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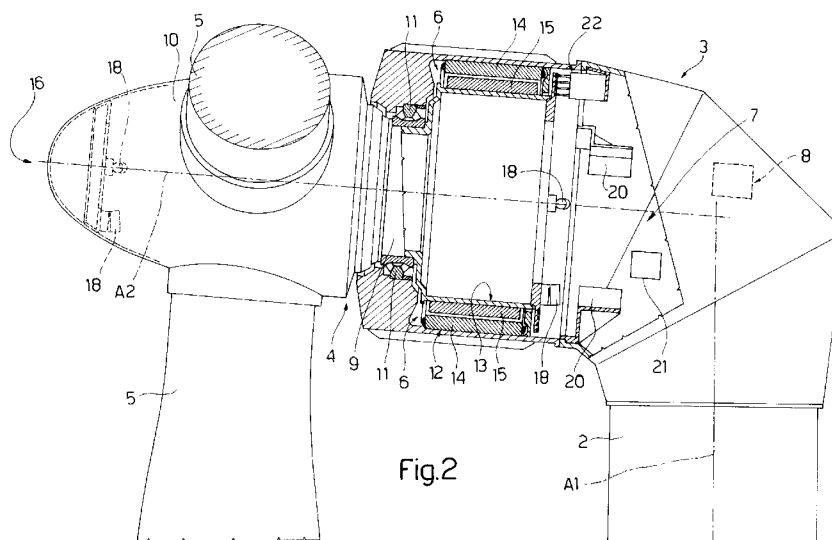
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(54) Title: WIND POWER ELECTRICITY GENERATING SYSTEM AND RELATIVE CONTROL METHOD



(57) Abstract: A wind power electricity generating system (1) having a nacelle (3); a rotary assembly (16) rotating about an axis (A2) with respect to the nacelle (3); and an angular speed detection device (7; 23) having at least one sensor (18; 24) rotating about the axis (A2) together with the rotary assembly (16), and supplies at least one signal related to angular speed.

WIND POWER ELECTRICITY GENERATING SYSTEM AND RELATIVE
CONTROL METHOD

TECHNICAL FIELD

5 The present invention relates to a wind power electricity generating system and relative control method.

More specifically, the present invention relates to a wind power electricity generating system comprising a nacelle; a rotary assembly rotating about an axis with
10 respect to the nacelle; and an angular speed detection device for detecting the angular speed of the rotary assembly.

BACKGROUND ART

15 The wind power electricity generating system comprises a hub; a number of blades fitted to the hub; and an electric machine comprising a stator and a rotor.

In actual use, the wind blows on the blades to rotate the hub about the axis, and so transfer the
20 kinetic energy of the wind to the hub; and rotation of the hub is transferred to the electric machine, in particular to the rotor which is connected to and rotates with the hub about the axis.

The hub, blades, and rotor define the rotary
25 assembly.

The angular speed of the rotary assembly must be detected to control the wind power system. More specifically, the angular speed of the rotor must be

detected to control an inverter coupled to the electric machine, and/or to control the pitch of the blades with respect to the wind, and/or to calculate the power coefficient of the system, and/or to monitor system
5 operation and efficiency, and/or to keep within a maximum angular speed.

The angular speed detection device most commonly employed in wind power systems is an encoder, of which there are various types. The most commonly used are
10 incremental and absolute encoders, which comprise a photodetector or proximity sensor.

Incremental and absolute encoders comprise a disk, the lateral face of which has at least one succession of holes arranged in at least one circle; and a device for
15 detecting the holes. The disk is fixed to the rotary assembly, and the hole detecting device is fixed to the nacelle.

An incremental encoder disk has at least one succession of equally spaced holes, and the hole
20 detecting device comprises at least one proximity sensor alongside the disk, or at least one light source and at least one photodetector on either side of the disk.

As the disk rotates, the hole detecting device detects the holes and generates a signal indicating the
25 angular distance travelled and the angular speed of the disk, and therefore of the rotary assembly.

Some incremental encoders have at least two proximity sensors or at least two photodetectors, and

holes arranged in at least two circles, and detect the rotation direction of the disk.

In absolute encoders, on the other hand, the holes are arranged unevenly in a given configuration in at least two circles, and the hole detecting device comprises at least two photodetectors or at least two proximity sensors. Absolute encoders process the signals from the proximity sensors or photodetectors to determine angular position with respect to a fixed reference.

One problem of using encoders in direct-transmission wind power systems lies in the encoder requiring a large disk fixed to the rotary assembly.

In some direct-transmission wind power systems, the rotor and hub are hollow, are connected directly to each other, and have inside diameters allowing access by workers to the inside for maintenance or inspection. In such cases, using an encoder calls for a disk fixed to the rotary assembly and large enough to permit easy access, which poses two problems: the weight of the disk itself, and the precision with which the holes are formed, which affects the accuracy with which angular speed is determined. Moreover, encoders are sensitive to vibration caused by the blades; and the holes are subject to clogging by dirt, thus impairing reliability of the hole detecting device.

DISCLOSURE OF INVENTION

It is an object of the present invention to provide

a wind power system equipped with an angular speed detection device designed to eliminate the drawbacks of the known art.

According to the present invention, there is
5 provided a wind power electricity generating system comprising a nacelle; a rotary assembly rotating about an axis with respect to the nacelle; and an angular speed detection device for detecting the angular speed of the rotary assembly; the wind power system being
10 characterized in that the angular speed detection device comprises at least one sensor rotating about the axis together with the rotary assembly, and supplies at least one signal related to angular speed.

In a preferred embodiment, the rotary assembly
15 comprises a hub; at least one blade fitted to the hub; and a rotor connected to the hub.

In another preferred embodiment, the sensor is fixed to the rotor.

It is a further object of the present invention to
20 provide a method of controlling a wind power system, designed to eliminate the drawbacks of the known art.

According to the present invention, there is provided a method of controlling a wind power electricity generating system; the wind power system
25 comprising a nacelle, a rotary assembly rotating about an axis with respect to the nacelle, and at least one sensor rotating about the axis together with the rotary assembly; and the method being characterized by

comprising the step of acquiring a signal, related to the angular speed of the rotary assembly, by means of the sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

5 A non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a partly sectioned side view, with parts removed for clarity, of a wind power electricity
10 generating system in accordance with one embodiment of the present invention;

Figure 2 shows a larger-scale, partly sectioned side view, with parts removed for clarity, of a detail in Figure 1;

15 Figure 3 shows a partly sectioned, schematic view in perspective, with parts removed for clarity, of a detail in Figure 1;

Figure 4 shows a larger-scale, partly sectioned side view, with parts removed for clarity, of a further
20 embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Number 1 in Figure 1 indicates a wind power electricity generating system.

In the example shown, system 1 is a variable-
25 angular-speed, direct-transmission wind power system.

Wind power system 1 comprises a pylon 2, a nacelle 3, a hub 4, three blades 5, an electric machine 6, an angular speed detection device 7 (Figure 2), and a

control device 8 (Figure 2).

The three blades 5 are fitted to hub 4, which in turn is fitted to nacelle 3, in turn fitted to pylon 2.

Nacelle 3 is mounted to rotate about an axis A1
5 with respect to pylon 2 to position blades 5 facing the wind; hub 4 is mounted to rotate about an axis A2 with respect to nacelle 3; and each blade 5 is mounted to rotate about a respective axis A3 with respect to hub 4.

In the Figure 1 example, axis A2 is tilted slightly
10 with respect to the horizontal, and axis A3 is substantially perpendicular to and radial with respect to axis A2.

With reference to Figure 2, hub 4 comprises a hollow shaft 9 and a body 10, which are connected
15 rigidly to each other and have inside diameters large enough to permit worker access to the inside for maintenance or inspection.

Hollow shaft 9 is fitted, on bearings 11, to nacelle 3 and connected directly to electric machine 6.

20 Electric machine 6 comprises a stator 12 and a rotor 13. Stator 12 defines a portion of nacelle 3 and comprises stator windings 14; and rotor 13 is hollow, comprises permanent magnets 15, and is fixed directly to hollow shaft 9.

25 In the example shown, electric machine 6 is synchronous.

The wind rotates hub 4 about axis A2; rotation of hub 4 is transferred to and so rotates rotor 13 about

axis A2; and the relative movement of permanent magnets 15 with respect to stator windings 14 - in the form of rotation of rotor 13 at variable angular speed - induces voltage at the terminals of stator windings 14.

5 Hub 4, blades 5, and rotor 13 are integral with one another, and define a rotary assembly 16 rotating about axis A2 with respect to nacelle 3.

With reference to Figure 1, the pitch of each blade 5 with respect to the wind is controlled by rotating
10 blade 5 about respective axis A3 to adjust the surface of incidence with respect to the wind. Rotation of each blade 5 about respective axis A3 is controlled on the basis of efficiency parameters of wind power system 1, and so as to keep rotary assembly 16 within a maximum
15 angular speed.

Angular speed is detected by angular speed detection device 7 (Figure 2).

With reference to Figure 3, angular speed detection device 7 comprises two sensors 18, each comprising a
20 transmitter 19; two receivers 20, each coupled to respective transmitter 19; and a processing unit 21 coupled to receivers 20.

More specifically, each sensor 18 is an accelerometer, and supplies a signal related to angular
25 speed.

Each sensor 18 determines the acceleration caused by gravitational force and/or centrifugal force along a respective detection axis A4 integral with respective

sensor 18.

Each sensor 18 is fixed to rotor 13, as shown by the continuous lines in Figures 2 and 3. In Figure 3, sensors 18 are so positioned that respective detection
5 axes A4 are perpendicular to each other and radial with respect to axis A2. Each detection axis A4, however, may be set to any position, except that in which it is parallel to axis A2 or aligned with the other detection axis A4.

10 In actual use, as rotor 13 rotates about axis A2, the force of gravity measured by each sensor 18 along respective detection axis A4 varies due the change in direction of respective detection axis A4 with respect to the ground, and each sensor 18 also detects along
15 respective detection axis A4 acceleration caused by the centrifugal force produced by rotation of rotor 13.

When rotor 13 rotates at angular speed, therefore, each sensor 18 emits a signal that, allowing for tolerances and variations in angular speed, is
20 practically sinusoidal; and, given that respective detection axes A4 of sensors 18 are perpendicular, the respective signals are phase shifted 90° .

With reference to Figure 2, receivers 20 and processing unit 21 are housed inside nacelle 3, close to
25 sensors 18, and integral with nacelle 3.

Each signal is received by respective receiver 20 which transmits it to processing unit 21.

Alternatively, instead of transmitters 19 and

receivers 20, angular speed detection device 7 comprises contact members 22 which provide sliding contacts; each sensor 18 is coupled by contact members 22 to processing unit 21; and the signal from each sensor 18 is supplied to processing unit 21 via contact members 22.

Processing unit 21 processes one or both of the signals from sensors 18 to determine the angular speed of rotary assembly 16.

Processing unit 21 also processes one or both of the signals from sensors 18 to determine the angular position of rotary assembly 16.

With reference to Figure 2, angular speed detection device 7 is coupled to control device 8.

Control device 8 controls wind power system 1 on the basis of the angular speed and/or angular position of rotary assembly 16 supplied by angular speed detection device 7. The control functions performed by control device 8 include : monitoring correct operation of wind power system 1; controlling the pitch of blades with respect to the wind; controlling the power coefficient of wind power system 1; controlling the inverter coupled to electric machine 6; controlling the efficiency of wind power system 1; and keeping rotary assembly 16 within the maximum angular speed.

Control device 8 also processes the angular speed and/or angular position of rotary assembly 16 by fast Fourier transform (FFT) to determine events.

Additional communication means (not shown in the

drawings) are preferably associated with control device 8 of wind power system 1 to transmit the angular speed and/or angular position of rotary assembly 16 to a remote control centre (not shown in the drawings) coupled by cable or radio to wind power system 1.

In one variation of the present invention, as opposed to being fixed to rotor 13, each sensor 18 is fixed to hub 4, and more specifically to an inner wall of body 10, as shown by the dash lines on the left of Figure 2.

In another variation of the present invention, not shown in the drawings, as opposed to being fixed to rotor 13, each sensor 18 is fixed to any one of the three blades 5, and more specifically to an inner wall of blade 5.

In another variation of the present invention, each sensor 18 is an inclinometer that supplies a signal related to angular speed; and processing unit 21 calculates angular speed by processing the signal from each inclinometer.

In another variation of the present invention, angular speed detection device 7 comprises only one sensor 18 fixed to rotor 13 or hub 4; sensor 18 supplies a signal related to angular speed; and processing unit 21 calculates angular speed on the basis of the signal from sensor 18.

In another variation of the present invention, angular speed detection device 7 comprises only one

sensor 18 in the form of a two-axis accelerometer or a two-axis inclinometer.

In a further embodiment of the present invention shown in Figure 4, in which parts similar to those of the first embodiment are indicated using the same reference numbers as in Figures 1 to 3, angular speed detection device 7 is replaced with an angular speed detection device 23.

Angular speed detection device 23 comprises a sensor 24 defined by a gyroscope based on detection of Coriolis forces; and contact members 25.

Sensor 24 is fixed to rotary assembly 16, and more specifically to rotor 13, as shown by the continuous line in Figure 4; or is fixed to hub 4, and more specifically to an inner wall of body 10, as shown by the dash line on the left in Figure 4.

Angular speed detection device 23 is coupled to control device 8 of wind power system 1 by contact members 25 to supply control device 8 with the angular speed of rotary assembly 16.

Sensor 24 is a gyroscope and supplies a signal related to angular speed. More specifically, the signal is a voltage proportional to the angular speed of rotary assembly 16.

Sensor 24 is coupled to control device 8 by contact members 25, which provide sliding contacts by which the signal from sensor 24 is supplied to control device 8. Alternatively, instead of contact members 25, the sensor

comprises a transmitter 26; angular speed detection device 23 comprises a receiver 27 coupled to control device 8 and for receiving signals from transmitter 26; and sensor 24 transmits signals to control device 8 by
5 means of transmitter 26 and receiver 27.

In a variation of the present invention, sensor 24 is fixed to the inside of body 10, as shown by the dash line in Figure 4.

In another variation of the present invention, not
10 shown in the drawings, sensor 24 is fixed to any one of the three blades 5, and more specifically to an inner wall of blade 5.

Though specific reference is made herein to a synchronous electric machine, the electric machine may
15 be of any other known type, e.g. asynchronous.

Clearly, changes may be made to the system and method as described herein without, however, departing from the scope of the accompanying Claims.

CLAIMS

1) A wind power electricity generating system (1) comprising a nacelle (3); a rotary assembly (16) rotating about an axis (A2) with respect to the nacelle (3); and an angular speed detection device (7; 23) for detecting the angular speed of the rotary assembly (16); the wind power system being characterized in that the angular speed detection device (7; 23) comprises at least one sensor (18; 24) rotating about the axis (A2) together with the rotary assembly (16), and supplies at least one signal related to angular speed.

2) A wind power system as claimed in Claim 1, wherein the rotary assembly (16) comprises a hub (4); at least one blade (5) fitted to the hub (4); and a rotor (13) connected to the hub (4).

3) A wind power system as claimed in Claim 1, wherein the sensor (18; 24) is fixed to the rotor (13).

4) A wind power system as claimed in Claim 2, wherein the sensor (18; 24) is fixed to the hub (4).

5) A wind power system as claimed in Claim 2, wherein the sensor (18; 24) is fixed to the blade (5).

6) A wind power system as claimed in any one of the foregoing Claims, comprising a control device (8) coupled to the angular speed detection device (7; 23); the control device (8) being designed to control the wind power system (1) on the basis of the angular speed supplied by the angular speed detection device (7; 23).

7) A wind power system as claimed in any one of the foregoing Claims, comprising an electric machine (6), and an inverter coupled to the electric machine (6); the angular speed detection device (7; 23) being coupled to
5 the inverter.

8) A wind power system as claimed in any one of the foregoing Claims, wherein the sensor (18) is an accelerometer or an inclinometer.

9) A wind power system as claimed in Claim 8,
10 wherein the angular speed detection device (7) comprises a processing unit (21) for processing the signal related to angular speed.

10) A wind power system as claimed in Claim 9,
wherein the sensor (18) comprises a transmitter (19),
15 preferably a wireless transmitter; the angular speed detection device (7) comprising a receiver (20) coupled to the processing unit (21) and preferably fixed with respect to stator (12); and the sensor (18) being coupled to the receiver (20) by the transmitter (19) to
20 supply the processing unit (21) with the signal related to angular speed.

11) A wind power system as claimed in Claim 9,
wherein the angular speed detection device (7) comprises contact members (22) for coupling the sensor (18) to the
25 processing unit (21).

12) A wind power system as claimed in any one of Claims 9 to 11, wherein the processing unit (21) processes the signal related to angular speed to

determine the angular position of the rotary assembly (16).

13) A wind power system as claimed in any one of Claims 8 to 12, wherein the sensor (18) has a detection
5 axis (A4) not parallel to the axis (A2) of the rotary assembly (16).

14) A wind power system as claimed in any one of Claims 8 to 13, wherein the angular speed detection
10 device (7) comprises at least one further sensor (18) rotating about the axis (A2) together with the rotary assembly (16) and supplies at least one further signal related to angular speed; and wherein the sensor (18) and the further sensor (18) have respective detection
15 axes (A4) not aligned with each other; the further sensor (18) preferably being an accelerometer or an inclinometer.

15) A wind power system as claimed in any one of Claims 8 to 14, wherein the sensor (18) is a two-axis sensor.

20 16) A wind power system as claimed in any one of Claims 1 to 7, wherein the sensor (24) is defined by a gyroscope.

17) A wind power system as claimed in Claim 16, wherein the sensor (24) is coupled to the control device
25 (8) by contact members (25).

18) A wind power system as claimed in Claim 16, wherein the sensor (24) comprises a transmitter (26), and the angular speed detection device (23) comprises a

receiver (27) coupled to the transmitter (26) and to the control device (8); the sensor (24) being coupled to the control device (8) by the transmitter (26) and the receiver (27).

5 19) A wind power system as claimed in any one of the foregoing Claims, and comprising a control device (8) designed to process the signal related to angular speed by fast Fourier transform (FFT) to determine events, preferably to monitor correct operation of the
10 wind power system (1).

20) A method of controlling a wind power electricity generating system (1); the wind power system (1) comprising a nacelle (3), a rotary assembly (16) rotating about an axis (A2) with respect to the nacelle
15 (3), and at least one sensor (18; 24) rotating about the axis (A2) together with the rotary assembly (16); and the method being characterized by comprising the step of acquiring a signal, related to the angular speed of the rotary assembly (16), by means of the sensor (18; 24).

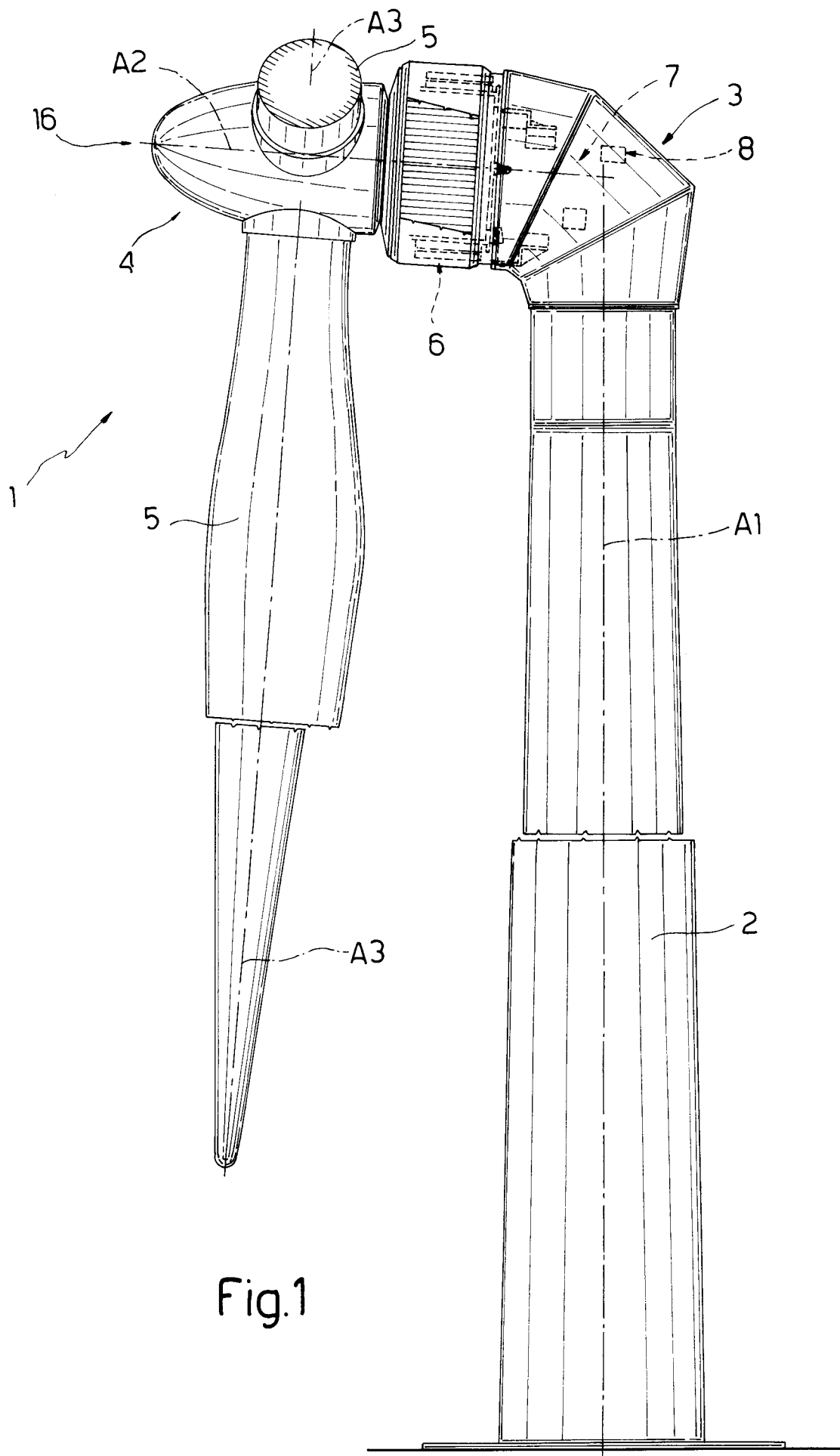
20 21) A method as claimed in Claim 20, wherein the wind power system (1) comprises a control device (8) connected to the sensor (18; 24); the method comprising the step of controlling the wind power system (1) by means of the control device (8) and on the basis of the
25 angular speed determined by means of the sensor (18; 24).

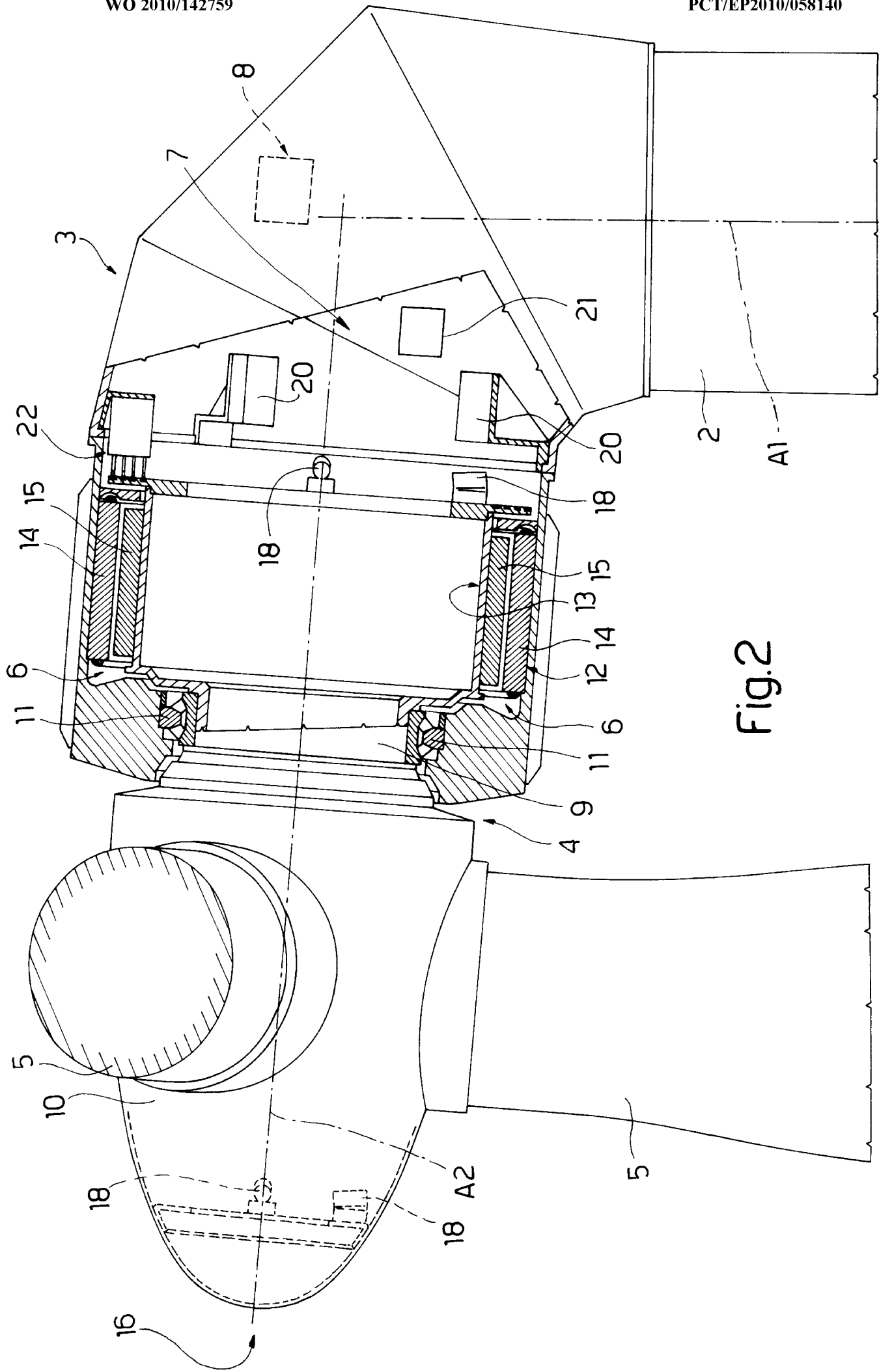
22) A method as claimed in Claim 20 or 21, comprising the step of processing the signal related to

angular speed by means of a processing unit (21) to determine the angular speed of the rotary assembly (16).

23) A method as claimed in Claim 22, comprising the step of processing the signal related to angular speed
5 by means of a processing unit (21) to determine the angular position of the rotary assembly (16).

24) A method as claimed in any one of Claims 20 to 23, wherein the sensor (18) has a detection axis (A4); the method comprising the step of positioning the sensor
10 (18) so that the detection axis (A4) is not parallel to the axis (A2) of the rotary assembly (16).





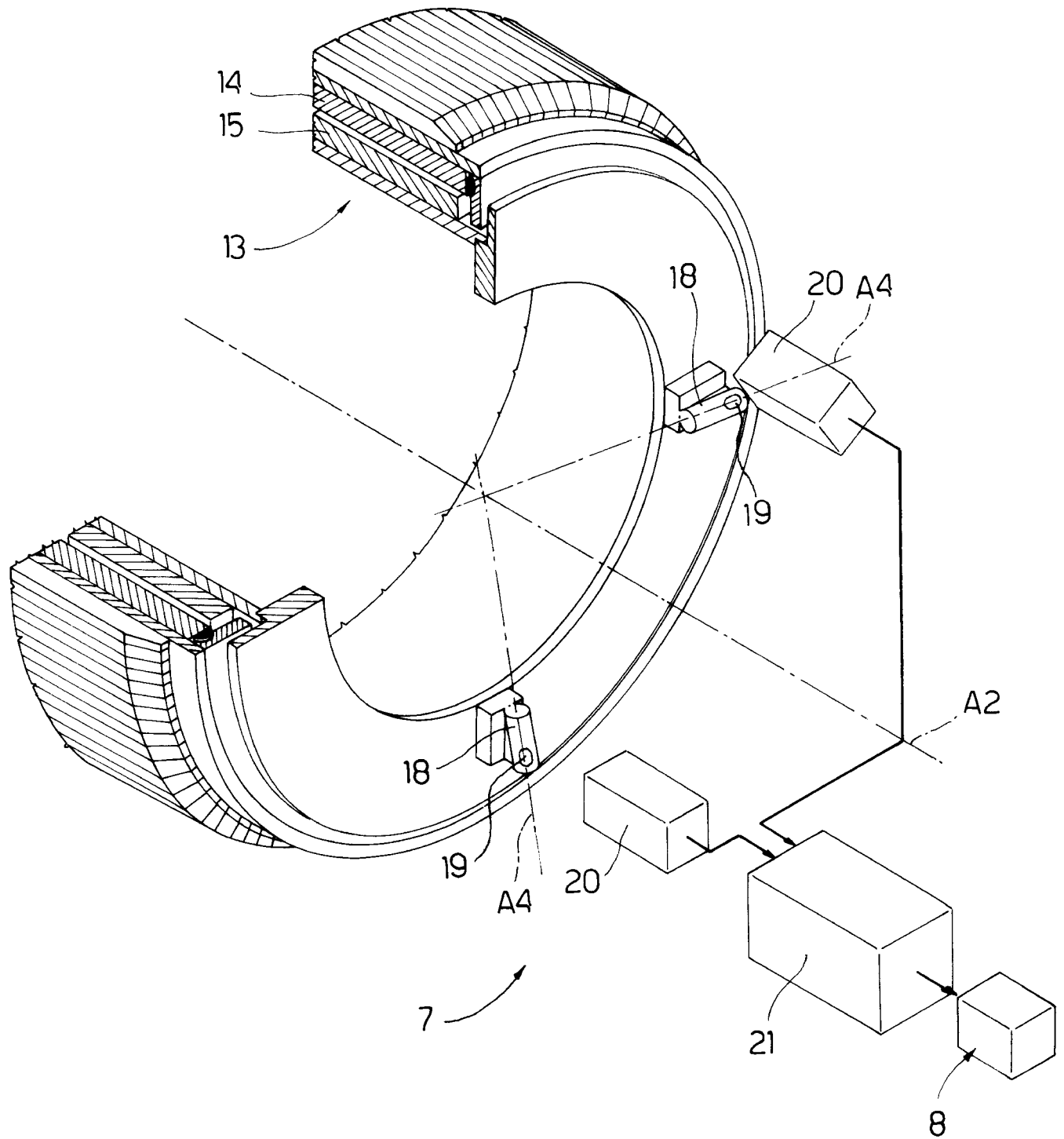
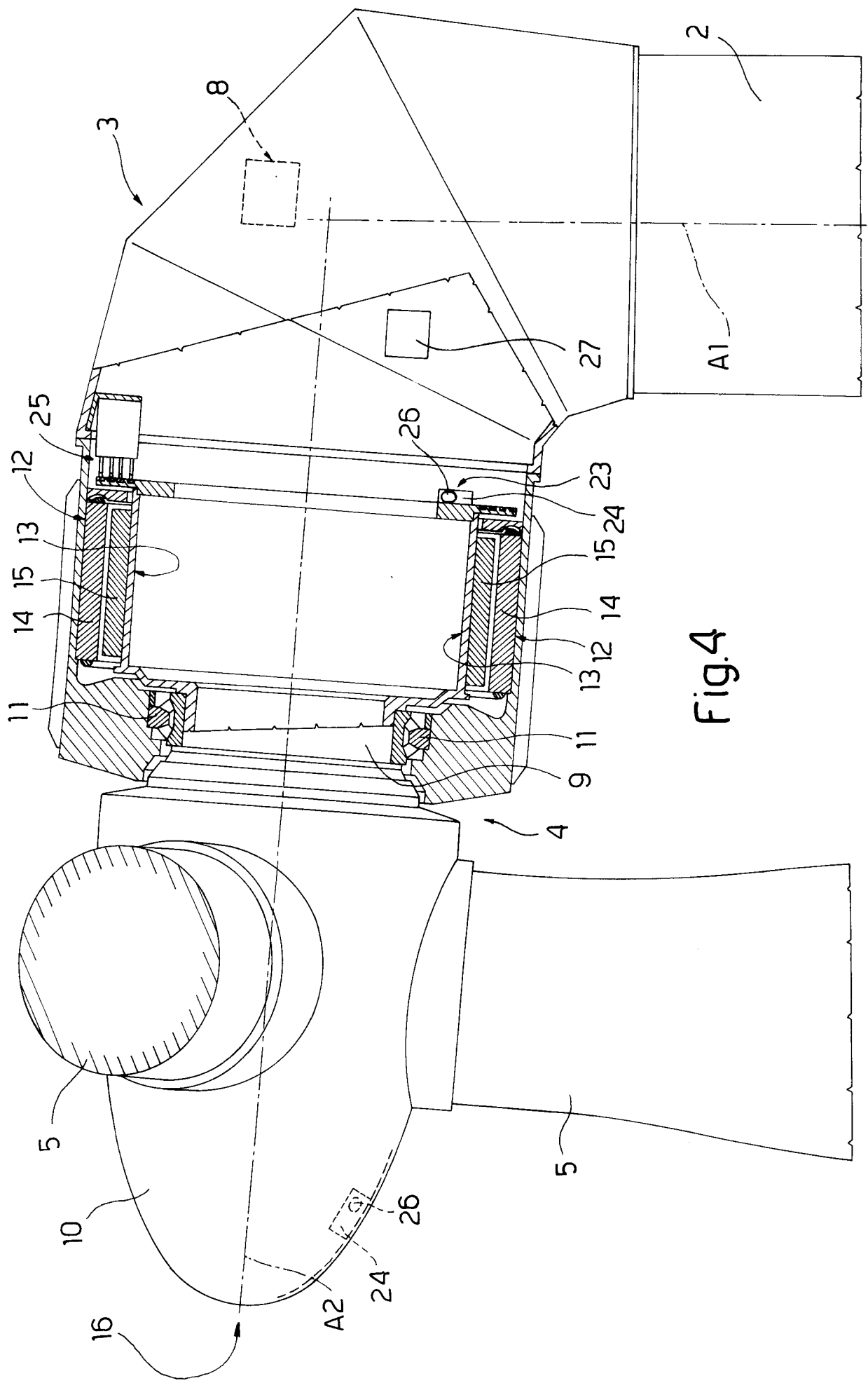


Fig.3



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/058140

A. CLASSIFICATION OF SUBJECT MATTER

INV. F03D11/00
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

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/047130 A1 (EGEDAL PER [DK]) 19 February 2009 (2009-02-19) * abstract figure 3 paragraph [0026] paragraph [0029] paragraph [0034]	1-18, 20-24
X	WO 2009/001310 A (UNIV DANMARKS TEKNISKE [DK]; PEDERSEN TROELS FRIIS [DK]) 31 December 2008 (2008-12-31) * abstract figure 4	1-15, 20-24
X	DE 10 2007 030268 A1 (LTI REENERGY GMBH [DE]) 2 January 2009 (2009-01-02) paragraph [0017] paragraph [0037]	1, 19
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"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

3 September 2010

Date of mailing of the international search report

13/09/2010

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/058140

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/249957 A1 (ITO RYOSUKE [JP] ET AL) 9 November 2006 (2006-11-09) paragraph [0036] figure 2 -----	7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2010/058140

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