US 20140010656A1

(19) United States

(12) Patent Application Publication

NIES

(10) Pub. No.: US 2014/0010656 A1

(43) Pub. Date: Jan. 9, 2014

(54) **FIXATION DEVICE**

(76) Inventor: **Jacob Johannes NIES**, Zwolle (NL)

(21) Appl. No.: **13/541,862**

(22) Filed: **Jul. 5, 2012**

Publication Classification

(51) **Int. Cl.**

F04D 29/34 (2006.01)

B21D 53/78 (2006.01)

(52) **U.S. Cl.**

USPC .... **416/204 R**; 29/889

(57) **ABSTRACT**

A fixation device for fixing a shaft connecting a rotor and a generator of a wind turbine, the fixation device comprising: a rotor lock for locking the shaft providing a locking clearance; and a rotor brake for braking the shaft; wherein the rotor lock is arranged for positioning the shaft in a selectable angular position within the locking clearance of the rotor lock.

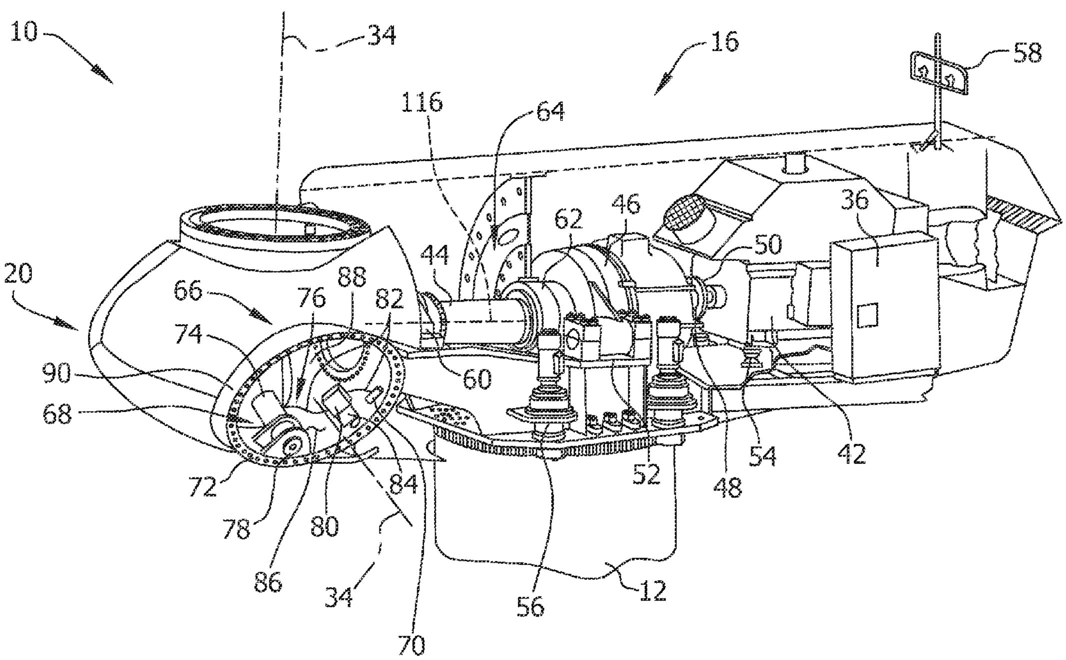
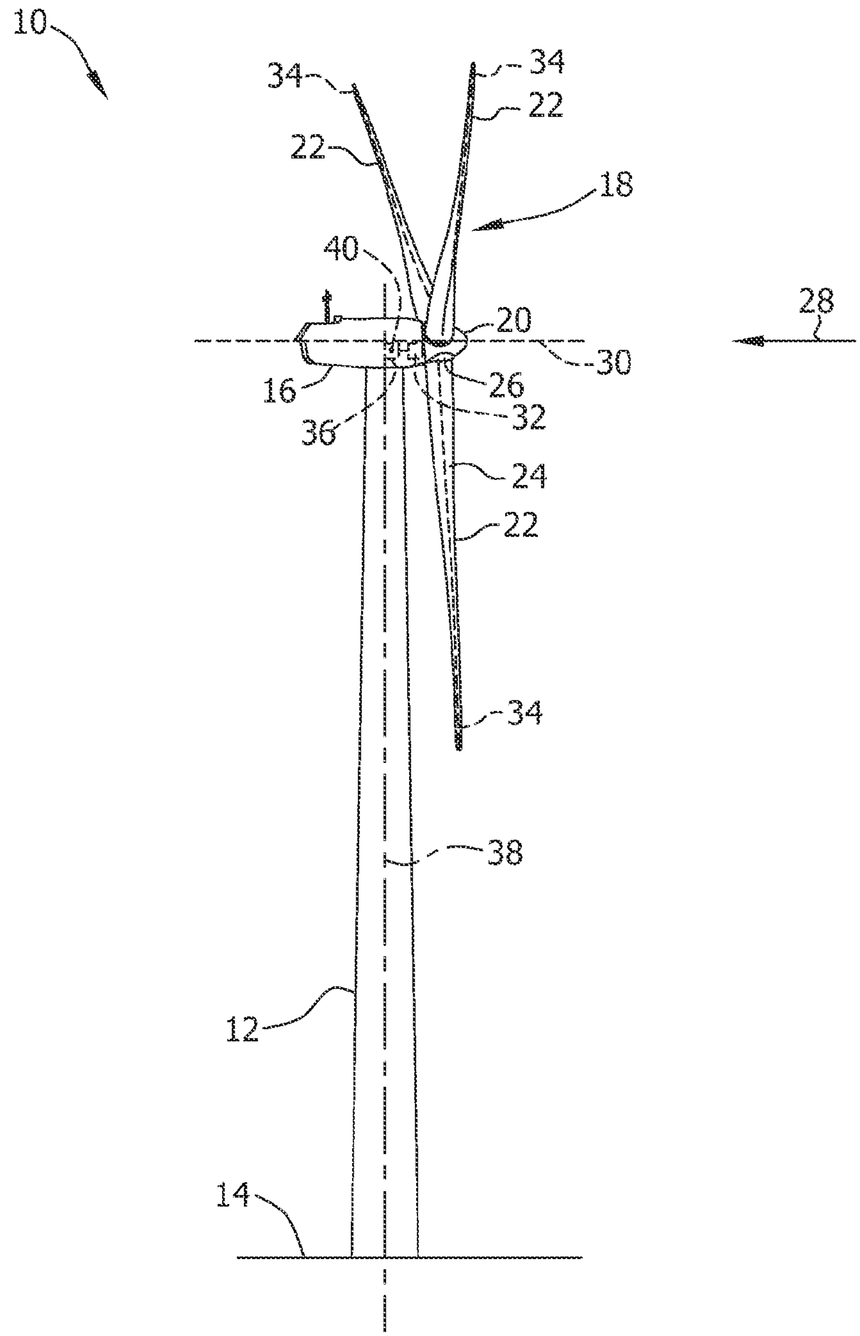


FIG. 1



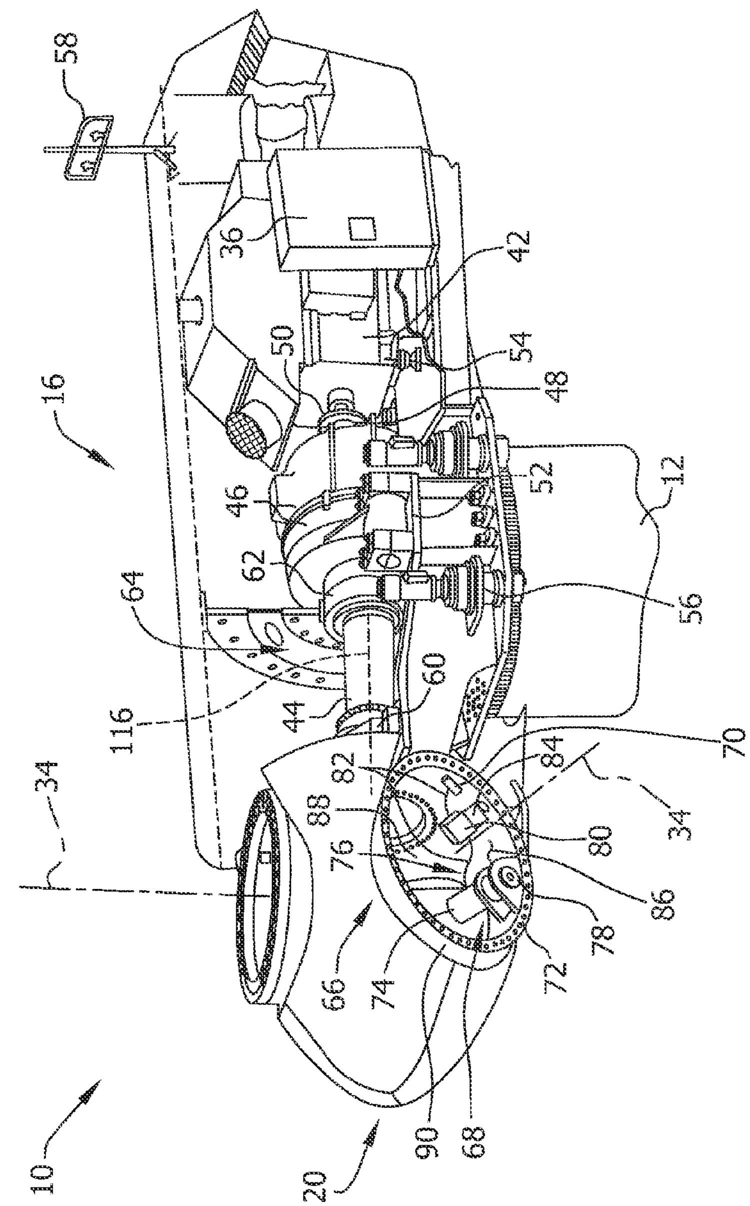

58
36
42
54
50
48
16
52
12
46
62
56
64
60
116
44
70
82
84
34
88
80
76
86
66
74
78
72
90
68
10
20

FIG. 2

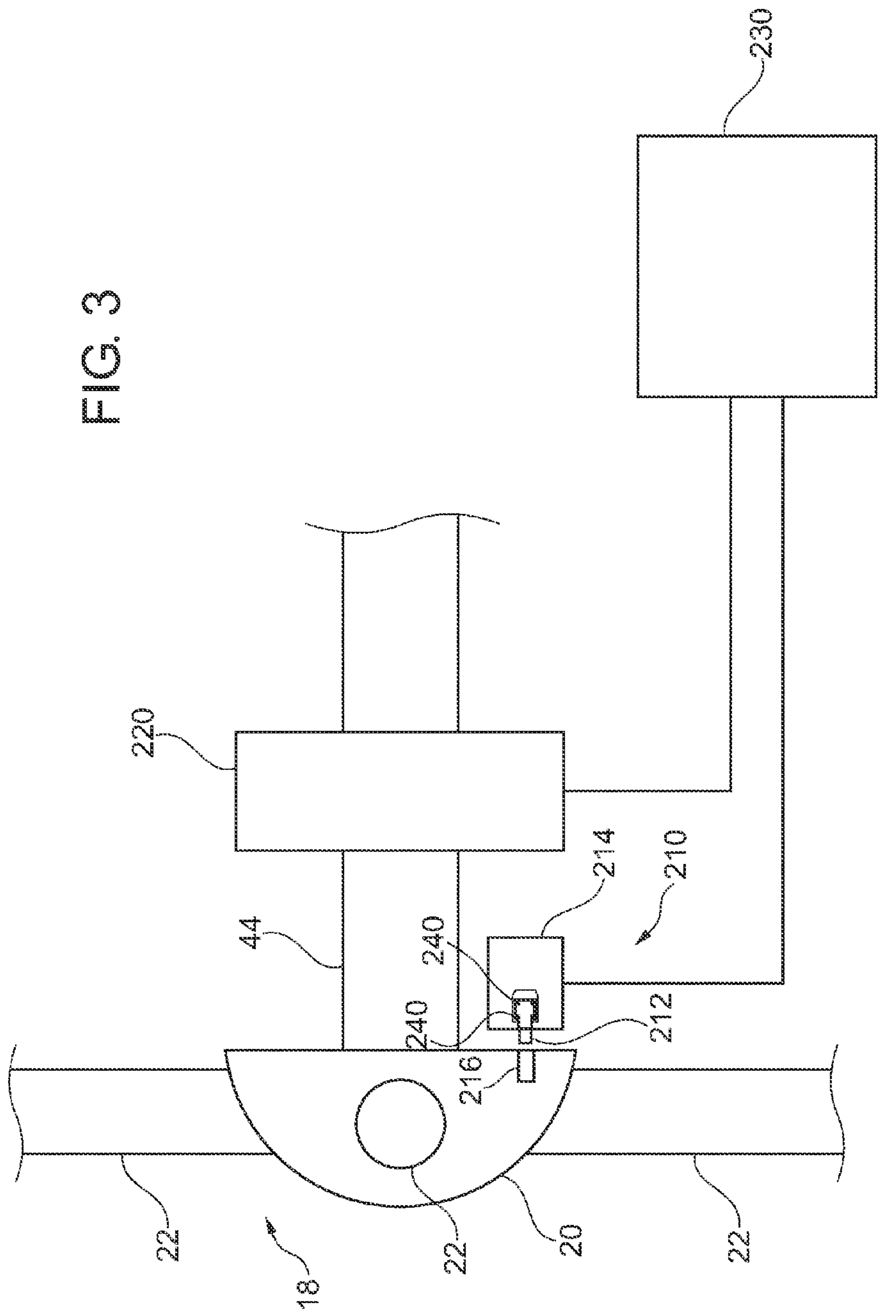


FIG. 3

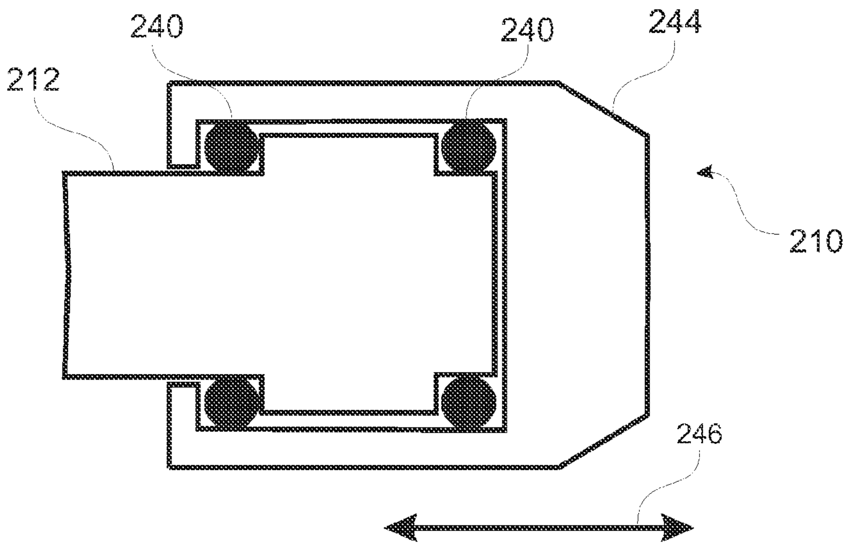


FIG. 4

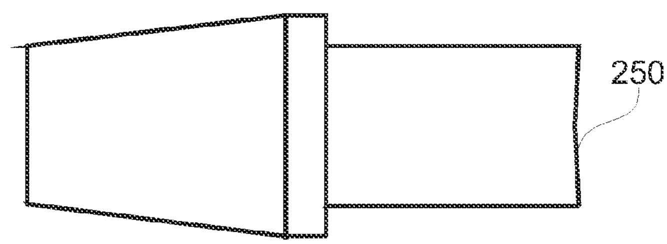


FIG. 5

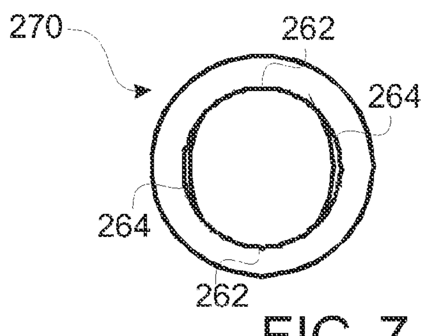


FIG. 7

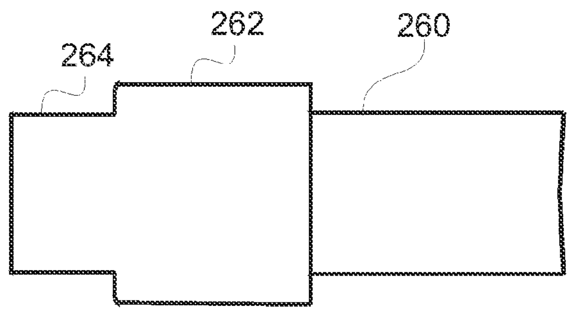
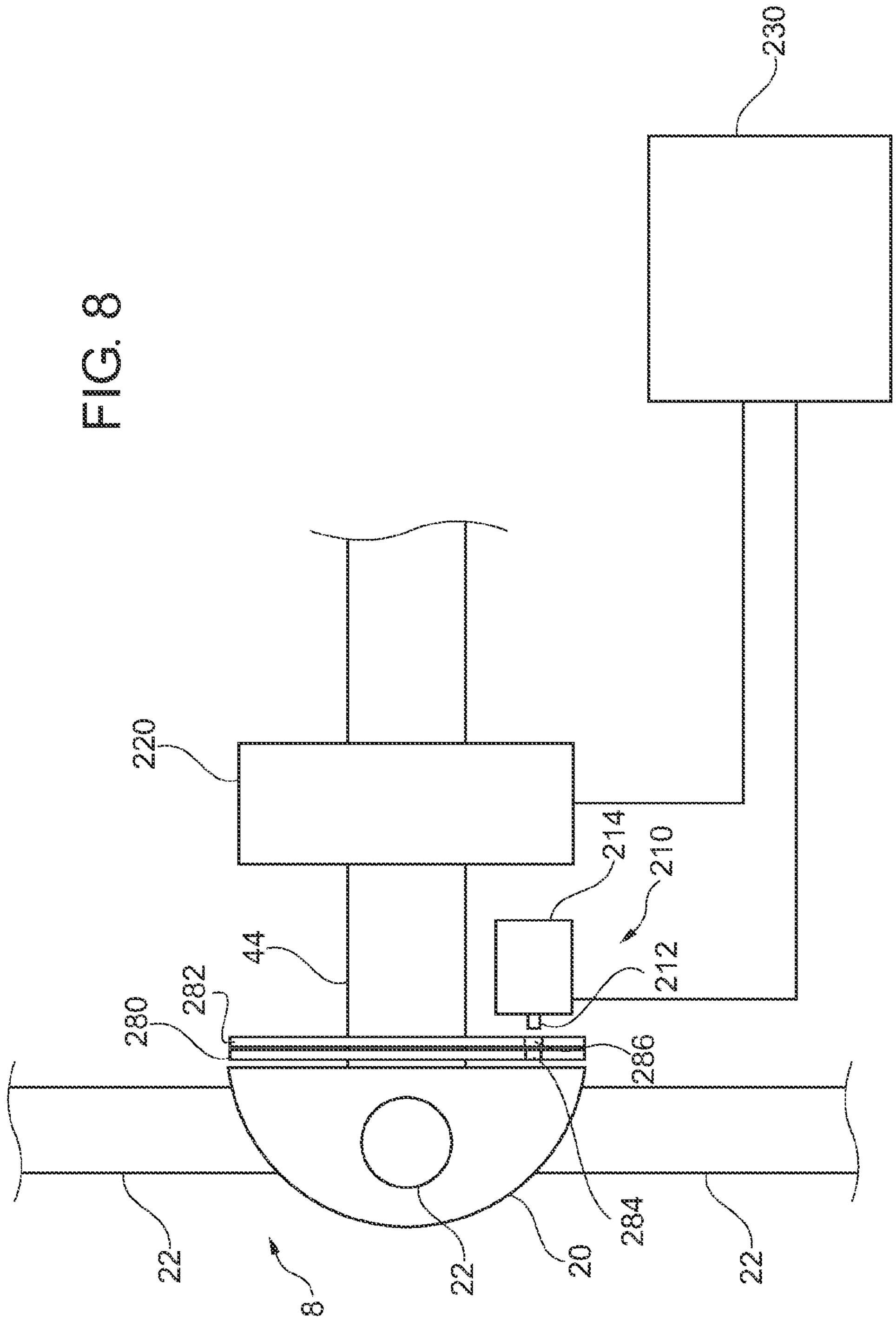


FIG. 6

FIG. 8



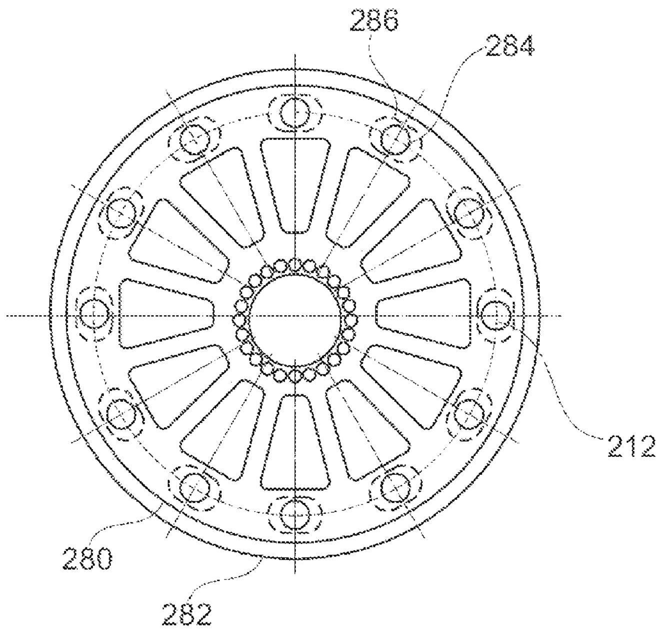


FIG. 9

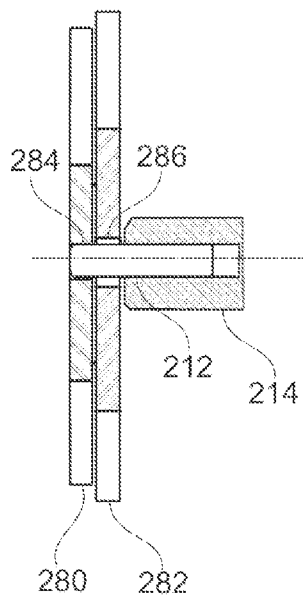


FIG. 10

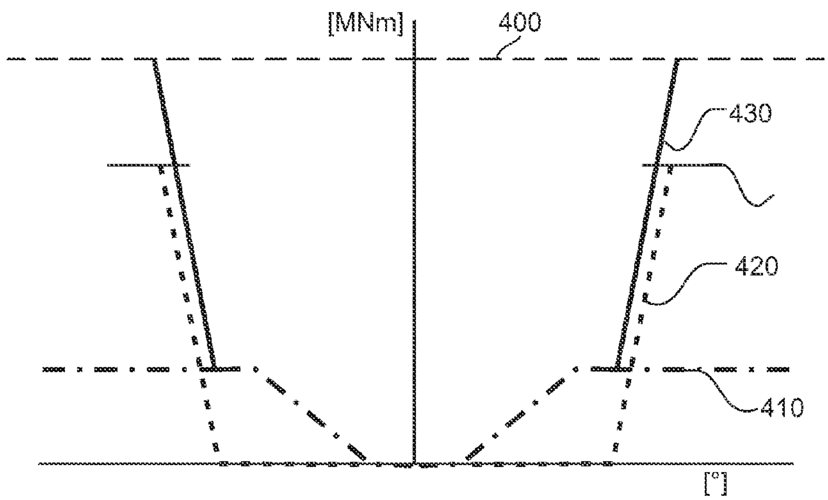


FIG. 11

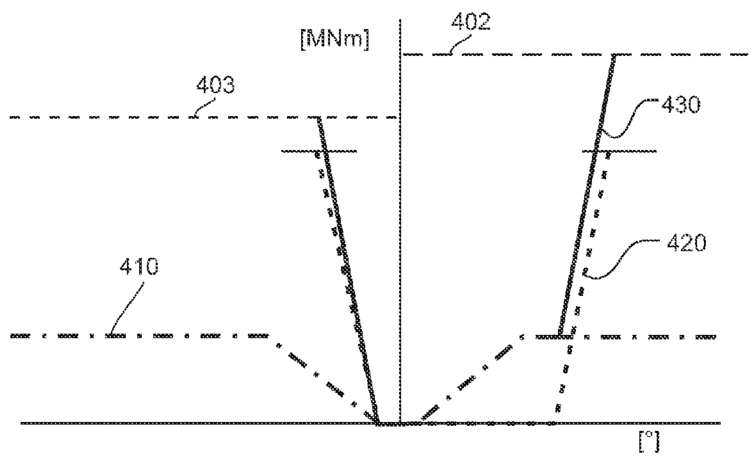


FIG. 12

FIXATION DEVICE

BACKGROUND OF THE INVENTION

[0001] The subject matter described herein relates generally to methods and systems for wind turbines, and more particularly, to methods and systems for fixing a shaft of a wind turbine.

[0002] At least some known wind turbines include a tower and a nacelle mounted on the tower. A rotor is rotatably mounted to the nacelle and is coupled to a generator by a shaft. A plurality of blades extend from the rotor. The blades are oriented such that wind passing over the blades turns the rotor and rotates the shaft, thereby driving the generator to generate electricity.

[0003] Some known wind turbines include a rotor-brake and a rotor-lock. The rotor-lock typically provides a higher load limit, especially when both the brake and the lock are applied at the low-speed shaft of the turbine. The load limit of the rotor-lock is designed for a maximum expected load, e.g. during a storm. The rotor-lock may only be applied when the rotor shaft of the wind turbine stands still. The rotor-brake typically provides a lower load limit, wherein higher loads do not lead to a damage of the rotor-brake. The rotor-brake provides slip if the load gets higher than the load limit of the rotor-brake. Rotor-brakes may sometimes also be used when the rotor shaft is rotating slowly to stop the rotor shaft completely. Technical background to rotor-brakes and rotor-locks, or other methods for applying a braking force to a rotor shaft of a wind turbine, may be found in U.S. Pat. No. 7,948,100.

[0004] The costs for the rotor-brake and the rotor-lock of a wind turbine contribute to the total costs of the wind turbine with several percent. There is therefore a need for a method and a wind turbine using the rotor-brake and the rotor-lock more efficient to maybe reduce the size and costs of the rotor-brake or the rotor-lock.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In one aspect, a fixation device for fixing a shaft connecting a rotor and a generator of a wind turbine is provided, the fixation device including a rotor lock for locking the shaft providing a locking clearance, and a rotor brake for braking the shaft, wherein the rotor lock is arranged for positioning the shaft in a selectable angular position within the locking clearance of the rotor lock.

[0006] In another aspect, a method for locking a shaft of a wind turbine with a rotor lock for locking the shaft, a rotor brake for braking the shaft and a positioning member for a positioning of the shaft in a selectable position is provided, the method including applying the positioning member; waiting until the shaft is positioned in a selectable position by the positioning member; applying the rotor brake; and, applying the rotor lock applying the positioning member, waiting until the shaft is positioned in a selectable position by the positioning member, applying the rotor brake and applying the rotor lock.

[0007] In yet another aspect, a wind turbine is provided, the wind turbine including a rotor, a generator, a shaft for transmitting torque between the rotor and the generator, and a fixation device for fixing the shaft, the fixation device including: a rotor lock for locking the shaft providing a lock clearance between a first limit stop and a second limit stop; and, a rotor brake for braking the shaft; wherein the rotor lock is arranged for positioning the rotor shaft within the lock clearance, wherein the positioning clearance is smaller than the lock clearance.

[0008] Further aspects, advantages and features of the present invention are apparent from the dependent claims, the description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A full and enabling disclosure including the best mode thereof, to one of ordinary skill in the art, is set forth more particularly in the remainder of the specification, including reference to the accompanying figures wherein:

[0010] FIG. **1** is a perspective view of an exemplary wind turbine.

[0011] FIG. **2** is an enlarged sectional view of a portion of the wind turbine shown in FIG. **1**.

[0012] FIG. **3** is a block diagram of an exemplary embodiment of a wind turbine.

[0013] FIG. **4** is shows parts of the exemplary embodiment of FIG. **3**.

[0014] FIG. **5** shows a tapered locking pin of typical embodiments.

[0015] FIG. **6** depicts a stepped locking pin of typical embodiments.

[0016] FIG. **7** shows an elliptical locking pin of typical embodiments.

[0017] FIG. **8** is a block diagram of an exemplary embodiment of a fixation device.

[0018] FIG. **9** is a front view of parts of the exemplary embodiment shown in FIG. **8**.

[0019] FIG. **10** is a side view of parts of the exemplary embodiment shown in FIG. **8**.

[0020] FIG. **11** is a diagram showing torques of typical rotor-brakes and rotor-locks for load cases.

[0021] FIG. **12** is another diagram showing torques of typical rotor-brakes and rotor-locks for load cases.

DETAILED DESCRIPTION OF THE INVENTION

[0022] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in each figure. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet further embodiments. It is intended that the present disclosure includes such modifications and variations.

[0023] The embodiments described herein include a wind turbine, having a rotor shaft using a rotor-brake and a rotor-lock, which is capable of withstanding high loads. For example, during a storm the rotor brake and the rotor lock may be used simultaneously. More specifically, the rotor-brake and the rotor-lock are used in parallel to yield a higher load limit. Thereby, costs of the wind turbine may be reduced. Typical embodiments include a method of locking a rotor of a wind turbine, wherein the method allows for using the rotor-brake and the rotor-lock in parallel. With wind turbines and methods of typical embodiments the capability of the wind turbine to withstand storms may be enhanced. Alternatively or in addition, the weight of the wind turbine, especially of the nacelle may be reduced due to the usage of smaller rotor-brakes or smaller rotor-locks.

[0024] As used herein, the term rotor-brake is intended to be representative of any brake capable of decelerating or fixing the rotor shaft, wherein a brake provides slip in case the torque of the rotor shaft is higher than a typical slip limit. One example for a rotor-brake is a disk brake using one or more disks. Typical rotor-brakes include an electro-hydraulic actuator, an electro-mechanical actuator or a spring-operated caliper. Other brakes providing slip are drum brakes, which may be used for typical embodiments. The rotor-brake may be arranged at a low-speed shaft or at a high-speed shaft in case a gearbox is incorporated in the wind turbine drive-train of typical wind turbines described herein. As used herein, the term rotor-lock is intended to be representative of locking mechanisms capable of locking the rotor shaft. Such locking mechanisms may include a hydraulically moveable pin or a spring-actuated pin attached to a solid or fixed or non-rotating part of the wind turbine nacelle. The term "non-rotating" typically refers to a member not rotating with the shaft of the wind turbine. Other locking mechanisms include pins or plates. Disks with holes may be used for an interaction with the bolt or the pin. Typical embodiments include a slot, a nut or a hole in the rotor hub for an engagement with a second locking part like a bolt, a pin or a plate. Typically, the rotor-lock may be applied at the low-speed shaft or at the high-speed shaft in case of a wind turbine providing a gearbox in the drive-train. Further typical wind turbines include a direct drive, wherein the rotor is coupled directly to the generator without a gearbox in the drive train between the rotor and the generator.

[0025] As used herein, the term "blade" is intended to be representative of any device that provides a reactive force when in motion relative to a surrounding fluid. As used herein, the term "wind turbine" is intended to be representative of any device that generates rotational energy from wind energy, and more specifically, converts kinetic energy of wind into mechanical energy. As used herein, the term "wind generator" is intended to be representative of any wind turbine that generates electrical power from rotational energy generated from wind energy, and more specifically, converts mechanical energy converted from kinetic energy of wind to electrical power.

[0026] FIG. **1** is a perspective view of an exemplary wind turbine **10**. In the exemplary embodiment, wind turbine **10** is a horizontal-axis wind turbine. Alternatively, wind turbine **10** may be a vertical-axis wind turbine. In the exemplary embodiment, wind turbine **10** includes a tower **12** that extends from a support system **14**, a nacelle **16** mounted on tower **12**, and a rotor **18** that is coupled to nacelle **16**. Rotor **18** includes a rotatable hub **20** and at least one rotor blade **22** coupled to and extending outward from hub **20**. In the exemplary embodiment, rotor **18** has three rotor blades **22**. In an alternative embodiment, rotor **18** includes more or less than three rotor blades **22**. In the exemplary embodiment, tower **12** is fabricated from tubular steel to define a cavity (not shown in FIG. **1**) between support system **14** and nacelle **16**. In an alternative embodiment, tower **12** is any suitable type of tower having any suitable height.

[0027] Rotor blades **22** are spaced about hub **20** to facilitate rotating rotor **18** to enable kinetic energy to be transferred from the wind into usable mechanical energy, and subsequently, electrical energy. Rotor blades **22** are mated to hub **20** by coupling a blade root portion **24** to hub **20** at a plurality of load transfer regions **26**. Load transfer regions **26** have a hub load transfer region and a blade load transfer region (both not shown in FIG. **1**). Loads induced to rotor blades **22** are transferred to hub **20** via load transfer regions **26**.

[0028] In one embodiment, rotor blades **22** have a length ranging from about 15 meters (m) to about 91 m. Alternatively, rotor blades **22** may have any suitable length that enables wind turbine **10** to function as described herein. For example, other non-limiting examples of blade lengths include 10 m or less, 20 m, 37 m, or a length that is greater than 91 m. As wind strikes rotor blades **22** from a direction **28**, rotor **18** is rotated about an axis of rotation **30**. As rotor blades **22** are rotated and subjected to centrifugal forces, rotor blades **22** are also subjected to various forces and moments. As such, rotor blades **22** may deflect and/or rotate from a neutral, or non-deflected, position to a deflected position.

[0029] Moreover, a pitch angle or blade pitch of rotor blades **22**, i.e., an angle that determines a perspective of rotor blades **22** with respect to direction **28** of the wind, may be changed by a pitch adjustment system **32** to control the load and power generated by wind turbine **10** by adjusting an angular position of at least one rotor blade **22** relative to wind vectors. Pitch axes **34** for rotor blades **22** are shown. During operation of wind turbine **10**, pitch adjustment system **32** may change a blade pitch of rotor blades **22** such that rotor blades **22** are moved to a feathered position, such that the perspective of at least one rotor blade **22** relative to wind vectors provides a minimal surface area of rotor blade **22** to be oriented towards the wind vectors, which facilitates reducing a rotational speed of rotor **18** and/or facilitates a stall of rotor **18**.

[0030] In the exemplary embodiment, a blade pitch of each rotor blade **22** is controlled individually by a control system **36**. Alternatively, the blade pitch for all rotor blades **22** may be controlled simultaneously by control system **36**. Further, in the exemplary embodiment, as direction **28** changes, a yaw direction of nacelle **16** may be controlled about a yaw axis **38** to position rotor blades **22** with respect to direction **28**.

[0031] In the exemplary embodiment, control system **36** is shown as being centralized within nacelle **16**, however, control system **36** may be a distributed system throughout wind turbine **10**, on support system **14**, within a wind farm, and/or at a remote control center. Control system **36** includes a processor **40** configured to perform the methods and/or steps described herein. Further, many of the other components described herein include a processor. As used herein, the term "processor" is not limited to integrated circuits referred to in the art as a computer, but broadly refers to a controller, a microcontroller, a microcomputer, a programmable logic controller (PLC), an application specific integrated circuit, and other programmable circuits, and these terms are used interchangeably herein. It should be understood that a processor and/or a control system can also include memory, input channels, and/or output channels.

[0032] In the embodiments described herein, memory may include, without limitation, a computer-readable medium, such as a random access memory (RAM), and a computer-readable non-volatile medium, such as flash memory. Alternatively, a floppy disk, a compact disk-read only memory (CD-ROM), a magneto-optical disk (MOD), and/or a digital versatile disk (DVD) may also be used. Also, in the embodiments described herein, input channels include, without limitation, sensors and/or computer peripherals associated with an operator interface, such as a mouse and a keyboard. Further, in the exemplary embodiment, output channels may include, without limitation, a control device, an operator interface monitor and/or a display.

[0033] Processors described herein process information transmitted from a plurality of electrical and electronic devices that may include, without limitation, sensors, actuators, compressors, control systems, and/or monitoring devices. Such processors may be physically located in, for example, a control system, a sensor, a monitoring device, a desktop computer, a laptop computer, a programmable logic controller (PLC) cabinet, and/or a distributed control system (DCS) cabinet. RAM and storage devices store and transfer information and instructions to be executed by the processor (s). RAM and storage devices can also be used to store and provide temporary variables, static (i.e., non-changing) information and instructions, or other intermediate information to the processors during execution of instructions by the processor(s). Instructions that are executed may include, without limitation, wind turbine control system control commands The execution of sequences of instructions is not limited to any specific combination of hardware circuitry and software instructions.

[0034] FIG. **2** is an enlarged sectional view of a portion of wind turbine **10**. In the exemplary embodiment, wind turbine **10** includes nacelle **16** and hub **20** that is rotatably coupled to nacelle **16**. More specifically, hub **20** is rotatably coupled to an electric generator **42** positioned within nacelle **16** by rotor shaft **44** (sometimes referred to as either a main shaft or a low speed shaft), a gearbox **46**, a high speed shaft **48**, and a coupling **50**. In the exemplary embodiment, rotor shaft **44** is disposed coaxial to longitudinal axis **116**. Rotation of rotor shaft **44** rotatably drives gearbox **46** that subsequently drives high speed shaft **48**. High speed shaft **48** rotatably drives generator **42** with coupling **50** and rotation of high speed shaft **48** facilitates the production of electrical power by generator **42**. Gearbox **46** and generator **42** are supported by a support **52** and a support **54**. In the exemplary embodiment, gearbox **46** utilizes a dual path geometry to drive high speed shaft **48**. Alternatively, rotor shaft **44** is coupled directly to generator **42** with coupling **50**.

[0035] Nacelle **16** also includes a yaw drive mechanism **56** that may be used to rotate nacelle **16** and hub **20** on yaw axis **38** (shown in FIG. **1**) to control the perspective of rotor blades **22** with respect to direction **28** of the wind. Nacelle **16** also includes at least one meteorological mast **58** that includes a wind vane and anemometer (neither shown in FIG. **2**). Mast **58** provides information to control system **36** that may include wind direction and/or wind speed. In the exemplary embodiment, nacelle **16** also includes a main forward support bearing **60** and a main aft support bearing **62**.

[0036] Forward support bearing **60** and aft support bearing **62** facilitate radial support and alignment of rotor shaft **44**. Forward support bearing **60** is coupled to rotor shaft **44** near hub **20**. Aft support bearing **62** is positioned on rotor shaft **44** near gearbox **46** and/or generator **42**. Alternatively, nacelle **16** includes any number of support bearings that enable wind turbine **10** to function as disclosed herein. Rotor shaft **44**, generator **42**, gearbox **46**, high speed shaft **48**, coupling **50**, and any associated fastening, support, and/or securing device including, but not limited to, support **52** and/or support **54**, and forward support bearing **60** and aft support bearing **62**, are sometimes referred to as a drive train **64**.

[0037] In the exemplary embodiment, hub **20** includes a pitch assembly **66**. Pitch assembly **66** includes one or more pitch drive systems **68** and at least one sensor **70**. Each pitch drive system **68** is coupled to a respective rotor blade **22** (shown in FIG. **1**) for modulating the blade pitch of associated rotor blade **22** along pitch axis **34**. Only one of three pitch drive systems **68** is shown in FIG. **2**.

[0038] In the exemplary embodiment, pitch assembly **66** includes at least one pitch bearing **72** coupled to hub **20** and to respective rotor blade **22** (shown in FIG. **1**) for rotating respective rotor blade **22** about pitch axis **34**. Pitch drive system **68** includes a pitch drive motor **74**, pitch drive gearbox **76**, and pitch drive pinion **78**. Pitch drive motor **74** is coupled to pitch drive gearbox **76** such that pitch drive motor **74** imparts mechanical force to pitch drive gearbox **76**. Pitch drive gearbox **76** is coupled to pitch drive pinion **78** such that pitch drive pinion **78** is rotated by pitch drive gearbox **76**. Pitch bearing **72** is coupled to pitch drive pinion **78** such that the rotation of pitch drive pinion **78** causes rotation of pitch bearing **72**. More specifically, in the exemplary embodiment, pitch drive pinion **78** is coupled to pitch bearing **72** such that rotation of pitch drive gearbox **76** rotates pitch bearing **72** and rotor blade **22** about pitch axis **34** to change the blade pitch of blade **22**.

[0039] Pitch drive system **68** is coupled to control system **36** for adjusting the blade pitch of rotor blade **22** upon receipt of one or more signals from control system **36**. In the exemplary embodiment, pitch drive motor **74** is any suitable motor driven by electrical power and/or a hydraulic system that enables pitch assembly **66** to function as described herein. Alternatively, pitch assembly **66** may include any suitable structure, configuration, arrangement, and/or components such as, but not limited to, hydraulic cylinders, springs, and/or servo-mechanisms. Moreover, pitch assembly **66** may be driven by any suitable means such as, but not limited to, hydraulic fluid, and/or mechanical power, such as, but not limited to, induced spring forces and/or electromagnetic forces. In certain embodiments, pitch drive motor **74** is driven by energy extracted from a rotational inertia of hub **20** and/or a stored energy source (not shown) that supplies energy to components of wind turbine **10**.

[0040] Pitch assembly **66** also includes one or more overspeed control systems **80** for controlling pitch drive system **68** during rotor overspeed. In the exemplary embodiment, pitch assembly **66** includes at least one overspeed control system **80** communicatively coupled to respective pitch drive system **68** for controlling pitch drive system **68** independently of control system **36**. In one embodiment, pitch assembly **66** includes a plurality of overspeed control systems **80** that are each communicatively coupled to respective pitch drive system **68** to operate respective pitch drive system **68** independently of control system **36**. Overspeed control system **80** is also communicatively coupled to sensor **70**. In the exemplary embodiment, overspeed control system **80** is coupled to pitch drive system **68** and to sensor **70** with a plurality of cables **82**. Alternatively, overspeed control system **80** is communicatively coupled to pitch drive system **68** and to sensor **70** using any suitable wired and/or wireless communications device. During normal operation of wind turbine **10**, control system **36** controls pitch drive system **68** to adjust a pitch of rotor blade **22**. In one embodiment, when rotor **18** operates at rotor overspeed, overspeed control system **80** overrides control system **36**, such that control system **36** no longer controls pitch drive system **68** and overspeed control system **80** controls pitch drive system **68** to move rotor blade **22** to a feathered position to slow a rotation of rotor **18**.

[0041] A power generator **84** is coupled to sensor **70**, overspeed control system **80**, and pitch drive system **68** to provide a source of power to pitch assembly **66**. In the exemplary embodiment, power generator **84** provides a continuing source of power to pitch assembly **66** during operation of wind turbine **10**. In an alternative embodiment, power generator **84** provides power to pitch assembly **66** during an electrical power loss event of wind turbine **10**. The electrical power loss event may include power grid loss, malfunctioning of the turbine electrical system, and/or failure of the wind turbine control system **36**. During the electrical power loss event, power generator **84** operates to provide electrical power to pitch assembly **66** such that pitch assembly **66** can operate during the electrical power loss event.

[0042] In the exemplary embodiment, pitch drive system **68**, sensor **70**, overspeed control system **80**, cables **82**, and power generator **84** are each positioned in a cavity **86** defined by an inner surface **88** of hub **20**. In a particular embodiment, pitch drive system **68**, sensor **70**, overspeed control system **80**, cables **82**, and/or power generator **84** are coupled, directly or indirectly, to inner surface **88**. In an alternative embodiment, pitch drive system **68**, sensor **70**, overspeed control system **80**, cables **82**, and power generator **84** are positioned with respect to an outer surface **90** of hub **20** and may be coupled, directly or indirectly, to outer surface **90**.

[0043] FIG. **3** is a block diagram of an exemplary embodiment of a wind turbine. FIG. **3** will be explained with reference to FIG. **1** and FIG. **2** showing several similar parts as shown in FIG. **3**. The embodiment of FIG. **3** comprises a rotor **18** with a rotor hub **20** to which rotor blades **22** are attached. The rotor hub **20** is mounted to a rotor shaft **44** for transmitting torque of the rotor to a generator.

[0044] Typical embodiments include a rotatable hub with at least one rotor blade coupled to and extending outward from the hub. Some embodiments of wind turbines comprise three rotor blades. Other exemplary embodiments comprise two or four rotor blades or another number of rotor blades. Typical embodiments comprise a rotor shaft coupled to a gearbox. The gearbox is connected with a generator. Further exemplary embodiments comprise a rotor shaft coupling the rotor hub directly to the generator, wherein the gearbox may be omitted.

[0045] The exemplary embodiment of a wind turbine, parts of which are shown in FIG. **3** includes a rotor-lock **210**. The rotor-lock **210** shown in FIG. **3** includes a locking pin **212**. The locking pin **212** is moveable by a locking actuator **214**. In case the locking pin **212** is actuated by the locking actuator **214**, the locking pin **212** is forced into a locking recess **216** of the rotor hub **20**. By doing so, the rotational position of the rotor hub **20** is locked relative to the nacelle. The locking recess **216** has a diameter slightly higher than the outer diameter of the locking pin **212**. With this arrangement the locking pin **212** can easily be urged into the locking recess **216** in case the rotor hub **20** is close to or in a correct position for locking.

[0046] Typical embodiments include a rotor-lock with a locking mechanism including a locking pin and a locking recess. Further embodiments include a rotor-lock with a locking plate which may be urged into a locking nut. Exemplary embodiments include one rotor-lock; other exemplary embodiments include two or more rotor-locks to enhance the load limit of the lock. Different types of rotor-locks are combined in exemplary embodiments. Typical rotor locks include an actuator such as a motor or a solenoid for moving a locking pin or a locking plate. Further embodiments include a manually actuated rotor lock.

[0047] The embodiment shown in FIG. **3** includes a rotor-brake **220**. The rotor-brake **220** of the exemplary embodiment shown in FIG. **3** is a disk brake allowing a considerable amount of slip in case a load limit for slipping is reached. Both the rotor-lock **210** and the rotor-brake **220** are fixed to a nacelle of the wind turbine. In embodiments, the rotor brake and the rotor lock are arranged at the low-speed shaft of the gearbox or between the rotor and the gearbox of the wind turbine. In embodiments, the rotor-brake, the rotor lock or both may be at the high-speed shaft of a gearbox or between the gearbox and the generator of the wind turbine.

[0048] The sum of a brake clearance of the rotor-brake **220** and a brake deflection at maximum brake load of the rotor-brake **220** is usually smaller than the sum of a lock clearance and a lock deflection at maximum lock load of the rotor-lock **210**. In the exemplary embodiment shown in FIG. **3** the sum of the lock clearance and the lock deflection at maximum lock load is 2.0 or at least 2.0 times the sum of the brake clearance of the rotor-brake **220** and the brake deflection at maximum brake load. Further embodiments comprise a rotor lock and a rotor brake, wherein the sum of the lock clearance and the lock deflection at maximum lock load is at least 2.5 or at least 3.0 of the sum of the brake clearance of the rotor-brake **220** and the brake deflection at maximum brake load.

[0049] With the sum of a brake clearance of the rotor-brake and a brake deflection at maximum brake load being smaller than two times the sum of a lock clearance and a lock deflection at maximum lock load of the rotor-lock, it is possible to use the rotor-lock and the rotor-brake in parallel for a maximum load. Such maximum load cases may be a extreme event load. Such an extreme event load may by way of example include wind conditions, grid failures, turbine malfunctioning and maintenance conditions. Typically, load cases are defined per regulations. As an example, the IEC 61400 guideline may be named. It shows several Design Load Cases (DLCs), wherein also extreme wind conditions including storms, gusts and wind direction changes, also in combination with the parked position, are named. With clearance combinations of typical embodiments, the rotor-lock, the rotor-brake or both may be smaller compared to other wind turbines. The brake clearance of the rotor-brake refers to the amount of rotation which is necessary before the rotor-brake has an effect. The brake deflection at maximum brake load depends on the stiffness of the rotor-brake and the stiffness of the mounting of the rotor-brake in the nacelle. The lock clearance depends mainly on the type of the rotor-lock. Exemplary embodiments having a rotor-lock with a locking pin have a lock clearance depending on the difference of the diameters of the locking recess and the locking bolt. Again, the lock deflection at maximum lock load depends on the rotor-lock and the mounting of the rotor-lock in the nacelle. One possibility used in embodiments to manipulate the sum of the lock clearance and the lock deflection is to vary the lock clearance. This can be done by reducing the diameter of the locking bolt. Another possibility is to enlarge the diameter of the lock recess. Furthermore, the mounting of the rotor-brake can be made very stiff to reduce the brake deflection at maximum brake load. Typically, the maximum brake load refers to the load at which slipping occurs. This load can also be referred to as the slip load of the rotor-brake.

[0050] The rotor-brake **220** and the rotor-lock **210** are controlled by control unit **230**. Typical embodiments comprise a control unit **230** arranged in a housing of a control system of the wind turbine. The control system is used for controlling at least a part of the main functions of the wind turbine. The control unit **230** as a part of the control system coordinates the actions of the rotor-lock **210** and the rotor-brake **220**. Typical embodiments include a control unit for positioning of the rotor in a locking position, inserting the rotor lock, forcing the rotor to turn in a first direction and applying the rotor-brake.

[0051] The rotor-lock of the embodiment shown in FIG. **3** includes a positioning member for positioning the shaft in a pre-determined angular position within the locking clearance of the rotor-lock **210**. The locking clearance of the rotor-lock **210** is based on a flexible support of the locking pin **212** in the locking actuator **214**. In detail, a flexible support **240**, including two O-rings, is used to fix the locking pin **212** in the locking actuator **214**. By doing so, the rotor is positioned in a middle position by the flexible support **240** in case no torque acts on the rotor. Typical methods of embodiments include a positioning of the rotor such that the locking pin may be shifted into the locking recess. Then, the torque is released and the rotor is positioned in a selectable angular position by the flexible supports. Afterwards, the rotor-brake is applied. In case of an extreme load, the torque is firstly acting on the brake and on the flexible support. At a certain load, further movement of the locking pin is blocked. The movement of the locking pin may be blocked by an end stop of the flexible support or by the housing of the locking actuator. Then, both the rotor-brake and the rotor-lock act together to withstand the high torque.

[0052] Typical embodiments comprise a flexible support for a locking pin of the rotor-lock. The flexible support represents a positioning member for positioning the shaft in a selectable angular position. Some embodiments include a flexible support for positioning the shaft in a middle position of the locking clearance of the rotor-lock. Other embodiments include a positioning member for positioning the shaft in an asymmetric position of the locking clearance of the rotor-lock. By doing so, asymmetric maximum loads on the rotor may be addressed. Further typical embodiments of fixation devices include a locking-pin with a flexible portion for engaging with a locking recess of the rotor-lock. The flexible portion may be used as positioning member for positioning the shaft in a selectable angular position within the locking clearance of the rotor-lock. Furthermore, the locking pin includes a stiff portion for an engagement with the locking recess of the rotor-lock only above a threshold torque. The terms "flexible" and "rigid" have to be construed as relative terms. The term "flexible" denotes typically a member being at least twice as flexible as the "rigid" member. Typical flexible members like flexible supports, or like flexible portions, include plastics or synthetic materials, wherein typical rigid elements or rigid portions include metal, steel or metal alloys. Typical flexible members provide a shape which allows a flexible reaction. Typically, the positioning member comprises a spring member for a flexible positioning of the shaft and the selectable angular position. By doing so, no additional energy must be expended for positioning the shaft in the selectable angular position.

[0053] In FIG. **4**, the actuator **214** with a part of the locking pin **212** of FIG. **3** is shown in more detail. In FIG. **4**, a frame **244** of the rotor-lock **210** is shown. The frame **244** maybe moved by control of the control unit **230** to retract or to engage the locking pin **210**. The locking pin **210** is of rigid material wherein the flexible support **240** includes O-rings of flexible material. The frame **244** may be retracted or moved in the direction of an arrow **246** depicting the direction of movement. The locking pin **210** has a constant diameter for engagement with the locking recess.

[0054] Typical embodiments comprise a locking pin with a constant diameter or a constant profile over an engagement region of the locking pin. Further typical embodiments of fixation devices of wind turbines include a locking pin with a conical pin surface or a stepped pin surface. Typically, the positioning member includes a positioning region and a locking region for an engagement with a locking recess. The positioning member may be construed as being part of a locking pin or a locking bolt. The positioning region is typically a region used for positioning the rotor in a selectable angular position. In case of a conical pin, the region with the larger diameter may be used for an engagement with a locking recess such as a locking hole or a locking groove, wherein the region with the smaller diameter may be used as the locking region for providing a bigger locking clearance. Typically, the positioning clearance is smaller than the lock clearance. Typical embodiments comprise positioning members having a positioning clearance which is only half or only one fifth or only one tenth of the lock clearance. Such proportions may be achieved by using conical or stepped pins or by using flexible supports for the pin or by other measures described herein. Typical positioning members include the locking pin. Typically, the positioning member and the locking pin are realized in one part or one group of elements of the fixation device on the wind turbine. Typically, the pin or the locking pin of the positioning member provides a profile providing a positioning region and a locking region. Such profiles may be chosen from a step profile or a tapered or a conical profile. By using a locking pin with a step profile or a tapered or conical profile different positioning and locking clearances may be achieved with minimal effort. By doing so, the rotor-lock and the rotor-brake may be used together in an optimal combination.

[0055] In FIG. **5**, a tapered locking pin **250** is shown. The conical locking pin **250** may be used with the embodiment shown in FIG. **3**. However, since the conical locking pin comprises a positioning region with a larger diameter of the conical surface and a locking region with the smaller diameter of the conical surface of the conical locking pin, the flexible support shown in FIG. **3** may be omitted. However, also a combination of the flexible support with the conical locking pin is used in typical embodiments.

[0056] In FIG. **6**, a stepped locking pin **260** is shown. The stepped locking pin **260** is shown in a side view and a front view. The stepped locking pin **260** includes a positioning region **262** with a larger diameter and a locking region **264** with a smaller diameter. By pushing the stepped locking pin **260** completely into a hole of the rotor-lock, the positioning region **262** gets in engagement with the hole. By doing so, the rotor is positioned in a selectable angular position.

[0057] Typical embodiments comprise a method, wherein after applying the positioning member, it is waited until the rotor is in a selected or a selectable position. The term "waiting" typically includes a forcing of the rotor to move in the selected position. In further typical embodiments during "waiting" it is just waited until the rotor reaches the selected position, e.g. by chance or by turning the rotor blades such that the wind drives the rotor in the selected position. Typical examples of forcing the rotor into a selected position include a turning of the rotor by hand, by an elastic member or by a generator used as a motor or other turning means. Then, the rotor-brake is supplied. After applying the rotor-brake, the rotor lock may be applied. One possibility is that the stepped locking pin is retracted, such that the locking region is in the region of the hole of the rotor-lock. Now, with the rotor-brake still in engagement, regular torque acting on the rotor or the shaft may be absorbed by the rotor-brake. In case the load excesses a selectable limit, namely the slipping limit of the rotor brake, the rotor lock gets in full engagement. In embodiments with a stepped locking pin, the locking region of the rotor-lock gets in engagement. By doing so, the forces or torques of the rotor-brake and the rotor-lock are added such that with this combination, the wind turbine may withstand higher loads.

[0058] In FIG. **7**, an elliptical locking pin **270** is shown in a front view. The elliptical locking pin **270** includes an elliptical profile providing a locking region in the region of the elliptical profile with the smaller diameter. The elliptical locking pin **270** may be used in connection with actuators which are not only capable of retracting or pushing the elliptical locking pin but also are of rotating the elliptical locking pin **270**. In case the elliptical locking pin **270** is rotated, one may choose which one of the regions of the positioning region **262** or locking region **264** gets in engagement with a recess or a hole of the rotor-lock. Further embodiments may use a cylindrical or conical pin where on one or two sides a shape is provided that is within the cylinder of cone and that has a locally larger radius than the cylinder or cone.

[0059] In typical embodiments, the positioning member is adjusted for a positioning of the shaft within a middle range between a first limit stop and a second limit stop of the rotor-lock. Further embodiments include a positioning member being adjusted for a positioning of the shaft outside of the middle range. Such a positioning may also be construed as an asymmetric positioning between the first limit stop and the second limit stop. Typically, the middle range is the middle third of the clearance between the first limit stop and the second limit stop. In further embodiments the middle range is 20% of the range between the first limit stop and the second limit stop. Typical flexible members, like a flexible support or a spring, are arranged for an exclusive engagement of the locking region of the locking pin, or of the locking pin itself with a locking stop in case of a torque of the shaft above a threshold torque. By doing so, the rotor is kept in a selectable angular position between different limit stops like the first limit stop and the second limit stop in case of small loads. The first limit stop and the second limit stop include the sides of a locking recess or of a locking hole. Further embodiments include different locking stops like noses or projections.

[0060] FIGS. **8** to **10** show a further embodiment of a fixation device for a wind turbine. FIG. **8** is an overview of a fixation device wherein FIG. **9** is a front view of a detail of the fixation device and FIG. **10** is a sectional view of a detail of the fixation device.

[0061] The fixation device of FIG. **8** includes some similar points as the fixation device of FIG. **3**. It should be noted that the locking pin **212** of the fixation device of FIG. **8** is only retractable in one direction by the actuator **214**. The locking pin **212** is moveable for an engagement with a positioning disk **280** and a lock disk **282**. The positioning disk **280** may be construed as being the positioning member for positioning the rotor **18**. The positioning disk **280** and the lock disk **282** are mounted on the rotor shaft **44**. The positioning disk **280** includes positioning holes **284** wherein the lock disk **282** includes locking holes **286**. The locking holes **286** of the lock disk **282** provide more slack or more locking clearance compared to the positioning clearance of the positioning holes **284** of the positioning disk **280**. Hence, by choosing the retracted position of the locking pin **212**, it is possible to engage the positioning hole **248** for positioning the rotor **18** in a selectable angular position. By retracting the locking pin a bit the engagement with the positioning disk is released. However, the locking pin **212** is still in a position for an engagement with the locking disk **282**. The rotor-brake **220** is actuated before the locking pin is retracted from the positioning disk **280**. Hence, the rotor shaft **44** keeps its position. In case of a torque or load above a threshold, namely the slipping torque of the rotor-brake **220**, the locking pin **212** gets in engagement with the edge of the locking hole **286** of the lock disk **282**. By choosing the rotor-brake deflection and the clearance of the rotor-lock (lock disk **282** with locking pin **212**) the rotor-brake **220** will be loaded first, reach its maximum torque and then starts to slip until the rotor-lock gets loaded.

[0062] Typical embodiments use lock disks with locking holes having a greater diameter or tangential clearance compared to the positioning holes. Further possible arrangements include slots in the lock disk. The positioning disk **280**, of typical embodiments, includes circular or conical holes. The holes in the positioning disk must not be lined with the holes of the locking disk exactly. By shifting the positioning hole with respect to the locking hole, the selectable angular position can be chosen outside of the centre of the clearance band of the locking clearance. Thereby, the fixation device benefits from asymmetric loads. Typically, most extreme loads on wind turbines are different and such asymmetric in both rotational directions. These are usually known by simulating different load conditions. Hence, usually it is known, in which direction the maximum torque is acting. Further embodiments of fixation devices of wind turbines include a spring between the rotor shaft and the positioning disk. With such a spring, a retraction of the locking pin from an engagement with the positioning disk may be omitted. Therefore, the locking pin may be left in the position for an engagement with the positioning disk. With this, the maximum torque of the rotor-lock may be enhanced.

[0063] FIG. **9** and FIG. **10** are described in connection with FIG. **8** since the same parts and the same embodiment is shown in FIGS. **8** to **10**.

[0064] FIG. **11** and FIG. **12** depict the torques of the rotor-brake and the rotor-lock for different load cases. The horizontal axis of FIG. **11** and of FIG. **12** depicts the shaft rotation, wherein the vertical axis represents the reacting torque, respectively. FIG. **11** relates to a positioning of the rotor in a middle position between the limit stops of the locking clearance. FIG. **12** relates to an asymmetric positioning of the rotor between the limit stops of the rotor-lock. The line **400** in FIG. **11** shows the maximum load of the combination of the rotor-lock and the rotor-brake for the symmetric case. It should be noted, that the sum of the lock clearance and the lock deflection at maximum load (line **400**) is more than twice the sum of the brake deflection and the brake clearance at maximum load. The torque acting on the rotor-brake is depicted by line **410**, wherein line **420** relates to the torque acting on the rotor-lock. The line **430** is the sum of the torques acting on the rotor-brake and the rotor-lock. For the asymmetric case in FIG. **12**, the angular position of the rotor at the beginning is near to one of the limit stops of the rotor-lock. Hence, the brake (line **410**) is not at its full load, when the rotor-lock reaches its limit. The limit of the rotor-lock is depicted by lines **440**. Due to the asymmetric arrangement, the maximum combined load is bigger in a first direction (**402**) than in the second opposite direction (line **403**).

[0065] Exemplary embodiments of systems and methods for wind turbines are described above in detail. The systems and methods are not limited to the specific embodiments described herein, but rather, components of the systems and/or steps of the methods may be utilized independently and separately from other components and/or steps described herein. For example, the exemplary methods for locking or braking of wind turbines are not limited to practice with only the wind turbine systems as described herein. Rather, the exemplary embodiment can be implemented and utilized in connection with many other rotor blade applications.

[0066] Although specific features of various embodiments of the invention may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the invention, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

[0067] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. While various specific embodiments have been disclosed in the foregoing, those skilled in the art will recognize that the spirit and scope of the claims allows for equally effective modifications. Especially, mutually non-exclusive features of the embodiments described above may be combined with each other. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A fixation device for fixing a shaft connecting a rotor and a generator of a wind turbine, the fixation device comprising:

a) a rotor lock for locking the shaft providing a locking clearance; and

b) a rotor brake for braking the shaft;

c) wherein the rotor lock is arranged for positioning the shaft in a selectable angular position within the locking clearance of the rotor lock.

2. The fixation device of claim **1**, wherein the rotor lock comprises a positioning member for positioning the shaft in the selectable angular position.

3. The fixation device of claim **2**, wherein the positioning member comprises a spring member for a flexible positioning of the shaft in the selectable angular position.

4. The fixation device of claim **2**, wherein the positioning member comprises a locking pin with a flexible portion for engagement with a locking recess of the rotor lock.

5. The fixation device of claim **4**, wherein the locking pin comprises a stiff portion for an engagement with the locking recess of the rotor lock only above a threshold torque.

6. The fixation device of claim **2**, wherein the positioning member comprises a flexible support for the locking pin of the rotor lock.

7. The fixation device of claim **2**, wherein the positioning member comprises a positioning disk with a positioning hole.

8. The fixation device of claim **7**, wherein the positioning disk with the positioning hole is arranged for an engagement of the positioning hole with the locking pin of the rotor lock.

9. The fixation device of claim **8**, wherein the positioning hole provides less clearance than the locking recess in case of an engagement with the locking pin.

10. The fixation device of claim **2**, the positioning member comprising a positioning region and a locking region for an engagement with a locking recess.

11. The fixation device of claim **2**, the positioning member comprising a pin with a profile selected from a stepped profile, an elliptical profile and a tapered profile.

12. The fixation device of claim **2**, wherein the positioning member provides a positioning clearance smaller than the lock clearance.

13. A method for locking a shaft of a wind turbine with a rotor lock for locking the shaft, a rotor brake for braking the shaft and a positioning member for a positioning of the shaft in a selectable position, the method comprising:

a) applying the positioning member;

b) waiting until the shaft is positioned in a selectable position by the positioning member;

c) applying the rotor brake; and,

d) applying the rotor lock.

14. The method of claim **13**, wherein the shaft is positioned in a selectable position within a middle range between a first limit stop and a second limit stop of the rotor lock using the positioning member.

15. The method of claim **14**, wherein the middle range is within the middle third of the clearance of the rotor lock.

16. A wind turbine comprising a rotor, a generator, a shaft for transmitting torque between the rotor and the generator, and a fixation device for fixing the shaft, the fixation device comprising:

a) a rotor lock for locking the shaft providing a lock clearance between a first limit stop and a second limit stop; and,

b) a rotor brake for braking the shaft;

c) wherein the rotor lock is arranged for positioning the rotor shaft within the lock clearance, wherein the positioning clearance is smaller than the lock clearance.

17. The wind turbine of claim **16**, wherein the rotor lock is adjusted for a positioning of the shaft within a middle range between the first limit stop and the second limit stop of the rotor lock.

18. The wind turbine of claim **16**, wherein a sum of the brake clearance and the brake deflection is smaller than half of the sum of the lock clearance and the lock deflection.

19. The wind turbine of claim **16**, wherein the rotor lock comprises a flexible member for a locking pin of the rotor lock.

20. The wind turbine of claim **19**, wherein the flexible member of the locking pin is arranged for an exclusive engagement with a locking stop in case of a torque of the shaft below a threshold torque.

* * * * *