



(51) International Patent Classification:
F03D 7/02 (2006.01) *G01C 9/00* (2006.01)

(21) International Application Number:
PCT/DK2011/050135

(22) International Filing Date:
28 April 2011 (28.04.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/329,333 29 April 2010 (29.04.2010) US
1007184.3 29 April 2010 (29.04.2010) GB

(71) Applicant (for all designated States except US): **VES-TAS WIND SYSTEMS A/S** [DK/DK]; Alsvej 21, DK-8940 Randers (DK).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **LI, Huaizhong** [SG/SG]; Blk 349 Bukit Batok St 34 #08-176, Singapore 650349 (SG). **SABANNAVAR, Anil** [IN/SG]; Blk 14B Lorong 7 Toa Payoh #07-241, Singapore 312014 (SG). **NARASIMALU, Srikanth** [SG/SG]; N° 19 Taman Sireh, Singapore 535206 (SG).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO,

[Continued on next page]

(54) Title: A METHOD AND SYSTEM FOR DETECTING ANGULAR DEFLECTION IN A WIND TURBINE BLADE OR COMPONENT

(57) Abstract: The invention relates to a method and system for detecting angular deflection in a wind turbine blade or component. In a wind turbine blade 20 the method and system can be used to detect blade tip deflection, either through spanwise bending or twisting, and to indicate when the blade tip is in danger of striking the tower. In other examples, the method and system can be used to indicate whether wind turbine components, such as pitch drive, a yaw drive are operating correctly.

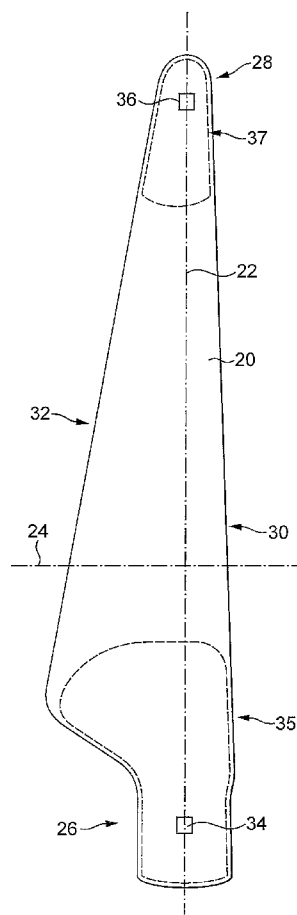


FIG. 2



DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

A METHOD AND SYSTEM FOR DETECTING
ANGULAR DEFLECTION IN A WIND TURBINE BLADE OR COMPONENT

5 The invention relates to a method and apparatus for detecting angular deflection in a wind turbine component, and in particular to a method and apparatus for detecting angular deflection in a wind turbine blade.

 Figure 1 illustrates a wind turbine 1, comprising a wind turbine tower 2 on which a wind turbine nacelle 3 is mounted. A wind turbine rotor 4 comprising at least one wind turbine blade 5 is mounted on a hub 6. The hub 6 is connected to the nacelle 3 through a low speed shaft (not shown) extending from the nacelle front. The wind turbine illustrated in Figure 1 may be a small model intended from domestic or light utility usage, or may be a large model used, such as those that are suitable for use in large scale electricity generation on a wind farm for example. In the latter case, the diameter of the rotor could be as large as 150 metres or more.

 In use, the wind turbine blades rotate and are subject to stresses from a number of different sources, including the force exerted by the wind, gravitational stresses resulting from their own weight as they rotate around the hub 6, and stresses arising from vibrational movements induced in the blade. Such stresses often result in temporary deforming of the wind turbine blade, which can cause a number of problems.

 A key problem is that the tip of the blade is typically lighter and more deformable than the rest of the blade body, and will bend more than the blade body itself. The bending is in different directions depending on whether the blade and tip are rotating above the tower or below. As the blade rotates past the tower at its lowest point, there is a risk that bending of the tip will cause it to come into contact with the tower, causing damage both to the tower and the blade.

 Additionally, as wind turbine blades are constructed to withstand bending of the blade up to a design limit, if the bending exceeds this limit, damage to the blade could ensue as the blade is exposed to an overly large strain.

 The bending need not be solely in the longitudinal direction of the blade, as it is also known for the blade tip to twist under operational forces and stresses.

 We have therefore appreciated that it would be desirable to provide a system for monitoring the bending of the wind turbine blade and in conjunction with a control system taking action to prevent damage to the blade and tower.

BRIEF DESCRIPTION OF THE DRAWINGS

Examples of the invention will now be described by way of example and with reference to the drawings in which:

Figure 1 is a schematic elevational view of a horizontal axis wind turbine (HAWT);

5 Figure 2 is a schematic view of a HAWT blade;

Figure 3 is a schematic illustration of the mounting of inclinometers along a wind turbine blade axis;

Figure 4 is a schematic illustration of an example of the invention in which the blade tip deflection is determined; and

10 Figure 5 is a schematic illustration of an example of the invention in which a blade twist angle is determined;

SUMMARY OF THE INVENTION

15 The invention is defined in the independent claims to which reference should be made. Advantageous features are set forth in the appendent claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 An example of a system for determining the relative angular deflection of wind turbine component will now be described for the purposes of illustration, and with reference to Figure 2.

Figure 2 is a schematic illustration of a wind turbine blade for a horizontal axis wind turbine. The blade 20 has a longitudinal axis 22 in what is known as the span wise
25 direction, and a lateral axis 24 in what is known as the chord wise direction. The longitudinal axis spans from the blade root 26 to the blade tip 28, while the lateral axis spans from the leading edge 30 of the blade to the trailing edge 32. These axes are largely schematic and intended merely to aid understanding.

The system comprises a first inclinometer 34 installed in the blade 20 so that it lies
30 within a region 35 of the blade close to the blade root 26, and at least a second inclinometer 36 also installed within the blade, but this time at the region 37 of the blade 20 near the tip 26. In this example, the second inclinometer 36 is located at a position that is as close to the blade tip as possible. In practice, securing the inclinometer securely to the tip region of the blade, and in a manner such that its weight does not inadvertently affect
35 the structural properties of the blade might require the inclinometer to be located at a

position slightly separate from the tip, but this will depend on the particular structure and shape of the wind turbine blade 20.

The inclinometers are of a type in which for each inclinometer at least one respective sensor axis is defined, and the output of the inclinometer indicates the orientation of the inclinometer relative to that sensor axis. Such inclinometers are known in the art, and can include one or more of a DC accelerometer, a pendulum accelerometer, a MEMS (micro electronic mechanical systems) type inclinometer, such as piezoelectric devices), a liquid type or a Gyro type inclinometer.

The operation of the inclinometer can be understood in more detail with reference to Figure 3, which shows a schematic perspective view of inclinometers 34 and 36. Each inclinometer 34, 36 is shown as comprising two separate inclinometer units 34a, 34b and 36a and 36b. Inclinometers 34a and 36a are single axis inclinometers arranged to detect tilt of the inclinometer with respect to the x axis, while 34b and 36b are dual axis inclinometers arranged to detect the tilt of the inclinometer separately with respect to the y and z axes. In this way, inclinometers 34 and 36 are three-axis inclinometers that can provide an output signal in respect of the tilt angle of the inclinometer along each of the x, y and z axis.

In this example, the y axis has been chosen to correspond to the length or span-wise direction of the blade, the x axis to the edge wise direction of the blade and the z direction as the axis out of the plane in which the blade 20 lies. The nomenclature for these axes is largely arbitrary and is intended merely to aid discussion. For ease of operation the inclinometers should be arranged so that there output relative to a common sensor axis can be given.

While each type of inclinometer operates in a different way, each inclinometer defines a reference axis and provides an output indicating the orientation of the inclinometer in comparison to the reference axis. In most inclinometers, the force (and direction) of gravity is used as an input in determining the orientation of the inclinometer. It will be appreciated that the magnitude and sign of the gravitational force will vary from +1 to -1 times the strength of the gravitational force "g", as the orientation of the inclinometer changes. Using this information, it is therefore possible to determine the orientation of the device housing with respect to at least two axes. For this example the output signal can be taken as a voltage signal, either analogue or digital. The output can additionally be amplified and processed to remove noise and improve the signal to noise ratio.

In practice, the measurement range can be up to several times g accommodating acceleration of the inclinometer in the vertical direction. The operation of inclinometers is understood in the art, and will not be described further here.

As the output of the inclinometers is a measurement of the tilt angle of the inclinometer itself (not therefore the blade) to a reference axis, it is advantageous thought not essential that the separate inclinometers 34 and 36 are mounted in the blade so that they are as closely aligned as possible with each other, and to the relevant reference axes.

5 For this purpose, the inclinometers 34 and 36 are fixed to mounting plates 38 and 40 that support the inclinometers in the required orientation. The mounting plates 38 and 40 are fixed to the inside of the blade 20 at suitable locations, for example to the spar or main beam. The dimensions of the mounting plates may be different.

Not shown in Figure 3 but also included in the system are a power supply for
10 supplying power to each of the inclinometers, an input-output communication link for providing input signals to the inclinometers and receiving output signals from the inclinometers, a lightning protection system to protect any electrical components of the sensor system employed in the blade from the risk of damage when a lightning strike occurs, a processing system for processing the output signal received from the inclinometers, and
15 a control system. The processing system and control system can be separate or combined.

Protection against lightning can be achieved by using electrical conductors around any electrical components of the sensor system, in the manner of a Faraday cage or conventional lightning conductor. Instead of electrical cabling signals may be carried along the blade 20 by using optical fibres for example. Further, all sensitive components, such as
20 the processing system and the control system can where possible be provided in the wind turbine nacelle or hub, where lightning strikes can be more readily dealt with.

The processing system is arranged to receive the output signals from the at least two inclinometers 34 and 36 and combine the output signal of one inclinometer with the at least one other to give a final result that can be output to the control system. As explained
25 below, in most cases this will involve subtracting one result from the other to give a result indicating a comparison between the inclinometer outputs.

Additionally, it is advantageous if the processing system carries out low frequency band pass filtering on the received inclinometer output signals in order to improve the accuracy of the final output provided to the control system. As indicated earlier,
30 components of the wind turbine, in particular the wind turbine blades 20 will be subject to vibrations that themselves depend on the position where the inclinometer is located, the material stiffness at the point, wind loading and so on. Typically, any such vibrations in the wind turbine component will have a higher frequency than movement of the component that is a result of more significant structural deformation, such as the tip deflection of a wind
35 turbine blade. It is therefore beneficial to filter out the elements of the signal that correspond to such vibrations.

A first mode of operation of the sensor system described above will now be explained with reference to Figure 4 in a system for sensing tip deflection of a wind turbine blade.

Figure 4 illustrates a wind turbine blade 20 viewed from the side, and extending from the blade root 26 at the left of the diagram to the blade tip 28 at the right. The inclinometers 34 and 36 are fixed to the blade, such that their reference axis is aligned as closely as possible with the longitudinal axis 22 of the blade 20. In this manner, each inclinometer 34 and 36 is arranged to give an output signal indicating the tilt angle between the inclinometer and the reference axis. As the inclinometers are rigidly attached to the wind turbine blade (as discussed above) the tilt angle indicated by the inclinometers is also taken as being representative of the tilt angle of the location of the wind turbine blade where the inclinometer is mounted to the reference axis.

In Figure 4, the tip of the wind turbine blade is shown in a deflected position in which there is a danger both of damage to the blade structure, but more significantly of contact between the blade tip and the wind turbine tower.

The output of inclinometer 34 will therefore be indicative of the orientation of the wind turbine blade 20, in the region of the blade root, relative to the axis 22. This output will be designated V_a for the discussion here. Similarly, the output of inclinometer 36 will be indicative of the orientation of the wind turbine blade 20 at that tip region relative to the axis 22. This output will be designated V_b .

Both of these outputs are passed to the processing system largely in real time by suitable transmission means, such as shielded electrical cable, wireless transmission, optical fibre, or other optical transmission, such as a laser. The processing system carries out low pass filtering of the signals to remove any modulation or variation in the signal due to unwanted vibrational modes to give signals V_{a1} and V_{b1} . The instantaneous tip deflection or tilt angle, that is the angular deflection between the blade root and the blade tip, can then be calculated by subtracting V_{a1} from V_{b1} in the processing system. As noted above, the filtering is optional but preferred, and the calculation could also be based on subtraction of V_a from V_b .

In one aspect of the invention, the processing system uses the angular tip deflection calculated above to determine the actual displacement of the wind turbine blade tip from its rest position. This can be achieved using the angular tip deflection as the key into a look-up tables indicating displacement values based on a given angular deflection. Respective look-up tables will need to be provided for each model and size of wind turbine blade in use, and will need to take into account other factors such as the positions of the inclinometers 34 and 36 in the blade, the blade material and so on. The processing system

is also arranged to interpolate between values in cases where an exact tip deflection angle is not provided.

Instead of a look up table, it will be appreciated that other techniques could be used to determine the actual tip displacement based on the calculated tilt angle, such as the use of an algorithm, a trained neural net.

Further, the actual tip displacement could be indicated as a physical measurement given in dimensions of length, or alternatively as a percentage or ratio.

The processing system is then operable to compare the determined actual tip displacement to a threshold value to confirm that the operation of the wind turbine and any deflection of the wind turbine blade remains within safe operating parameters. If this comparison indicates an unsafe condition, then an output signal can be provided to the control system in the form of an alarm signal. Depending on the circumstances and the configuration of the control system, the control system can then take a number of possible operational steps, such as pitching the wind turbine blades to spill some of the incident wind thereby reducing the load on the wind turbine blade or applying a braking action to the hub to slow the rotation of the blades.

In a modification of this aspect of the invention, the step of calculating the actual tip displacement can be omitted, so that the processing system compares the instantaneous angular deflection of the blade with a threshold value, and outputs a control signal based on whether the threshold is exceeded or not.

In a further aspect of the invention, illustrated in Figure 5, the output of the inclinometers can be used to indicate whether the blade is twisting between the blade root and the tip. Twisting of the blade tip can occur for a number of reasons, including: the oscillations of the blade due to wind loads and the blade rotation; the anisotropic material properties of the blade composite material that results in twisting when the blade bends; and gyroscopic forces occurring due when the blade pitching and tower yawing mechanisms operate in tandem.

In this example, therefore, the inclinometers 34 and 36 are provided in the blade as before, only now they are arranged to be sensitive to their orientation with respect to at least the x axis also. As before the output of each inclinometer indicates its orientation, and therefore that of the blade region to which it is attached, relative to the reference axis, and by subtracting the output V_a of one sensor from the output V_b of the other, a relative twist angle can be given that is independent of the actual orientation of the wind turbine blade in space. The processing is then carried out in the same way as described above, except that there is no need for a look up table.

A correction can be applied to the tip deflection indication given by the inclinometers to take into account both twisting of the blade tip and rotation of the blade 20 itself due to pitch control actuation. Both twisting of the blade tip and rotation due to pitch control will have the effect of angling the deflected tip away from the direction normal to the blade surface and will therefore increase slightly the clearance between the blade tip and the tower.

To account for this first the total twist angle (T) of the blade tip is calculated by summing the torsional twisting angle of the blade tip and the pitch angle applied to the blade by the pitch actuator. It will be appreciated that the pitch of the blade and the twist angle are essentially aligned with respect to the same axis.

This angle is then projected onto the YZ plane (which as illustrated in Figure 3 can be thought of as bisecting the wind turbine blade along its longitudinal axis from the pressure side to the suction side and which therefore essentially extends in the direction of the tower) to give an additional 'twisting' component of displacement. This twisting component reduces the blade tip displacement from spanwise bending in the tower direction. The correction is given by the product of the cosine of the total twist angle (T) and the tip displacement calculated from the inclinometers.

Assuming D is the actual tip displacement calculated earlier the corrected tip displacement D_c is given by:

$$D_c = D \cos (T)$$

Use of the corrected Tip Displacement taking into account twisting and pitch control of the blade can therefore avoid unnecessary activation of the control system.

In the examples of Figures 4 and 5, use has been made of inclinometer outputs relative to only a single sensor axis. It will be appreciated however that if desired all three sensor axes could be monitored and used as the basis of comparison carried out by the processing system. In this way, the processing system could build up a more complete picture of deflection and twisting of the blade in real time.

In the previous discussion, the system has been described as including only two inclinometers 34 and 36. It will however be appreciated that the system may include a greater number of inclinometers, so that a more detailed profile of the blade bending can be constructed. For example, each of a plurality of inclinometers could be located at a respective position on the longitudinal axis 22 of the blade 20. The tilt angle indicated by each inclinometer could then be compared with a reference value, such as the output angle of another inclinometer in the plurality, to provide a contour. This would provide an instantaneous indication of how the blade is bending and could be used to give a visual representation of the real time shape of the blade. The plurality of inclinometers need not

be limited in location to positions lying along the longitudinal axis of the blade 20 and could be provided at any suitable position on the blade.

Through the use of two or more inclinometers it will be appreciated that the system can readily provide a measure of the relative angular deflection of the wind turbine blade, irrespective of its actual orientation in space. This is a particular problem as the blades are constantly rotating. Thus, the processing required to give an accurate result is greatly simplified and the results themselves can be made more accurate.

Although other system are known for the calculation of the bending of a wind turbine blade, these cannot operate as accurately. Known systems based on strain gauges for example determine the strain on the blade at different blade positions and from the measured strain determine indirectly the magnitude of the deformation of the blade. Once the extent to which blade has deformed has been determined, it is possible to estimate the angular tip deflection or tip displacement.

Other known techniques for example rely on the use of dynamic type accelerometers to calculate the vibration at respective positions within the blade. The vibrational signal from the blade is a function of strain from and therefore the blade deformation. However, in practice the output from such dynamic type accelerometers is a an acceleration signal indicating vibrational movement it is necessary to perform a double integration in order to obtain a displacement. Such techniques are not only indirect, and cumbersome, but also therefore suffer from the accumulation of errors in the integrated sensor signal.

Although the blade deflection technique has been described in connection with a horizontal axis wind turbine having three blades, it will be appreciated that it can be used with wind turbines having any number of blades, and with vertical axis wind turbines.

Further, in the above discussion, although a number of different examples of operation have been given, it will be appreciated that these can be implemented separately or in combination with one another.

Furthermore, the sensing technique is not limited to wind turbine blades but could also be used to measure the angular deflection or twisting of other wind turbine components, for example the wind turbine tower. By placing an inclinometer at the nacelle base or the tower top, and a corresponding inclinometer at the tower base, it is possible for example to determine how much the tower is swaying. Twisting between a wind turbine tower and an offshore wind turbine foundation due to wind and wave forces could also be detected. This would allow the correction of the yaw angle applied to the nacelle allowing more accurate positioning of the wind turbine.

CLAIMS

1. A method of determining the angular deflection of a wind turbine blade, comprising:
5 receiving an output from a first inclinometer located in the wind turbine blade at a first position;
receiving an output from a second inclinometer located in the wind turbine blade at a second position;
wherein the second position is in a different region of the blade to the first position,
10 and the first and second inclinometers each have at least one respective sensor axis and provide an output that indicates the orientation of the respective inclinometer relative to the sensor axis;
subtracting the outputs from the first and second inclinometers from one another to provide a measurement of the relative angular deflection of the blade between the first and
15 the second positions.
2. The method of any previous claim comprising:
installing the first inclinometer and the second inclinometer in the wind turbine blade at the first and second positions.
20
3. The method of any previous claim wherein the first position is located in the region of the blade near the blade root
4. The method of any previous claim wherein the second position is located in the
25 region of the blade near the blade tip.
5. The method of claim 4, wherein the second location is at the tip of the blade.
6. The method of any previous claim, wherein the at least one sensor axis of each
30 inclinometer is arranged to lie substantially parallel with the longitudinal axis of the wind turbine blade, such that the relative angular deflection measured by the first and second inclinometers indicates the tip deflection of the wind turbine blade.
7. The method of any preceding claim, wherein at least one sensor axis of each
35 inclinometer is arranged to lie substantially parallel with the lateral axis of the wind turbine

blade, such that the relative angular deflection measured by the first and second inclinometers indicates the twist angle of the wind turbine blade.

8. The method of claim 6, comprising:

- 5 determining the displacement of the blade tip away from its rest position;
 based on the determined displacement of the blade tip, indicating a safe or unsafe operating condition based on whether the tip of the wind turbine blade is in danger of striking the wind turbine tower during rotation of the blade.

10 9. The method of claim 8, comprising:

 detecting the pitch angle of the blade and reducing the displacement of the blade tip according to the pitch angle.

10. The method of claim 8 or 9, comprising:

- 15 determining the twist angle of the blade tip and reducing the determined displacement of the blade tip according to the twist angle.

11. The method of any preceding claim, comprising:

- determining whether the blade tip deflection indicates an unsafe condition;
20 controlling the operation of the rotor blade or wind turbine tower based on the determination.

12. The method of any previous claim comprising:

- filtering the output from one or more of the inclinometers to remove a signal
25 component corresponding to vibrations of the wind turbine blade.

13. The method of any of previous claim, wherein the inclinometers include one or more of a DC accelerometer, a pendulum accelerometer, a MEMS type inclinometer, a liquid type or a Gyro type inclinometer.

30

14. The method of any previous claim, comprising

- receiving an output from one or more further inclinometers located in the wind turbine blade at one or more further positions wherein the one or more further positions are in different regions of the blade to the first and second positions, and the first, second and
35 one or more further inclinometers each have at least one respective sensor axis and

provide an output that indicates the orientation of the respective inclinometer relative to the sensor axis;

comparing the outputs of the first, second and one or more further inclinometers to one another to provide a profile of the relative angular deflection of the blade between the first, second and one or more further positions.

15. A method of determining the angular deflection of a wind turbine component, comprising:

receiving an output from a first inclinometer located in the wind turbine component at a first position;

receiving an output from a second inclinometer located in the wind turbine component at a second position;

wherein the second position is in a different region of the component to the first position, and the first and second inclinometers each have at least one respective sensor axis and provide an output that indicates the orientation of the respective inclinometer relative to the sensor axis;

subtracting the outputs from the first and second inclinometers from one another to provide a measurement of the relative angular deflection of the component between the first and the second positions.

16. The method of claim 15, wherein the wind turbine component is a wind turbine tower.

17. A method of determining the angular deflection between first and second wind turbine components, comprising:

receiving an output from a first inclinometer located in the first wind turbine component at a first position;

receiving an output from a second inclinometer located in the second wind turbine component at a second position;

wherein the first and second inclinometers each have at least one respective sensor axis and provide an output that indicates the orientation of the respective inclinometer relative to the sensor axis;

subtracting the outputs from the first and second inclinometers from one another to provide a measurement of the relative angular deflection between the first and second wind turbine components.

18. The method of claim 17, wherein the first and second wind turbine components are the wind turbine blade and rotor hub.

19. The method of claim 17, wherein the first and second wind turbine components are the nacelle and tower.

20. The method of claim 17, wherein the first and second wind turbine components are the wind turbine tower or nacelle and an offshore foundation.

21. A method substantially as described herein and with respect to the drawings.

22. A wind turbine component angular deflection system comprising:

a first inclinometer located in a wind turbine component at a first position;

a second inclinometer located in a wind turbine component at a second position;

wherein the first and second inclinometers each have at least one respective sensor axis and provide an output that indicates the orientation of the respective inclinometer relative to the sensor axis;

a processor arranged to receive the outputs from the first and second inclinometers and compare one orientation to another to provide a measurement of the relative angular deflection between the first and second positions.

23. The system of claim 22 comprising a controller arranged to receive an output from the processor and based on the output control the wind turbine component.

24. The system of claim 22 or 23, wherein the wind turbine component is a wind turbine blade and the first and second positions lie in the wind turbine blade.

25. The system of claim 22 or 23, wherein the wind turbine component is a wind turbine tower and the first and second positions are displaced along the longitudinal axis of the tower.

26. The system of claim 22 or 23, wherein the first position is in a wind turbine blade, and the second position is in the rotor hub.

27. The system of claim 22 or 23, wherein the first position is in a wind turbine nacelle, and the second position is in the wind turbine tower.

28. The system of claim 22 or 23, wherein the first position is in a wind turbine tower or nacelle and the second position is in the wind turbine offshore foundation.

1 / 5

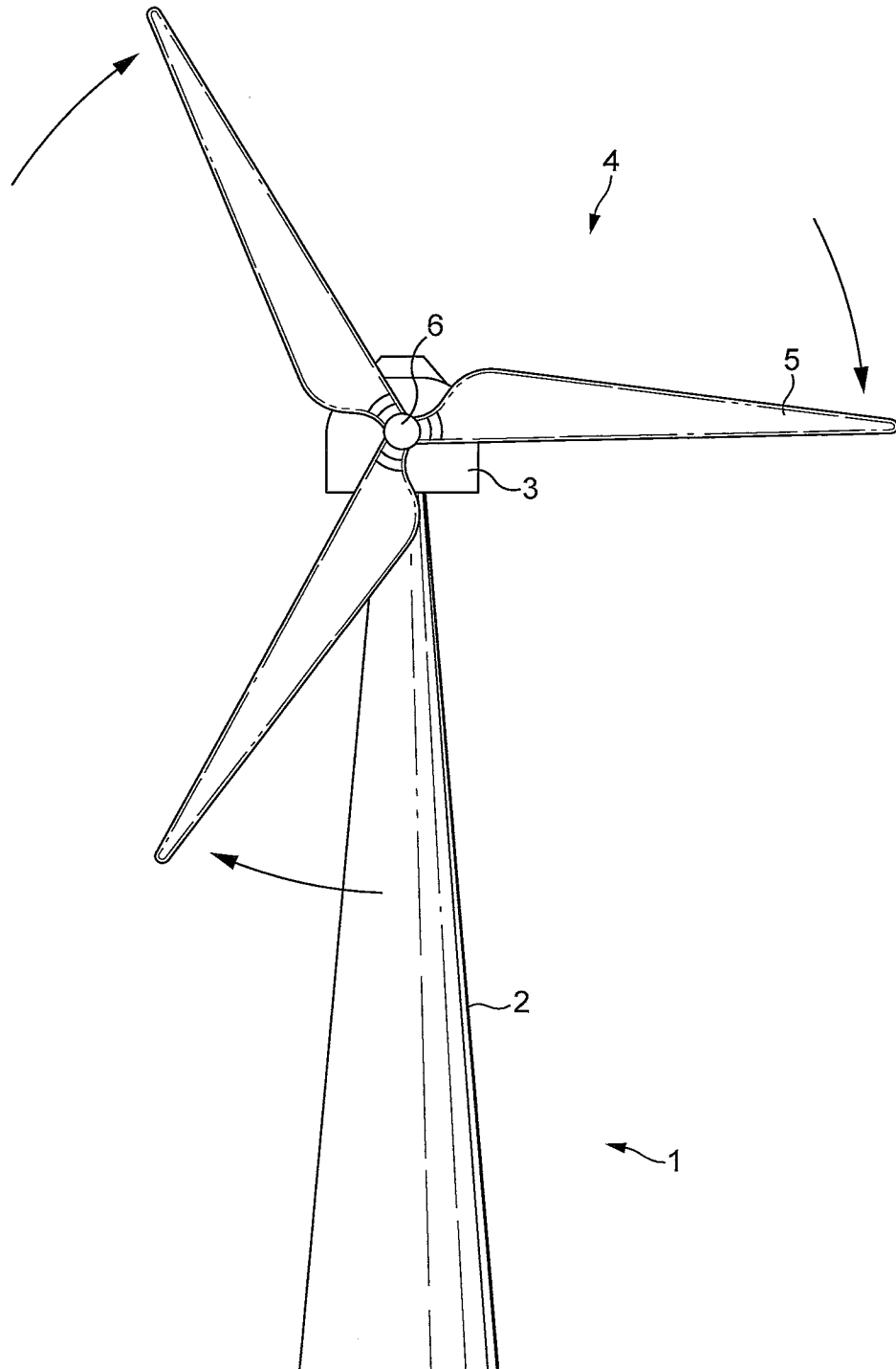


FIG. 1

2 / 5

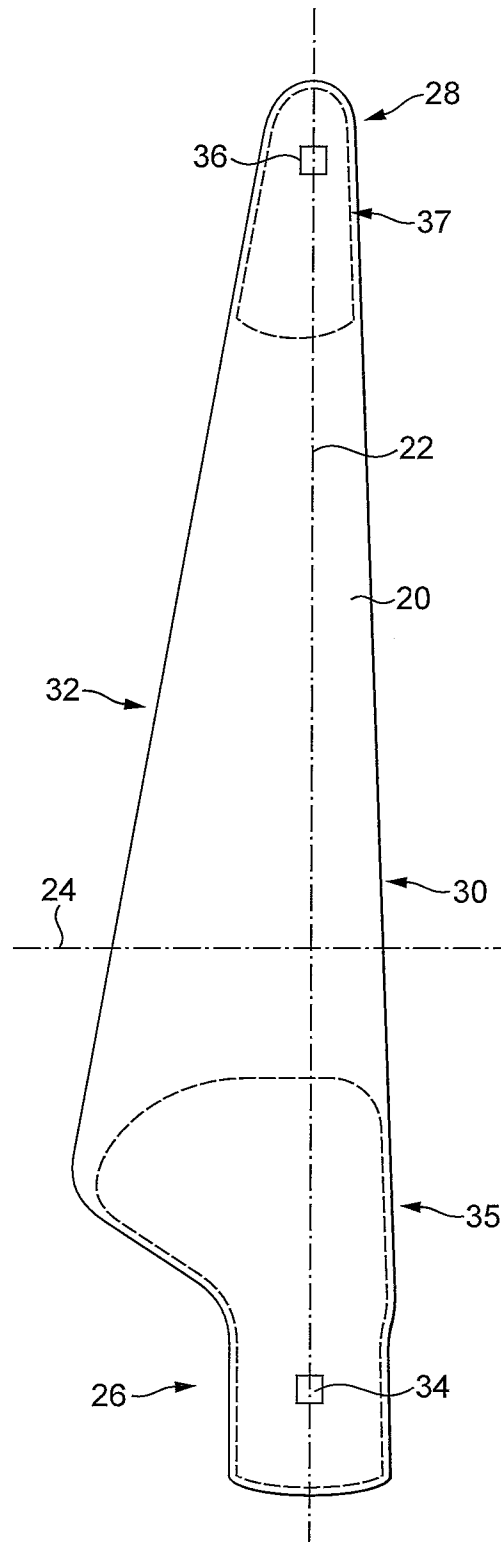
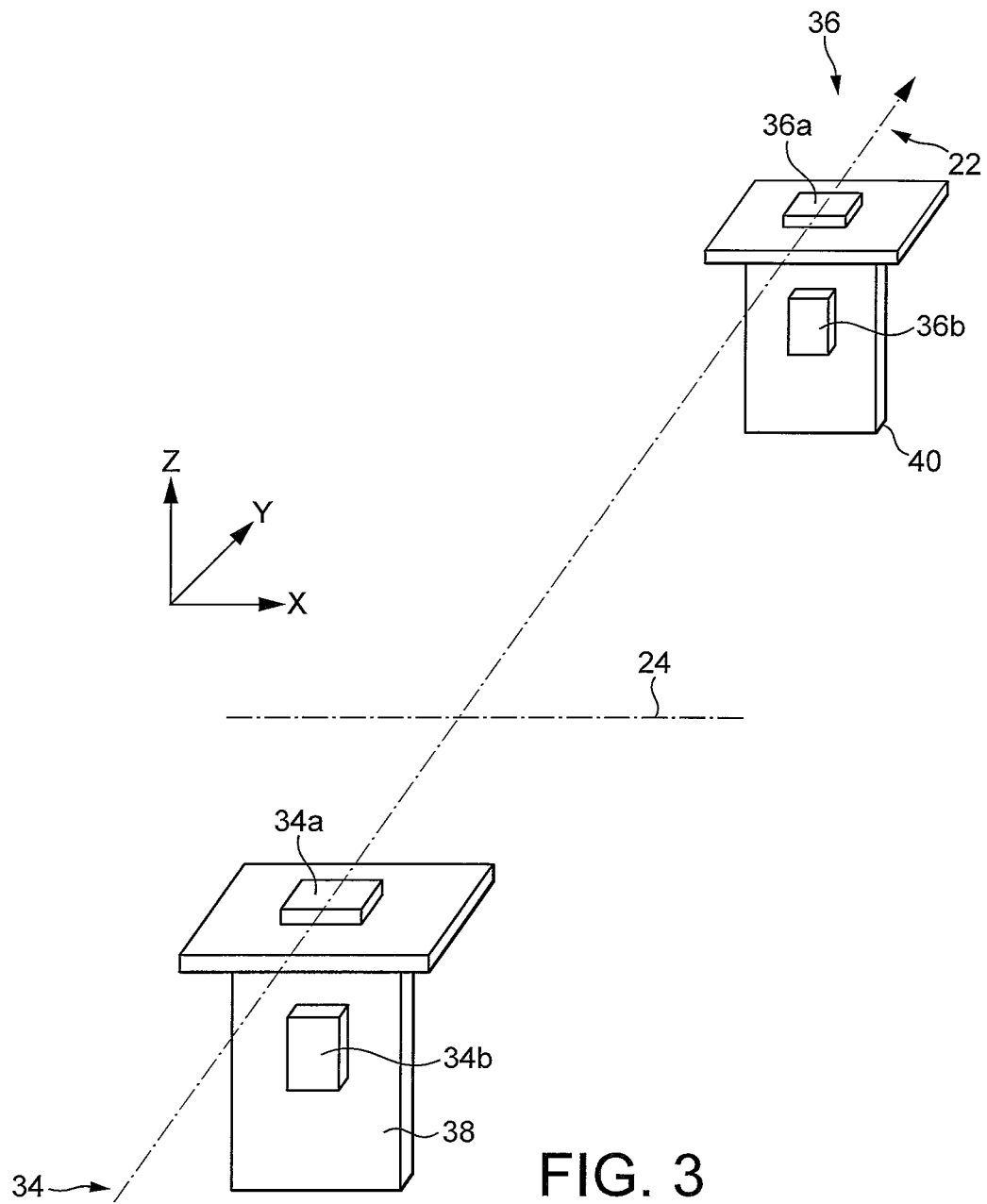


FIG. 2



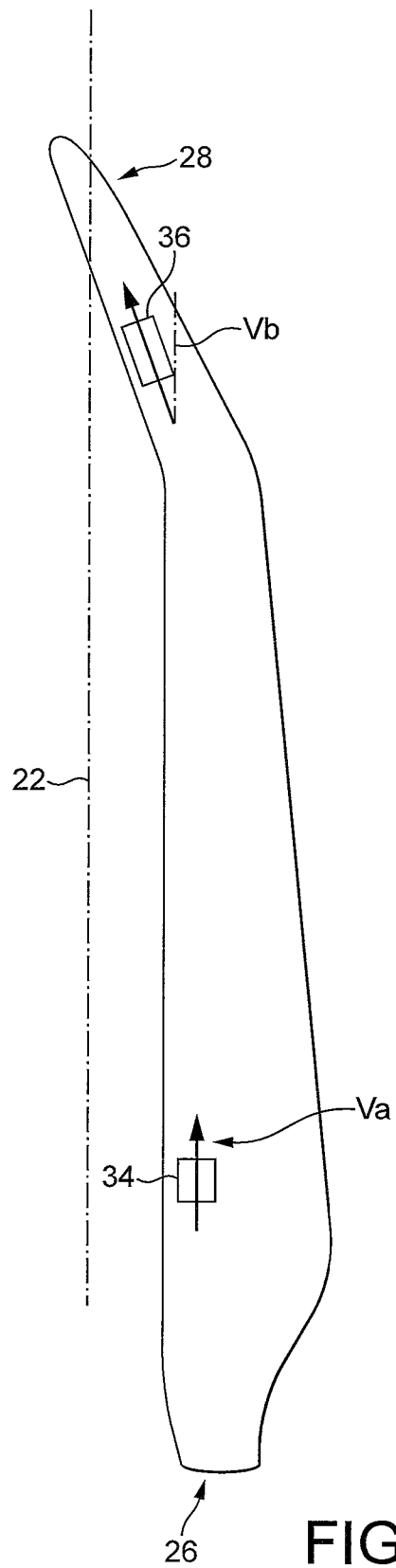
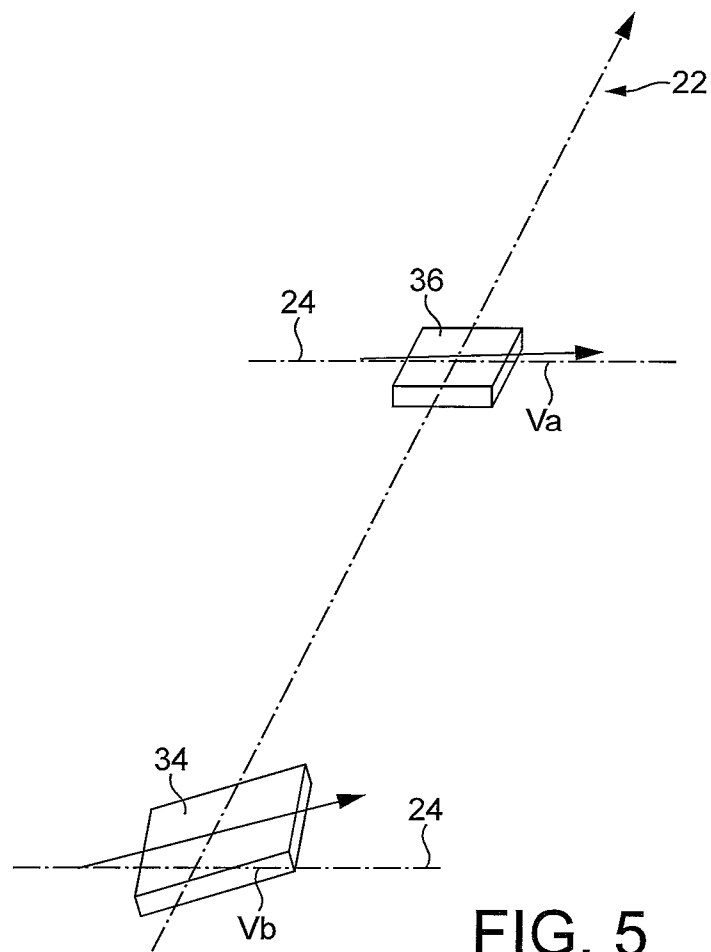


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2011/050135

A. CLASSIFICATION OF SUBJECT MATTER INV. F03D7/02 G01C9/00 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 G01C		
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, PAJ, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 1 359 321 A1 (GEN ELECTRIC [US]) 5 November 2003 (2003-11-05) paragraphs [0010], [0011], [0013], [0015], [0021]; figures 1-3 -----	1,2,6,7, 12-15, 21-24
Y	WO 2009/140435 A1 (PURDUE RESEARCH FOUNDATION [US]; WHITE JON RAYMOND [US]; ADAMS DOUGLAS) 19 November 2009 (2009-11-19) page 7, line 26 - page 8, line 3 page 10, line 5 - page 13, line 2; claim 1; figures 1-4 ----- -/--	1,2,6,7, 12-15, 21-24
☒ Further documents are listed in the continuation of Box C. ☒ 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 19 September 2011		Date of mailing of the international search report 10/10/2011
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Jucker, Chava

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2011/050135

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	WO 2010/046403 A2 (VESTAS WIND SYS AS [DK]; LI XIAO QIAN [SG]; HVAS SANDVAD INGEMANN [SG] 29 April 2010 (2010-04-29) page 1, line 28 - page 3, line 4 page 11, line 5 - page 15, line 10; figures 1-4	1-4,6,7, 12-15, 21-24
A	----- EP 1 985 848 A2 (SEN GMBH [DE]) 29 October 2008 (2008-10-29) paragraphs [0002], [0018], [0032] - [0036]; figure 1 -----	15,16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2011/050135

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1359321	A1	05-11-2003	AU 2003203979 A1 20-11-2003
			CA 2426711 A1 02-11-2003
			CN 1461882 A 17-12-2003
			JP 2004036612 A 05-02-2004
			MX PA03003859 A 03-09-2004
			US 2004108732 A1 10-06-2004
-----	-----	-----	-----
WO 2009140435	A1	19-11-2009	CA 2724311 A1 19-11-2009
			EP 2288808 A1 02-03-2011
			US 2011150649 A1 23-06-2011
-----	-----	-----	-----
WO 2010046403	A2	29-04-2010	NONE
-----	-----	-----	-----
EP 1985848	A2	29-10-2008	DE 102007011835 A1 02-10-2008
-----	-----	-----	-----