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(54) **Title**: A BEARING ASSEMBLY FOR A VERTICAL AXIS WIND TURBINE

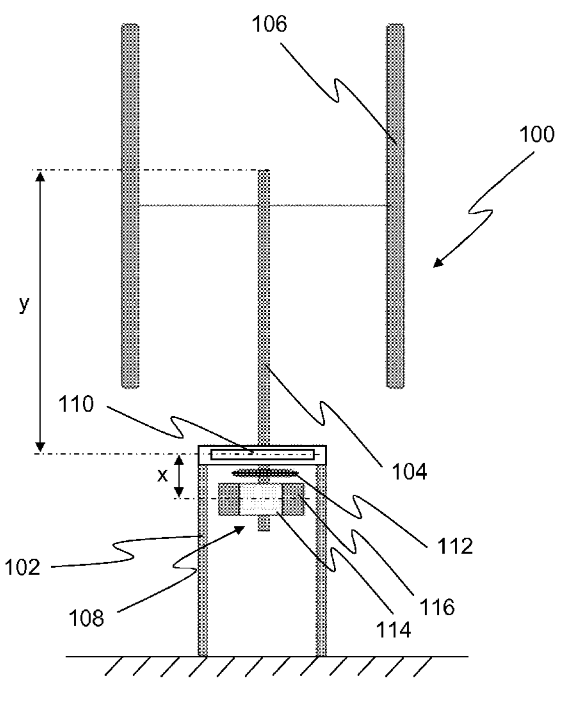

Figure 1

(57) **Abstract**: The present invention relates to a vertical axis wind turbine. The wind turbine comprises: a tower; a generator, comprising a rotor and a stator; and a bearing assembly. The bearing assembly is coupled to the tower, and is adapted to support a substantially vertical main mast of the wind turbine. The bearing assembly is also adapted to resist axial loads, radial loads and moment loads from the main mast. The stator of the generator is coupled to the bearing assembly, and the rotor of the generator is adapted to be coupled to the substantially vertical main mast by means of the bearing assembly. The ratio of the distance from the mid plane of the bearing to the mid plane of the generator rotor to the length of the main mast is less than 0.1. The invention also relates to a bearing assembly for a vertical axis wind turbine, and to methods of installing a vertical axis wind turbine and maintaining a vertical axis wind turbine.

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A BEARING ASSEMBLY FOR A VERTICAL AXIS WIND TURBINE

The present invention relates to a vertical axis wind turbine having a bearing assembly coupled to a stator of a generator. The invention also relates to a bearing assembly for a vertical axis wind turbine. The invention also relates to a method for installing such a vertical axis wind turbine, and a method for maintaining such a vertical axis wind turbine.

Wind turbines and windmills have been used for centuries to harness the energy from the wind. Typically, conventional wind turbines have been of a horizontal axis type construction, with blades arranged around a horizontal shaft. However, vertical axis wind turbines (VAWTs) are also known. In wind turbines of a vertical axis construction, the blades are typically arranged around a central, vertical mast and are connected to the mast by means of one or more support arms.

A number of different types of VAWT exist, each having a different arrangement and configuration of the blades. For example, in an H-type VAWT, the blades are typically arranged substantially vertically at an approximately constant distance from the central mast and the aerodynamic flow and associated angle of attack are almost constant along the length of the blade.

Conventional VAWT machinery arrangements involve a number of spaced apart bearings acting to support the vertical mast and the associated generator and braking system. The bearings are required to resist the weight of the vertical mast and blade assembly, and the horizontal and moment loads generated by the aerodynamic loading on the blades. The generator and braking system are generally positioned below the spaced apart bearings. This arrangement requires a large structurally rigid tower to house the bearings and generator such that the deflections due to the loads are minimised. In other conventional VAWT machinery arrangements a flexible coupling is utilised between the mast and the generator rotor to de-couple the mast displacements due to the deformations of the loaded bearing, pedestal and main structure from the generator rotor. The flexible couplings are expensive, and increase the difficulty of aligning the rotor within the stator.

In addition to the problems associated with ensuring alignment of the generator rotor and the generator stator, in order to undertake maintenance of the machinery components lateral access ports must be provided in the tower. The lateral access ports result in a larger diameter tower than would otherwise be required.

It would therefore be desirable to provide a vertical axis wind turbine that allows the size and cost of the tower to be reduced without compromising the efficiency or safety of the VAWT. It would also be desirable to provide a VAWT that is easier to install, and that has machinery components that are easier to set-up, such as aligning the generator rotor and the wind turbine mast and ensuring that the generator rotor and stator are concentric and coaxial. Finally, it would also be desirable to provide a VAWT that is easier to maintain than conventional VAWTS.

According to a first aspect of the present invention, there is provided a vertical axis wind turbine. The wind turbine comprises: a tower; a generator, comprising a rotor and a stator; and a bearing assembly. The bearing assembly is coupled to the tower, and is adapted to support a substantially vertical main mast of the wind turbine. The bearing assembly is also adapted to resist axial loads, radial loads and moment loads from the main mast. The stator of the generator is coupled to the bearing assembly, and the rotor of the generator is adapted to be coupled to the substantially vertical main mast by means of the bearing assembly. The ratio of the distance from the mid plane of the bearing to the mid plane of the generator rotor to the length of the main mast is less than 0.1.

By providing such a bearing assembly, the structural rigidity of the wind turbine tower may be reduced as compared to a conventional VAWT tower. Any deflection of the main mast also acts to deflect the bearing assembly, and thus the generator stator. The generator rotor is coupled to the mast, and so the deflections of the generator rotor and the generator stator are coupled reducing the possibility of the rotor contacting the stator. Therefore, the structural rigidity of the tower can be reduced as larger overall deflections are acceptable because the relative deflection between the rotor and stator is reduced.

In addition, utilising a bearing assembly adapted to resist axial loads, radial loads and moment loads, such as tilting moments, from the main mast allows for a simpler, and cheaper, VAWT as compared to conventional VAWTs.

By providing such a low ratio, the deflection of the generator rotor relative to the generator stator can be reduced, and thus advantageously, the air gap between the rotor and the stator can be reduced. Therefore, the relative displacement between the generator rotor and the generator stator is reduced. The relative deflection is reduced because the distance between the bearing and the generator is reduced, and thus for a given angular deflection of the main mast the horizontal displacement of the generator rotor within the generator stator is less than for a conventional VAWT main mast having a longer distance between the bearing and the generator. Utilising a relatively low ratio enables the flexible coupling often used in conventional VAWTs to be removed without comprising on having a low air gap between the generator rotor and the generator stator, and enables the cost and complexity of the VAWT to be reduced.

The term “vertical axis wind turbine” (VAWT) is used to refer to a wind turbine for the conversion of wind energy to electrical energy in which the wind turbine blades are mounted for rotation around a central, vertical axis. This type of wind turbine would be known to the skilled person. Well known VAWT constructions include the H-type or “Darrieus” VAWT, which include vertical blades mounted around central shafts or masts. Other known types of VAWT incorporate a helical blade configuration, or a troposkein (“egg beater”) blade configuration.

Vertical axis wind turbines of the present invention find application as onshore wind turbines for use on land as well as offshore wind turbines, either bottom mounted or floating. For example, in certain embodiments wind turbines according to the invention may be floating wind turbines for offshore use.

Preferably, the bearing assembly comprises an inner support structure, an outer support structure and at least one bearing. The rolling elements of the or each bearing are preferably rollers because they are able to withstand higher loads. Alternatively, the rolling elements may be balls. Other types of bearings such as magnetic bearings may also be utilised. The inner support structure of the bearing assembly is preferably coupled to the rotor of the generator, and the outer support structure of the bearing is preferably coupled to the generator stator. The inner support structure is also preferably coupled to the main mast.

Preferably, the rolling elements are housed in a bearing comprising an inner ring, and an outer ring, wherein the inner ring is coupled to the inner rotating support structure, and the outer ring is coupled to the outer substantially static support structure. Alternatively, the inner ring of the bearing is coupled to a substantially static inner support structure, and the outer ring is coupled to an outer rotating support structure. This alternative is described in further detail below.

The bearing assembly preferably comprises a guide shaft adapted to couple the rotor to the substantially vertical main mast. The rotor of the generator may be slidable on the guide shaft for maintenance access. The rotor is preferably detachably retainable in an operating position. The operating position corresponds to the rotor being positioned within the stator such that when the main mast rotates the rotor rotates within the stator and thus electricity is generated.

The guide shaft is preferably coupled to the rotating inner support structure of the bearing. The inner support structure may be a wheel shaft. The guide shaft and the wheel shaft may be integral.

In a preferred embodiment, the bearing assembly integrates a slewing bearing. Preferably, the slewing bearing comprises two or three sets of roller bearings. In the three sets configuration, the longitudinal axes of each roller in the first and second sets of the roller bearings are preferably arranged at an angle of approximately 90 degrees to the longitudinal axis of the main mast, and the longitudinal axes of each roller bearing in the third set of roller bearings are preferably substantially parallel to the longitudinal axis of the main mast. Preferably, the first and second sets of roller bearings are adapted to resist axial and moment loads from the main mast, and the third set of roller bearings are adapted to resist radial loads from the main mast. The slewing bearing may be provided with seals to prevent the ingress of dirt and debris to the bearing surfaces and/or the egress of the bearing lubricating oil or grease.

The vertical axis wind turbine may further comprise mounting means for mounting the bearing assembly to the tower of the wind turbine. The mounting means is preferably adapted to couple the outer ring of the bearing to the tower of the wind turbine through the outer support structure, and to couple the generator stator to the outer support structure of the bearing.

Preferably, the vertical axis wind turbine further comprises a brake adapted to be coupled to the substantially vertical main mast directly or via the guide shaft. The brake is preferably a mechanical brake. The brake preferably comprises a brake disc and at least one brake calliper, wherein the brake disc is coupled to the substantially vertical main mast above the bearing assembly. Alternatively, the brake preferably comprises a brake disc and at least one brake calliper, wherein the brake disc is coupled to the substantially vertical main mast between the bearing assembly and the generator. Preferably, the brake disc is coupled to the main mast by the inner support structure. Preferably, the at least one brake calliper is coupled to the portion of the bearing assembly coupled to the stator. In a further alternative, the brake may comprise a brake disc and at least one brake calliper, wherein the brake disc is coupled to the guide shaft below the generator. In this further alternative, the at least one brake calliper may be coupled to the tower.

The generator may be a synchronous generator, such as a permanent magnet type generator, or any other type of synchronous generator such as a wound rotor type generator. The generator may be any other type of generator suitable for use in a direct drive arrangement, that is to say an arrangement that does not utilise a gearbox between the main mast and the generator. Alternatively, the generator may be an asynchronous generator. As the present invention utilises a direct drive between the main mast and the generator rotor (i.e. it does not require a gearbox), the asynchronous generator is the least preferred type of generator.

Preferably, the vertical axis wind turbine further comprises a substantially vertical main mast having rotor blades, wherein the main mast is coupled to the rotor of the generator. The main mast and rotor blades may be in an H-type configuration. Preferably, the main mast is coupled to the rotor of the generator by the guide shaft. The main mast may be coupled to the guide shaft by the inner support structure, such as by directly attaching the main mast to the inner support structure utilising retaining bolts or the like.

Preferably, the wind turbine is adapted to be installed offshore. The wind turbine may be installed on a tower piled in to the seabed, on a floating structure anchored to the seabed, or on any other suitable type of installation.

In an alternative embodiment, the bearing assembly is arranged such that the generator rotor is external to the generator stator. In this alternative embodiment, the generator stator is coupled to the inner support structure, which is coupled to a tower of a wind turbine. The generator rotor is coupled to the outer support structure of the bearing assembly via the guide shaft. The main mast is also coupled to the outer support structure of the bearing assembly. A slewing bearing, as described above, may be utilised. As will be appreciated, in this alternative embodiment the generator rotor rotates around the generator stator rather than within the generator stator.

According to a further aspect of the present invention, there is provided a bearing assembly for a vertical axis wind turbine. The bearing assembly comprises: a generator, comprising a rotor and a stator; and a bearing adapted to support a substantially vertical main mast of the wind turbine, wherein the bearing is adapted to resist axial loads, radial loads and moment loads from the main mast. The stator of the generator is coupled to the bearing assembly, and the rotor of the generator is adapted to be coupled to the substantially vertical main mast by means of the bearing assembly.

By providing such a bearing assembly, a more efficient generator may be provided since advantageously the air gap between the rotor and the stator can be reduced. The air gap can be reduced because the rotor and stator can be coupled to the bearing assembly in a controlled environment, such as a factory, and then installed in a wind turbine at a later time. In addition, because the stator is coupled to the bearing assembly, the relative deflection between the rotor and the stator is minimised.

Preferably, the bearing is a slewing bearing as described herein.

Preferably, the bearing assembly further comprises a guide shaft adapted to couple the substantially vertical main mast to the rotor of the generator. The rotor of the generator may be slidable on the guide shaft for maintenance access. The guide shaft is preferably mounted within the bearing assembly by coupling it to the inner ring of the bearing through the inner support structure. The guide shaft may be integral to the inner support structure.

Preferably, the bearing assembly further comprises a brake disc and at least one brake calliper, the brake disc being coupled to the substantially vertical main mast by means of the rotating part of the bearing assembly. Where the bearing assembly comprises a guide shaft, the guide shaft may also be further adapted to couple the substantially vertical main mast to the brake disc.

Preferably, the bearing assembly further comprises mounting means for mounting the bearing to a tower of a wind turbine. The mounting means may be the outer support structure, and may be adapted to couple the outer ring of the bearing to the generator stator. Where the bearing assembly comprises a brake, the mounting means is further adapted to couple the at least one brake calliper to the outer support structure of the bearing.

According to another aspect of the present invention, there is provided a method of installing a vertical axis wind turbine. The method comprises, in an off-site location, assembling a bearing assembly having a guide shaft as described herein, coupling the stator of the generator to the bearing assembly, coupling the rotor of the generator to the guide shaft of the bearing assembly, and aligning the guide shaft within the bearing assembly such that the axis of rotation of the rotor is substantially coincident with the geometrical axis of the stator.

Providing such a method of installation reduces the cost associated with installing a vertical axis wind turbine because the complex and time consuming step of aligning the rotor and stator of the generator can be conducted in an off-site location. Furthermore, this may enable the air gap between the rotor and the stator to be reduced, and thus reduces the overall material cost of the generator and increases the efficiency of the generator. As used herein, the term “off-site location” connotes a factory, or other, controlled environment where achieving small working tolerances is possible.

The method of installing a vertical axis wind turbine may further comprise, in an on-site location: installing a bearing assembly having a guide shaft as described herein on a tower of the wind turbine, wherein the bearing assembly has an aligned guide shaft such that the axis of rotation of the rotor is substantially coincident with the geometrical axis of the stator.

According to another aspect of the present invention, there is provided a method of maintenance for a vertical axis wind turbine as described above. The method comprises:

decoupling the generator rotor from the main mast, the generator rotor being coupled to the main mast by means of a guide shaft; moving the generator rotor from an operating position to a maintenance position to expose the generator stator and generator rotor by sliding the rotor axially along the guide shaft; conducting maintenance on the generator stator, or on the generator rotor; moving the generator rotor from the maintenance position to the operating position by sliding the rotor axially along the guide shaft; and re-coupling the rotor to the main mast by means of the guide shaft.

Providing such a method enables a vertical axis wind turbine to be maintained more easily and less expensively because the main mast of the wind turbine, and thus the rotor blades, does not require disassembly to allow maintenance. In conventional VAWTs, maintenance can be a costly and time consuming process that may require the generator to be removed from the VAWT to enable the rotor to be removed from the stator. The present invention looks to mitigate that disadvantage. In addition, the diameter of the wind turbine tower may be reduced because the requirement for lateral access to the generator is removed, and thus the overall cost of the wind turbine may be reduced.

Preferably, the main mast is coupled to the guide shaft by an inner support structure, such as a wheel shaft as described herein.

According to a further aspect of the present invention, there is provided a vertical axis wind turbine substantially as herein described with reference to the accompanying figures.

According to a further aspect of the present invention, there is provided a bearing assembly for a vertical axis wind turbine substantially as herein described with reference to the accompanying figures.

According to a yet further aspect of the present invention, there is provided a method of installing a vertical axis wind turbine substantially as herein described with reference to the accompanying figures.

According to a still further aspect of the present invention, there is provided a method of maintenance for a vertical axis wind turbine substantially as herein described with reference to the accompanying figures.

Any feature in one aspect of the invention may be applied to other aspects of the invention, in any appropriate combination. In particular, method aspects may be applied to apparatus aspects, and vice versa. Furthermore, any, some and/or all features in one aspect can be applied to any, some and/or all features in any other aspect, in any appropriate combination.

It should also be appreciated that particular combinations of the various features described and defined in any aspects of the invention can be implemented and/or supplied and/or used independently.

The invention will be further described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a schematic diagram of a vertical axis wind turbine;

Figure 2 shows a cross-section of a tower comprising a bearing assembly and generator; and

Figure 3 shows a cross-section of a tower comprising an alternative bearing assembly and generator.

Figure 1 shows a schematic diagram of a vertical axis wind turbine (VAWT) 100. The VAWT comprises an elongate tower 102 which is mounted such that its longitudinal axis is vertical. A main central mast 104 couples rotor blades 106 to an electrical generator 108, such as a synchronous generator. The main mast 104 is coupled to the tower through a slewing bearing 110. The slewing bearing 110 is adapted to resist vertical, horizontal and moment loads applied to it by the main mast. Wind acting on the rotor blades 106 causes the main mast to rotate within the slewing bearing 110, which in turn powers the generator to generate electricity. A brake system 112 is provided to enable the main mast to be braked to reduce the rotational speed of the main mast, or to prevent the main mast from rotating during maintenance operations. The generator comprises a rotor 114, and a stator 116. The rotor is coupled to the main mast 104, and the stator is coupled to the portion of the bearing 110 connected to the tower. The arrangement of the bearing and generator is discussed in further detail below.

The slewing bearing 110 comprises an inner ring and an outer ring with three sets of roller bearings, the outer ring comprises two portions. The first portion being a ring portion housing the first set of roller bearings. The second portion is a corresponding ring portion housing the second set of roller bearings. The third set of roller bearings are housed between the first and second ring portions. The two portions of the outer ring enable the inner ring to be positioned within the outer ring and with two of the three sets of roller bearings acting on two opposed bearing surfaces. The third of the three sets of roller bearings acting on the outer surface of the inner ring. The outer surface is between the two opposed surfaces.

An inner support structure is provided and is attached to the inner ring of the slewing bearing to enable the main mast, and the generator rotor, to be coupled to the rotating portion of the slewing bearing. The inner support structure comprises a guide shaft, and a wheel shaft; the generator rotor is attached to the guide shaft. An outer support structure is provided and is attached to the outer ring of the slewing bearing, to couple the bearing assembly to the tower of the wind turbine. The arrangement of the bearing assembly and associated support structures is discussed in further detail below.

In order to reduce the deflection, or displacement, of the generator rotor within the generator stator, the distance X is minimised. The distance X is the distance from the mid plane of the slewing bearing 110 to the mid plane of the generator rotor 114. The length Y is the length of the main mast 104 from the mounting point at the slewing bearing 110 to the top of the main mast. The ratio of the distance X to the length Y is less than 0.1; i.e. the distance X is less than 10% of the overall length of the main mast.

Figure 2 shows a cross-section of the tower 102 comprising the slewing bearing assembly 110 and the generator 108. As described above, the slewing bearing assembly 110 comprises an inner ring 200, an outer ring 202 and three sets of roller bearings 204, 206 and 208. The two sets of roller bearings 204 and 208 resist both axial loads and moment loads acting on the inner ring. The set of roller bearings 206 resist radial loads acting on the inner ring. The loads from the main mast are transmitted through the slewing bearing 110, and the roller bearings 204, 206 and 208, via the inner support structure, such as the wheel shaft 212, . The main mast is bolted to the wheel shaft 214 (inner support structure). The main mast is therefore coupled to the guide shaft through the wheel-shaft so that it can be removed if necessary for maintenance. Thus, the main mast is coupled to the generator rotor through the wheel shaft 212 and the guide shaft 210.

As can be seen, the wheel shaft 212 may be integrally formed with the guide shaft 210, and the outer portion of the wheel shaft is bolted to the inner ring 200 of the slewing bearing 110. The wheel shaft 212 is provided with a plurality of spokes to reduce the weight of the overall bearing assembly. As described above, the guide shaft 210 is also adapted to receive the rotor 216 of the generator. The rotor 216 is slidably mounted on the guide shaft, and, when in an operational position, abuts the wheel shaft 212. The rotor is held in the operational position by retaining means such as retaining bolts, or the like. When the generator requires maintenance, the retaining means are removed, and the rotor slides along the guide shaft to allow access to both the rotor and the stator. This allows maintenance of the generator without the requirement to disassemble the entire wind turbine.

In this example, the brake 112 is provided above the slewing bearing assembly, and comprises the brake disc 218 and the callipers 220. The brake callipers 220 are coupled to the tower 202 via the outer support structure, and the brake disc 218 is coupled to the wheel shaft 212.

The stator 222 of the generator is coupled to the outer support structure 224 of the slewing bearing. As can be seen, the mounting means in the form of the outer support structure 224 couples the generator stator 222 to the tower 102, the outer ring 202 of the slewing bearing to the tower 102, and the brake callipers 220 to the tower 102. The stator 222 is suspended from the outer support structure. Therefore, the outer ring 202 of the slewing bearing, the stator 222 of the generator and the brake callipers 220 are all coupled together via a coupling member: the outer support structure 224. The outer support structure 224 is directly connected to the tower 102. This configuration enables the slewing bearing, guide shaft and wheel shaft, and the brake system to be assembled together in a factory and then installed as a single unit on-site. Assembling the bearing assembly off-site allows the generator rotor and generator stator of the generator to be aligned with greater precision than that achievable during on-site assembly. Therefore, the generator can be manufactured with improved/reduced tolerances as compared to conventional VAWT generators, and so, for example, the air gap between the rotor and the stator can be reduced.

In addition, providing such a configuration minimises the relative deflections between the generator rotor and the generator stator. The generator stator is directly connected to the outer ring of the bearing assembly through the outer support structure of the slewing bearing, and the generator rotor is directly connected to the inner ring of the bearing assembly via the guide shaft and wheel shaft that constitutes the inner support structure of the slewing bearing. Therefore, any deflection, or displacement, in the guide shaft caused by loads on the main mast are transmitted to the outer support structure of the bearing assembly. As the generator stator is directly connected to the outer support structure, any deflection in the outer support structure also deflects the generator stator. Therefore, the deflections, and displacements, of the generator stator and generator rotor are coupled together, and are independent of the deflections of the tower. This enables the tower to be less stiff than for conventional VAWTs where the generator stator and bearings are each spaced apart and coupled separately to the tower; in this conventional arrangement, the deflections, and displacement, of the stator and rotor are independent from each other, and thus can be large.

Figure 3 shows a cross-section of a tower comprising an alternative slewing bearing assembly and generator. In this alternative, the brake disc 300 and the brake callipers 302 are provided below the generator. The brake callipers 302 are provided on the inner surface of the tower 102. The brake disc is directly coupled to the bottom of the guide shaft 210. The other components are arranged as described above. By providing the brake disc within the tower it can be provided with protection from the weather. In this example, and similarly to the previous example described above, the brake disc is mounted to the guide shaft in the off-site factory location, and then installed on the wind turbine tower together with the bearing assembly. The brake callipers are installed within the tower before the bearing assembly is installed, but are engaged with the brake disc after installation.

Alternatively, to install the brake system and bearing assembly, the brake disc is inserted into the tower before being attached to the guide shaft, and before the bearing assembly is connected to the tower. When the brake disc is within the tower, the bearing assembly is connected to the tower, and then the brake disc is connected to the guide shaft.

The VAWT as described herein can be installed in an offshore location, or in an onshore location. When in an offshore location, the VAWT may be part of a large network of similar VAWTs.

CLAIMS:

1. A vertical axis wind turbine, comprising:

    a tower;

    a generator, comprising a rotor and a stator; and

    a bearing assembly, coupled to the tower, for supporting a substantially vertical main mast of the wind turbine, wherein the bearing assembly is adapted to resist axial loads, radial loads and moment loads from the main mast,

    wherein, the stator of the generator is coupled to the bearing assembly, and the rotor of the generator is adapted to be coupled to the substantially vertical main mast by means of the bearing assembly, and

    wherein, the ratio of the distance from the mid plane of the bearing to the mid plane of the generator rotor to the length of the main mast is less than 0.1.

2. A vertical axis wind turbine according to Claim 1, wherein the bearing assembly comprises a guide shaft adapted to couple the generator rotor to the substantially vertical main mast.

3. A vertical axis wind turbine according to Claim 2, wherein the generator rotor is slidable on the guide shaft for maintenance access.

4. A vertical axis wind turbine according to any of Claims 1 to 3, further comprising a brake adapted to be coupled to the substantially vertical main mast.

5. A vertical axis wind turbine according Claim 4, the brake comprising a brake disc and at least one brake calliper, wherein the brake disc is coupled to the substantially vertical main mast vertically above the bearing assembly.

6. A vertical axis wind turbine according to Claim 4, the brake comprising a brake disc and at least one brake calliper, wherein the brake disc is coupled to the substantially vertical main mast between the bearing assembly and the generator.

7. A vertical axis wind turbine according to Claim 5 or 6, wherein the at least one brake calliper is coupled to the portion of the bearing assembly coupled to the stator.

8. A vertical axis wind turbine according to Claim 4, the brake comprising a brake disc and at least one brake calliper, wherein the brake disc is coupled to the substantially vertical main mast below the generator.

9. A vertical axis wind turbine according to Claim 8, wherein the at least one brake calliper is coupled to the tower.

10. A vertical axis wind turbine according to any of the preceding claims, wherein the bearing assembly comprises a slewing bearing.

11. A vertical axis wind turbine according to any of the preceding claims, wherein the generator is a synchronous generator.

12. A vertical axis wind turbine according to any of the preceding claims, further comprising a substantially vertical main mast having rotor blades, wherein the main mast is coupled to the rotor of the generator.

13. A vertical axis wind turbine according to any of the preceding claims, wherein the wind turbine is adapted to be installed offshore.

14. A bearing assembly for a vertical axis wind turbine, comprising:

a generator, comprising a rotor and a stator; and

a bearing adapted to support a substantially vertical main mast of the wind turbine, wherein the bearing is adapted to resist axial loads, radial loads and moment loads from the main mast,

wherein, the stator of the generator is coupled to the bearing assembly, and the rotor of the generator is adapted to be coupled to the substantially vertical main mast by means of the bearing assembly.

15. A bearing assembly according to claim 14, wherein the bearing is a slewing bearing.

16. A bearing assembly according to Claim 14 or 15, further comprising a guide shaft adapted to couple the substantially vertical main mast to the rotor of the generator.

17. A bearing assembly according to Claim 14, 15 or 16, further comprising a brake disc and at least one brake calliper, the brake disc being coupled to the substantially vertical main mast by means of the bearing assembly.

18. A bearing assembly according to Claim 17 when dependent on Claim 16, wherein the guide shaft is further adapted to couple the substantially vertical main mast to the brake disc.

19. A method of installing a vertical axis wind turbine, comprising:

in an off-site location;

assembling a bearing assembly according to any of Claims 16, 17 or 18;

coupling the stator of the generator to the bearing assembly;

coupling the rotor of the generator to the guide shaft of the bearing assembly;

aligning the guide shaft within the bearing assembly such that the axis of rotation of the rotor is substantially coincident with the axis of rotation of the stator.

20. A method of installing a vertical axis wind turbine, comprising:

in an on-site location;

installing a bearing assembly according to any of Claims 16, 17 or 18 on a tower of the wind turbine, wherein the bearing assembly has an aligned guide shaft such that the axis of rotation of the rotor is substantially coincident with the geometrical axis of the stator.

21. A method of maintenance for a vertical axis wind turbine according to any of claims 1 to 13, comprising:

decoupling the generator rotor from the main mast, the generator rotor being coupled to the main mast by means of a guide shaft;

moving the generator rotor from an operating position to a maintenance position to expose the stator by sliding the rotor axially along the guide shaft;

conducting maintenance on the stator;

moving the rotor from the maintenance position to the operating position by sliding the rotor axially along the guide shaft; and re-coupling the rotor to the main mast by means of the guide shaft.

22. A vertical axis wind turbine substantially as herein described with reference to the accompanying figures.

23. A bearing assembly for a vertical axis wind turbine substantially as herein described with reference to the accompanying figures.

24. A method of installing a vertical axis wind turbine substantially as herein described with reference to the accompanying figures.

25. A method of maintenance for a vertical axis wind turbine substantially as herein described with reference to the accompanying figures.

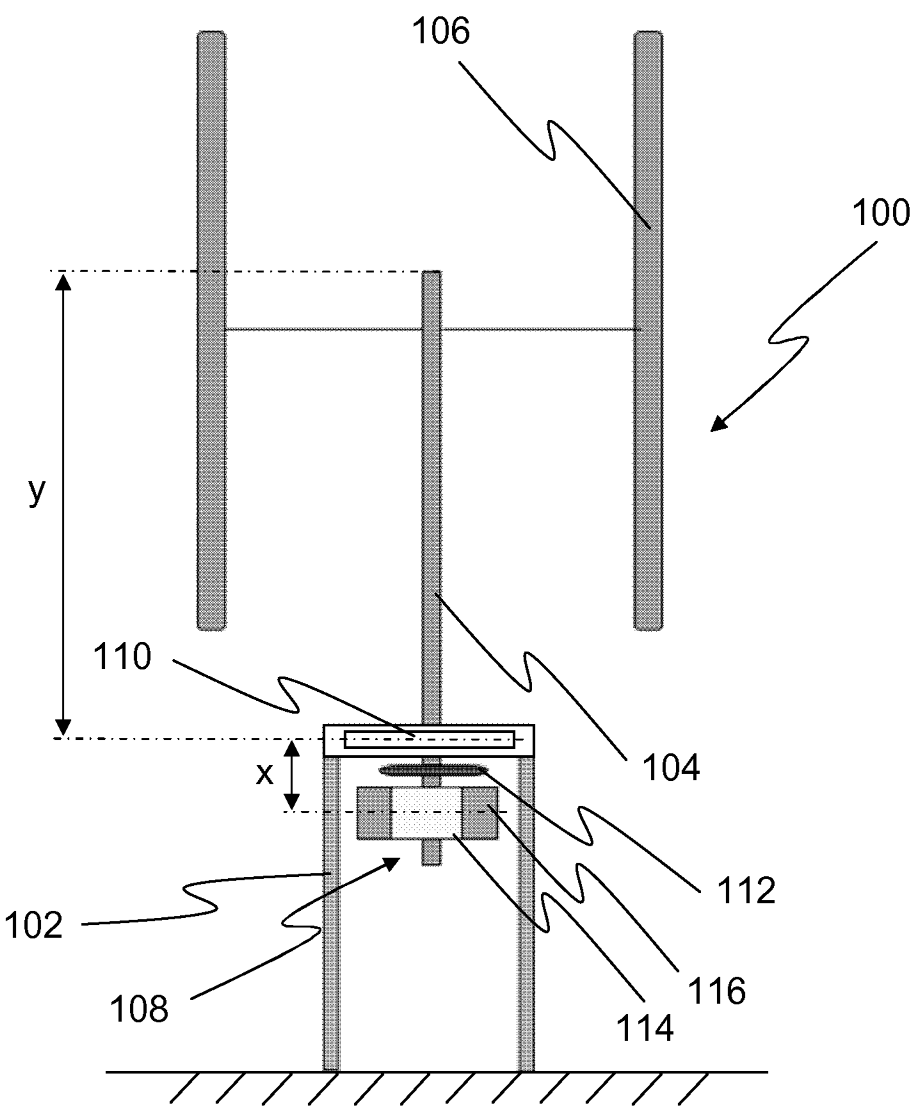

Figure 1

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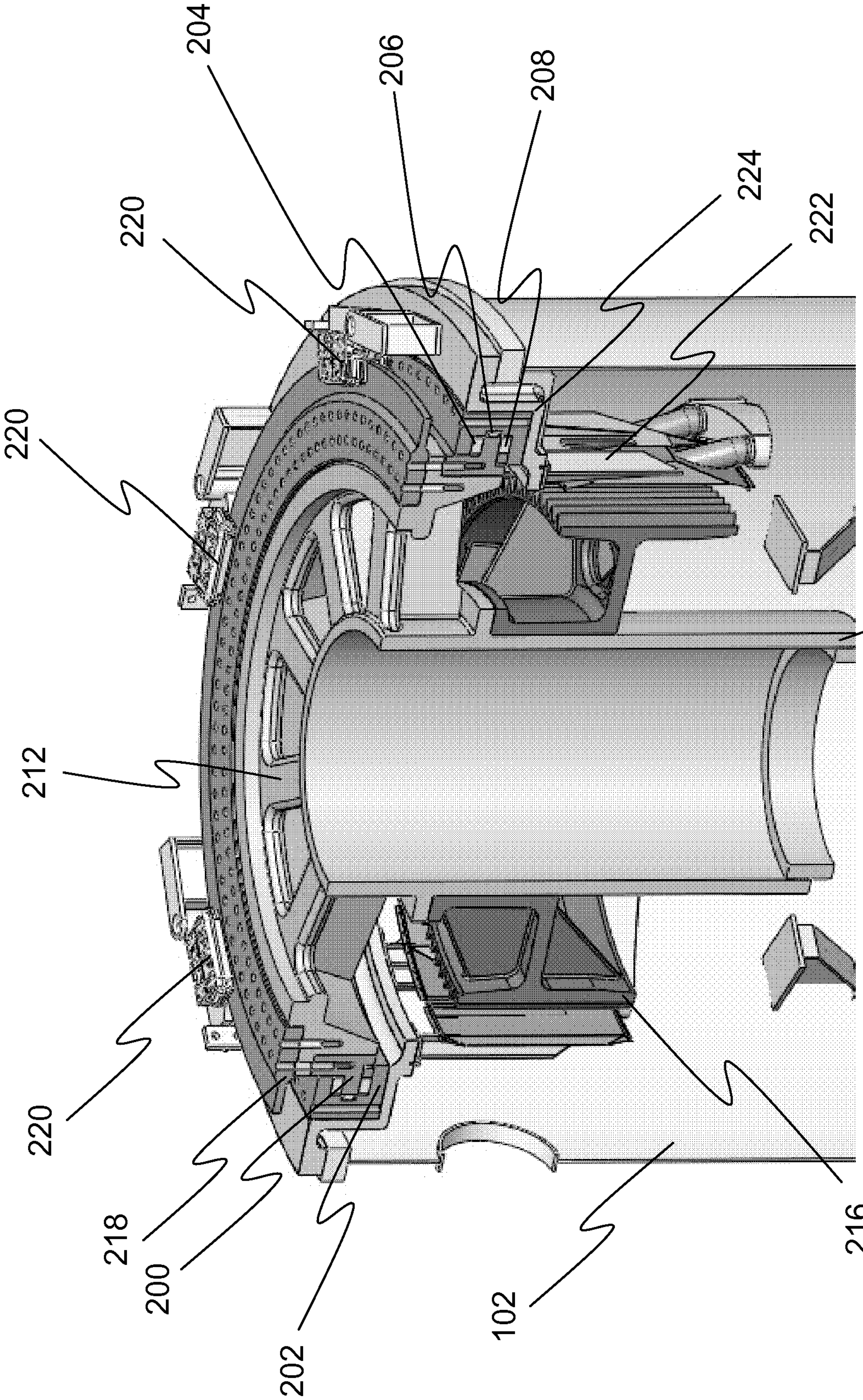

Figure 2

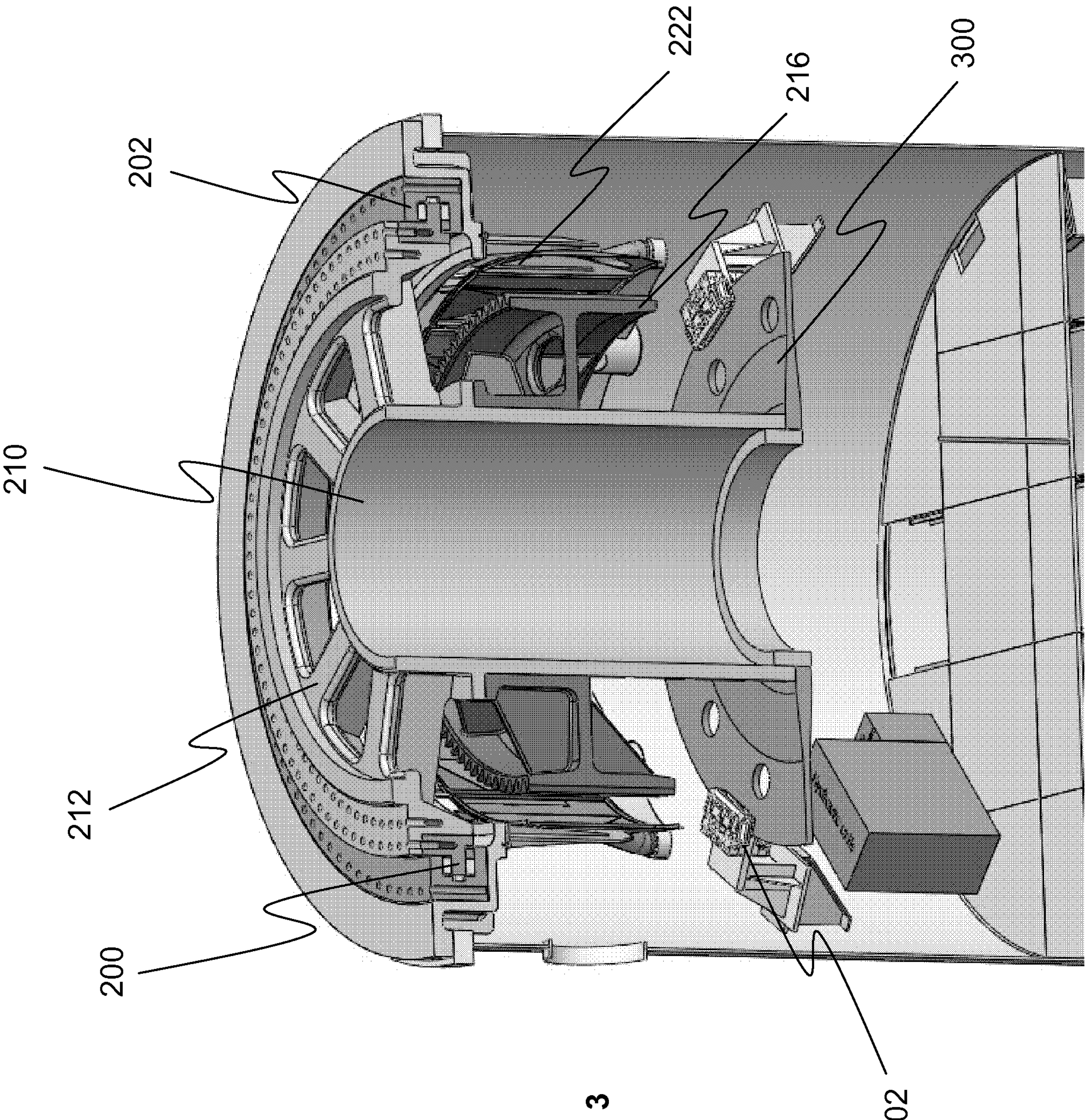

Figure 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/052444

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D9/00 F03D11/00 F03D3/00 H02K7/08 H02K7/18
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)
F03D 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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/248510 A1 (YAN QIANG [CN] ET AL) 13 October 2011 (2011-10-13)	1,2, 10-16, 19,20
Y	abstract	18
A	column 13 - column 41 figures	4,17,21

X	WO 2007/140397 A2 (ANALYTICAL DESIGN SERVICE CORP [US]; NIGAM DILIP K [US]; EL-SAYED MOHA) 6 December 2007 (2007-12-06)	1,4-15, 17,19,20
Y	abstract	18
A	paragraph [0030] - paragraph [0040] figures 1-4	2,16,21

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

[X] See patent family annex.

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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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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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
17 May 2013	27/05/2013

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	Kolby, Lars

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 2007/012195 A1 (CLEANFIELD ENERGY CORP [CA]; STERN MIHAIL [CA]; TRICA ALEXANDER [CA];) 1 February 2007 (2007-02-01) abstract page 11, line 18 - page 18, line 25 figures -----	1,4-6, 10-15, 17,19,20 7-9,16, 21
X A	WO 2011/153945 A1 (ZHANG XIAOHE [CN]) 15 December 2011 (2011-12-15) abstract figure 1 -----	1,2, 10-17 4,19-21

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/052444

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011248510 A1	13-10-2011	CN 101435412 A	20-05-2009
		US 2011248510 A1	13-10-2011
		WO 2010069127 A1	24-06-2010
WO 2007140397 A2	06-12-2007	CA 2659071 A1	06-12-2007
		CN 101512144 A	19-08-2009
		EP 2021626 A2	11-02-2009
		JP 5001358 B2	15-08-2012
		JP 2009539032 A	12-11-2009
		US 2008008575 A1	10-01-2008
		US 2010007144 A1	14-01-2010
		WO 2007140397 A2	06-12-2007
WO 2007012195 A1	01-02-2007	CA 2614929 A1	01-02-2007
		CN 101233316 A	30-07-2008
		EP 1907693 A1	09-04-2008
		US 2008309090 A1	18-12-2008
		WO 2007012195 A1	01-02-2007
WO 2011153945 A1	15-12-2011	CN 102072081 A	25-05-2011
		CN 201943888 U	24-08-2011
		WO 2011153945 A1	15-12-2011