



(51) International Patent Classification:
F03D 7/04 (2006.01)

(21) International Application Number:
PCT/EP2010/057382

(22) International Filing Date:
28 May 2010 (28.05.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PA 2009 00695 3 June 2009 (03.06.2009) DK
61/183,691 3 June 2009 (03.06.2009) US

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(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, 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, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
- of inventorship (Rule 4.17(iv))

[Continued on next page]

(54) Title: HUB-SITED TOWER MONITORING AND CONTROL SYSTEM FOR WIND TURBINES

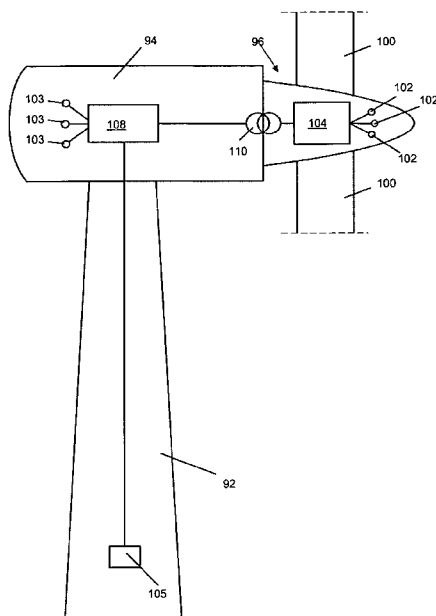


Fig. 3

(57) Abstract: In order to protect a wind turbine tower from extreme loads, e.g. during an emergency stop or to ensure safe operation in the event of a functional failure of a nacelle-housed control system, the wind turbine comprises a hub-sited control circuitry arranged in a hub section of the wind turbine, the hub section supporting the rotor blades. A measurement unit is provided in the hub section for determining at least one parameter, such as an acceleration of a component of the wind turbine, a load of a component of the wind turbine, or a rotational speed of the rotor or the turbine shaft. The hub-sited control circuitry is configured to determine a load, acceleration, velocity or deflection of the tower or a wind turbine blade on the basis of the at least one parameter measured by the measurement unit, and to control the wind turbine on the basis of the determined load, deflection, velocity, or acceleration of the tower or blade and a desired value for said load, deflection, velocity or acceleration.

WO 2010/139613 A2

Published:

- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

HUB-SITED TOWER MONITORING AND CONTROL SYSTEM FOR WIND TURBINES

FIELD OF THE INVENTION

The present invention relates to control of wind turbine rotors, notably during abrupt changes of the operating conditions of the wind turbine, such as during wind gusts or emergency
5 stops. Some of the embodiments of the invention rely on aerodynamic control of the wind turbine blades for achieving the desired control effects, such as pitch control or the control of surface-altering devices.

BACKGROUND OF THE INVENTION

The power output and the structural loads on a wind turbine are commonly controlled by
10 controlling the aerodynamics of the blades i.e. by controlling the blade angle into the wind (pitch control) or by controlling surface-altering devices, such as flaps. Generally, a decreasing pitch angle increases the load on the blades of the wind turbine rotor and hence the amount of energy that can be extracted from the wind at a given wind velocity. However,
15 the pitch needs to be kept within limits in order to avoid aerodynamic stall or overload on the blades. Pitch control also serves the purpose of controlling the rotor rotational speed (or rpm) in off-grid scenarios where the rotor rotation is not limited by power production. Accordingly, most modern wind turbines are equipped with pitch control systems for controlling the pitch angles of the blades based on measured or estimated parameters, such as output power of the wind turbine or load on the blades or driving shaft of the wind turbine.

20 Recent research of the assignee of the present invention, Vestas Wind System A/S, has also revealed that pitch or teeter control and/or other types of aerodynamic control may be efficiently employed in order to avoid excessive loads on wind turbine components during emergency stops of the wind turbine.

Usually, the actuator which causes an aerodynamic change of the wind turbine blade, e.g.
25 causes the blade to rotate around its longitudinal axis (pitch), or which actuates a surface-altering device, such as a flap, is arranged at a hub section of the wind turbine, i.e. within a nose-shaped housing on the front face of the nacelle, which is arranged to rotate with the rotor during operation of the wind turbine. In order to convey electrical control signals from the wind turbine control system, which is typically housed within the nacelle, to the
30 aerodynamics-altering actuators in the rotating hub section, a so-called slip ring is typically provided in the control signal pathway at the interface between stationary and rotational parts of the pitch control system.

EP 1 903 213 discloses a pitch controller disposed in the rotor of a wind turbine along with an uninterruptible power supply and a rotational speed detector. The appropriate pitch angle is under normal operational conditions continuously fed to the pitch controller from a turbine controller placed in the nacelle. However, in case the pitch angle command is not received correctly due to e.g. failure of the slip ring between the rotor and the nacelle, electric noise, or failure of the controller, the pitch controller in the rotor internally creates an appropriate pitch angle command. This may be e.g. to stop the rotor by gradually increasing pitch, to wait for some time without changing the pitch, or to change the pitch based on locally measured information from the rotational speed detector keeping the rotational speed of the rotor within certain limits etc. The pitch control is thus in special situations performed as a function of a rotational speed measured locally in the rotor.

However, EP 1 903 213 does not address the issue of excessive loads occurring during abrupt changes of the operating conditions of the wind turbine, such as e.g. at emergency stops or extreme wind gusts. In particular, as the technological trend is to make wind turbines larger and higher, loads on the tower or blades cannot be neglected and must be monitored and controlled, notably during abrupt changes of operating conditions. Moreover, though the rotational speed in many instances is a reliable and useful control parameter, there are instances, in which the rotational speed is not sufficient as a control parameter for avoiding undesirable physical effects.

SUMMARY OF THE INVENTION

It is an object of embodiments of the invention to provide a wind turbine and a method for control thereof, which are useful in the event of communication failure between stationary and rotational parts of the rotor control system, and which address issues of overload and other undesirable effects in the event of abrupt changes to the operational conditions of the wind turbine, such as at emergency stops or extreme wind gusts. It is a further object of embodiments of the invention to provide a tower monitoring and control system, which is useful for avoiding excessive loads on the tower, in particular during abrupt changes of operating conditions.

To meet these object, a first aspect of the present invention provides a method for controlling the operation of a wind turbine comprising:

- a tower;
- a nacelle supported by the tower at the upper end of the tower;
- a rotor comprising said wind turbine blades;
- a shaft, which is driven by the rotor;
- a hub section, at which the rotor is mounted to the shaft, the hub section being arranged

outside the nacelle;

- a hub-sited control circuitry arranged in the hub section, the hub-sited control circuitry being configured to control operation of the wind turbine;

- at least one measurement unit in the hub section for determining at least one parameter among an acceleration of a component of the wind turbine, a load of a component of the wind turbine, a deflection of a component of the wind turbine, a rotor teeter angle;

the method comprising:

- measuring, by means of said at least one measurement unit in the hub section, at least one of said parameters and transmitting output signals provided by the measurement unit to the hub-sited control circuitry;

- determining, within the hub-sited control circuitry, a load, acceleration, velocity or deflection of the tower or of the rotor plane of the wind turbine on the basis of at least one of said parameters;

- controlling operation of the wind turbine by means of the hub-sited control circuitry on the basis of said determined load, deflection, velocity or acceleration and a desired value for said load, deflection, velocity or acceleration.

A second aspect of the invention provides a wind turbine comprising:

- a tower;

- a nacelle supported by the tower at the upper end of the tower;

- a rotor comprising a plurality of wind turbine blades;

- a shaft drivable by the rotor during operation of the wind turbine;

- a hub section, at which the rotor is mounted to the shaft, the hub section being arranged outside the nacelle;

- a hub-sited control circuitry arranged in the hub section, the hub-sited control circuitry being configured to control operation of the wind turbine;

- at least one measurement unit in the hub section for determining at least one parameter among an acceleration of a component of the wind turbine, a load of a component of the wind turbine, a deflection of a component of the wind turbine, a rotor teeter angle;

wherein the hub-sited control circuitry is configured to:

- receive output signals provided by the measurement unit;

- determine a load, acceleration, velocity or deflection of the tower or of the rotor plane of the wind turbine on the basis of the at least one parameter measured by the measurement unit;

- control the wind turbine on the basis of said determined load, deflection, velocity, or acceleration and a desired value for said load, deflection, velocity or acceleration.

Due to the provision of the hub-sited control circuitry, the present invention results in a control method and control system for wind turbines, in which those control elements and

signal pathways, which require great reliability, can be restricted to the hub of the wind turbine. For most applications, public regulations and insurance requirements prescribe that essential parts of wind turbine control systems be built and configured to meet strict safety requirements. For example, replicated sensors systems, control computers and signal pathways are often required, so that if one component fails, a duplicate of that component takes over its operation. In consequence, such control equipment is rendered expensive and complex. By arranging the at least one measurement unit and the control circuitry at the hub of the wind turbine, it is possible not only to restrict the complex and expensive parts to the hub of the wind turbine, i.e. that part of the wind turbine which rotates along with the rotor, but also to avoid redundancy and special protection of signal transmission pathways between non-rotatable control elements, e.g. in the nacelle of the wind turbine, and rotatable control elements in the hub section.

In an embodiment, the wind turbine comprises a rotational speed sensor for measuring a rotational speed of the rotor or the shaft, and the hub-sited control circuitry is configured to receive output signals from the rotational speed sensor, and control operation of the wind turbine by on the additional basis of the rotational speed of the rotor or the shaft.

In another embodiment, the wind turbine further comprises at least one blade measurement unit for determining a load or deflection of at least one blade of the wind turbine and the hub-sited control circuitry is configured to receive output signals from the blade measurement unit, and control operation of the wind turbine by on the additional basis of the load or deflection of the blade.

The hub-sited control circuitry may preferably be configured to control blade bending, i.e. blade load, and tower deflection. Further, blade oscillations may have to be addressed and controlled, e.g. by pitch control or surface-altering device on the blades, and accordingly the hub-sited control circuitry may further be configured to control blade oscillations based on an appropriate input from sensors for determining vibrations, loads, deflections, accelerations or other parameters, from which possible oscillations of the blades are derivable. Control of blade oscillations is of particular interest in respect of wind turbines with a rotor diameter of 150 m or more.

It should be understood that by determination of a deflection of the rotor plane should be understood as determination of a rotor teeter angle.

In one embodiment as described in detail below, the present invention also provides a nacelle-housed control circuitry in addition to the hub-sited control circuitry, which may control e.g. tower or blade load, deflection, velocity or acceleration. The nacelle-housed control circuitry may be replicated or partly replicated to the hub-sited control circuitry, so that the hub-sited control circuitry may take over operations of the nacelle-housed control circuitry in the case of a functional failure in the nacelle-housed control circuitry. The control may, however, alternatively or additionally perform other control operations, which are not performed by the hub-sited control circuitry.

Thanks to the hub-sited control circuitry, the present invention confers the further benefit that the load, deflection, velocity of acceleration of the tower or one or more of the blades may be controlled even in the case of a communication interruption between the nacelle and the hub. As the hub-sited control circuitry allows the wind turbine to be controlled, e.g. by increasing or alleviating load on the rotor, the control does not rely on a properly functioning interface between the rotatable hub and the stationary nacelle or by a reliably functioning nacelle control system. Measurement signals from the hub or from sensors on the blades or shaft in the hub may be conveniently transmitted to the hub-sited control circuitry without any need for interfacing signals between movable and stationary parts. Likewise, control signals from the hub-sited control circuitry to the hub or rotor, e.g. for pitching the blades or altering the aerodynamic surface of the blades such as by means of controllable flaps, do not have to pass through an interface between movable and non-movable parts.

As the tower and the blades constitute particularly critical components of large wind turbines, the provision of means for determining tower and blade load, acceleration, velocity and/or position within the hub reduces the risk of tower or blade overload in general, and, in particular, it completely eliminates the risk of tower or blade overload due to the interruption in the communication between the hub and the nacelle.

The hub-sited control circuitry may conveniently be powered by means of electrical power delivered by the generator of the wind turbine housed within the nacelle or by a separate generator within the hub dedicated to power generation for hub-sited elements. Alternatively, an uninterruptible power supply or other means of energy storage may be included in the hub.

In addition to the hub-sited control circuitry, an embodiment of the present invention may further comprise a nacelle-housed control circuitry for controlling operation of the wind turbine, i.e. a further control circuitry arranged in the nacelle, and a signal pathway for conveying control signals between the nacelle-housed control circuitry and the hub. In such an embodiment, the hub-sited control circuitry may be configured to control the wind turbine

during normal operation in the event of an interruption of communication between the nacelle-housed control circuitry and the hub section or in the event of a critical operating condition, such as an emergency stop or functional failure in the nacelle control system, whereas the nacelle-housed control circuitry may be configured to control the wind turbine in the event of non-interruption of the signal pathways between the nacelle-housed control circuitry and the hub. For example, the nacelle-housed control circuitry may be more advanced than the hub-sited control circuitry, in the sense that it may take parameters into account, which are not readily available at the hub, such as for example parameters of the wind turbine generator, gearbox etc., or parameters communicated to the wind turbine from remote facilities. The hub-sited control circuitry and the nacelle-housed control circuitry may be set up in such a way as to be replicated, i.e. if one fails the other takes over control of the wind turbine.

The hub-sited control circuitry may be configured to check control signals provided by the nacelle-housed control circuitry, before these are passed on to appropriate control mechanisms. Hence, the hub-sited control circuitry may be configured to perform a check of control commands provided by the nacelle-housed control circuitry in order to avoid that erroneous control commands are passed to e.g. pitch control actuators or mechanisms for controlling surface-altering devices of the blades. Such erroneous control commands may e.g. result from hardware failures or from software errors in the nacelle-housed control circuitry.

In one embodiment, the hub-sited control circuitry and/or the nacelle-housed control circuitry may be configured to control a teeter mechanism, i.e. a mechanism for controlling the inclination of the plane defined by the rotor with respect to a vertical plane. The teeter mechanism, which may e.g. be for active damping of a teeter rotor, may be exclusively executed by the hub-sited control circuitry.

The wind turbine of the present invention may be a pitch-regulated wind turbine, in which case at least one pitch-regulating actuator may be provided for pitching the blades. The at least one pitch-regulating actuator may be arranged in the hub section, and the hub-sited control circuitry and the nacelle-housed control circuitry may be configured to control the pitch-regulating actuator. Hence, under normal operating conditions, the nacelle-housed circuitry may control the pitch of the blades, whereas the hub-sited control circuitry may be provided as a failsafe system, which takes over control of the blade pitch in case of disruption of the signal pathways between the nacelle and the hub, or if the nacelle-housed control system fails to operate within safe limits. It should be understood, however, that the hub-sited control circuitry additionally or alternatively may be configured to control the wind turbine, in particular the blades thereof, in other ways. For example, it may be configured to

control elements for modifying the aerodynamic shape of the wind turbine blades, e.g. by means of trailing edge flaps, spoilers, vortex generating elements, etc. Preferably, the control provided by the hub-sited control circuitry is for controlling elements, which may increase and/or decrease the load on the rotor to thereby alleviate or increase the load on the tower of the wind turbine.

Generally, the rotor may comprise at least one surface altering device for altering the aerodynamic surface of at least one of the blades. The surface altering device may be controllable by the hub-sited control circuitry or the nacelle-housed control circuitry to increase the aerodynamic load on the rotor during an upwind movement of the tower and/or to decrease the aerodynamic load on the rotor during a downwind movement of the tower. The hub-sited control circuitry may be configured to control the surface altering device during normal operation in the event of an interruption of communication between the nacelle-housed control circuitry and the hub section, or in the event of a critical operating condition, such as an emergency stop or functional failure in the nacelle control system, whereas the nacelle-housed control circuitry may be configured to control the wind turbine in the event of non-interruption of the signal pathways between the nacelle-housed control circuitry and the hub.

It will hence be understood that the hub-sited control circuitry may e.g. be configured to counteract or limit the tower's movement, rate of movement or acceleration during a stop process of the wind turbine. Hence, if the tower for example accelerates in the upwind direction during an emergency stop process of the wind turbine, the hub-sited control circuitry may be configured to increase the load on the rotor, thereby delaying the stop process but reducing acceleration of the tower. Likewise, once the tower has reached its extreme upwind position and starts to move in the downwind direction, the wind turbine may be controlled to limit the movement in the downwind direction. The nacelle-housed control circuitry may likewise be configured to perform these operations.

In one embodiment, the hub-sited control circuitry and/or the nacelle-housed control circuitry is configured to monitor the load, acceleration, velocity and/or deflection of the tower and to control the pitch of the wind turbine in order to keep the tower load, acceleration, velocity and/or deflection below a predetermined threshold value.

At least one load measuring device, e.g. a strain gauge, for measuring a parameter indicative of the load on the wind turbine blades and/or on the shaft may be provided, the at least one load measuring device being connected to the nacelle-housed control circuitry via the signal pathway and/or to the hub-sited control circuitry. Thereby, the control of the wind turbine may be conducted in response to the loads experienced by the rotor, which in turn result in

loads on the tower. Additionally or alternatively, at least one load measuring device may be provided at the tower itself. The communication from the load measuring device (or devices) to the control circuitries may be provided via wired communication paths or via wireless communication, such as by radio frequency communication. In one embodiment, the measurement unit in the hub section comprises a combined accelerometer and rpm measurement unit. For example, Micro-Electronic Mechanical Sensors (MEMS) may be deployed to measure tower acceleration and rotor rpm. The measurement unit may be equipped with a computing device e.g. a Digital Signal Processor, which enables advanced signal analysis of the measured parameters. One embodiment of the measurement unit for rpm measurement may, for example, be designed in accordance with the suggestions and recommendations given in Heiselberg T.A.D. and Gottschalk M.A. in "Undersøgelsesprojekt, Måling af lavfrekvente rotationer, HAP, Hastighed Acceleration Position", Ingeniørhøjskolen Århus, project id. 2008-05-29 (Project Report 2008-05-29, measurement of low frequency rotations, HAP, velocity acceleration position, Engineering College, Aarhus, Denmark) dated 30 June 2008. The at least one measurement unit may further comprise at least one measuring device for measuring a parameter indicative of rotor teeter angle.

In one embodiment, the measurement unit may be configured to measure a position, velocity or acceleration in more than one direction, e.g. by means of a GPS unit. Alternatively, the measurement unit may comprise of multiple MEMS accelerometers which are set to provide readings for motion in each physical dimension/direction.

Generally, the wind turbine of the present invention may comprise a non-contact, wireless interface between the hub and the nacelle in order to avoid possible disruptions in wired or communication pathways or other communication channels based on mechanical/physical contact.

25 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 generally illustrates a wind turbine;

Fig. 2 shows a cross-sectional view of a nacelle and hub section of a wind turbine;

Fig. 3 illustrates a general control system of a wind turbine according to the present invention;

30 Fig. 4 generally illustrates a replicated control system;

Fig. 5 is a block diagram of a control system of a wind turbine according to the present invention;

Fig. 6 illustrates tower oscillations during an emergency stop of the wind turbine;

5 Figs. 7 and 8 are illustrations of a controllable shape-deformable trailing edge section of a wind turbine blade.

DETAILED DISCLOSURE OF THE INVENTION

As shown in Fig. 1, a wind turbine 90 comprises a tower 92, a nacelle 94 at the tower top, the nacelle housing machine components, such as gearbox, generator etc. (not shown). At one end of the nacelle, a hub section 96 supports a plurality of wind turbine blades 100. The rotor of the wind turbine includes the blades and possibly other rotating parts. One or more measurement units 102 are provided with the hub section 96. The measurement unit(s) 102 is/are arranged to measure an acceleration of a component of the wind turbine, a load of a component of the wind turbine, a deflection of a component of the wind turbine, or a rotational speed of a component of the wind turbine. The load measurement may e.g. be a torque measurement at the hub carried out by suitable means, such as strain gauges. The acceleration measurement may be performed by means of an accelerometer arranged within the hub section. The deflection measurement may be performed by an angle measurement device. The rpm measurement may conveniently be performed on the main shaft of the turbine or on a rotatable part within the hub section, to measure the rpm of the rotor. Alternatively, it may be performed by an instrument, which is independent of access to the main shaft of the wind turbine.

In an embodiment, the measurement unit 102 is a MEMS accelerator module, which measures the acceleration of the hub or tower in a certain direction. The speed and distance of motion may then be determined from the acceleration measurement. The measurement unit could also be a module comprising at least three MEMS accelerators, each configured to measure an acceleration of the hub or tower in a distinct direction, in order to provide a three-dimensional understanding of the motion of the hub or tower. The measurement unit may also comprise multiple MEMS accelerometers. This provides for redundancy of the accelerator modules as well as allowing fault tolerant operation of the measurement unit.

30 The control system of the wind turbine 90 is illustrated in Fig. 2. The measurement unit 102 feeds its measurement signals into a hub-sited control circuitry 104, which is connected to a rotor control system 106, such as e.g. a pitch control system for controlling the pitch of the

blades 100. All parts within the hub section 96, including the load measurement unit 102, hub-sited control circuitry 104 and pitch control system are arranged to rotate with the rotor of the wind turbine.

Alternatively, the hub-sited control circuitry 104 may comprise three controllers located at the blade root of each blade in the hub, where each controller is configured to receive input from separate measurement units.

Under normal operating conditions, the rotor control system 106 is controlled by a nacelle-housed control circuitry 108, which may receive input signals from various measurement devices or sensors (not shown), such as in particular power output sensors, rpm sensors, load or torque sensors of the driven parts of the turbine and/or of the tower 92. In one embodiment of the invention, the nacelle-housed control circuitry receives input signals from the measurement unit 102 via an interface 110 between the hub section 96 and the nacelle 94. The nacelle-housed control circuitry 108 is stationary within the nacelle. The control signals from the nacelle-housed control circuitry 108 are fed to the rotor control system 106 through the interface 110, which e.g. includes a slip ring or other means of rotational signal transfer.

In case of a failure in the signal communication between the nacelle-housed control circuitry 108 and the hub 96, the hub-sited control circuitry 104 takes over control of the rotor control system.

Fig. 3 generally illustrates a control system of an embodiment of a wind turbine according to the invention. Within the nacelle 94 the wind turbine comprises the nacelle-housed control circuitry 108, which communicates with the hub-sited control circuitry 104 via interface 110 between non-movable and parts within the nacelle and rotatable parts within the hub 96. The nacelle-housed control circuitry receives input from a set of sensors or measurement units 103, and from a control unit or sensor system 105 provided near the bottom of the tower for measuring e.g. tower loads. The measurement units 103 may provide input data to the nacelle-housed control circuitry 108 related to e.g. power output of the wind turbine, wind direction, wind velocity and/or other parameters. The hub-sited control circuitry 104 receives input data from a plurality of measurement units 102 arranged to measure e.g. loads on the blades 100 (i.e. blade bending), blade oscillation, rpm, acceleration, velocity or load of the tower 92 and/or other parameters. The sensors 102 and 103 may be provided for individual purposes, or some of them may replicate others. For example, two of the sensors 102 may be provided for measuring blade load, whereby one of the sensors 102 is provided to take over if the other fails.

Fig. 4 generally illustrates an embodiment of the hub-sited control circuitry 104, comprising replicated control circuitries 104a and 104b. Each of the measurement units 102 communicates their output signals to each of the circuitries 104a and 104b, which in turn are connected to an actuator 107 for effecting a change in the wind turbine operation, e.g. activation of surface-altering devices of the blades and/or change of the blades' pitch angles. The actuator 107 may be replicated. In Fig. 5, the hub-sited control system of Fig. 4 is shown as implemented in a hub section 96 of a wind turbine according to the present invention. As shown, the hub-sited control circuitry 104 receives control signals (i.e. control commands) provided by the nacelle-housed control system 108 during normal operation. In the event of a failure in the signal communication between the nacelle-housed control circuitry 108 and the hub 96, or in the event of a functional failure in the nacelle-housed control circuitry 108, the hub-sited control circuitry 104 controls operation of the wind turbine in an autonomous manner. Further, the hub-sited control circuitry 104 may be configured to check control commands provided by the nacelle-housed control circuitry 108, even during normal operation of the wind turbine. It may hence be avoided that erroneous control commands are passed to e.g. pitch control actuators or mechanisms for controlling surface-altering devices of the blades. Such erroneous control commands may e.g. result from hardware failures or from software errors in the nacelle-housed control circuitry 108, which in some embodiments of the invention does not have to fulfil the same strict safety standards as the hub-sited control circuitry 104.

Fig. 6 illustrates four conditions of the wind turbine occurring during an emergency stop of the wind turbine. Initially, at condition 1, the tower is deflected in the downwind direction under the influence of the wind. As an emergency stop procedure is initiated, e.g. by pitching the blades out of the wind, thereby removing thrust from the rotor, the tower moves in the upwind direction, see condition 2. At condition 3, the turbine has reached its extreme upwind direction and starts to move back in the downwind direction, i.e. towards condition 4. Thereby, tower oscillations are induced, which may be reduced by appropriate control of the rotor, such as the pitch of the blades or activation of surface-altering devices. For example, the movement in the upwind direction, see conditions 2 and 3, may be counteracted by pitching the blades into the wind, thereby providing thrust on the rotor, and movement in the downwind direction as shown in condition 4, may be counteracted by pitching the blades out of the wind again, i.e. by removing thrust from the rotor.

Figs. 7 and 8 are illustrations of a controllable surface-altering device of a wind turbine blade 100, embodied by a shape-deformable trailing edge section 112 of a wind turbine blade 100. The trailing edge section 112 may e.g. be controllable to reduce or increase the aerodynamic load on the blade 100. The trailing edge section may be controllable by the hub-sited control circuitry 102 and/or by the nacelle-housed control circuitry 108 (see Figs. 2, 3 and 5) in

accordance with the present invention. Means known per se may be provided for controlling the trailing edge section 112, such as pneumatic or hydraulic actuators. Other shape-deformable elements may alternatively or additionally be provided, such as vortex generators or trailing edge or leading edge flaps.

CLAIMS

1. A method for controlling the operation of a wind turbine comprising:

- a tower;
- a nacelle supported by the tower at the upper end of the tower;
- 5 - a rotor comprising a plurality of wind turbine blades;
- a shaft, which is driven by the rotor;
- a hub section, at which the rotor is mounted to the shaft, the hub section being arranged outside the nacelle;
- a hub-sited control circuitry arranged in the hub section, the hub-sited control circuitry
- 10 being configured to control operation of the wind turbine;

- at least one measurement unit in the hub section for determining at least one parameter among an acceleration of a component of the wind turbine, a load of a component of the wind turbine, a deflection of a component of the wind turbine, a rotor teeter angle;

the method comprising:

- 15 - measuring, by means of said at least one measurement unit in the hub section, at least one of said parameters and transmitting output signals provided by the measurement unit to the hub-sited control circuitry;
- determining, within the hub-sited control circuitry, a load, acceleration, velocity or deflection of the tower or of the rotor plane of the wind turbine on the basis of at least one of
- 20 said parameters;
- controlling operation of the wind turbine by means of the hub-sited control circuitry on the basis of said determined load, deflection, velocity or acceleration and a desired value for said load, deflection, velocity or acceleration.

2. A method according to claim 1, wherein the wind turbine further comprises

- 25 - a nacelle-housed control circuitry for controlling operation of the wind turbine;
- a signal pathway for conveying control signals between the nacelle-housed control circuitry and the hub;
- the wind turbine being controlled by means of the nacelle-housed control circuitry during normal operation conditions;

30 wherein said step of controlling the wind turbine by means of the hub-sited control circuitry is performed in the event of a failure in the signal communication between the nacelle-housed control circuitry and the hub or in the event of a functional failure in the nacelle-housed control system.

3. A method according to claim 1 or 2, further comprising measuring a rotational speed of

35 the rotor or the shaft and transmitting the measurement to the hub-sited control circuitry,

and controlling operation of the wind turbine by means of the hub-sited control circuitry on the additional basis of the rotational speed of the rotor or the shaft.

4. A method according to any of the preceding claims, further comprising measuring and determining, with the hub-sited control circuitry, a load or deflection of at least one blade of the wind turbine and controlling operation of the wind turbine by means of the hub-sited control circuitry on the additional basis of the load or deflection of the blade.

5. A method according to any of the preceding claims, wherein the wind turbine further comprises at least one pitch-regulating actuator for pitching the blades, the at least one actuator being arranged in the hub section, and wherein said step of controlling operation of the wind turbine comprises controlling the at least one pitch-regulating actuator.

6. A wind turbine comprising:

- a tower;
 - a nacelle supported by the tower at the upper end of the tower;
 - a rotor comprising a plurality of wind turbine blades;
 - 15 - a shaft drivable by the rotor during operation of the wind turbine;
 - a hub section, at which the rotor is mounted to the shaft, the hub section being arranged outside the nacelle;
 - a hub-sited control circuitry arranged in the hub section, the hub-sited control circuitry being configured to control operation of the wind turbine;
 - 20 - at least one measurement unit in the hub section for determining at least one parameter among an acceleration of a component of the wind turbine, a load of a component of the wind turbine, a deflection of a component of the wind turbine, a rotor teeter angle;
- wherein the hub-sited control circuitry is configured to:
- receive output signals provided by the at least one measurement unit;
 - 25 - determine a load, acceleration, velocity or deflection of the tower or of the rotor plane of the wind turbine on the basis of the at least one parameter measured by the measurement unit;
 - control the wind turbine on the basis of said determined load, deflection, velocity, or acceleration and a desired value for said load, deflection, velocity or acceleration.

7. A wind turbine according to claim 6, further comprising:

- a nacelle-housed control circuitry for controlling operation of the wind turbine, said nacelle-housed control circuitry being arranged in the nacelle;
- a signal pathway for conveying control signals between the nacelle-housed control circuitry and the hub;
- 35 wherein the nacelle-housed control circuitry is configured to control the wind turbine during

normal operation conditions, and wherein the hub-sited control circuitry is configured to control the wind turbine in the event of a failure in the signal communication between the nacelle-housed control circuitry and the hub or in the event of a functional failure in the nacelle-housed control system.

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8. A wind turbine according to claim 6 or 7, further comprising a rotational speed sensor for measuring a rotational speed of the rotor or the shaft, wherein the hub-sited control circuitry is configured to receive output signals from the rotational speed sensor, and control operation of the wind turbine by on the additional basis of the rotational speed of the rotor or the shaft.

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9. A wind turbine according to any of claims 6 to 8, further comprising at least one blade measurement unit for determining a load or deflection of at least one blade of the wind turbine wherein the hub-sited control circuitry is configured to receive output signals from the blade measurement unit, and control operation of the wind turbine by on the additional basis of the load or deflection of the blade.

15

10. A wind turbine according to any of claims 6-9, further comprising at least one pitch-regulating actuator for pitching the blades, the at least one actuator being arranged in the hub section, and wherein the hub-sited control circuitry and the nacelle-housed circuitry are configured to control the pitch-regulating actuator.

20

11. A wind turbine according to any of claims 6-10, further comprising a controllable mechanism for altering the aerodynamic surface of at least one of the blades of the wind turbine, wherein the nacelle-housed control circuitry and the hub-sited control circuitry are configured to control said controllable mechanism.

25

12. A wind turbine according to any claims 6-11, further comprising a controllable mechanism for active damping of a teeter rotor, wherein at least one of the hub-sited control circuitry and the nacelle-housed circuitry are configured to control the rotor teeter damping.

30

13. A wind turbine according to any of claims 6-12, wherein the hub-sited control circuitry is configured to counteract the tower's movement during a stop process of the wind turbine or in the event of a functional failure in the nacelle-housed control circuitry.

35

14. A wind turbine according to any of claims 6-13, comprising a non-contact or wireless interface between the hub and the nacelle.

15. A wind turbine according to any of claims 6-14, wherein the measurement unit is configured to measure a position, velocity or acceleration in more than one direction.

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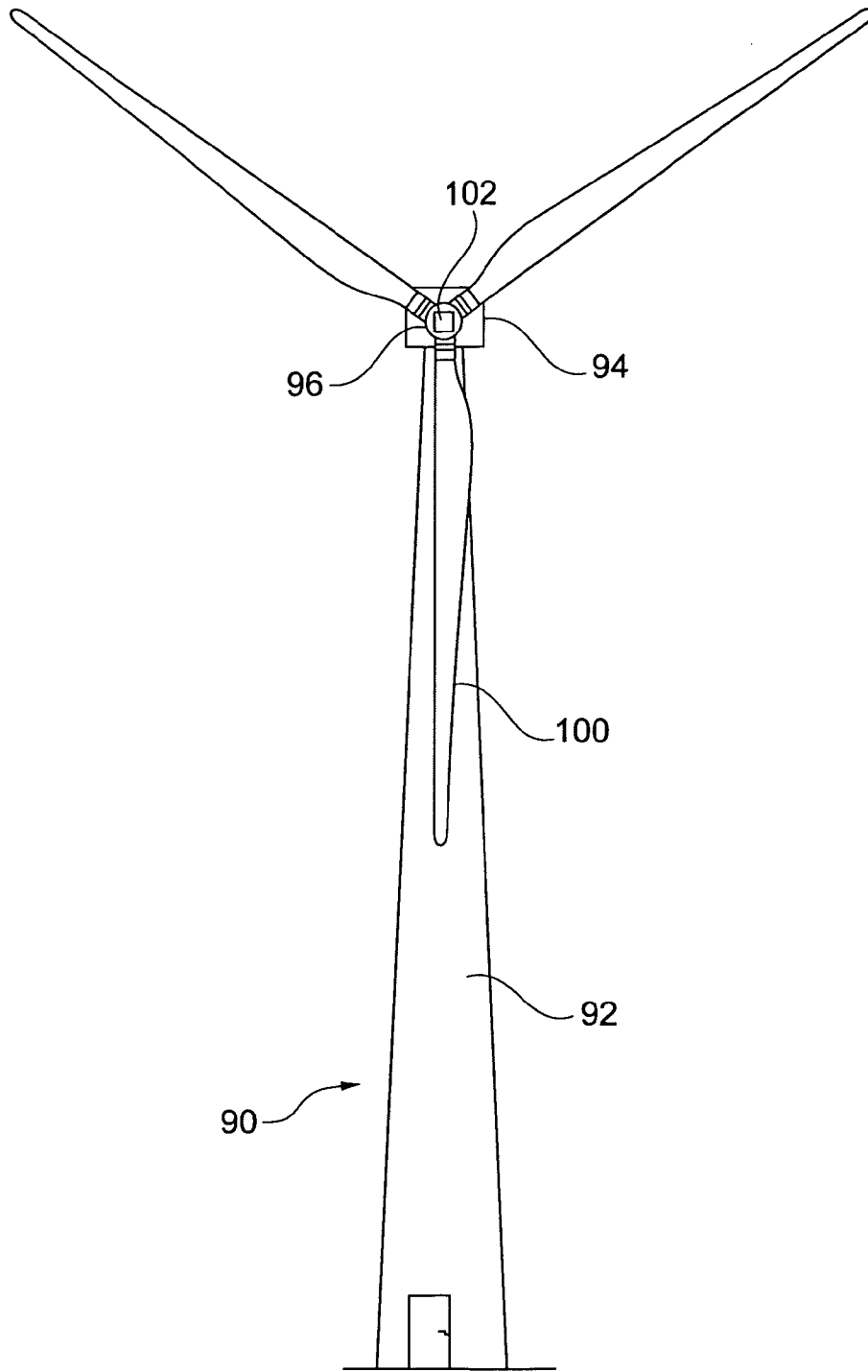


Fig. 1

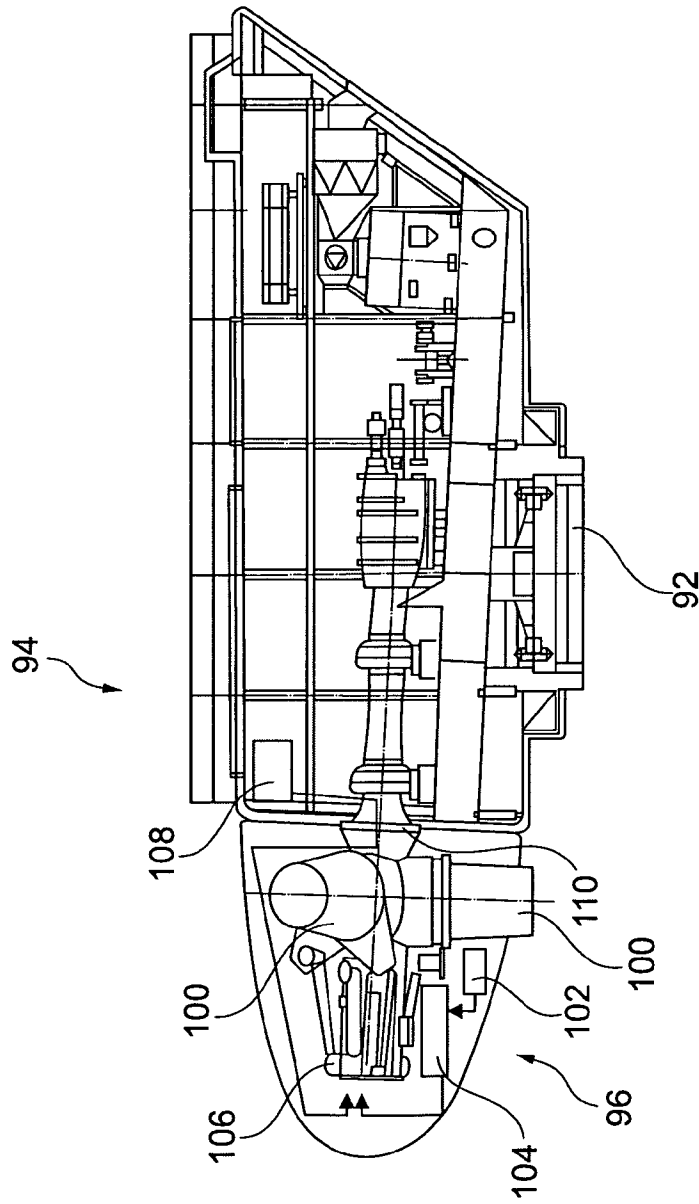


Fig. 2

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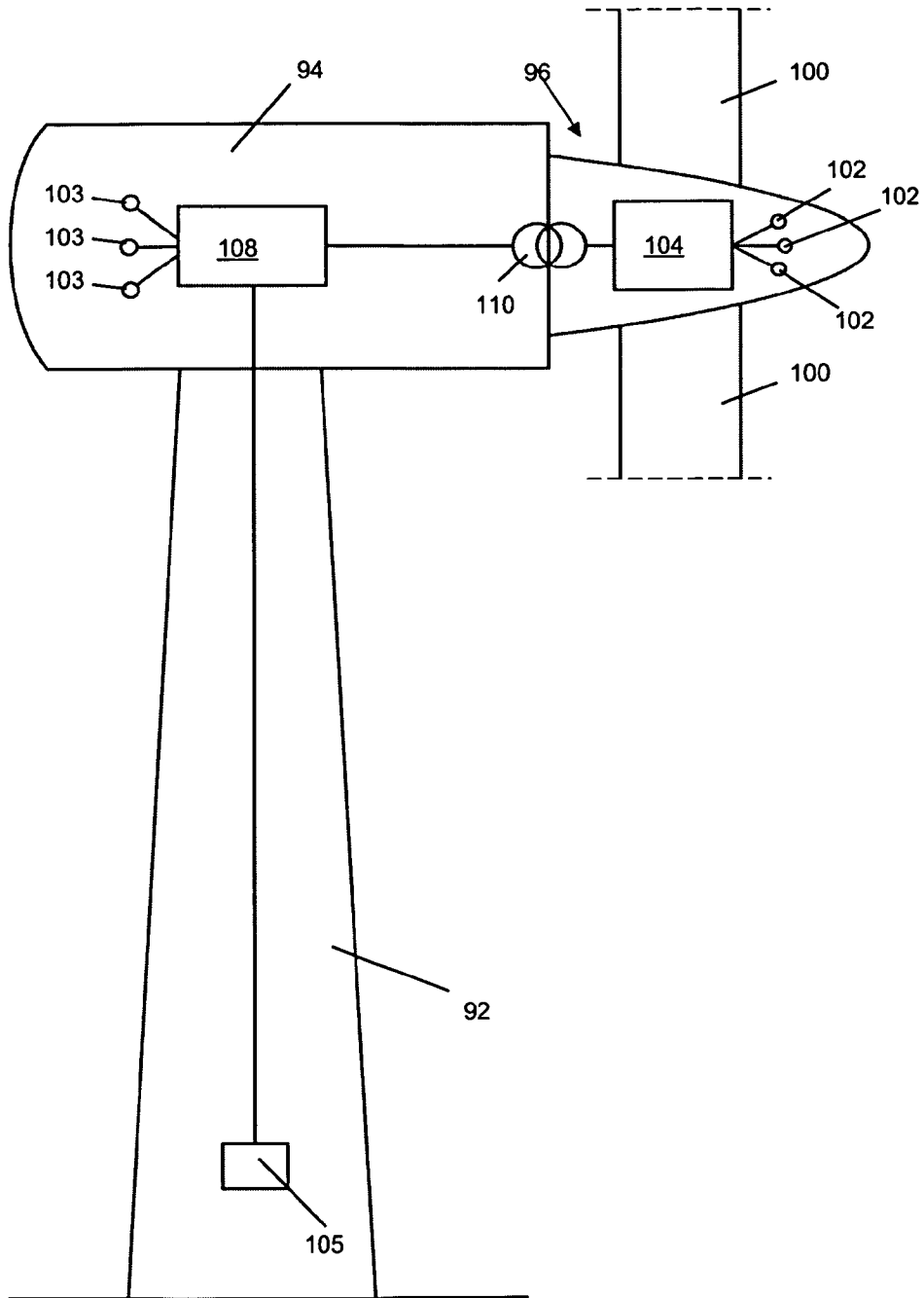


Fig. 3

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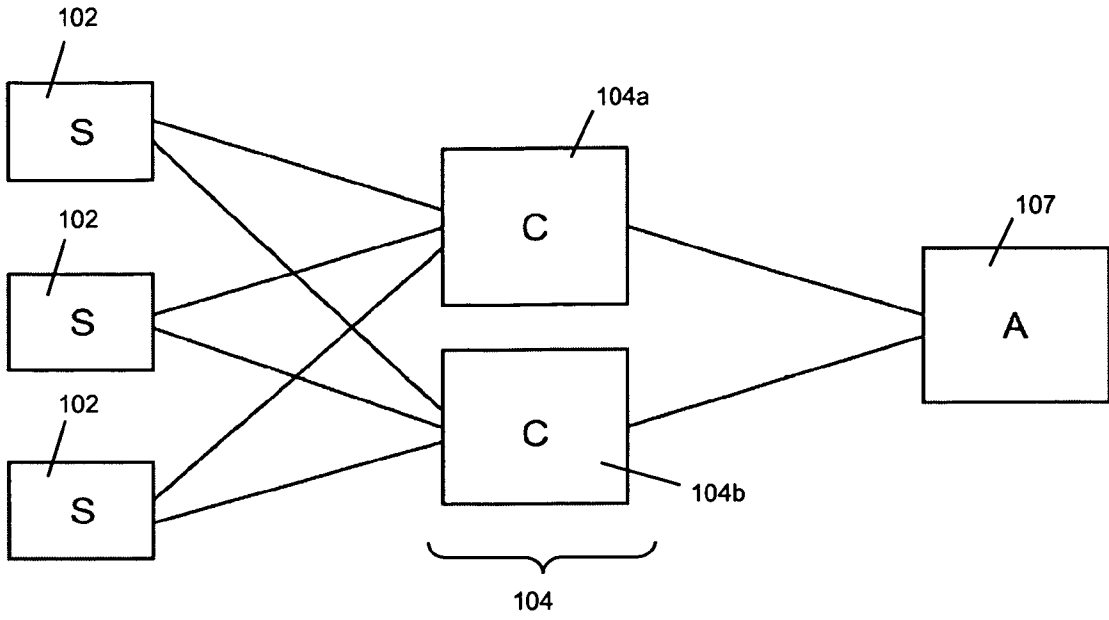


Fig. 4

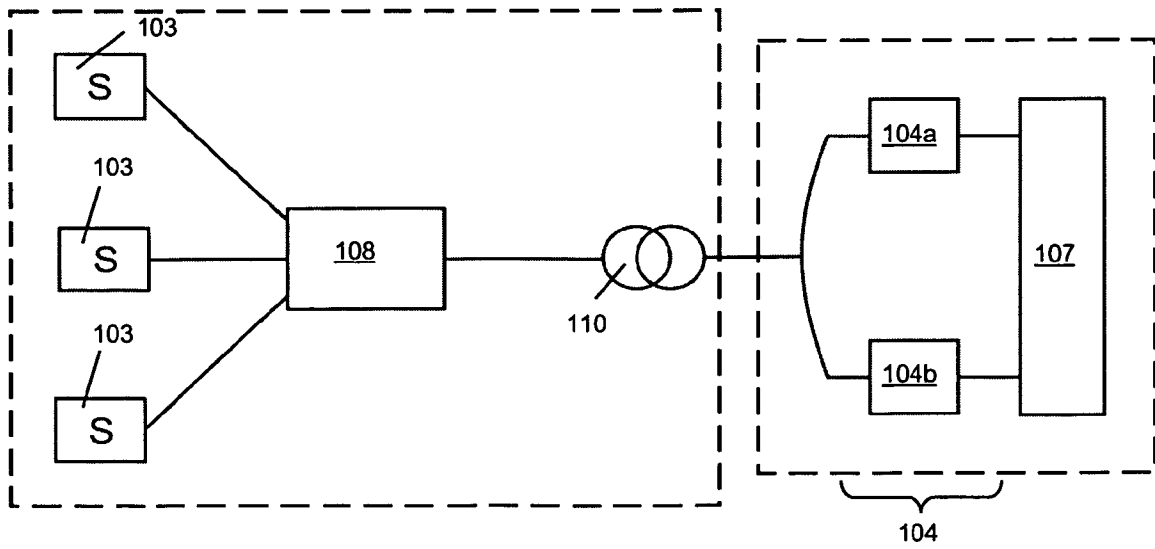


Fig. 5

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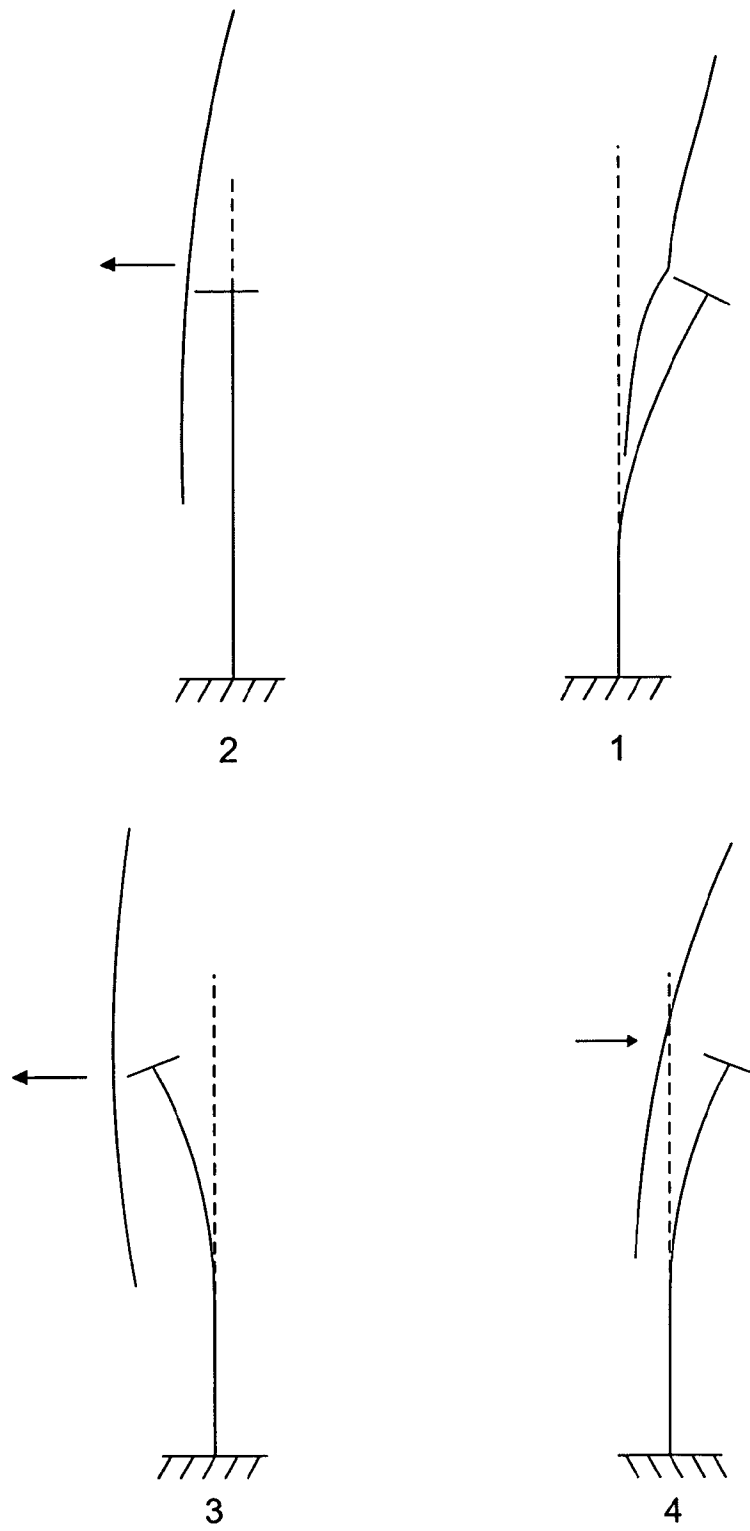


Fig. 6

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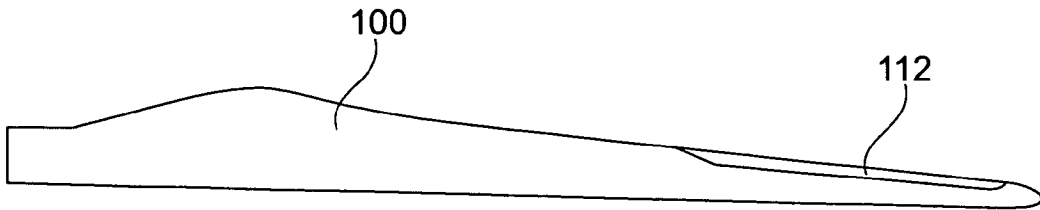


Fig. 7

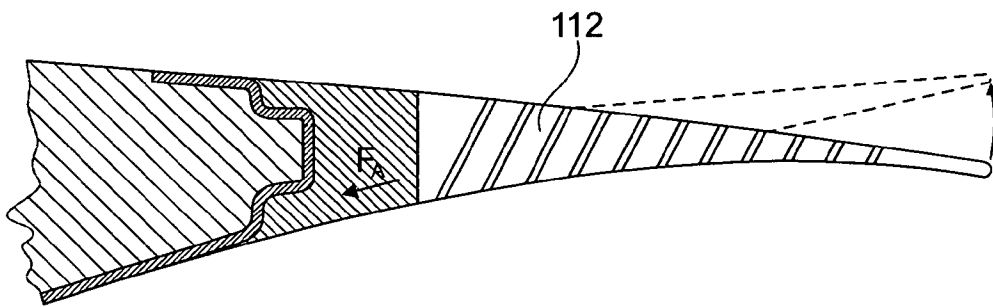


Fig. 8