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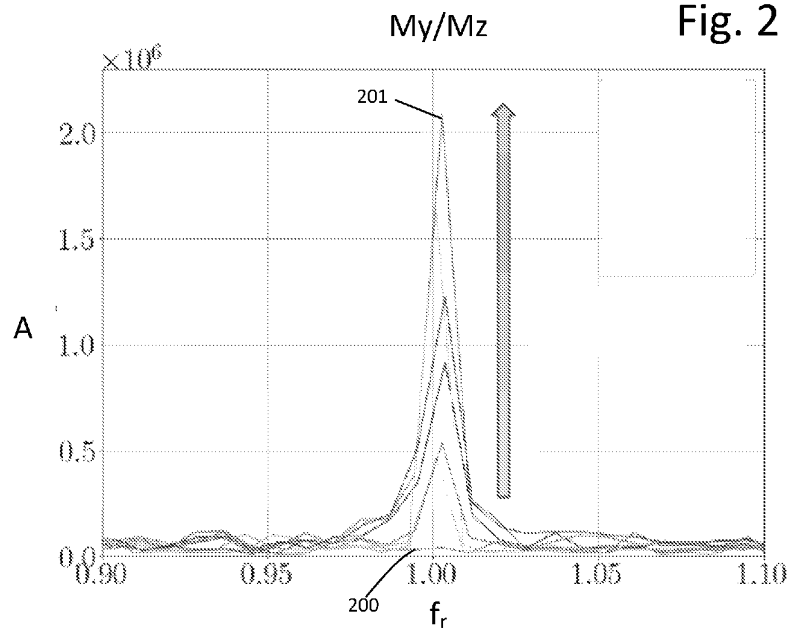
(54) **Title:** SYSTEM AND METHOD FOR DETECTING MISALIGNMENTS IN THE PITCH OF ONE OR MORE BLADES OF A WIND TURBINE

Fig. 2



(57) **Abstract:** The present invention relates to a system (1) for detecting misalignments in the pitch of one or more blades (104) of a rotor (103) of a wind turbine (100) during its operation, comprising: - one or more fixed sensors (2), associated with a fixed portion of the wind turbine (100) comprising a pylon (101) extending in height along a fixed axis x perpendicular to a fixed plane defined by fixed axes y-z, and capable of detecting a momentum or angular acceleration or acceleration along said fixed axes y and/or z and providing representative signals thereof; - a control unit (3) configured to receive as input signals provided by said fixed sensors (2), calculate the frequency spectrum thereof, and determine the presence of a misalignment in the pitch of at least one of the blades (104) if the frequency spectrum of at least one of said signals from said fixed sensors (2) exhibits a peak at the rotor rotation frequency (fr). The present invention further relates to a method for detecting misalignments in the pitch of one or more blades (104) of a rotor (103) of a wind turbine (100) during its operation.

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'System and method for detecting misalignments in the pitch of one or more blades of a wind turbine'

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Technical field of the invention

The present invention concerns a system and method for detecting anomalies in the operation of wind turbines, in particular for detecting misalignments in the pitch of one or more blades of a wind turbine.

Prior art

Wind turbines are systems for converting the kinetic energy of wind into electrical energy.

Wind turbines generally comprise a fixed pylon, a nacelle that can be swivelled relative to the fixed pylon (to align with the wind) and a rotor with blades supported by the nacelle.

As is well known, wind turbines are complex systems that require various control systems to optimise power generation according to wind characteristics.

One of the control systems with which wind turbines are equipped is blade pitch control, which modifies the incidence of the blades themselves (i.e. rotates them around their own longitudinal axis) according to the detected wind conditions. For this purpose, an actuator is placed at the base of each blade that moves them according to the instructions provided by the pitch control system.

An anomaly in the pitch of even a single rotor blade can have more or less serious consequences, ranging from sub-optimal electricity production to vibrations that jeopardise the strength of the wind turbine as well as the safety of its surroundings.

The causes that can cause anomalies in the pitch alignment of blades are varied and include, for example: manufacturing defects in the blades or their material, faults in the actuators that regulate pitch, environmental causes.

In order to detect such faults, wind turbines and blades are periodically overhauled. However, as blade pitch anomalies are often not immediately visible or do not have an immediately detectable effect, it can happen that the fault can be detected with a certain delay after its occurrence and that this delay requires the wind turbine to be shut down for an extended period to remedy it. Of course, the failure of a wind turbine, which is typically located in areas that are difficult to reach (offshore or in mountainous terrain), and its repair have a considerable impact due to the loss of electricity production and the associated downtime and maintenance costs.

Summary of the invention

The purpose of the present invention is therefore to make available a system and method for detecting anomalies in a wind turbine, in particular anomalies in the alignment of the pitch of the blades, in substantially real time, in such a way as to provide indications that allow intervention only if and when necessary on the wind turbine itself, and if necessary to modify its setting so as to allow, even in the presence of anomalies, to keep the wind turbine active until the next scheduled maintenance intervention.

This and other purposes are achieved by a system for detecting misalignments in the pitch of one or more blades of a wind turbine according to claim 1 and by a method for detecting misalignments in the pitch of one or more blades of a wind turbine according to claim 11.

Dependent claims define possible advantageous embodiments of the invention.

Brief description of the figures

In order to better understand the invention and appreciate its advantages, some non-limiting example embodiments of the invention will be described below, with reference to the attached figures, in which:

Figure 1 is a schematic illustration of a system for fault detection in a wind turbine according to an embodiment;

Figure 2 represents possible frequency spectra of signals from fixed system sensors applied to a fixed portion of the wind turbine;

Figure 3 represents a map linking the areas subtended by the spectra of the signals illustrated in figure 2 along fixed y, z axes around the peaks;

Figure 4 depicts a map linking the differences in average values of bending moments measured by movable sensors applied to wind turbine blades under different pitch misalignment conditions.

Detailed description of the invention

With reference to the attached figure 1, a wind turbine 100, in particular a wind turbine of the horizontal axis type, is schematically illustrated therein. The wind turbine 100 preferably comprises a fixed pylon 101 extending longitudinally in height (x-axis in the figure, orthogonal to a fixed y-z plane) and a nacelle 102 that can be oriented by rotation about the x-axis of the pylon 101. The turbine 100 further comprises a rotor 103, rotatable about an axis of rotation R relative to the nacelle 102, comprising a plurality of blades 104, three in the example shown. The blades 104 extend radially along a direction X from the axis of rotation R of the rotor 103 (perpendicular to a plane Y-Z, such that the three axes X-Y-Z rotate together with the blade). The term "blade pitch" refers to the angular position of each blade about the X direction. As mentioned in the introductory part of this description, the pitch of each blade is adjusted during the operation of the turbine by means of special actuators and may be subject to anomalies, i.e. the blade may lose its correct pitch.

<u>System for detecting misalignments in the pitch of one or more rotor blades of a wind turbine during its operation</u>

A system for detecting anomalies in wind turbine 100, in particular blade pitch misalignments 104, is shown in figure 1 as a whole with reference 1.

First of all, the system 1 intends to detect the presence or absence of such an anomaly on one or more of the blades 104. According to a further possible implementation variant, the system 1 further intends to determine and classify the magnitude of the anomaly. According to a further possible implementation variant, the system 1 further intends to determine on which blade or blades of the wind turbine the pitch anomaly has occurred. All the above-mentioned variants will be described in detail below.

The system 1 comprises one or more fixed momentum or acceleration or angular acceleration sensors 2 associated with a fixed portion of the wind turbine 100. It should be noted that in the present description and the appended claims, the expression "fixed portion" means a portion of the wind turbine that does not rotate together with the blades 104. Thus, for example, according to the wind turbine diagram in Figure 1, the fixed portion includes the pylon 101 and the nacelle 102, but not the rotor 103 and the blades 104. Instead, the latter are included in what will conventionally be referred to as the "rotating portion" of the wind turbine.

The fixed moment/acceleration/angular acceleration sensors 2 are suitable for measuring such quantities along the y and/or z axes, which therefore have a bending (not torsional) impact on the pylon 101. For example, the fixed sensors 2 may comprise one or more inertial measurement units, associated, for example, with the pylon 101 or the nacelle 102, capable of measuring accelerations along the y and/or z axes, or angular accelerations around the same y and/or z axes, and providing as output signals representative of the same.

The system 1 further comprises a control unit 3 configured to perform a frequency analysis, for example by means of "Fast Fourier Transform" FFT, of the representative angular momentum/acceleration/acceleration signals according to the y and/or z axes and to determine the presence of a pitch anomaly of at least one of the blades 104 if the frequency spectrum of at least one of said signals exhibits a peak at the rotor rotation frequency 103.

It should be noted that, advantageously, the control unit 3 is also configured to control the rotational speed of the rotor 103 (from which the rotational frequency is derived) in a manner known per se. For this purpose, the system 1 may comprise, for example, a sensor (not shown in the figures) for detecting the rotation speed of the rotor 103 about the rotation axis R, configured to provide the control unit 3 with a signal representative thereof.

Figure 2 shows, by way of example, the spectra of the moments M_z and M_y detected by the fixed sensors 2 relating respectively to the z-axis and y-axis for different anomalies in the pitch of the blades, i.e. for misalignments on one or more blades that are more or less intense, and for different wind conditions (both in terms of speed and in terms of type of motion, e.g. laminar and turbulent) from which it can be deduced that in all cases, in the presence of any anomaly (i.e. misalignment in any one of the blades, even in more than one of them), a peak 201 in the amplitude A is detected at the rotor rotation frequency f_r . This peak, on the other hand, is not present in the absence of an anomaly (curve 200).

It has also been observed that the amplitude of the above-mentioned peaks 201 is correlated with the magnitude of the blade misalignment. In other words, as the magnitude of the misalignment increases, being other conditions equal, the amplitude of the peaks also increases.

From this observation, it is therefore possible to classify the severity of the anomaly according to two or more levels, e.g. low severity (e.g. for misalignments less than 0.5°), medium severity (e.g. for misalignments between 0.5° and 1.5°), high severity (e.g. for misalignments greater than 1.5°). To this end, control unit 3 is advantageously configured to determine a severity level of the fault depending on the amplitude of the above-mentioned peaks.

According to one possible embodiment, the control unit 3 is also configured in such a way as to:

- calculate, for the spectra of the signals of the fixed sensor 2 along the fixed z- and y-axes, e.g. the moments M_z and M_y relative to the z-axis and y-axis respectively, the area subtended by the spectra themselves in the same peak frequency region (coinciding with the rotor rotation frequency f_r);
- compare the resulting pair of values with a predetermined map;
- determine the severity level of the anomaly based on the position of the pair of values obtained on the map.

An example of such a map is depicted in figure 3, where it is possible to detect zones of increasing severity of anomaly, e.g. three zones 301, 302, 303, from the origin. The zone 300 closest to the origin can be considered healthy, i.e. a zone in which there is essentially no blade misalignment.

The above-mentioned classification of the fault magnitude can be carried out by means of a suitable machine learning algorithm for detection and isolation of faults, e.g. by means of a Random Forest algorithm.

What has been described so far allows the system 1 to determine whether there is an anomaly in the pitch of one or more blades, and if so, to classify the anomaly according to a different level of severity, to which different actions may correspond. By way of example only, if the severity level is low, the wind turbine can be kept in operation, possibly anticipating maintenance. If the severity level is medium, one can keep the wind turbine running by, for example, modifying its performance. If the level of severity is high, the wind turbine can be stopped to avoid serious damage and safety problems by intervening as early as possible with maintenance.

With further advantage, the system 1 according to the invention is also able to determine in which blade or blades the fault occurred. For this purpose, different approaches can be adopted.

According to a first approach, the control unit 3 is configured to determine which blade(s) are affected by the anomaly on the basis of the phases of the harmonics corresponding to the rotational speed of the rotor f_r of the signals detected on the fixed portion of the wind turbine 100, the frequency analysis of which has already been carried out according to the aforementioned methods. For this purpose, the system 1 may further comprise a sensor 4 for detecting the angular position of the rotor 103, which provides the control unit 3 with a signal representative thereof. By correlating the above-mentioned signal phases to the angular position of the turbine rotor 103, and therefore of each blade 104, it is possible to determine the origin of the anomaly, i.e. which blade or blades present a pitch misalignment. It is in fact in this way possible to correlate the course of the signals from the fixed sensors with the position of the blades and thus to establish which blade/blades are responsible for the peaks in the signals from the fixed sensors over time.

In accordance with a further approach, alternative or additional to the previous one but less computationally onerous, the system 1 comprises one or more movable sensors 5 of momentum or acceleration or angular acceleration associated with the blades

104 of the wind turbine 100, which are part of the rotating portion of the wind turbine, according to the definitions given above. The movable sensors 5 of angular momentum/acceleration/acceleration are suitable for measuring these quantities according to the Y and/or Z axes of each blade (movable with them), which therefore have a bending (not torsional) impact on them. For example, the movable sensors 5 may comprise one or more inertial measurement units, associated with the blades 104, capable of measuring the accelerations along the Y and/or Z axes, or the angular accelerations around the same Y and/or Z axes, and to provide in output signals representative of the same.

According to this design variant, control unit 3 is configured to receive these signals from movable sensors 5 as input and determine which blade(s) are affected by the fault based on them.

In particular, the control unit 3 is configured to determine which blade(s) are affected by the fault based on the average value trend of these signals received from the movable sensors 5 over a predetermined and preferably movable time interval.

In fact, it has been observed that, in the presence of a fault in one of the blades, the average value of the bending moment measured in the predetermined time interval is greater than in the case where the blade is healthy and is greater than the average value of the same bending moment measured on the other healthy blades in the same predetermined time interval.

It is therefore possible to construct three-dimensional maps (for three blades) whose three axes represent the difference $\Delta M_{i,j}$ in absolute value between the bending moments of the i-th and j-th blade:

$$\Delta M_{i,j} = |M_i - M_j|$$

$$i,\ j = 1,\ 2,\ 3$$

An example of such maps is shown in Figure 4. Each “plot” depicts one of the possible anomaly conditions:

- blade 1 faulty, blades 2,3 healthy
- blade 2 faulty, blades 1,3 healthy
- blade 3 faulty, blades 1,2 healthy
- blades 1,2 faulty, blade 3 healthy
- blades 1,3 faulty, blade 2 healthy

- blades 2,3 faulty, blade 1 healthy
- blades 1, 2, 3 faulty

Method for detecting misalignments in the pitch of one or more rotor blades of the wind turbine during its operation

According to a further aspect of the present invention, a method for detecting misalignments in the pitch of one or more blades 104 of the rotor 103 of the wind turbine 100 during its operation comprises the steps of:

- detect a moment or acceleration or angular acceleration along the fixed y and/or z axes on the fixed portion of wind turbine 100. This step can be carried out by means of the fixed sensors 2;
- calculate the frequency spectrum;
- determine the presence of pitch misalignment of at least one of the blades 104 if the frequency spectrum of the momentum or acceleration or angular acceleration along the fixed y- and/or z-axes exhibits a peak at the rotor rotation frequency f_r . The latter steps can be performed by the control unit 3.

In an embodiment, the method further comprises the step of determining a severity level of the pitch misalignment of at least one of the blades 104 as a function of the amplitude of said peak of the frequency spectrum of the momentum or acceleration or angular acceleration along said fixed y and/or z axes at the rotor rotation frequency f_r . This step can be performed by the control unit 3.

In an embodiment, the step of determining a severity level of pitch misalignment of at least one of the blades comprises the sub-steps of:

- calculate the area subtended by said frequency spectra of the momentum or acceleration or angular acceleration along said fixed y- and/or z-axes in a circle of the rotor's rotational frequency f_r ;
- compare the pair of values of areas calculated for the fixed z and y axes with a predetermined map
- determine the severity level of the blade pitch misalignment based on the position of the pair of values of areas calculated for the fixed z- and y-axes on the map.

In an embodiment, the method also includes the steps of:

- detect the angular position of rotor 103, in particular via the sensor 4;
- calculate the phases of the harmonics corresponding to the rotor's rotational speed f_r of the angular momentum or acceleration along said fixed y and/or z axes;
- determine which blade or blades have a pitch misalignment on the basis of said phases and angular position of the rotor 103. The latter two steps can be carried out by the control unit 3.

In an embodiment, the method also includes the steps of:
- detect a moment or acceleration or angular acceleration along the movable axes Y and/or Z on each blade. This step can be performed by the movable sensors 5;
- determine which blade or blades have a pitch misalignment based on said moment or acceleration or angular acceleration along the movable Y and/or Z axes. This step can be performed by control unit 3.

In one embodiment, the step of determining which blade or blades have a pitch misalignment is obtained on the basis of the trend in movable time windows of the average value of the angular momentum or acceleration along said movable Y and/or Z axes.

In an embodiment, the step of determining which blade or blades exhibit pitch misalignment comprises the sub-step of comparing the differences between said average values of the moment or acceleration or angular acceleration along said movable axes Y and/or Z of all the blades with predetermined maps. This step allows for the identification of specific misaligned blades; to this end, the invention provides a comparison by considering the average vibration signals for each blade in the time domain. The vibrations are derived from average values of the mechanical moment signals My, Mz. Therefore, the analysis of the frequency behaviour of the signal estimated via Fourier transform is applied to at least one mechanical moment signal My, Mz, preferably to both mechanical moment signals My, Mz.

Note that, in this description and the accompanying claims, the control unit 3 may be implemented by means of hardware devices (e.g. control devices, computer processors, or the like), by means of software, or by means of a combination of hardware and software.

Signal analysis

The signal analysis is preferably carried out, according to the invention, in frequency in the "azimuth" domain. In this domain, the term "azimuth" refers to the horizontal angle of orientation of the rotor 103 with respect to a reference wind direction, typically measured in degrees. Using the Fourier transform with respect to this signal (azimuth value), the frequency components present in the azimuth distribution are analysed. In essence, the orientation change is broken down into angular frequency components. These angular frequency components derived from the Fourier transform in azimuth can reveal patterns or structures in the measured blade 104 orientation.

In practice, to perform the Fourier transform on the azimuth signal, each signal of interest is re-sampled based on the azimuth signal distribution, thus eliminating the dependence on wind turbine 100 speed. Once the Fourier transform has been applied, the spectrum is expressed in terms of number of revolutions of the rotor 103, allowing for the analysis of unexpected revolution frequencies in the event of an anomaly, such as 1xRev, i.e. the frequency corresponding to the rotor speed (rotor rotation frequency).

In the analysis implemented by the Applicant, this enables the detection of peaks in the power spectrum of the mechanical moments measured in the fixed reference frame of the wind turbine 100. In particular, the 1xRev component (rotor rotation frequency) is of significant importance in detecting pitch misalignment anomalies, as discussed above. A key advantage of using the Fourier transform based on the moments expressed with respect to the azimuthal domain is that the peak remains fixed at the 1xRev position (rotor rotation frequency); in contrast, when calculating the Fourier transform based on the time domain (time analysis which is not used by the system and method according to the invention), the position of the peak shifts depending on the rotation speed of the turbine 100. Advantageously, applying the Fourier transform in relation to the azimuth signal further increases the robustness of the system 1, especially in the case of turbulent weather conditions. It should also be noted that the above approach implemented by the invention differs in that it does not only consider stationary wind conditions, but also addresses scenarios characterised by turbulence.

The ability to detect and diagnose anomalies, such as pitch misalignment due to the presence of 1xRev (rotor rotation frequency), at an early stage can advantageously help reduce maintenance costs and increase the operational efficiency of turbines 100.

The combination of spectral azimuth analysis with artificial intelligence algorithms for the sophisticated analysis of data obtained from the wind turbines 100 advantageously allows optimisation of blade alignment 104. This optimisation aims to maximise energy production and reduce negative impacts on structural components; it also has the potential to improve the control systems of the wind turbines 100.

This frequency analysis in the azimuth domain is implemented by the system 1 and the method according to the invention, preferably by means of the control unit 3.

Final notes

The invention provides for the detection of misalignments in the pitch of one or more blades 104 of a rotor 103 of a wind turbine 100 during its operation, thus in real time.

The invention described herein, thus both the system 1 and the method, aims at the identification of misalignment conditions and fault detection for predictive maintenance and diagnostics applications rather than on the optimisation of energy production by adjusting blade orientation.

From the above description, the skilled person will be able to appreciate how the system and method for detecting misalignments in the pitch of the blades of a wind turbine enable optimisation of energy production, avoiding an undesirable reduction in energy production and avoiding uncontrolled increases in fatigue or wear of components. The system and method according to the invention also make it possible to avoid unnecessary maintenance work. The system and method according to the invention operate with any wind regime (including turbulent, not just axial or stationary) and integrate with existing control systems on wind turbines, without requiring modifications of the latter.

To the described embodiments of the system and method for detecting misalignments in the pitch of the blades of a wind turbine, the skilled person, in order to meet specific contingent needs, may make numerous additions, modifications, or replacements of elements with functionally equivalent ones, without, however, going beyond the scope of the attached claims.

CLAIMS

1. System (1) for detecting misalignments in the pitch of one or more blades (104) of a rotor (103) of a wind turbine (100) during the operation thereof, comprising:

- one or more stationary sensors (2), associated to a stationary portion of the wind turbine (100) comprising a pylon (101) extending in height along a stationary axis x perpendicular to a stationary plane defined by stationary axes y-z, and apt to detect a momentum or acceleration or angular acceleration along said stationary axes y and/or z and to supply signals representative of the same;

- a control unit (3) configured to receive at the inlet the signals supplied by said stationary sensors (2), to calculate the frequency spectrum of the same, and to determine the presence of a misalignment of the pitch of at least one of the blades (104) if the frequency spectrum of at least one of said signals from the stationary sensors (2) has a peak at the rotor rotation frequency (f_r).

2. System (1) according to the preceding claim, wherein said control unit (3) is further configured to, preferably for maintenance and/or diagnostic purposes, in particular predictive diagnostics, determine a level of severity of the misalignment of the pitch of at least one of the blades (104) as a function of the width of said peak of the frequency spectrum of at least one of said signals from the stationary sensors (2) at the rotor rotation frequency (f_r).

3. System (1) according to claim 2, wherein said severity level is determined based on a predefined discrete classification of the severity levels.

4. System (1) according to claim 2 or 3, wherein said control unit (3) is further configured to:

- calculate the area subtended by said frequency spectra of the signals from the stationary sensors (2) along the stationary axes z and y around the rotor rotation frequency (f_r);

- compare the pair of values of areas calculated for the stationary axes z and y with a predetermined map;

- determine the severity level of the misalignment of the pitch of the blades based on the position of the pair of values of areas calculated for the stationary axes z and y on the map.

5. System (1) according to any of claims from 2 to 4, wherein said step of determining the severity level of the misalignment of the pitch of the blades (104) is performed by a machine learning algorithm, for example by a Random Forest algorithm, preferably Aimed at the detection and isolation of faults.

6. System (1) according to any of the preceding claims, wherein said stationary portion of the wind turbine (100) further comprises a nacelle (102) steerable with respect to the pylon (101) around said stationary axis x, said stationary sensors (2) being positioned on the pylon (101) and/or on the nacelle (102).

7. System (1) according to any of the preceding claims, further comprising a sensor (4) for detecting the angular position of the rotor (103), suitable to supply a signal representative of the same, said control unit (3) being further configured to:

- calculate the phases of the harmonics corresponding to the rotation speed of the rotor (f_r) of the signals supplied by the stationary sensors (2);

- determine which blade or which blades have a misalignment of the pitch based on said phases and on said signal representative of the angular position of the rotor (103).

8. System (1) according to any of the preceding claims, wherein each of said blades (104) radially extends, from the rotation axis (R) of the rotor (103), along a movable axis X perpendicular to a plane defined by the movable axes Y-Z, so that the three movable axes X-Y-Z rotate together with the respective blade, said system (1) further comprising one or more movable sensors (5) associated to each of the blades (104) apt to detect a momentum or acceleration or angular acceleration along said movable axes Y and/or Z and to supply signals representative of the same, wherein said control unit (3) is further configured to receive at the input said signals supplied by the movable sensors (5) and to determine which blade or which blades have a misalignment of the pitch based on them.

9. System (1) according to claim 8, wherein said control unit (3) is configured to determine which blade or which blades have a

misalignment of the pitch based on the trend, within movable time windows, of the average value of the signals supplied by said movable sensors (4).

10. System (1) according to the claim 9, wherein said control unit (3) is configured to determine which blade or which blades have a misalignment of the pitch by comparing the differences between said average values of the signals supplied by said movable sensors (5) on all the blades by predetermined maps.

11. System according to any one of the preceding claims, wherein the control unit (3) is configured to perform the operation of determining the presence of a pitch misalignment of at least one of the blades (104) by an analysis of the frequency behavior of at least one signal estimated by Fourier transform, preferably of both estimated signals.

12. Method of detecting misalignments of the pitch of one or more blades (104) of a rotor (103) of a wind turbine (100) during the operation thereof, said wind turbine (100) comprising a stationary portion comprising a pylon (101) extending in height along a stationary axis x perpendicular to a stationary plane defined by stationary axes y-z, the method comprising the steps of:

- detecting on the stationary portion of the wind turbine (100) a momentum or acceleration or angular acceleration along said stationary axes y and/or z;
- calculating the frequency spectrum thereof;
- determining the presence of the misalignment of the pitch of at least one of the blades (104) if the frequency spectrum of the momentum or acceleration or angular acceleration along said stationary axes y and/or z has a peak at the rotor rotation frequency (f_r).

13. Method according to claim 12, further comprising the step of determining a severity level of the misalignment of the pitch of at least one of the blades (104) as a function of the width of said peak of the frequency spectrum of the momentum or acceleration or angular acceleration along said stationary axes y and/or z at the rotor rotation frequency (f_r).

14. Method according to claim 13, wherein said step of determining a severity level of the misalignment of the pitch of at

least one of the blades comprises the subs-steps of:

- calculating the area subtended by said frequency spectra of the momentum or acceleration or angular acceleration along said stationary axes y and/or z in the range of the rotor rotation frequency (f_r);

- comparing the pair of values of areas calculated for the stationary axes z and y by a predetermined map;

- determining the severity level of the misalignment of the pitch of the blades based on the position of the pair of values of areas calculated for the stationary axes z and y on the map.

15. Method according to any of claims from 12 to 14, further comprising the steps of:

- detecting the angular position of the rotor (103);

- calculating the phases of the harmonics corresponding to the rotor rotation speed (f_r) of the momentum or acceleration or angular acceleration along said stationary axes y and/or z;

- determining which blade or which blades have a misalignment of the pitch based on said phases and on said angular position of the rotor (103).

16. Method according to any of claims from 12 to 15, wherein each of said blades (104) radially extends, from the rotation axis (R) of the rotor (103), along a movable axis X perpendicular to a plane defined by movable axes Y-Z, so that the three movable axes X-Y-Z rotate together with the blade, the method further comprising the steps of:

- detecting on each blade a momentum or acceleration or angular acceleration along said movable axes Y and/or Z;

- determining which blade or which blades have a misalignment of the pitch based on said momentum or acceleration or angular acceleration along the movable axes Y and/or Z.

17. Method according to claim 16, wherein said step of determining which blade or which blades have a misalignment of the pitch is obtained based on the trend in movable time windows of the average value of the momentum or acceleration or angular acceleration along said movable axes Y and/or Z.

18. Method according to claim 17, wherein said step of determining which blade or which blades have a misalignment of the

pitch comprises the sub-step of comparing the differences between said average values of the momentum or acceleration or angular acceleration along said movable axes Y and/or Z of all the blades by predetermined maps.

19. Method according to any of claims 12 to 18, in which the step of determining the presence of the misalignment of the pitch of at least one of the blades (104) is performed by an analysis of the frequency behavior of at least one signal estimated by Fourier transform, preferably of both estimated signals.

20. System according to claim 11 or method according to claim 19, wherein the Fourier transform frequency analysis is carried out in the "azimuth" domain, wherein "azimuth" refers to the horizontal angle of orientation of the rotor (103) with respect to a reference wind direction.

21. System according to any one of claims 1 to 11 or claim 20 or method according to any one of claims 12 to 20, wherein the system (1) or the method is for detecting misalignments in the pitch of one or more blades (104) of a rotor (103) of a wind turbine (100) during its operation for maintenance and/or diagnostic purposes, in particular predictive diagnostics.

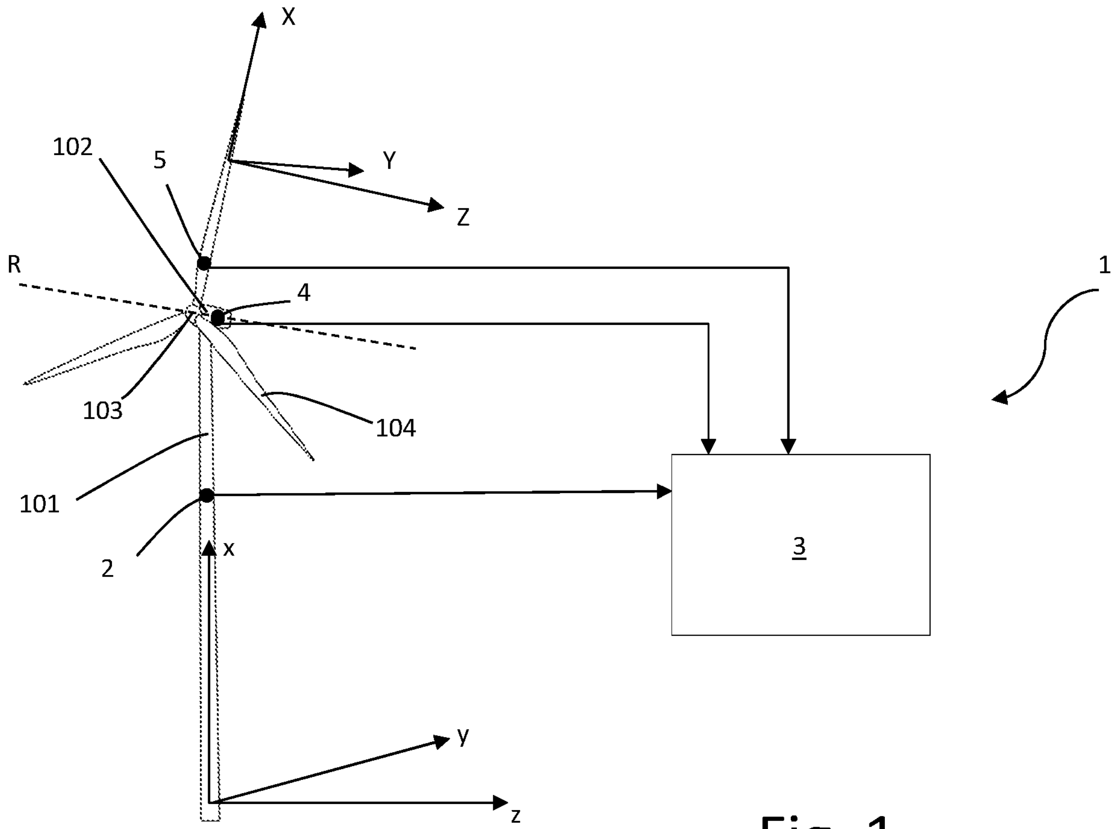
X
Y
Z
102
5
R
4
1
103
104
101
2
x
3
y
z

Fig. 1

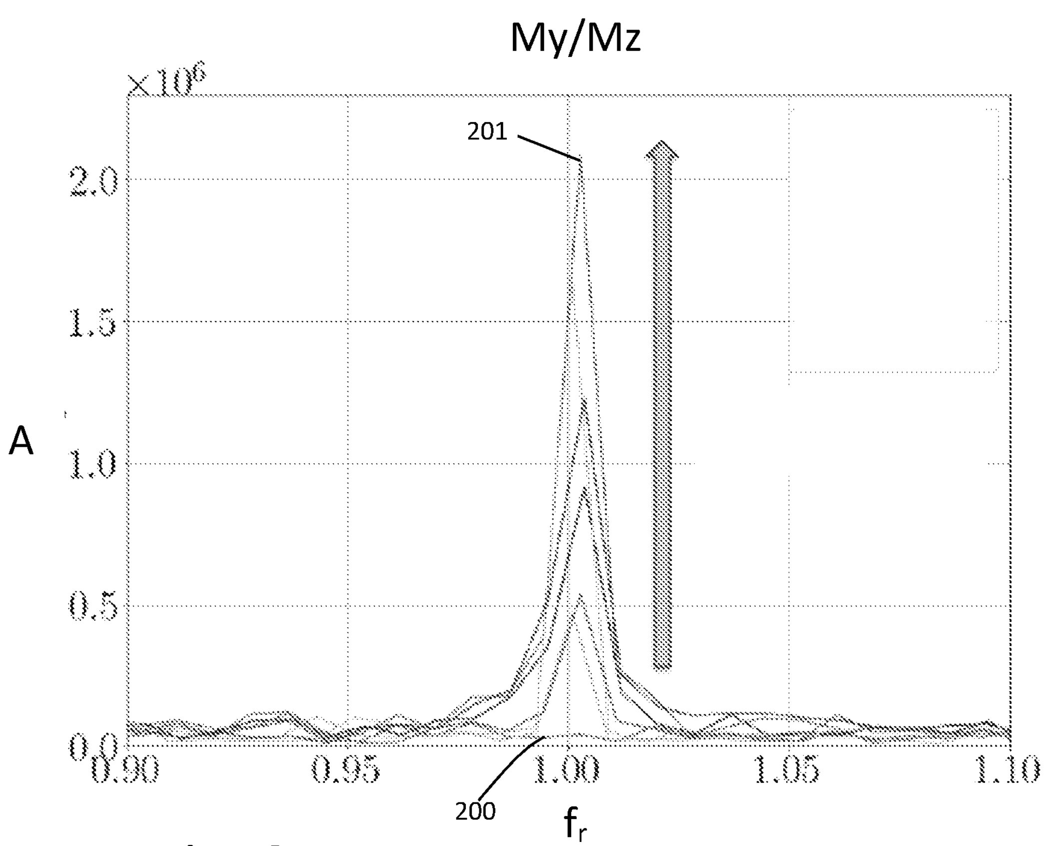
My/Mz
$\times 10^6$
201
2.0
1.5
1.0
0.5
0.0
A
0.90
0.95
1.00
1.05
1.10
200
f_r

Fig. 2

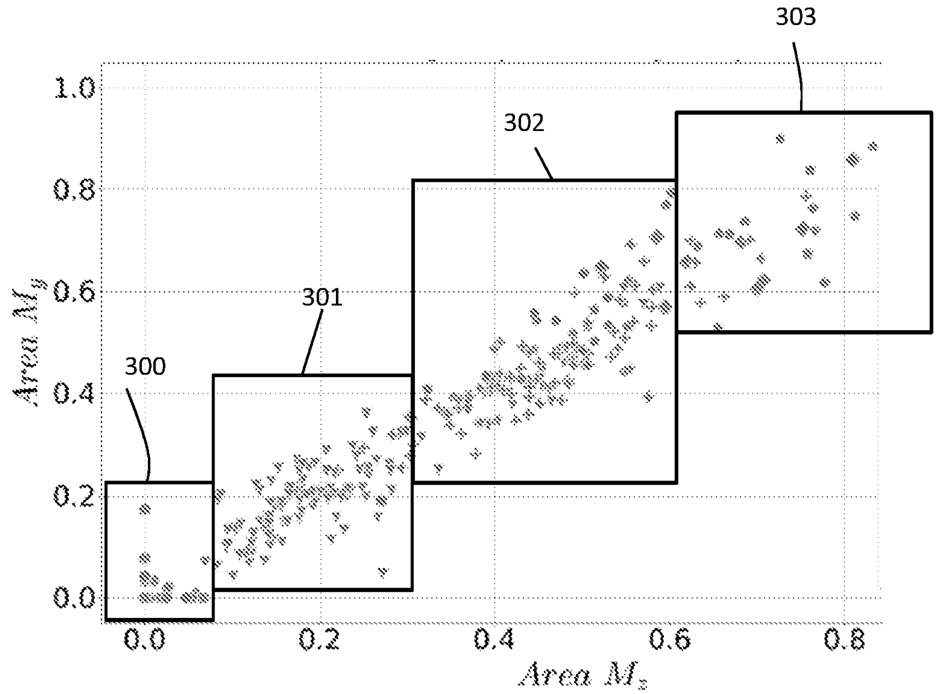
303
302
301
300
1.0
0.8
0.6
0.4
0.2
0.0
$Area\ M_y$
0.0
0.2
0.4
0.6
0.8
$Area\ M_z$

Fig. 3

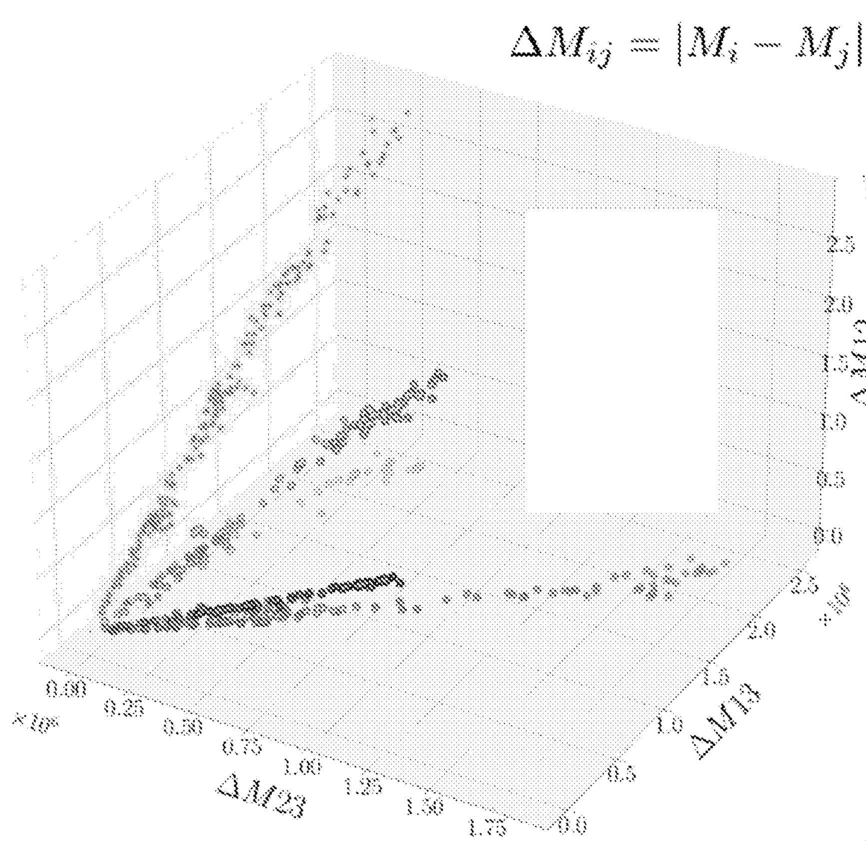
$\Delta M_{ij} = |M_i - M_j|$
$\Delta M12$
$\Delta M13$
$\Delta M23$
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/055688

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D7/04
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 practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 4 076123 B2 (FUJI HEAVY IND LTD) 16 April 2008 (2008-04-16)	1-3, 6-13, 15-21
Y	paragraphs [0036] - [0043] figures	1,5,12

Y	Milani S ET AL: "Active Monitoring of Blades Pitch Misalignment for Wind Turbines", , 23 May 2023 (2023-05-23), XP093112589, Retrieved from the Internet: URL:https://re.public.polimi.it/retrieve/c17aeda8-c803-403f-802d-f361e495cca6/MILAS01-23.pdf [retrieved on 2023-12-15] page 1, lines 1-29	1,12

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

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"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
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 August 2024	03/09/2024

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	Rini, Pietro

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/055688

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP 2 582 973 B1 (VESTAS WIND SYS AS [DK]) 27 July 2016 (2016-07-27) abstract figures -----	1-21
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INTERNATIONAL SEARCH REPORT

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