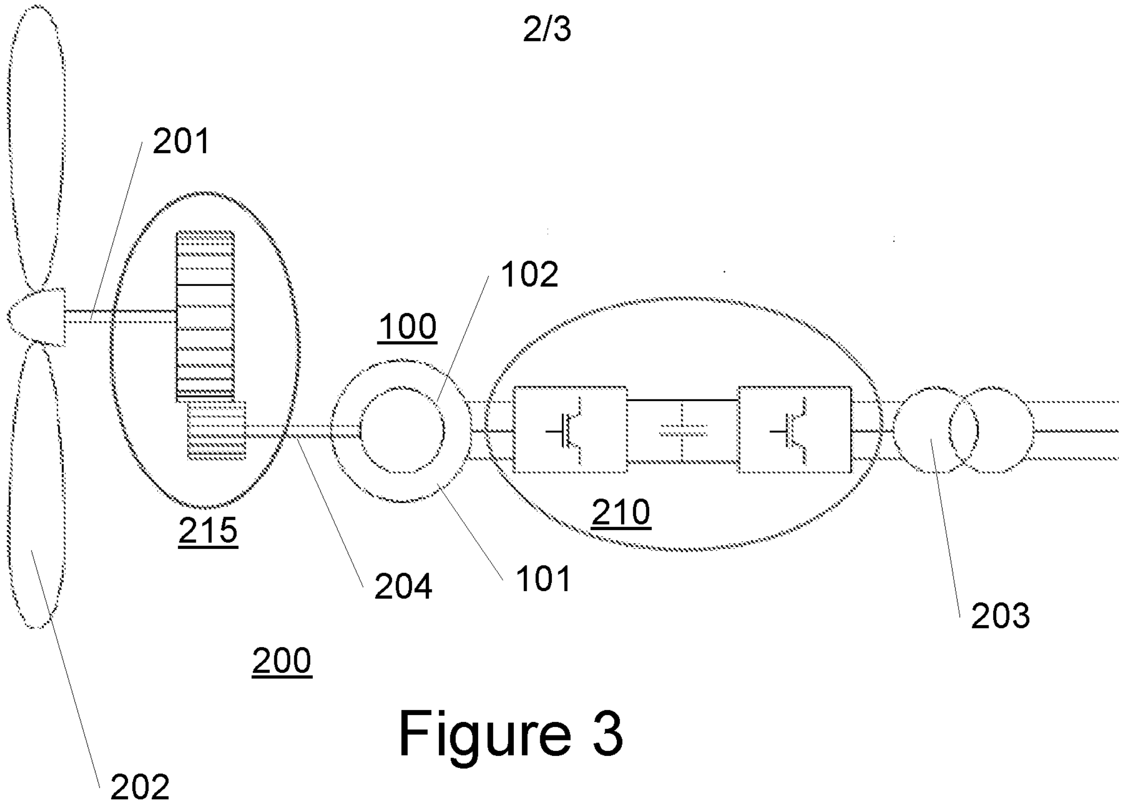

Figure 3

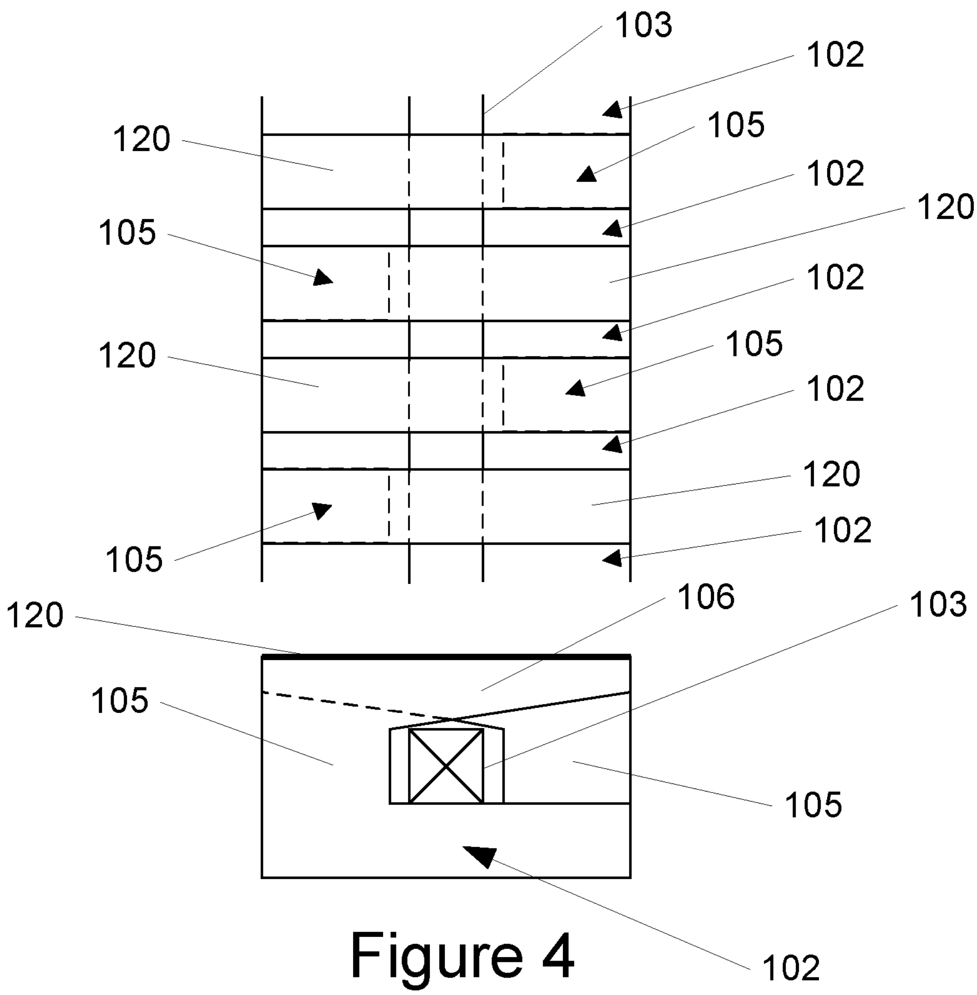

Figure 4

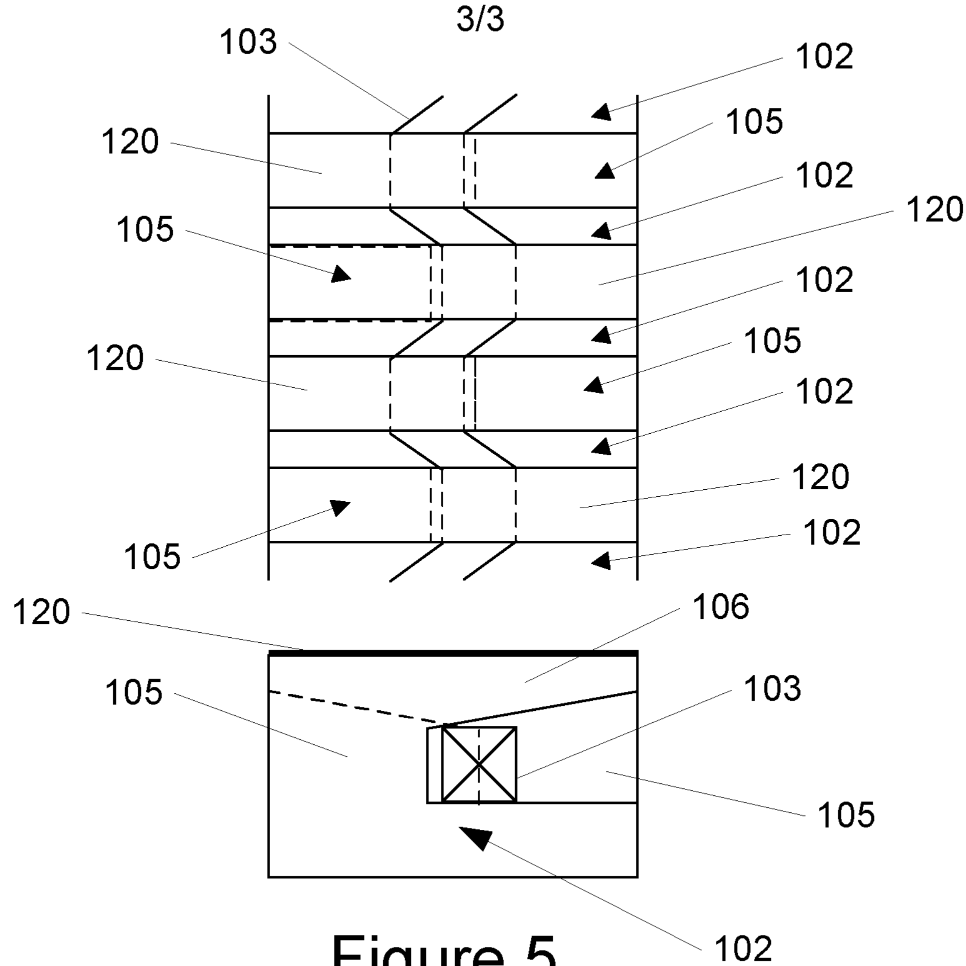

Figure 5

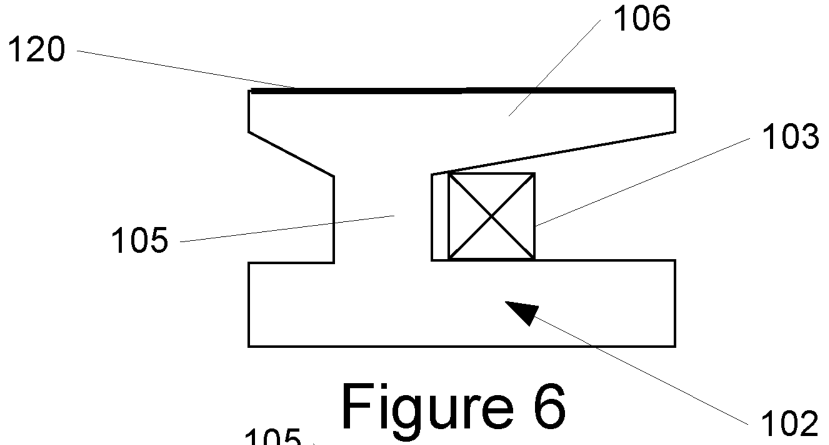

Figure 6

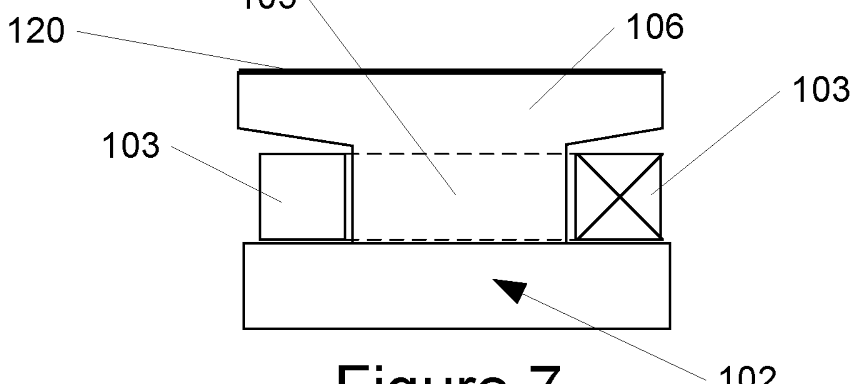

Figure 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2014/050157

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02K1/24 H02K3/04 H02K7/18 H02K19/22
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2007 166876 A (DENSO CORP) 28 June 2007 (2007-06-28) abstract; figures 1-5 paragraph [0062] - paragraph [0068]	1-5, 7-10,13, 14
X	EP 2 053 721 A2 (HITACHI LTD [JP]) 29 April 2009 (2009-04-29) paragraph [0041] - paragraphs [0071], [0183]; figures 1-9,12A-12F	1-6,8,9, 11,15
X	GB 2 062 977 A (NORTHERN ENG IND) 28 May 1981 (1981-05-28) page 1, line 11 - line 44; figures 1-3	1-6,8,9, 12,15,16

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 August 2014	22/08/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Sedlmeyer, Rafael

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	DE 10 2007 043537 A1 (BOSCH GMBH ROBERT [DE]) 19 March 2009 (2009-03-19) paragraphs [0001], [0002], [0032] - paragraph [0036]; figures 1,2 -----	13,14
A	FR 2 833 774 A1 (VALEO EQUIP ELECTR MOTEUR [FR]) 20 June 2003 (2003-06-20) page 6, line 10 - line 17; figures 6,7 -----	10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2014/050157

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