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(71) Applicant *(for all designated States except US)*: **AMSC WINDTEC GMBH** [AT/AT]; Lakeside B08, A-9020 Klagenfurt (AT).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **JANDL, Armin** [AT/AT]; Erlach 12, A-9130 Poggersdorf (AT). **SCHWARZ, Michael** [AT/AT]; Afritschstrasse 77, A-9020 Klagenfurt (AT). **WOLF, Anton** [DE/DE]; Hoelderlinstrasse 2, 73765 Neuhausen (DE).

(74) Agent: **MCGLASHEN, Kelly**; 10 Fawcett Street, Cambridge, Massachusetts 02138 (US).

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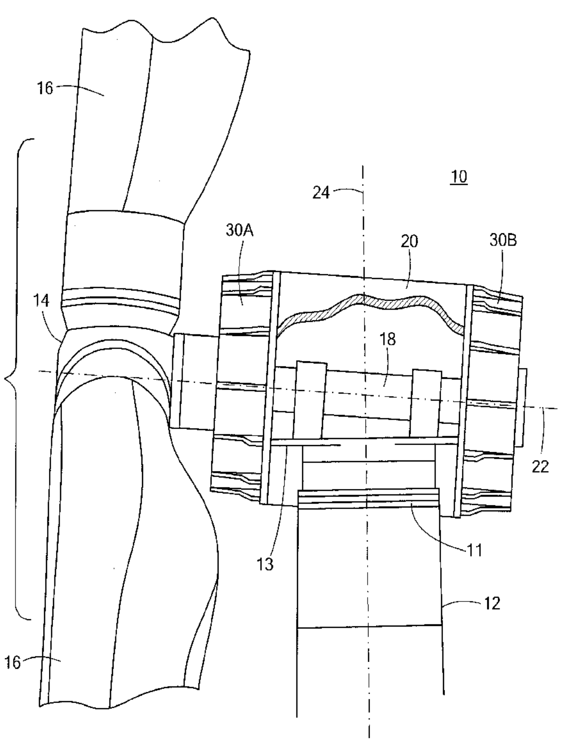

FIG. 1

(57) Abstract: A wind power plant includes a turbine rotor and a drive shaft that is fixed to the turbine rotor and rotatably supported by drive shaft support bearings on a tower. The wind power plant further includes a first direct-drive generator including a first generator rotor connected to and driven by the drive shaft, and a second direct-drive generator including a second generator rotor connected to and driven by the drive shaft. The first generator is disposed on one side of the tower, and the second generator is disposed on an opposed side of the tower, and the drive shaft support bearings are located between the first and second generators.

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DUAL-GENERATOR ARRANGEMENT FOR A WIND POWER PLANT

BACKGROUND OF THE INVENTION

As the use of wind turbines to create usable energy becomes more prevalent and a larger portion of the overall power input to the electric power grid, wind power plants having higher power output become desirable. Some conventional individual wind power plants can provide an output of approximately 5 MWatt. A goal is to provide a wind power plant which produces 10 MWatts of power. However, some approaches that include scaling up a 5 MWatt to a 10 MWatt machine are expensive to implement, as well as technically and logistically challenging. One approach is to employ a synchronous, permanent magnet generator in the wind power plant. An advantage of using a permanent magnet generator in this environment is that permanent magnet generators can operate at low speeds, permitting elimination of gearing used to step up rotational speeds intermediate the turbine rotor and generator. This can be a significant advantage, since step-up gears are costly to implement, particularly at the large sizes needed. In addition, since much of the wear and tear that takes place in conventional wind power plants occurs in the step-up gear systems, expensive maintenance can be avoided.

However, use of a permanent magnet generator requires a very accurately defined air gap between the generator rotor and the generator stator. In particular, the permanent magnet generator works efficiently for an air gap of 5 to 8 mm, regardless of machine diameter. The efficiency of the generator drops very sharply for an air gap outside this range. To maintain the required air gap of 5 to 8 mm in a generator large enough for these power requirements requires great stiffness in the generator design.

SUMMARY

In some aspects, a wind power plant is provided that includes a turbine rotor, and a drive shaft fixed to the turbine rotor. The wind power plant also includes a first direct-drive

generator including a first generator rotor connected to and driven by the drive shaft, and a second direct-drive generator including a second generator rotor connected to and driven by the drive shaft.

In some aspects, a wind power plant is provided that includes a turbine rotor, a drive shaft fixed to the turbine rotor, a tower and a shaft support bearing configured to rotatably support the drive shaft on the tower. The wind power plant further includes a first generator including a first generator rotor connected to and driven by the drive shaft; and a second generator including a second generator rotor connected to and driven by the drive shaft. The shaft support bearing is disposed between the first and second generators.

The wind power plant may include one or more of the following features: The wind power plant further comprises a tower and the drive shaft is rotatably supported on the tower and the first generator is disposed on one side of the tower, and the second generator is disposed on an opposed side of the tower. The wind power plant is configured to provide at least 10 megawatts of power. The first and second generator are each a permanent magnet generator. The wind power plant further comprises a base plate, and shaft support bearings configured to rotatably support the drive shaft relative to the base plate. The shaft support bearings are located externally relative to the first and second generators, and include two axially-spaced bearings. The shaft support bearings include tapered roller bearings or spherical roller bearings. The rotor of each of the first and second generator rotates at the same speed as the turbine rotor. The first and second generator are each a direct-drive generator.

The wind power plant may include one or more of the following additional features: The first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings. The generator support bearings include tapered roller bearings. The wind power plant further comprises a tower and the drive shaft is rotatably supported on the tower, the first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings. In addition, the wind power plant further includes a first stator mount device configured to secure the first stator to the tower and a second stator mount device configured to secure the second generator to the tower, and the first and second stator mount devices are configured to permit translation along and traverse to the longitudinal axis of the drive shaft and prevent rotation about the longitudinal axis of the drive shaft. The stator mount device comprises an active control system configured to detect at least one of drive shaft displacement and deformation, and to control the position of the stator relative to the drive shaft based on detected displacement or deformation of the drive shaft. The generator has an axial orientation that is opposed to that of the second generator.

In some aspects, an electric rotating machine is provided. The machine includes a base, a drive shaft, and a shaft support bearing configured to rotatably support the drive shaft relative to the base. In addition, the machine includes a first generator including a first rotor connected to and driven by the drive shaft; and a second generator including a second rotor connected to and driven by the drive shaft. The shaft support bearing is disposed between the first and second generators.

The electric rotating machine may include one or more of the following features: The first generator is disposed on one side of the base, and the second generator is disposed on an opposed side of the base. The electric rotating machine is configured to provide at least 10 megawatts of power. The rotor of each of the first and second generator rotates at the same speed as the drive shaft. The first and second generator are each a direct-drive generator. The first and second generator are each a permanent magnet generator. The shaft support bearings are located externally relative to the first and second generators. The shaft support bearings include two axially-spaced bearings. The shaft support bearings include tapered roller bearings or spherical roller bearings. The first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings. The generator support bearings include tapered roller bearings.

The electric rotating machine may include one or more of the following additional features: The first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings. The electric rotating machine further includes a first stator mount device configured to secure the first stator to the base and a second stator mount device configured to secure the second generator to the base, and the first and second stator mount devices are configured to permit translation along and traverse to the longitudinal axis of the drive shaft and prevent rotation about the longitudinal axis of the drive shaft. Each stator mount device comprises an active control system configured to detect at least one of drive shaft displacement and deformation, and to control the position of the respective stator relative to the drive shaft based on detected displacement or deformation of the drive shaft. The first generator has an axial orientation that is opposed to that of the second generator.

In some aspects, an electric rotating machine is provided that includes a support, a drive shaft rotatably supported by the support, and a generator. The generator includes a rotor connected to and driven by the drive shaft; and a stator supported by and arranged coaxially with the rotor. The electric rotating machine further includes a stator mount device configured to actively control the position of the stator relative to the support.

The electric rotating machine may include one or more of the following features: The stator mount device further comprises a control system configured to detect at least one of drive shaft displacement and deformation, and to control the position of the stator relative to the drive shaft based on detected displacement and/or deformation of the drive shaft. The stator mount device is configured such that the stator can translate along and traverse to the longitudinal axis of the drive shaft, but is prevented from rotating about the longitudinal axis of the drive shaft. The stator mount device includes hydraulic actuators disposed between the stator and the support. The rotating electric machine is a wind power plant, the support is a tower, and the drive shaft is driven by a turbine rotor.

In order to provide a wind power plant which produces 10 MWatts of power, a wind power plant is disclosed in which two 5 MW generators are arranged on a single drive shaft. The drive shaft is driven by a turbine rotor and supported on a tower by a pair of large axially-spaced drive shaft support bearings supported on the tower. A first generator is positioned on the drive shaft between the turbine rotor and the tower, and a second generator is positioned on the drive shaft on a side of the tower opposed to the first generator. Each of the generators is supported on the drive shaft using generator support bearings which are separate from the drive shaft support bearings. The generator support bearings are small relative to drive shaft support bearings since they only support the weight of the respective generator, whereas the drive shaft support bearings support the loads transmitted between the drive shaft and the tower and are thus required to be very large. The dual-generator arrangement is advantageous since the smaller power requirements of each generator permit use of smaller generators in which technologies related to maintaining an 8 mm air gap between the stator and rotor are known and proven. This is advantageous relative to using a single, large 10 MWatt generator, in which it is very difficult and costly to maintain the air gap of 8mm. Moreover, the relatively smaller 5 MWatt generators is easier to manufacture and transport than a 10 MWatt generator.

Providing the wind power plant with two direct-drive generators arranged as shown advantageously permits easier power testing of each of the generators, since one generator can act as a motor and the other can act as the tested generator. The generator test therefore can be done without a test bench, which normally includes a motor to test the generator.

Advantageously, devices are disclosed that active control of the position of the direct-drive generator relative to the drive shaft, reducing drive shaft loads. This can be achieved using computer controlled hydraulic devices disposed between the stator and the tower base.

Active control hydraulic devices can also be used in a non-direct drive system. That is, by employing hydraulic control of the position of the generator and/or the gear box, the relative positions of these devices can be controlled, eliminating the need for expensive couplings between the generator and gear box.

Modes for carrying out the present invention are explained below by reference to an embodiment of the present invention shown in the attached drawings. The above-mentioned object, other objects, characteristics and advantages of the present invention will become apparent from the detailed description of the embodiment of the invention presented below in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side view of a dual-generator wind power plant with a portion of the nacelle removed.

Fig. 2 is a top view of the wind power plant of Fig. 1 shown without the nacelle.

Fig. 3 is a sectional view of the wind power plant of Fig. 1 as seen along line 3—3 of Fig. 2.

Fig. 4 is an exploded sectional view of the first generator as seen along line 4—4 of Fig. 2.

Fig. 5 is a schematic diagram of the electrical connection between the wind power plant and the electric power grid.

Fig. 6 is an end view of an alternative embodiment stator support device.

Fig. 7 is a side sectional view of the stator support device of Fig. 6.

Fig. 8 is a schematic diagram of an active stator support device.

Fig. 9 is a side view of a prior art wind power plant.

Fig 10 is a side view of a wind power plant including an active compensation device.

DETAILED DESCRIPTION

Referring now to Figs. 1 and 2, a wind power plant 10 includes a wind turbine 15 in the form of a turbine rotor 14 which supports three rotor blades 16. A drive shaft 18 extends from and is driven by the turbine rotor 14, and is rotatably supported on a tower 12, as discussed further below. The wind power plant 10 further includes a first generator 30A and a second generator 30B, which are each supported on and driven by the drive shaft 18. The first and second generators 30A, 30B and at least a portion of the drive shaft 18 are enclosed within a nacelle 20. The tower 12 terminates at its upper end in a base plate 13, and a yaw system 11 permits the base plate 13 to rotate about the vertical axis of the tower 12 so that the turbine rotor 14 can be turned to a direction parallel to the wind direction.

The first and second generators 30A, 30B are arranged on the drive shaft 18 so that the first generator 30A and second generator 30B are disposed on opposed sides of the tower 12. That is, the first generator 30A is supported on the drive shaft 18 between the turbine rotor 14 and the tower 12, and the second generator 30B is supported on the drive shaft 18 at a location on the opposed side of the tower 12 relative to the first generator 30A.

The drive shaft 18 is supported on the base plate 13 through two drive shaft support bearings 110. The drive shaft support bearings 110 support the drive shaft 18 including the first and second generators 30A, 30B and the wind turbine 15, and permit axial rotation of the drive shaft 18 relative to the base plate 13. The shaft support bearings 110 may be one of, but are not limited to, spherical roller bearings, tapered roller bearings or a double row tapered roller bearing plus a cylindrical roller bearing. In the illustrated embodiment, the two drive shaft support bearings 110 are axially spaced apart, and located generally centrally on the base plate 13. In the illustrated embodiment, the drive shaft support bearings 110 are supported within bearing housings 115 located equidistantly from the axial (e.g., vertical) centerline 24 of the tower 12 and on opposed sides thereof. The drive shaft 18 is supported by the drive shaft support bearings 110 so as to be angled relative to the horizontal, such that the turbine rotor 14 at one end of the drive shaft 18 is higher than the opposed end 19 of the drive shaft 18, providing clearance between the rotor blades 16 and the tower 12. For example, in some embodiments the drive shaft 18 is angled between 4 and 6 degrees relative to the horizontal, depending on the blade length.

Referring to Figs. 3 and 4, each of the first and second generators 30A, 30B are driven by the drive shaft 18 such that the first and second generators 30A, 30B are direct-drive generators. As used herein, the term “direct-drive generator” means that the generator is directly connected to the turbine rotor via the drive shaft without intermediate gearing such that the rotational speed of the respective generator rotors 62 corresponds to the rotational speed of the turbine rotor 14.

The first generator 30A and second generator 30B are substantially identical in construction. For this reason, only the first generator 30A will be described in detail, and common structures of the two generators 30A, 30B are identified in the figures using common reference numbers.

The first generator 30A includes a rotor 62 that is fixed to and rotates with the drive shaft 18. The rotor 62 includes a set of permanent magnets 86 supported on a ferromagnetic rotor support structure that includes an inner cylinder 64, an outer cylinder 74, and an annular rotor end plate 84 that joins an end 70 of the inner cylinder 64 to an end 80 of the outer cylinder 74. The rotor inner cylinder 64 has an inner surface 66 that is shaped and dimensioned to corresponds to the shape and outer dimension of the drive shaft 18, and is fixed thereto so that the rotor 62 rotates as one with the drive shaft 18. In addition, generator support bearings 120 are fixed to the outer surface 68 of the rotor inner cylinder 64, as discussed further below. The rotor outer cylinder 74 being joined to the inner cylinder 64, also rotates with the drive shaft. The permanent magnets 86 are secured to an outer surface 78 of the rotor outer cylinder 74, and may be formed of, but are not limited to, materials such as neodymium-boron-iron or samarium-cobalt.

The first generator 30A further includes a stator 32 that does not rotate relative to the rotational axis of the drive shaft 18. The stator 32 includes stator windings 56 supported on a stator support structure that includes an inner cylinder 34, an outer cylinder 44, and an annular stator end plate 54 that joins an end 40 of the stator inner cylinder 34 to an end 50 of the stator outer cylinder 44. The rotor 62 is nested within the stator 32 such that the rotor inner cylinder 64 is disposed within the stator inner cylinder 34, and the rotor outer cylinder 74 is disposed within the stator outer cylinder 44. In addition, the stator inner cylinder 34 has an inner surface 36 that is supported by the generator support bearings 120 provided on the rotor inner cylinder 64, whereby the rotor 62 can rotate concentrically within the stator 32. The stator 32 includes a pair of stator arms 58 that extend radially outward from opposed sides of the outer surface 48 of the stator outer cylinder 44 so as to lie in a generally horizontal plane. The stator arms 58 are used to support the stator 32 relative to the base plate 13 as discussed further below.

Stator windings 56 are fixed to the inner surface 46 of the stator outer cylinder 44, as discussed further below. In this configuration, the stator windings 56 face and confront the permanent magnets 86 disposed on the rotor outer cylinder outer surface 78. The stator windings 56 are spaced apart from the permanent magnets 86 by a distance referred to as the air gap 100. In this embodiment, the air gap is 5 to 8 mm.

The stator windings 56 windings are formed of transposed wire cables (not shown), in which the individual copper wire conductors (not shown) are twisted and/or woven to form a pattern which reduces eddy current losses. The transposed cables may include Litz wire, Rutherford wire, Robel wire, or any other suitable transposed wire. The wires can also be a series of individual turns, for example in the form of a cranked winding.

Referring to also Fig. 5, when torque is applied to the turbine rotor 14 causing rotation of the output shaft 18, alternating magnetic flux is produced which extends through the air gap 100 from the permanent magnets 86 of the generator rotor 62 and interacts with the stator windings 56 to generate power. In particular, the first generator 30A is connected to the power grid 500 via a first converter 505, and the second generator 30B is connected to the power grid independently of the first generator 30A, via a second converter 515.

The air gap 100 is determined and maintained by the generator support bearings 120. In particular, the stator support bearings 120 are configured to maintain an air gap 100 between the stator 32 and rotor 62 of between 5mm and 8 mm, inclusive. The generator support bearings 120 may be, but are not limited to, two tapered roller bearings or a double-row tapered roller bearing.

The function of the generator support bearings 120 is solely to support the stator 32 relative to the rotor 62. This is in contrast to the function of the drive shaft support bearings 110, which is to support the drive shaft 18, turbine rotor 14 and turbine blades 16. As a result, the stator support bearings 120 can be made relatively small as compared to the shaft support bearings 110. This in turn permits the first generator 30A to be reduced in size and cost compared to conventional generators in which a single set of bearings support the generator as well as the drive shaft and wind turbine.

The first generator 30A and the second generator 30B are arranged on the drive shaft 18 so as to have opposed axial orientations. For example, in the illustrated embodiment, the first generator 30A is arranged on the drive shaft 18 so that its annular stator end plate 54 faces the turbine rotor 14, and its annular rotor end plate 84 faces the tower 12. In addition, the second generator 30B is arranged on the drive shaft 18 so that its annular stator end plate 54 faces the tower 12, and its annular rotor endplate 84 faces the terminal (free) end 19 of the drive shaft 18. As a result, the first and second generators 30A, 30B mirror each other on opposed sides of the tower 12, and assembly of the wind power plant 10 is made easier.

The stator 32 is supported relative to the base plate 13 using a stator mount device 200. In the illustrated embodiment, the stator mount device 200 is configured to secure the stator 32 to the shaft support bearings 110 such that it can translate along and traverse to the longitudinal axis 22 of the drive shaft 18, but is prevented from rotating about the longitudinal axis 22 of the drive shaft 18. As a result, loads on the drive shaft support bearings 110 due to relative movements and eccentricities of the rotors 42 and stators 32, and from relative movements and eccentricities of the generators 30A, 30B relative to the drive shaft 18 are minimized. In particular, the stator mount device 200 helps reduce deformations of the drive shaft and base plate due to applied loads, and improves the durability of the generator 30A.

Referring again to Fig. 3, the stator mount device 200 includes a pair of passive, flexible multi-bar linkages 202. In the illustrated embodiment, the linkages 202 are disposed on opposed sides of the stator 32. Each linkage 202 include five bars 205, 206, 207, 207, 208, connected end-to-end via hinge connections 210, 212, 213, 214. At one end of the linkage 202, the first bar 205 is connected at a first end 215 to the stator arm 58 via a hinge connection. At the other end of the linkage 202, the fifth bar 209 is connected at a second end 216 to housing 115 that supports the shaft support bearings. The term "hinge connection" as used here means that the respective connected bars are configured to rotate about a single axis. In the linkage 202, the hinge connection pivot axis is oriented transverse to the longitudinal axis 22 of the drive shaft 18.

Referring to Figs. 6 and 7, an alternative stator mount device 300 includes an elastic connection between the generator stator 32 and the base plate 13. Like the linkage 202, the stator mount device 300 is passive device that supports the stator 32 via the stator arms 58. The stator mount device 300 includes elastic members 310 supported by the tower base plate 13 and disposed on upper and lower sides of each stator arm 58. The elastic members 310 permit the stator 32 to translate along and traverse to the longitudinal axis 22 of the drive shaft 18. Although some rotation of the stator 32 about the longitudinal axis 22 of the drive shaft 18 is permitted resulting from slight compression of the elastic members 310, such rotations are relatively small.

Referring to Fig. 8, another alternative stator mount device 400 includes an active control system configured to detect drive shaft displacement and/or deformation, and to control the position of the stator 32 relative to the drive shaft 18 based on the detected displacement and/or deformation of the drive shaft 18. In the illustrated embodiment, the stator mount device 400 is a hydraulic system. The stator mount device 400 includes a hydraulic cylinder 402, 404, 406, 408 disposed on upper and lower sides of each stator arm 58 so that each hydraulic cylinder 402, 404, 406, 408 is disposed between the stator arm 58 and the tower base plate 13. A pressure sensor 412, 414, 416, 418 is connected to, and detects the hydraulic pressure within, each respective hydraulic cylinder 402, 404, 406, 408, and outputs the detected pressure to a controller 430. In addition, the stator mount device 400 includes drive shaft sensors 450, 452 configured to detect the bending moment applied to the drive shaft 18. The drive shaft sensors 450, 452 may be, but are not limited to, strain gauges. For example, the drive shaft sensors 450, 452 are positioned at locations of known high stress, so that the actual stresses can be reduced via the stator mount device.

Based on the pressure detected in each of the hydraulic cylinders 402, 404, 406, 408, and the loads detected by the drive shaft sensors 450, 452, the controller 430 controls a pump

440 so as to adjust the hydraulic pressure with each respective hydraulic cylinder 402, 404, 406, 408. In particular, the controller 430 controls the position of the generator 30A, 30B so as to minimize or eliminate loads on the drive shaft 18. Because the loads on the drive shaft 18 are minimized or eliminated, the size of the drive shaft 18 and/or drive shaft bearings 110 can be reduced.

For large generators, two or more stator mount devices 400 can be used for each generator. For example, if a pair of stator mount devices 400 are provided for a given generator and arranged in a spaced apart configuration along the longitudinal axis 22 of the drive shaft 18, rotational movements of the generator about a horizontal axis transverse to the longitudinal axis 22 can be controlled. In addition, the stator mount device 400 is not limited to use in direct-drive generators. For example, it can be used in a generator that is driven by a turbine rotor through a gear box. Use of the stator mount device 400 permits a connection between a gearbox and the generator to be effected without using couplings, whereby costs and size can be reduced.

Although the relatively low-frequency movements (on the order of 12 rpm, or 2 Hz) of the wind power plant 10 lend themselves to control by a hydraulic active control system such as stator mount device 400, the stator mount device 400 is not limited to hydraulic actuation, and other types of actuators and corresponding sensors, including but not limited to linear motors and displacement sensors, can be employed in the device 400 as a replacement for the hydraulic cylinders and hydraulic pressure sensors.

Referring to Figs. 9 and 10, as discussed above, it is a challenge to provide direct-drive turbine designs of peak dimensions due to the very high stiffness requirements needed to avoid unacceptable deformations of the system. For example, a direct drive generator 500 is mounted on a drive shaft 518, and the magnetic field between generator rotor and stator results in undesirable deformations within the system. A conventional approach to providing sufficient stiffness to prevent such deformations is to provide a rigid external support 520 of the generator 500. For a direct drive turbine of 5 MWatts or more, a very large external support 520 is required to sufficiently reduce deformations. In the embodiment illustrated in Fig. 9, the external support 520 is generally triangle shaped, and includes cut-outs 522 to reduce overall mass. An alternative approach is to provide active compensation for the deformations. With reference to Fig. 10, active compensation can be achieved by replacing the external support 520 with a support device 620 including a compensator 625 whose dimensions can be changed by a controller 630, based on detected deformations of the support structure and/or the turbine drive shaft as identified by appropriately-located sensors 632, 634. For example, under conditions of high loads and/or deformations, the compensator 625 would be controlled to be shorter in length, increasing the stiffness of the support device 620, whereas under conditions of low lows and/or deformations, the compensator 625 would be controlled to be relatively longer in length, reducing stiffness of the support device 620. In some embodiments, the controller 630 controls the compensator so as to eliminate deformations.

As discussed above, the first generator 30A and second generator 30B are each a synchronous, permanent magnet generator. The dual-generator configuration illustrated here provides a wind power plant capable of producing 10 MWatts of power or more, while having sufficient design stiffness to maintain a 5 to 8 mm air gap. The arrangement of the first and second generators 30A, 30B as shown in Figs. 1-3, in which the first generator 30A is disposed on the drive shaft between the turbine rotor and the tower, and the second generator 30B is disposed on the drive shaft so as to be disposed on a side of the tower that is opposed to the first generator 30A, provides stiffness to the wind plant design since the tower 12 is disposed between the first generator 30A and the second generator 30B and the drive shaft is supported for rotation on the tower by the relatively large shaft support bearings 110. That is, by positioning the shaft support bearings 110 in the middle of the tower and between the first and second generators 30A, 30B, a very stiff support is provided for the generators 30A, 30B.

Although an arrangement in which both generators 30A, 30B are positioned adjacent each other on one side of the tower 12 is possible, such an arrangement would create a very large moment on the shaft support bearings 110.

Moreover, by providing relatively large shaft support bearings 110 externally of the first and second generators 30A, 30B to support the drive shaft 18, turbine rotor 14, and rotor blades 16, the rotor support bearings 120 disposed within the respective generators 30A, 30B and used to control the air gap 100, have only to support the weight of the (stator) rotor. As such, the rotor support bearings 120 are relatively small as compared to the shaft support bearings 110, whereby the cost and complexity of manufacturing and maintaining the generators is reduced.

A selected illustrative embodiment of the invention is described above in some detail. It should be understood that only structures considered necessary for clarifying the present invention have been described herein. Other conventional structures, and those of ancillary and auxiliary components of the system, are assumed to be known and understood by those skilled in the art. Moreover, while a working example of the present invention has been described above, the present invention is not limited to the working example described above, but various design alterations may be carried out without departing from the present invention as set forth in the claims.

What is claimed is,

1. A wind power plant comprising

a turbine rotor;

a drive shaft fixed to the turbine rotor;

a first direct-drive generator including a first generator rotor connected to and driven by the drive shaft; and

a second direct-drive generator including a second generator rotor connected to and driven by the drive shaft.

2. The wind power plant of claim 1, wherein the wind power plant further comprises a tower and the drive shaft is rotatably supported on the tower, and

the first generator is disposed on one side of the tower, and the second generator is disposed on an opposed side of the tower.

3. The wind power plant of claim 1, wherein the wind power plant is configured to provide at least 10 megawatts of power.

4. The wind power plant of claim 1, wherein the first and second generator are each a permanent magnet generator.

5. The wind power plant of claim 1, wherein the wind power plant further comprises

a base plate, and

shaft support bearings configured to rotatably support the drive shaft relative to the base plate,

wherein the shaft support bearings are located externally relative to the first and second generators.

6. The wind power plant of claim 5, wherein the shaft support bearings include two axially-spaced bearings.

7. The wind power plant of claim 5, wherein the shaft support bearings include spherical roller bearings.

8. The wind power plant of claim 1, wherein the first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings.

9. The wind power plant of claim 8, wherein the generator support bearings include tapered roller bearings.

10. The wind power plant of claim 1 wherein

wherein the wind power plant further comprises a tower and the drive shaft is rotatably supported on the tower,

the first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings, and

the wind power plant further includes a first stator mount device configured to secure the first stator to the tower and a second stator mount device configured to secure the second generator to the tower, and the first and second stator mount devices are configured to permit translation along and traverse to the longitudinal axis of the drive shaft and prevent rotation about the longitudinal axis of the drive shaft.

11. The wind power plant of claim 10, wherein the stator mount device comprises an active control system configured to detect at least one of drive shaft displacement and deformation, and to control the position of the stator relative to the drive shaft based on detected displacement or deformation of the drive shaft.

12. The wind power plant of claim 1, wherein the first generator has an axial orientation that is opposed to that of the second generator.

13. An electric rotating machine comprising

a base;

a drive shaft;

a shaft support bearing configured to rotatably support the drive shaft relative to the base;

a first generator including a first rotor connected to and driven by the drive shaft; and

a second generator including a second rotor connected to and driven by the drive shaft,

wherein the shaft support bearing is disposed between the first and second generators.

14. The electric rotating machine of claim 13, wherein

the first generator is disposed on one side of the base, and the second generator is disposed on an opposed side of the base.

15. The electric rotating machine of claim 13, wherein the electric rotating machine is configured to provide at least 10 megawatts of power.

16. The electric rotating machine of claim 13, wherein the rotor of each of the first and second generator rotates at the same speed as the drive shaft.

17. The electric rotating machine of claim 13, wherein the first and second generator are each a direct-drive generator.

18. The electric rotating machine of claim 13, wherein the first and second generator are each a permanent magnet generator.

19. The electric rotating machine of claim 13, wherein the shaft support bearings are located externally relative to the first and second generators.

20. The electric rotating machine of claim 19, wherein the shaft support bearings include two axially-spaced bearings.

21. The electric rotating machine of claim 19, wherein the shaft support bearings include spherical roller bearings.

22. The electric rotating machine of claim 13, wherein the first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings.

23. The electric rotating machine of claim 22, wherein the generator support bearings include tapered roller bearings.

24. The electric rotating machine of claim 13 wherein

the first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings, and

the electric rotating machine further includes a first stator mount device configured to secure the first stator to the base and a second stator mount device configured to secure the second generator to the base, and the first and second stator mount devices are configured to permit translation along and traverse to the longitudinal axis of the drive shaft and prevent rotation about the longitudinal axis of the drive shaft.

25. The electric rotating machine of claim 24, wherein each stator mount device comprises an active control system configured to detect at least one of drive shaft displacement and deformation, and to control the position of the respective stator relative to the drive shaft based on detected displacement or deformation of the drive shaft.

26. The electric rotating machine of claim 13, wherein the first generator has an axial

orientation that is opposed to that of the second generator.

27. A wind power plant comprising

a turbine rotor;

a drive shaft fixed to the turbine rotor;

a tower;

a shaft support bearing configured to rotatably support the drive shaft on the tower;

a first generator including a first generator rotor connected to and driven by the drive shaft; and

a second generator including a second generator rotor connected to and driven by the drive shaft,

wherein the shaft support bearing is disposed between the first and second generators.

28. The wind power plant of claim 27, wherein

the first generator is disposed on one side of the tower, and the second generator is disposed on an opposed side of the tower.

29. The wind power plant of claim 27, wherein the wind power plant is configured to provide at least 10 megawatts of power.

30. The wind power plant of claim 27, wherein the rotor of each of the first and second generator rotates at the same speed as the turbine rotor.

31. The wind power plant of claim 27, wherein the first and second generator are each a direct-drive generator.

32. The wind power plant of claim 27, wherein the first and second generator are each a permanent magnet generator.

33. The wind power plant of claim 27, wherein the shaft support bearings are located externally relative to the first and second generators.

34. The wind power plant of claim 33, wherein the shaft support bearings include two axially-spaced bearings.

35. The wind power plant of claim 33, wherein the shaft support bearings include spherical roller bearings.

36. The wind power plant of claim 27, wherein the first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings.

37. The wind power plant of claim 36, wherein the generator support bearings include tapered roller bearings.

38. The wind power plant of claim 27 wherein

the first generator includes a first stator that is supported on the drive shaft through first generator support bearings, and the second generator includes a second stator that is supported on the drive shaft through second generator support bearings, and

the wind power plant further includes a first stator mount device configured to secure the first stator to the tower and a second stator mount device configured to secure the second generator to the tower, and the first and second stator mount devices are configured to permit translation along and traverse to the longitudinal axis of the drive shaft and prevent rotation about the longitudinal axis of the drive shaft.

39. The wind power plant of claim 38, wherein each stator mount device comprises an active control system configured to detect at least one of drive shaft displacement and deformation, and to control the position of the respective stator relative to the drive shaft based on detected displacement or deformation of the drive shaft.

40. The wind power plant of claim 27, wherein the first generator has an axial orientation that is opposed to that of the second generator.

41. An electric rotating machine comprising

a support,

a drive shaft rotatably supported by the support;

a generator including

a rotor connected to and driven by the drive shaft; and

a stator supported by and arranged coaxially with the rotor, and

a stator mount device configured to actively control the position of the stator relative to the support.

42. The electric rotating machine of claim 41, wherein the stator mount device further comprises a control system configured to detect at least one of drive shaft displacement and deformation, and to control the position of the stator relative to the drive shaft based on detected displacement or deformation of the drive shaft.

43. The electric rotating machine of claim 41, wherein the stator mount device is configured such that the stator can translate along and traverse to the longitudinal axis of the drive shaft, but is prevented from rotating about the longitudinal axis of the drive shaft.

44. The electric rotating machine of claim 41, wherein the stator mount device includes hydraulic actuators disposed between the stator and the support.

45. The electric rotating machine of claim 41, wherein the rotating electric machine is a wind power plant, the support is a tower, and the drive shaft is driven by a turbine rotor.

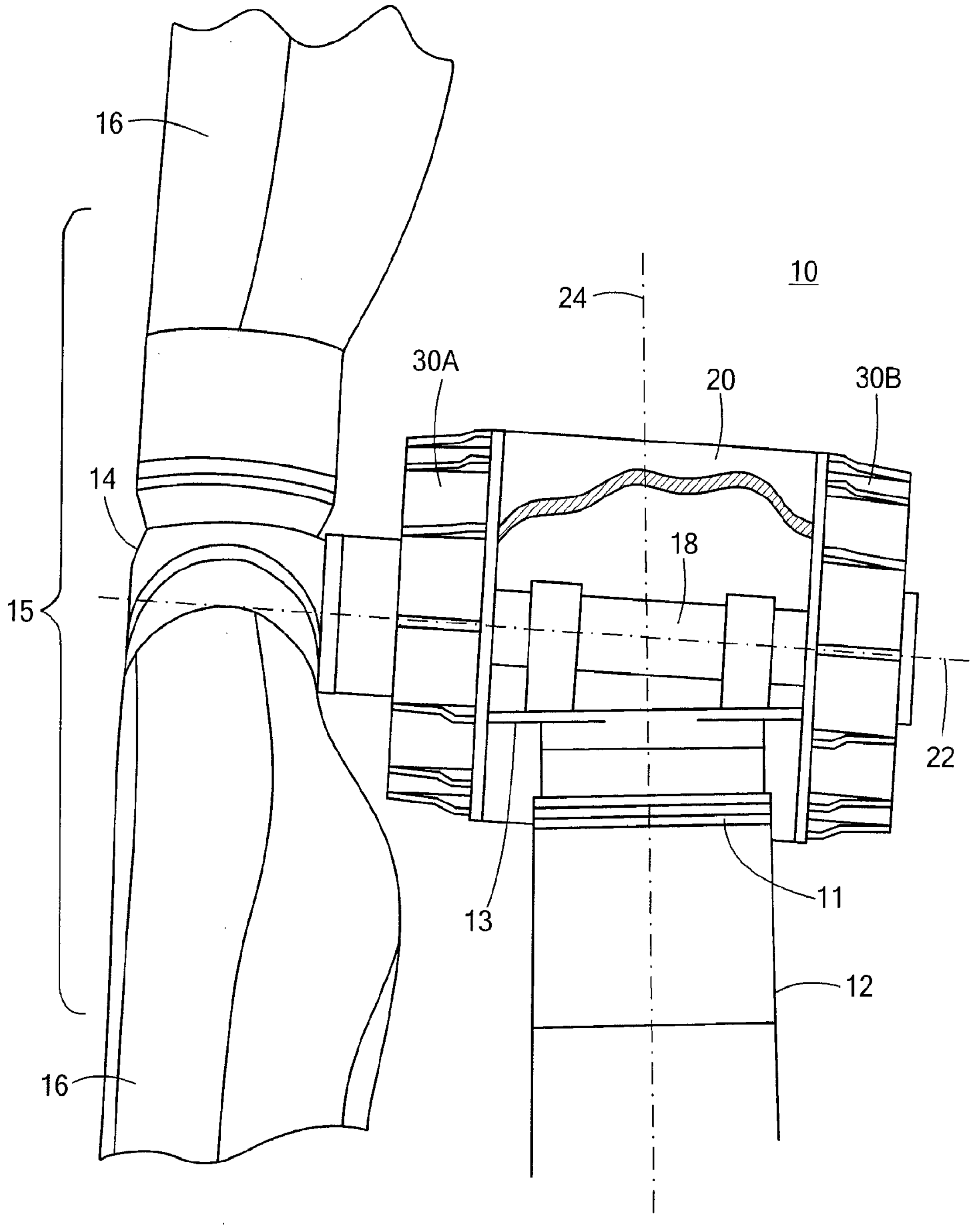

FIG. 1

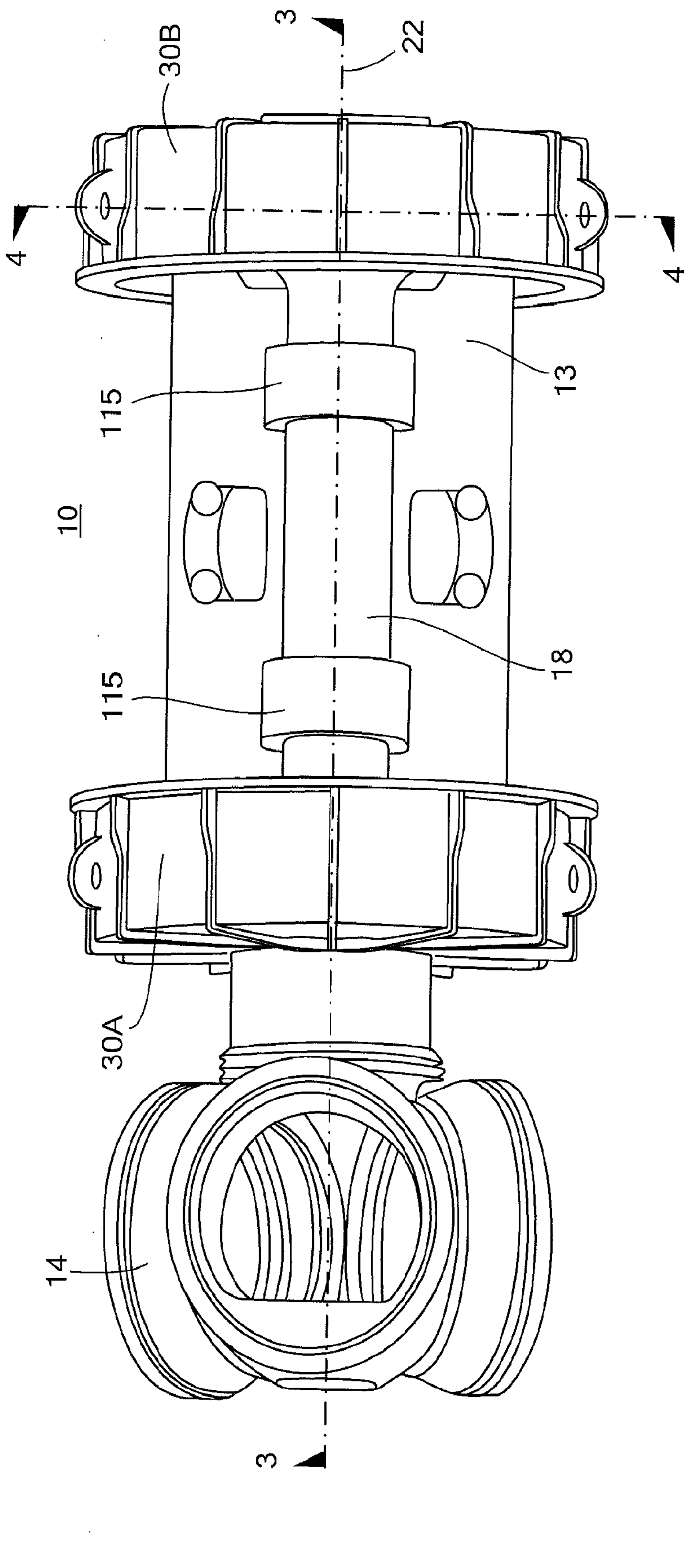

FIG. 2

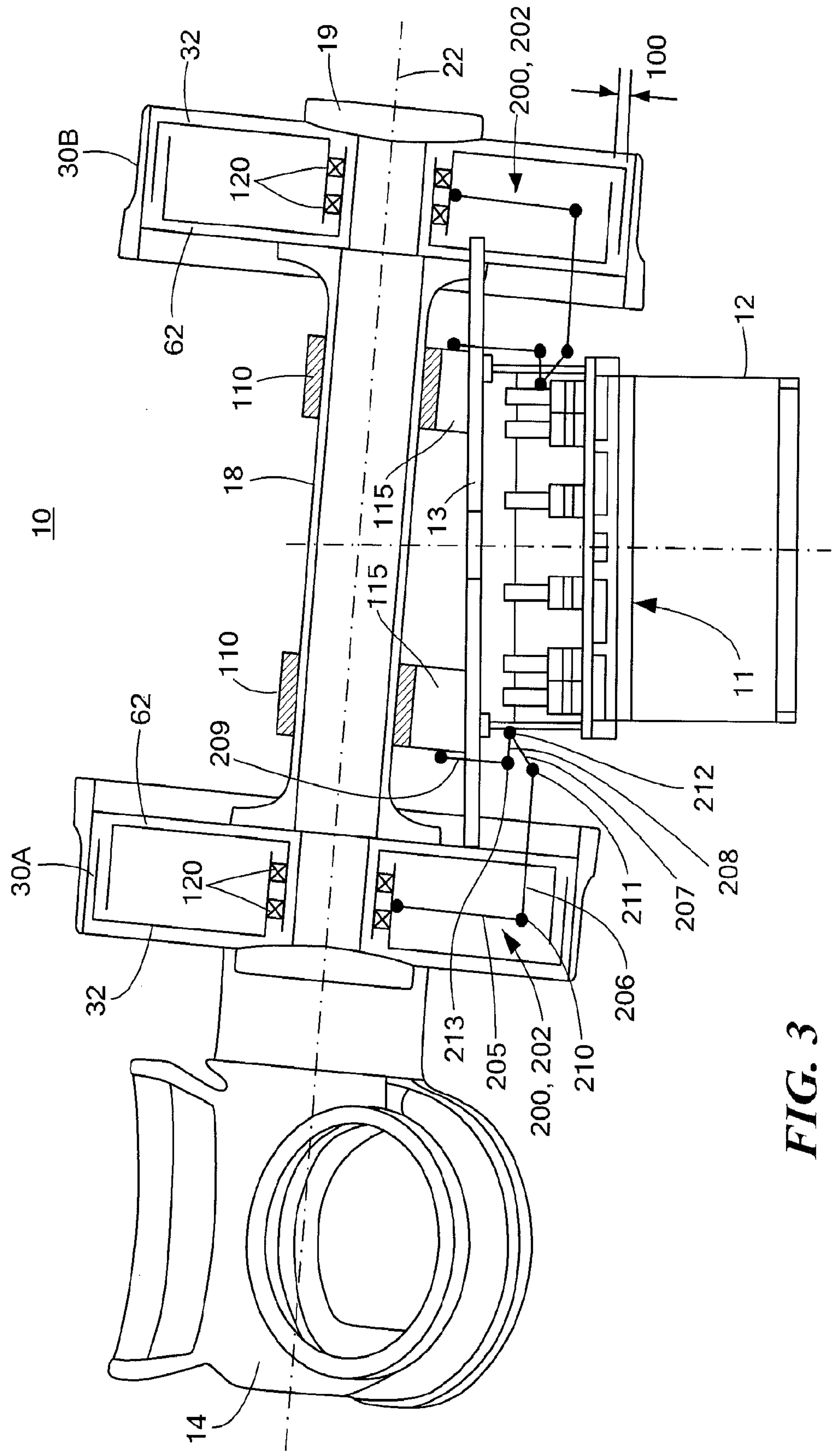
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FIG. 3

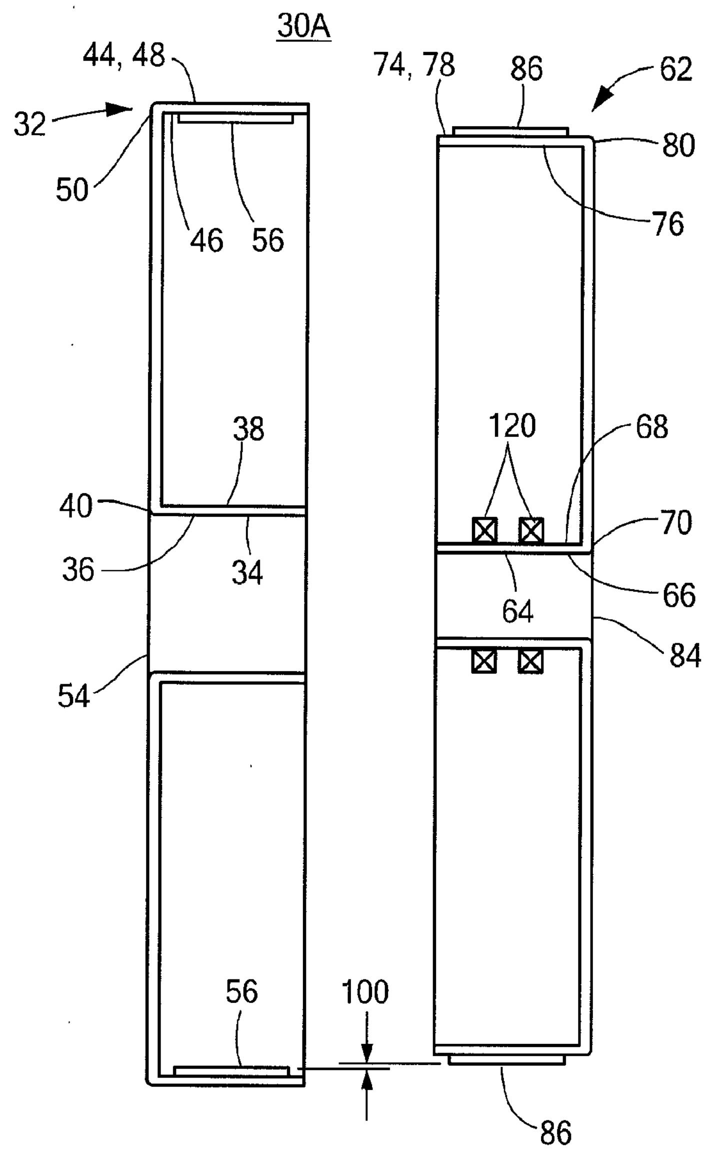
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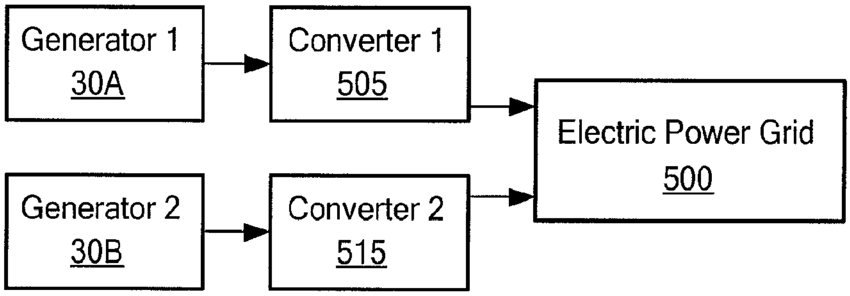
FIG. 4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Converter 1
505
Electric Power Grid
500
Generator 2
30B
Converter 2
515

FIG. 5

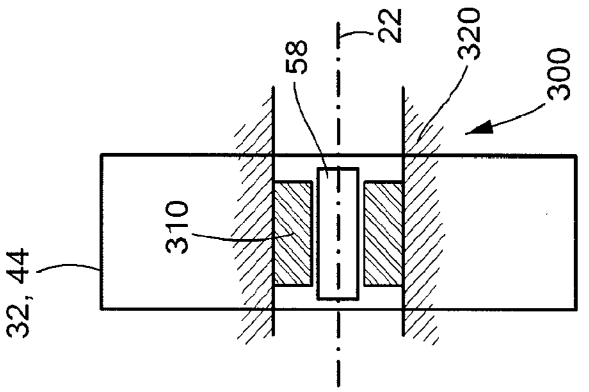

FIG. 7

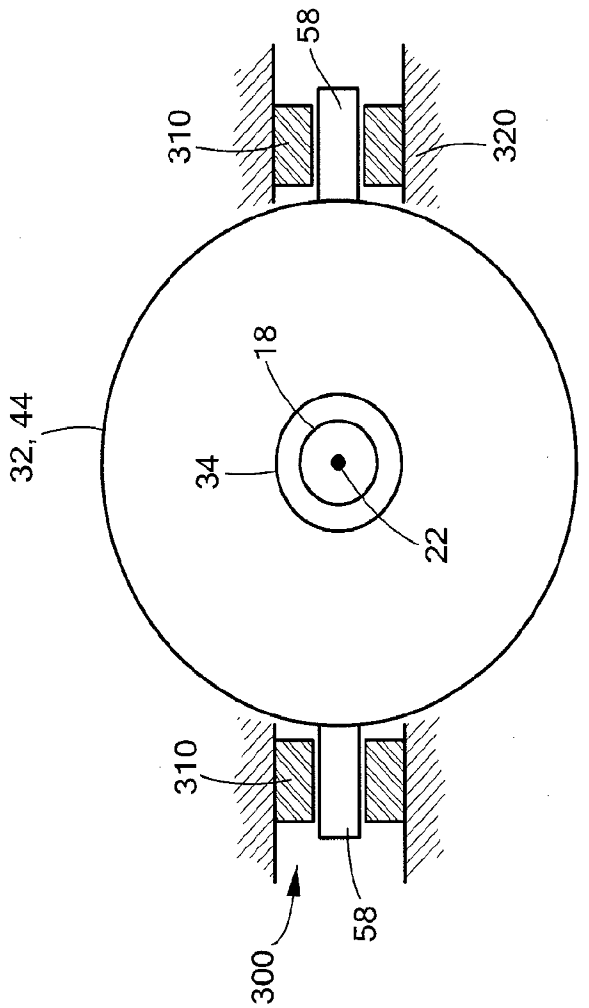

FIG. 6

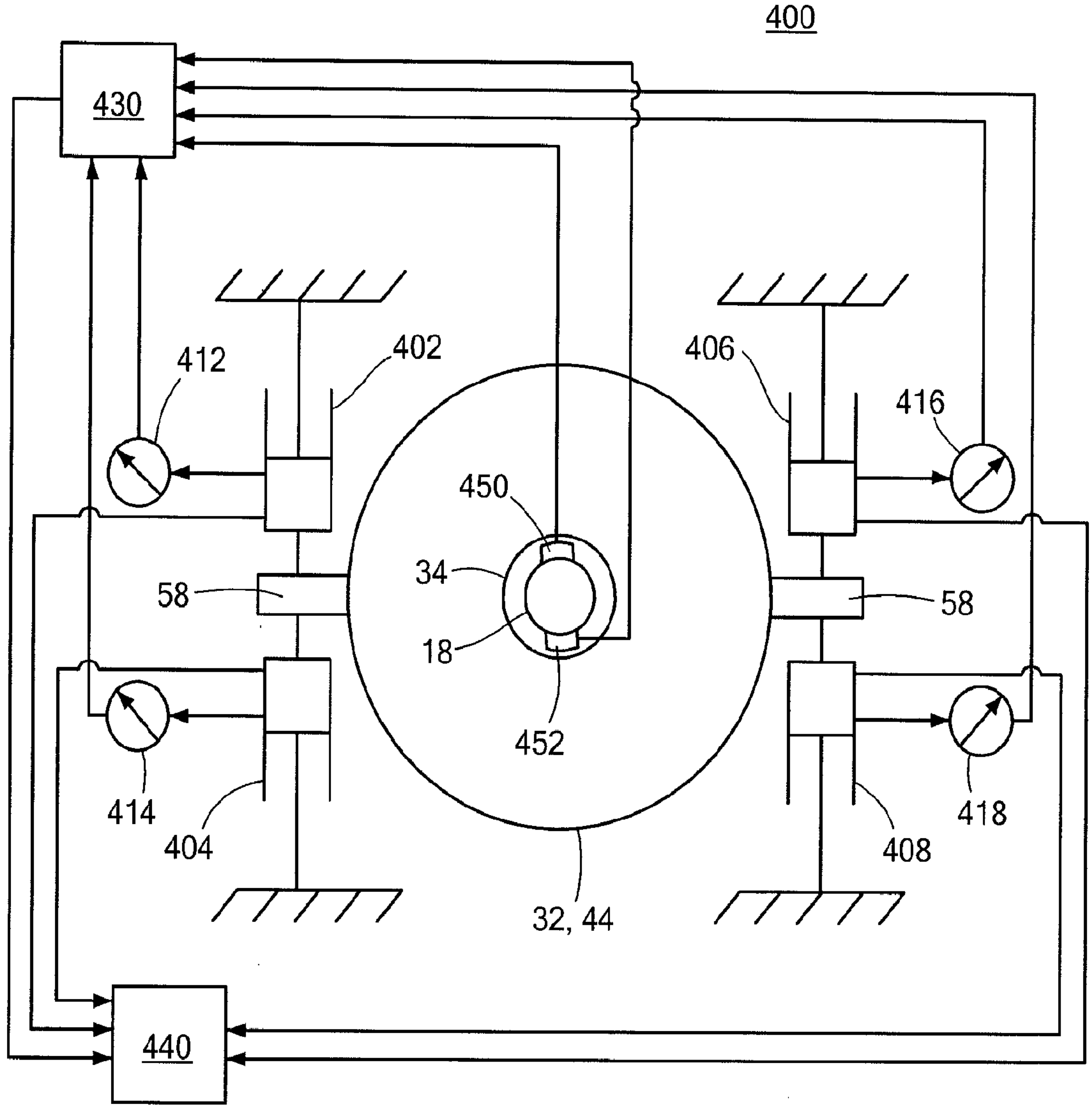
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FIG. 8

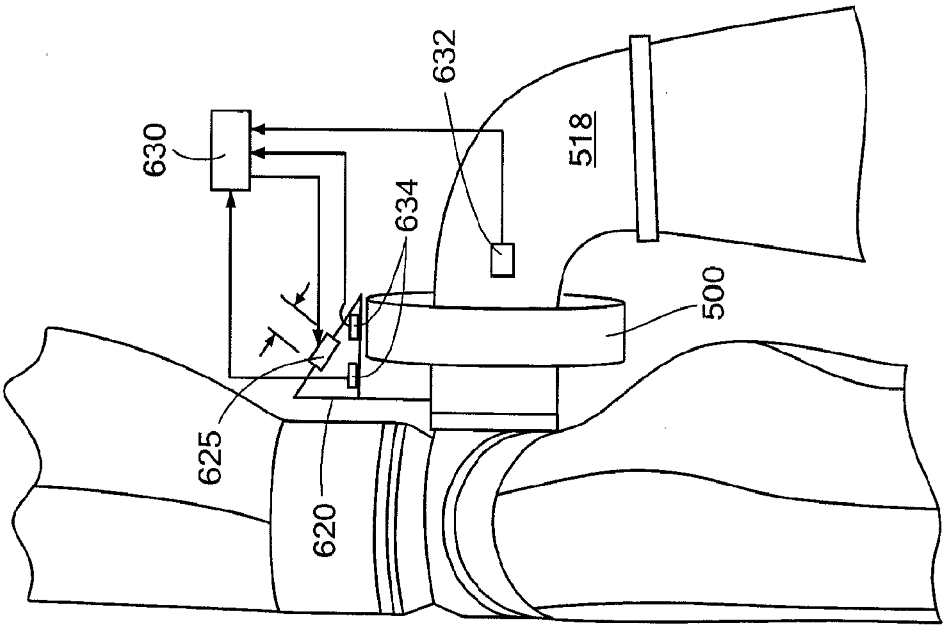
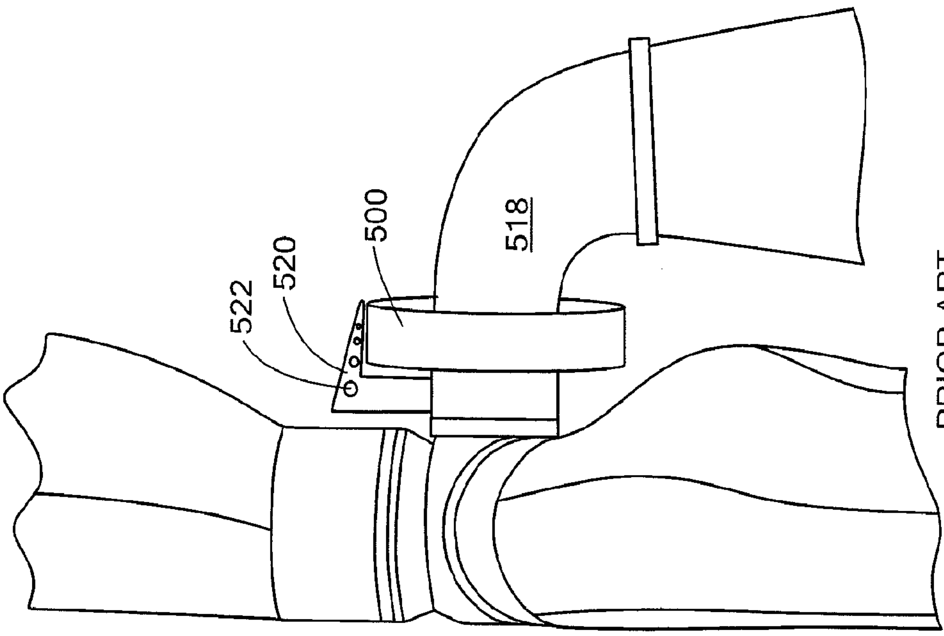


FIG. 10



PRIOR ART

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/030477

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D9/00 H02K1/18
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 practical, 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	WO 2008/078342 A1 (HIGH TECHNOLOGY INVEST BV [NL]; PABST OTTO [IT]) 3 July 2008 (2008-07-03) page 4, line 7 - page 5, line 6; figures 1-17 -----	1-8, 11-22, 24-36, 38-40
X	DE 10 2009 015926 A1 (SCHULER PRESSEN GMBH & CO [DE]) 7 October 2010 (2010-10-07) paragraphs [0012], [0026]; figures 1,5 -----	1-8, 11-22, 24-36, 38-40
X	WO 2010/063052 A2 (HEHENBERGER GERALD [AT]) 10 June 2010 (2010-06-10) figures 8,11,12 -----	1-8, 11-22, 24-36, 38-40
	-/--	

[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
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 December 2011	09/12/2011

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	Bradley, David

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/030477

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-40

   Wind power plant having two direct-drive generators

   ---

2. claims: 41-45

   An electric rotating machine comprising a generator, a rotor, a stator and a stator mount device to actively control the position of the stator.

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 589 222 A2 (TRIMMER S A [CH] CEUTE SA [CH]) 26 October 2005 (2005-10-26) paragraph [0024] - paragraph [0037]; figures 1,2	1-8, 11-22, 24-36, 38-40
X	EP 1 363 019 A2 (SIEMENS AG [DE]) 19 November 2003 (2003-11-19) figures 1,2	1-8, 11-22, 24-36, 38-40
A	DE 10 2009 008805 A1 (SEMAKIN SERGEJ [DE]) 28 October 2010 (2010-10-28) paragraph [0015]; figures 1-7	1,13,27
X	EP 2 237 398 A1 (SIEMENS AG [DE]) 6 October 2010 (2010-10-06) paragraphs [0022], [0035], [0036], [0043]; figure 1	41-45
A	EP 2 014 917 A1 (SIEMENS AG [DE]) 14 January 2009 (2009-01-14) abstract	41-45

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2011/030477

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