(19) DANMARK

(10) DK/EP 2807370 T5

Patent- og Varemærkestyrelsen

(12) # Rettet oversættelse af europæisk patentskrift

(51) Int.Cl.: ***F 03 D 7/02 (2006.01)*** ***F 03 D 7/04 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2016-08-15**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2016-05-18**

(86) Europæisk ansøgning nr.: **12733693.1**

(86) Europæisk indleveringsdag: **2012-07-06**

(87) Den europæiske ansøgnings publiceringsdag: **2014-12-03**

(86) International ansøgning nr.: **EP2012063240**

(87) Internationalt publikationsnr.: **WO2013010814**

(30) Prioritet: **2011-07-15 DE 102011079269**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(73) Patenthaver: **Suzlon Energy GmbH, Kurt-Dunkelmann-Str. 5, 18057 Rostock, Tyskland**

(72) Opfinder: **VILBRANDT, Reinhard, Platz der Freundschaft 15, 18059 Rostock, Tyskland**
IBENDORF, Ingo, Feldstrasse 29, 18057 Rostock, Tyskland

(74) Fuldmægtig i Danmark: **Patentgruppen A/S, Arosgården, Åboulevarden 31, 8000 Århus C, Danmark**

(54) Benævnelse: **SIKKERHEDSKÆDE OG FREMGANGSMÅDE TIL DRIFT AF VINDMØLLE**

(56) Fremdragne publikationer:
WO-A1-2007/132303
DE-A1-102005 034 899

Description

[0001] The invention relates to a wind turbine with a safety chain for monitoring and shutdown of a wind turbine, a blade adjusting device required for this purpose, and a method for monitoring and shutdown of a wind turbine.

[0002] The wind turbine comprises a tower, a nacelle mountable on the tower, a generator mountable in the nacelle, and a rotor connected to the generator via a drive shaft. The rotor comprises a hub, at least one rotor blade, a bearing and an adjusting device mountable between the rotor blade and hub. The bearing comprises an inner ring and an outer ring that are rotatable with respect to one another. The rotor blade is thus substantially arranged on the hub to be rotatable about its longitudinal axis. The rotor blade may be adjusted and stopped in various adjustment positions by means of the adjusting device. The adjusting device comprises at least an electric servomotor to drive a gear wheel connected to the rotor blade, a converter which is coupled to an electric network and drives the servomotor, and a control unit to control the converter and to monitor the components of the blade adjusting devices. To ensure that the wind turbine does not continue to rotate in the event of a system error, the wind turbine has a turbine safety chain, which is designed as a cable and which connects various components of the wind turbine, e.g. the rotor blade adjusting device and a central turbine control. A safety drive of the rotor blades is initiated by opening the turbine safety chain upon the detection of an error in one of the components.

[0003] In known wind turbines, the function of monitoring components of the wind turbine is performed by the turbine control. The turbine control system is connected to the adjusting devices of the rotor blades and can communicate with the respective adjusting devices. The adjusting devices of the rotor blades are normally supplied via a general external control voltage. A safety drive is initiated, for example, in the event of an operating error or a strong wind, in order to protect the wind turbine, wherein the rotor blades are rotated to the so-called feathered position. The feathering is achieved when the rotor blade is turned out of the wind, so that only a minimal attack surface of the rotor blade is exposed to the wind. Normally, all blade adjusting devices of the rotor blades are simultaneously driven by the turbine control system to initiate a safety drive. However, when the control unit of the blade adjusting devices detects a critical error, then according to the prior art, the defective pitch control may immediately initiate a safety drive. An error message is simultaneously sent from the control unit to the turbine control. The turbine control processes the error message and then outputs the command to initiate a safety drive to the other blade adjusting devices. In the event of failure of the turbine control system, the risk of damage to the wind turbine is high, since then communication between the blade adjusting devices stops. In the event of failure of communication between the blade adjusting devices, the blade adjusting devices must autonomously initiate the safety drive. If the individual blade adjusting devices initiate an adjustment of the rotor blades at different times, then this leads to uneven loading on the rotor due to the different angle of attack of the rotor blades during the adjustment. This imbalance leads to damage to the rotor and turbine.

[0004] DE 10 2005 034 899 A1 discloses a wind turbine with a system for avoiding this high rotor loading. The blade adjusting devices of the wind turbine in this case have a subsidiary module, wherein the subsidiary module is adapted to monitor the operating state of the other blade adjusting devices. Signals relating to initiation of a safety drive or a failure in one of the blade adjusting devices is detected or received by one of the other blade adjusting devices, in particular by means of the subsidiary module. Normally, an adjustment of the rotor blades is always commanded by a central control unit of the wind turbine. However, if the central control unit fails and one of the blade adjusting devices is in an operating state that lies outside a previously defined range and therefore initiates a safety drive of its associated rotor blade, the other blade adjusting devices can respectively recognize this through their subsidiary module. The blade adjusting devices are thus capable of initiating a safety drive in order to effect a synchronous safety drive of the other two rotor blades. A disadvantage of this system is, inter alia, the complex structure involving one subsidiary module per adjusting device and the associated high cost.

[0005] It is an object of the invention to provide an improved monitoring function, which avoids, inter alia, the drawbacks of the prior art. In particular, to propose a cost-effective and secure method for performing a safety drive of the rotor blades

[0006] The object is solved according to the invention with the features of the main claim 1, wherein the blade adjusting devices has an internal safety chain and a turbine safety chain. In the case of the internal safety chain, the control unit of the blade adjusting devices is designed to monitor, inter alia, all safety-related functions and operating parameters of the components of the blade adjusting devices, such as the converter, servomotor, brake, resolver, limit switches and/or power supply, as well as the turbine control. The operating parameters that may be monitored may include temperature, position, voltage, vibration and/or speed. The control unit of the blade adjusting devices is connected with a turbine control system, e.g. via a CAN-bus, and can exchange data with the control unit via this connection. Both the control unit of the blade adjusting devices and the turbine control system is connected with a physical turbine safety chain via a switch, and can open and/or close this turbine safety chain via the switch. The turbine safety chain is connected with signal inputs in the control unit of the blade adjusting devices, so that an open system safety chain initiates a safety drive of the blade adjusting devices or prevents the blades from leaving the feathered position. Upon opening the turbine safety chain, the signal to all the signal inputs of the blade adjusting devices changes at the same time. It is thus achieved that a substantially synchronous safety drive of at least two rotor blades may be performed. Although it is not described further, the internal safety chain and the turbine safety chain may also be used in other types of wind turbines, such as gearless turbines, and turbines with other types of blade adjusting devices, such as drive shaft driven or hydraulic blade adjusting devices.

[0007] Before starting the wind turbine, it is conceivable to carry out a functional check of the system. In this way, the monitored operating parameters of the components of the blade adjusting devices are read into the control unit via signal inputs. The control unit then compares the read values against threshold values stored in a memory module. If the monitored values are within a range delimited by the threshold values, then the controller signals that the functions and operating parameters of the components of the blade adjusting devices are in order. Thereafter, the internal safety circuit sends a signal to the switch and to the turbine control to close the turbine safety chain. If there are no errors in the turbine control, the turbine control also sends a signal to the switch to close the turbine safety chain. By closing the turbine safety chain, the signal changes at the signal inputs of the turbine safety chain. By changing the signal, a departure from the feathered position is permitted.

[0008] During operation of the wind turbine, the operational parameters of the control unit and the turbine control may be continuously monitored. If an error in the blade adjusting devices occurs, the blade adjusting devices may always signal these errors to the turbine control. The turbine control may initiate a blade drive towards the feathered position upon receipt of the error message from the blade adjusting devices. For small errors, e.g. in the operating parameters, which lie outside the permitted range but do not threaten the functioning of the blade adjusting devices, the turbine control may pass on the command for the blade drive in the feathered direction to the control units of the blade adjusting devices via the direct connection between the control unit of the blade adjusting device and the turbine control, for example, via a CAN bus. Upon receipt of the command via this communication path, a slow blade drive towards the feathered position may be carried out.

[0009] In the event of errors in the blade adjusting devices that may result in damage to the wind turbine, the turbine safety chain may be opened through the turbine controller. At the same time, a signal for blade adjustment may be sent via the direct connection between the turbine control and control unit of the blade adjusting devices for redundancy reasons. No current flows through the turbine safety chain upon opening the turbine safety chain, and thus there is also no voltage to the components connected to the turbine safety chain. The signal in the turbine safety chain is thereby set to low. The control units of the blade adjusting devices simultaneously receive the low signal from the turbine safety chain and thus initiate a synchronous safety drive of the rotor blades.

[0010] In the event of a failure of the turbine control system, the safety chain is normally opened by the turbine control. But it may also happen that the turbine safety chain remains closed despite a defect in the turbine control. Such a defect may, for example, be a software bug wherein the turbine control, while acknowledging no internal error because the operating parameters are in order, can not, however, correctly process the error message from the control unit. In this case, the turbine safety chain may also be opened from the blade adjusting devices. The control units of the blade adjusting devices are thus so configured that the control units, when they have not received any feedback from the turbine control within a certain period following an error message, automatically open the turbine safety chain. This time window may be 500 milliseconds, but preferably the turbine safety chain is opened after 300 milliseconds following the sending of the error message from the control unit of the blade adjusting devices. If one of the control units of the blade adjusting devices registers a failure of the turbine control and opens the turbine safety chain, the drive towards the feathered position is only initiated by the blade adjusting devices when the low signal from the turbine safety chain is present at the signal inputs of the control units. This ensures that the adjustment of the three blades is initiated synchronously and thus the load on the turbine is kept low.

[0011] However, for safety reasons, if the control unit of the blade adjusting devices registers a really critical internal error, it may also initiate an immediate safety drive and simultaneously open the turbine safety chain. This is a state of emergency and only occurs for faults that affect the operation of the blade adjusting devices, for example, in the event of failure of the converter, brake failure or failure of the resolver, for example, due to overheating or overcurrent. The reduced function of a blade adjusting device, need not, or only slowly, initiate a safety drive. An attempt to initiate a safety drive is therefore started as soon as possible. However, the simultaneous opening of the turbine safety chain will ensure that at least the two still functional blade adjusting devices will synchronously initiate a safety drive.

[0012] The inventive solution has surprisingly shown that for the first time the problem of a non-synchronous safety drive of all the blades may be achieved. Through intensive studies of wind turbines, it has been found that a non-synchronous safety drive of the various blades can still arise even when using the solution of the prior art. Because, by sending the signals and processing the error message, there occurs a certain delay in the switching operations of the individual blade adjusting devices. Thus the safety drive of the last blade occurs somewhat later than that of the first blade. The unsynchronized safety drive of the rotor blades creates an imbalance in the rotor which leads to high loads on the wind turbine. Even an angular difference of 2 – 3° between the rotor blades can cause damage to the turbine.

[0013] The invention thus discloses that each blade adjusting device comprises its own internal safety chain, which acts exclusively on the switch of the turbine safety chain and on the turbine control. Thus no direct communication takes place between the individual internal safety chains. The internal safety chains are only indirectly connected together logically via the turbine safety chain for their effect as a release signal for the wind turbine or as an enable signal of a safety drive of the blade adjusting devices.

[0014] The turbine safety chain may also be connected to the turbine control system and a chain of emergency stops via a switch, and may be opened both from the turbine control as well as from the chain of emergency stops.

[0015] Thus, the turbine safety chain is opened when at least one of the internal safety chains is open, and/or the chain of emergency stops is opened, and/or the turbine control does not signal operational readiness. The turbine safety chain is only closed when all of the internal safety chains are closed, the turbine control indicates operational readiness, and the chain of emergency stops is closed. Advantageously, the systems for opening and/or closing the turbine safety chain are each connected with the system safety chain via a separate switch. Thus if one switch fails, the turbine safety chain can still be operated by the other switches. In a further embodiment, the turbine safety chain may also be opened and closed by other components of the wind turbine, such as service hatches. As a last resort - if both the internal safety chains of the blade adjusting devices and the turbine control fail - the turbine safety chain may preferably also be opened upon detecting overspeeding of the rotor via a speed sensor, or via a vibration sensor when a threshold value is exceeded.

[0016] The turbine safety chain advantageously comprises a cable and at least a switch for opening and/or closing the turbine safety chain. A signal dependent on the status of the monitored component is passed through the cable. The signal may have two different states; in the first state, the signal preferably consists of a voltage having a value within a first high range, while in the second state, the signal consists of a voltage having a value within a second low range. The signal with the higher voltage corresponds to a binary digit one, while the signal with the lower voltage corresponds to a binary digit zero. The ranges of the voltage signal are selected so that they are clearly separate from each other. For example, the first section extends from 2.0V to 5.0V, while the second region extends from 0V up to 0.8V. If all the monitored systems are in order, the turbine safety chain is closed and the high signal, the binary one, is sent to the components connected with the turbine safety chain. When the turbine safety chain is closed, a current can flow through the turbine safety chain, and thus a voltage is present at the components connected to the turbine safety chain. If an error is detected, the safety chain opens and the signal is set to low, which corresponds to the binary 0. Upon receipt of the low signal, the blade adjusting devices may automatically initiate a safety drive of their rotor blades. It would also be possible to set a high signal to indicate an error, and a low signal to indicate a properly functioning system. However, in the case of an open turbine safety chain, no current can flow through the turbine safety chain, and thus there is also no voltage present at the components connected to the turbine safety chain, and the signal has a low value. Advantageously, therefore, a low signal is used to indicate an error, because it is thus ensured that the blade adjusting devices initiate a safety drive in the event of a failure of the safety chain, for example, through a cable break.

[0017] In particular, the invention is characterized in that a substantially synchronous safety drive of the blade adjusting devices may be performed. The solution according to the invention is explained in detail below.

[0018] Upon starting the wind turbine, the rotor blades are usually in the feathered position and the turbine safety chain and the internal safety chains are open. Before the rotor blades can leave the feathered position, it is conceivable that the functioning of the converter and the other components of the blade adjusting devices are controlled by the control unit of the blade adjusting devices. When monitoring, the operating parameters of the monitored components of the blade adjusting devices are compared with pre-defined lower and/or higher threshold values. If the operating parameters are within the allowable range defined by the threshold values, the state of the component is set as being in order, i.e. free of errors.

[0019] Since the converter can not generate a control voltage from the mains voltage when switched off, the converter may be connected to a general external control voltage supply upon starting up the wind turbine. Advantageously, the general external control voltage supply voltage has the same value as the operating voltage of the blade adjusting devices, which is typically 24 volts. The external control voltage supply may be supplied, for example, to the blade adjusting devices from a control cabinet in the nacelle of the wind turbine via a slip ring. The converter is powered up with the help of the general external control voltage supply. Thereafter, the control unit of the blade adjusting devices switches on a power supply and a battery that may be connected to a voltage intermediate circuit of the converter for an emergency supply to the blade adjusting devices in the event of failure of the power supply. After the power supply and the battery have been turned on, the control unit may check the function of the battery and the power supply. If there are no errors, an internal control voltage is generated from the mains voltage via a power supply arranged in a DC intermediate circuit of the converter. The power supply is so designed that a constant, usually lower, voltage is always generated regardless of the voltage present in the DC intermediate circuit. Since an error in the general external control voltage supply could affect all the blade adjusting devices alike and, in a worst case scenario, could lead to the destruction of the entire system in the event of a failure of the blade adjusting devices, the control voltage supply to the blade adjusting devices is switched from the general external voltage supply to the internal supply by a switch before starting the wind turbine. The control voltage supplies to the blade adjusting devices may thus be completely galvanically separated from each other and an error in one of the control voltage supplies can not affect the other control power supplies in any way.

[0020] By switching to the internal control voltage supply, the blade adjusting devices may be decoupled from each other, and thus an error in the control voltage supply may affect only one of the blade adjusting devices. The other blade adjusting devices may position their blades in the feathered position and thus slow down the wind turbine despite a failure of the control voltage supply to the first of the blade adjusting devices. A further functional test of the components of the blade adjusting devices may be carried out before the general external control voltage supply is turned off and the internal control voltage supply is turned on. If this functional test also shows that there are no errors present and the operating parameters lie within a permitted range, switching to the internal control voltage supply is effected, and the control unit of the blade adjusting devices can close the internal safety chain and send a signal to close the turbine safety chain to the switch of the turbine safety chain. A signal to indicate the operational readiness may also be sent to the turbine control.

[0021] After all the internal safety chains and the chain of emergency stops have been closed, and the turbine controller has indicated operational readiness, the turbine safety chain may be closed. By closing the turbine safety chain, the blade adjusting devices receives a high voltage signal corresponding to a binary one, and movement away from the feathered position is iniitiated.

[0022] The critical functions of the converter and the other components of the blade adjusting devices may be continuously monitored by the control unit of the respective blade adjusting devices during operation of the wind turbine. The state of the blade adjusting devices is forwarded by the control of the blade adjusting devices to the turbine control. If an error is detected in one of the blade adjusting devices, the turbine control normally controls the blade adjusting devices in such a way that a synchronous drive of the rotor blades is initiated in the direction of the feathered position. In the case of non-critical errors, a slow drive, with a reduced angular velocity relative to the maximum angular velocity, is advantageously initiated in the direction of the feathered position, because, in this way, the loads on the wind turbine may be kept low. This blade drive may be controlled via the direct connection between the control units of the blade adjusting devices and the turbine control.

[0023] In the event of critical errors, the rotor blades may be driven by a safety drive into the feathered position. In the case of the safety drive, the rotor blades are rotated out of the wind at maximum angular velocity of the blade adjusting devices allowing rapid deceleration of the wind turbine. However, the rapid deceleration subjects the wind turbine to high loads because the force acting on the rotor blades is taken away abruptly. The turbine safety chain is opened by the turbine control to start the safety drive. However, for reasons of redundancy, a signal may also be sent via the direct connection between the control units of the blade adjusting devices and the turbine control. However, since the signal transmission via the turbine safety chain is much faster, this signal is the first to arrive at the control units. Measurements on a turbine have shown that starting a blade drive via the direct connection between the control units of the blade adjusting devices and the turbine control may take between 50 and 200 milliseconds, while starting via the turbine safety chain only takes about 5 milliseconds. Opening the turbine safety chain changes the signal applied to the signal inputs of the control units, while the control units synchronously start the safety drives of the rotor blades. In this way, there arises no imbalance in the rotor due to different angles of the rotor blades. During the blade adjusting process and after reaching the feathered position, the blade adjusting devices may remain on the internal power supply. After reaching the feathered position, it is conceivable that the function of the components of the blade adjusting devices and the drive may be checked. If an error is detected, the wind turbine is switched off; otherwise a new start attempt is carried out.

[0024] In the event of a failure of the internal power supply during operation, for example due to the absence of the power supply from the mains, the battery may be connected for an emergency power supply to the blade adjusting devices. The battery supplies the DC intermediate circuit of the converter with a voltage so that the converter may supply the motor with an operating voltage. In order to be able to further operate the converter, a control voltage is derived from the battery via the power supply arranged in the DC intermediate circuit. Thus, the functioning of the blade adjusting devices may be maintained.

[0025] If the turbine controller detects a failure of the mains supply, the turbine controller can control the blade adjusting devices to move the rotor blades towards the feathered position. Depending on the nature of the fault, either a slow drive or a safety drive may be initiated. Upon reaching the feathered position, the battery may be disconnected and the external general power supply turned on after a certain time in order to avoid discharging the batteries too much. In the event of critical errors, for example, if the internal power supply fails despite the presence of mains voltage, it is conceivable that the power supply from the battery could be turned off even before a predetermined time, and the external general control voltage switched on by the control unit of the blade adjusting devices, and thus check the blade adjusting devices for errors. Upon return to the mains voltage, a new starting operation of the wind turbine may then be automatically initiated.

[0026] Further details of the invention will become apparent from the drawings with reference to the description.

[0027] In the drawings:

Fig. 1 shows a wind turbine,

Fig. 2 shows an adjusting device of the wind turbine,

Fig. 3 shows the function of the internal safety chain in the control of the blade adjusting devices

Fig. 4 shows a turbine safety chain of the wind turbine.

[0028] Fig. 1 shows a wind turbine 2 with a tower 3, a rotatably mounted nacelle 4 on the tower 3 and a rotor 5 connected to a generator via a rotor shaft arranged in the nacelle 4. The rotor 5 comprises a hub 8, three rotor blades 6 rotatably mounted about a blade axis 7 and a bearing mounted between the hub 8 and the rotor blade 6. Each rotor blade comprises a blade adjusting device P1, P2, P3 (Fig. 4) to adjust the setting position of the rotor blade 6, and a brake to hold the blade in a desired set position. The blade adjusting devices P1, P2, P3 comprise a servomotor 9, a drive pinion 11 arranged on an output shaft 10 of the servomotor 9, a gear engaged with the drive pinion 11, a converter 12 to supply a current and/or voltage to the servomotor 9, and a control unit 13 to control and/or regulate the converter 12.

[0029] Fig. 2 shows the blade adjusting devices P1, P2, P3 of the wind turbine 2. The adjustment of the rotor blade 6 is effected via the servomotor 9 connected to the hub 8, which drives the rotor blade 6 rotatably mounted on the hub 8 via a drive pinion 11 that is fixable on a drive shaft 10 of the servomotor 9. The blade adjusting devices P1, P2, P3 are supplied with an operating voltage via a respective converter 12. To control or regulate the operating voltage output from the converter 12 to the adjusting motor 9, and to monitor the status and functions of the components in the blade adjusting devices P1, P2, P3, the blade adjusting devices P1, P2, P3 each also have a control unit 13. In this embodiment, the control unit 13 is integrated in the converter 12,

[0030] To start up the blade adjusting device P1, P2, P3, the control unit 13 of the converter 12 of the blade adjusting device P1, P2, P3 is supplied from a common external control voltage U_{ext}.

After the control unit 13 has powered up the converter 12, the power supply U_N and the battery 21 for the emergency supply of the blade adjusting device P1, P2, P3 is turned on. After checking the battery 21 and the power supply U_N for errors and if no errors are present, the converter 12 of the blade adjusting devices P1, P2, P3 generates an internal control voltage U_{int} from the mains voltage U_N via the power supply 25 arranged in the DC voltage intermediate circuit 27. After checking the internal control voltage U_{int} for errors and if no errors are present, the general external control voltage is switched over to the internal control voltage via a switch 26 and the control unit 13 of the converter 12 is supplied with the internal control voltage U_{int}. The switch 26 may thus be connected to the control unit 13 and may be controlled by the control unit 13. To end the blade adjustment process, the control unit 13 is connected to a plurality of limit switches 14, which send a signal to the control unit 13 upon reaching a certain setting position. The function of the components of the blade adjusting devices P1, P2, P3 is monitored by an internal safety chain 23 which is integrated in the control unit 13.

[0031] Fig. 3 shows the functioning of the internal safety chain 23 integrated in the control unit 13 of the converter 12. In order to check the function and condition of the components of the blade adjusting devices P1, P2, P3, the control unit 13 sends a request to the respective components of the blade adjusting devices P1, P2, P3 in step (1). The components respond to the request with the respective operating parameters x_{1-n}. In step (2), the operating parameters x_{1-n} are compared with the threshold values Y_{11-1n} and Y_{21-2n} stored in a memory module of the control unit 13. The operating parameters may be, inter alia, temperature, position, voltage, vibration and speed and controlled so that the conditions within which the threshold values Y_{11-1n} and Y_{21-2n} lie are within the defined allowed range. If the monitored operating parameters are in order, a signal to close the turbine safety chain 1 is sent to the switch 17, otherwise a signal to open the turbine safety chain is sent to the switch 17. The control unit 13 also indicates operational readiness of the turbine control 15, i.e. that there are no errors.

[0032] Fig. 4 shows a turbine safety chain 1 with the blade adjusting devices P1, P2, P3 of the three rotor blades 6, a turbine control 15 and the communication paths of the components. The blade adjusting devices P 1, P2, P3 are connected via their control units 13 with the turbine controller 15 via the communications path 24, and may transmit data to the turbine control 15, as well as receive data from the turbine control 15. During normal operation of the wind turbine 2, the communication and the control of the blade adjusting devices P1, P2, P3 pass through the communication path 24. In addition to the communication between the control unit 13 and the turbine control 15, the internal safety chains 23 integrated in the control units 13 of the blade adjusting devices P1, P2, P3 and the turbine control 15 are connected with the turbine safety chain 1 via at least a switch 17, so that it may open and/or close the turbine safety chain 1. Further systems may be connected to the switch 17 to open and/or close the turbine safety chain 1. These systems may be, for example, a chain 18 of emergency stops 19 for the manual opening of the turbine safety chain 1, or a sensor 20 to monitor the operating parameters of the wind turbine 2, such as temperature, vibration, and/or speed. Advantageously, the systems for opening and/or closing the turbine safety chain 1 each have their own switch 17 connected with the turbine safety chain 1. The turbine safety chain 1 is connected to signal inputs 16 of the blade adjusting devices P1, P2, P3 and the turbine control 15. When the turbine safety chain is closed, a signal with a high voltage is sent from the turbine safety chain 1 to the control units 13 of the blade adjusting devices P1, P2, P3 in order to initiate a blade adjusting process. When the turbine safety chain 1 is open, no current flows through the turbine safety chain 1, and therefore no voltage is applied to the components connected to the system safety chain 1. The voltage of the signal thus changes from a high to a low value when the turbine safety chain 1 is open. If the control units 13 of the blade adjusting devices P1, P2, P3 receive a low signal from the turbine safety chain 1, the release for the blade adjustment is canceled and the blade adjusting devices P1, P2, P3 remain in the feathered position, or initiate a safety drive when the rotor blades 6 are not already in the feathered position.

[0033] When the wind turbine 2 is turned off, the rotor blades 6 are in the feathered position and both the internal safety chains of the blade adjusting devices P1, P2, P3 and the turbine safety chain 1 are open. Since the converter 12 can not produce a control voltage from the mains voltage U_N when switched off, the blade adjusting devices P1, P2, P3 are supplied with a general external control voltage U_{ext} for the start-up. Before the rotor blades 6 can leave the feathered position, the condition of the converter 12 and the other components of the blade adjusting devices P1, P2, P3 are checked. If no errors are present in the blade adjusting devices P1, P2, P3, the control unit 13 of the blade adjusting devices P1, P2, P3 switch on the mains voltage U_N and the battery 21 for the emergency supply of the blade adjusting devices. Thereafter, the battery 21 and the power supply from the control unit 13 are checked for errors.

[0034] If there are no errors, the converter switches the U_{ext} from the external power supply to the internal control voltage U_{int} generated by the power supply 25 arranged in the DC voltage intermediate circuit 27. The internal control voltage supply U_{int} is so designed that the control voltage supplies of the blade adjusting devices P1, P2, P3 are electrically isolated from each other and an error in one of the control voltage supplies can not affect the other control voltage supplies. The functions of the blade adjusting devices P1, P2, P3 are checked a second time and, if everything is in order, the general external control voltage supply U_{ext} is turned off, and the internal control voltage supply U_{int} is turned on. Thereafter, the internal safety chain in the blade adjusting devices is closed. The control unit 13 then sends a signal to the switch 17 to close the turbine safety chain 1, and a signal to indicate the operational readiness of the turbine control 15.

[0035] When the turbine control 15 and further components connected to the turbine safety chain 1, such as at least a sensor 20, measures the speed and/or vibration, and the chain 18 of emergency stops 19 indicates operational readiness, the turbine safety chain 1 is closed. By closing the turbine safety chain 1, a current may flow through the turbine safety chain again, and a high voltage signal is present at the signal inputs 16 of the control units 13 connected to the turbine safety chain 1. When a high signal is present at the signal input 16 of the control unit 13 of the blade adjusting devices P1, P2, P3, the blade adjusting devices P1, P2, P3 have permission to move the rotor blade 6 from the feathered position and the wind turbine 2 may be started.

[0036] During operation of the wind turbine 2, the state of the blade adjusting devices P1, P2, P3 is normally transmitted continuously from the respective control units 13 to the turbine control 15. In the event of an error in one of the blade adjusting devices P1, P2, P3, this is communicated to the turbine control 15. The turbine control then commands a synchronous drive of the rotor blades 6 in the direction of the feathered position either via the direct connection 24 or via the switch 17.

[0037] In the event of a failure of the mains supply, the emergency supply to the blade adjusting devices P1, P2, P3 is turned on by the battery 21. The battery is connected to the DC intermediate circuit 27 of the converter and can therefore both send an operating voltage to the servomotor 9 via the converter 12, as well as a control voltage to the control unit 13 via the power supply 25. Thus, the blade adjusting devices P1, P2, P3 may position the rotor blades 6 in the feathered position despite a failure of the mains voltage.

[0038] In the event of critical errors, such as failure of the turbine control 15 or faulty or disturbed communication between the turbine control 15 and the control unit 13 of the blade adjusting devices P1, P2, P3, the turbine safety chain 1 of one of the controllers 13 may be opened. Upon opening the turbine safety chain, the signal is set to low and the blade adjusting devices P1, P2, P3 synchronously initiate a safety drive upon receipt of the low signal at the signal input 16 of the control unit 13. If the control units 16 of the blade adjusting devices P1, P2, P3 all fail, the turbine safety chain 1 may also be opened from the at least one sensor 20 or from the chain 18 of emergency stops 19.

[0039] The combinations of features disclosed in the described embodiments do not have a limiting effect on the invention, but rather the features of the various embodiments may be combined with each other.

List of reference numerals

1	Turbine safety chain
2	Wind Turbine
3	Tower
4	Nacelle
5	Rotor
6	Rotor blade
7	Blade axis
8	Hub
9	Servomotor
10	Drive shaft
11	Pinion
12	Converter
13	Control unit
14	Limit switches
15	Turbine control
16	Signal input
17	Switch
18	Chain of emergency stops
19	Emergency stop
20	Sensor
21	Battery
22	Signal output
23	Internal safety chain
24	Communication path
25	Power supply
26	Switch
27	DC voltage intermediate circuit
P1	Blade adjusting device
P2	Blade adjusting device
P3	Blade adjusting device
U_N	Mains voltage
U_{ext}	External control voltage supply
U_{int}	Internal control voltage supply

Patentkrav

1. Bladjusteringsindretning (P1, P2, P3) til et rotorblad (6) af en rotor (5) i en vindmølle (2),

- hvor rotoren (5) omfatter et nav (8), mindst ét rotorblad (6), der er drejeligt lejret på navet (8) omkring en længdeakse (7) af rotorbladet (6), og rotoren (5) er drejeligt anbragt på en nacelle (4) af vindmøllen (2),

- rotorbladet (6) er drejeligt via bladjusteringsindretningen (P1, P2, P3) og kan standses i forskellige indstillingspositioner,

- vindmøllen (2) har en central møllestyring (15) til overvågning og styring af komponenter i vindmøllen (2), blandt andet bladjusteringsindretningen (P1, P2, P3),

- og hvor bladjusteringsindretningen (P1, P2, P3) omfatter en justeringsmotor (9) til at drive og/eller fastgøre rotorbladet (6), en omformer (12) til styring af justeringsmotoren (9), en styreenhed (13) til styring af omformeren (12) og et batteri (21) til nødforsyning af bladjusteringsindretningen (P1, P2, P3),

- bladjusteringsindretningen (P1, P2, P3) har en anlægssikkerhedskæde (1) og en intern sikkerhedskæde (23), der er integreret i justeringsindretningens (P1, P2, P3) styreenhed (13),

kendetegnet ved, at omformeren (12) omfatter en strømforsyning (25) til frembringelse af en intern styrespænding (U_{int}) ud fra netspændingen (U_N), hvor strømforsyningen (25) er anbragt i en jævnspændingsmellemkreds (27) af omformeren (12).

2. Bladjusteringsindretning (P1, P2, P3) ifølge krav 1, **kendetegnet ved, at** anlægssikkerhedskæden (1) har mindst én afbryder (17), hvilken afbryder er forbundet med signaludgange (23) af bladjusteringsindretningens (P1, P2, P3) styreenhed (13) og af møllestyringen (15), og styreenhedens (13) interne sikkerhedskæde og/eller møllestyringen (15) er udformet til at kunne frembringe signaler til åbning og/eller lukning af anlægssikkerhedskæden (1) og afgive disse signaler til afbryderen (17).

3. Bladjusteringsindretning (P1, P2, P3) ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** anlægssikkerhedskæden (1) afgiver et signal, der er afhængigt af anlægssikkerhedskædens (1) tilstand, til en signalindgang (22) af bladjusteringsindretningens (P1, P2, P3) styreenhed (13) og/eller af møllestyringen (15).

4. Bladjusteringsindretning (P1, P2, P3) ifølge krav 3, **kendetegnet ved, at** signalet kan have to forskellige tilstande, hvor signalet ved lukket anlægssikkerhedskæde (1) har en høj spændingsværdi og ved åben anlægssikkerhedskæde (1) har en lav spændingsværdi.

5. Bladjusteringsindretning (P1, P2, P3) ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** bladjusteringsindretningens (P1, P2, P3) omformers (12) styreenhed (13) kan forbindes med en almen ekstern styrespændingsforsyning (U_{ext}) og den interne styrespændingsforsyning (U_{int}).

6. Bladjusteringsindretning (P1, P2, P3) ifølge krav 5, **kendetegnet ved, at** bladjusteringsindretningen (P1, P2, P3) omformers (12) styreenhed (13) forsynes af den almene eksterne styrespænding (U_{ext}) ved ibrugtagning.

7. Bladjusteringsindretning (P1, P2, P3) ifølge krav 5 eller 6, **kendetegnet ved, at** bladjusteringsindretningens (P1, P2, P3) omformers (12) styreenhed (13) forsynes af den interne styrespænding (U_{int}) ved lukket intern sikkerhedskæde.

8. Vindmølle (2) med en nacelle (4), der er lejret drejeligt på et tårn (3), og en rotor (5), som ved hjælp af en drivaksel (10) er forbundet med en generator, der er monteret i nacellen (4), hvor rotoren (5) omfatter et nav (8) og mindst ét rotorblad (6), hvilket rotorblad (6) er drejeligt forbundet med navet (8) omkring sin bladakse (7), som strækker sig i aksial retning, ved hjælp af et leje, og hvilket rotorblad (6) kan drives af en bladjusteringsindretning (P1, P2, P3) og standses i forskellige indstillingspositioner, **kendetegnet ved, at** bladjusteringsindretningen (P1, P2, P3) er udformet ifølge et eller flere af de foregående krav.

9. Fremgangsmåde til opstart af en vindmølle (2), hvor vindmøllen (2) omfatter en bladjusteringsindretning ifølge et hvilket som helst af kravene 1 til 7, og rotorbladene (6) står i kantstillet position i udgangspositionen, hvilken fremgangsmåde omfatter følgende trin:

- forsyning af bladjusteringsindretningens (P1, P2, P3) omformers (12) styreenhed (13) via en almen ekstern styrespændingsforsyning (U_{ext}),

- opstart af omformeren (12),

- kontrol af omformerens (12) og/eller de yderligere af bladjusteringsindretningens (P1, P2, P3) komponenters funktion gennem bladjusteringsindretningens (P1, P2, P3) styreenhed (13),

- tilkobling af batteriet (21) og netforsyningen (U_N),

- gennemførsel af en funktionskontrol af batteriet (21) og netforsyningen (U_N) gennem justeringsindretningens (P1, P2, P3) styreenhed (13),

- frembringelse af en intern styrespænding (U_{int}) gennem strømforsyningen (25), der er anbragt i omformerens jævnspændingsmellemkreds (27), såfremt ingen fejl findes,

- gennemførsel af en funktionskontrol af den interne styrespændingsforsyning (U_{int}) gennem bladjusteringsindretningens (P1, P2, P3) styreenhed (13),

- skift fra den almene eksterne styrespændingsforsyning (U_{ext}) til den interne styrespænding (U_{int}) og lukning af den interne sikkerhedskæde, hvis den interne styrespændingsforsyning (U_{int}) fungerer korrekt,

- lukning af anlægssikkerhedskæden (1), såfremt bladjusteringsindretningernes (P1, P2, P3) interne sikkerhedskæder er lukket, og møllestyringen (15) melder om driftsklarhed,

- indstilling af signalet i anlægssikkerhedskæden (1) til høj med henblik på at frigive en forladen af den kantstillede position.

10. Fremgangsmåde ifølge krav 9, hvor fremgangsmåden ved normal drift af vindmøllen (2) omfatter følgende trin:

- overvågning af kritiske funktioner af omformeren (12) og/eller bladjusteringsindretningens (P1, P2, P3) komponenter ved hjælp af bladjusteringsindretningens (P1, P2, P3) styreenhed (13),

- afsendelse af bladjusteringsindretningens (P1, P2, P3) tilstand til møllestyringen (15),

ved konstatering af en fejltilstand:

- styring af bladjusteringsindretningerne (P1, P2, P3) ved hjælp af møllestyringen (15) med henblik på at indlede en langsom synkron kørsel i retning af kantstillet position,

- bevaring af bladjusteringsindretningerne (P1, P2, P3) ved den interne spændingsforsyning (U_{int}) under sikkerhedskørslen og i den kantstillede position,

- kontrol af omformerens (12) funktion og/eller bladjusteringsindretningens (P1, P2, P3) komponenter og fornyet startforsøg, hvis alt fungerer korrekt.

11. Fremgangsmåde ifølge krav 9, hvilken fremgangsmåde omfatter følgende trin ved netspændingssvigt:

- tilkobling af batteri (21) til nødforsyning af bladjusteringsindretningen (P1, P2, P3),

- styring af bladjusteringsindretningernes (P1, P2, P3) sikkerhedskørsel ved hjælp af møllestyringen (15),

- afbrydelse af batteriet (21) efter en vis tid ved opnåelse af den kantstillede position og tilslutning af den eksterne almene spændingsforsyning (U_{ext}),

- kobling til ekstern almen spændingsforsyning (U_{ext}), inden tiden udløber, og åbning af anlægssikkerhedskæden (1) ved kritiske fejl,

- kontrol af omformerens (12) og/eller bladjusteringsindretningens (P1, P2, P3) yderligere komponenters funktion og fornyet startforsøg, hvis alt fungerer korrekt.

12. Fremgangsmåde ifølge krav 9, hvilken fremgangsmåde omfatter følgende trin ved kritiske fejl, f.eks. maskinstop i møllestyringen (15) eller kritisk fejl i bladjusteringsindretningen (P1, P2, P3):

- registrering af en fejltilstand ved hjælp af justeringsindretningens (P1, P2, P3) styreenhed (13),

- åbning af den interne sikkerhedskæde i styreenheden (13) og dermed åbning af anlægssikkerhedskæden (1),

- indstilling af signal til lav ved åbning af anlægssikkerhedskæden (1),

- simultan sikkerhedskørsel af bladjusteringsindretningerne (P1, P2, P3) ved modtagelse af det lave signal.

Fig. 1

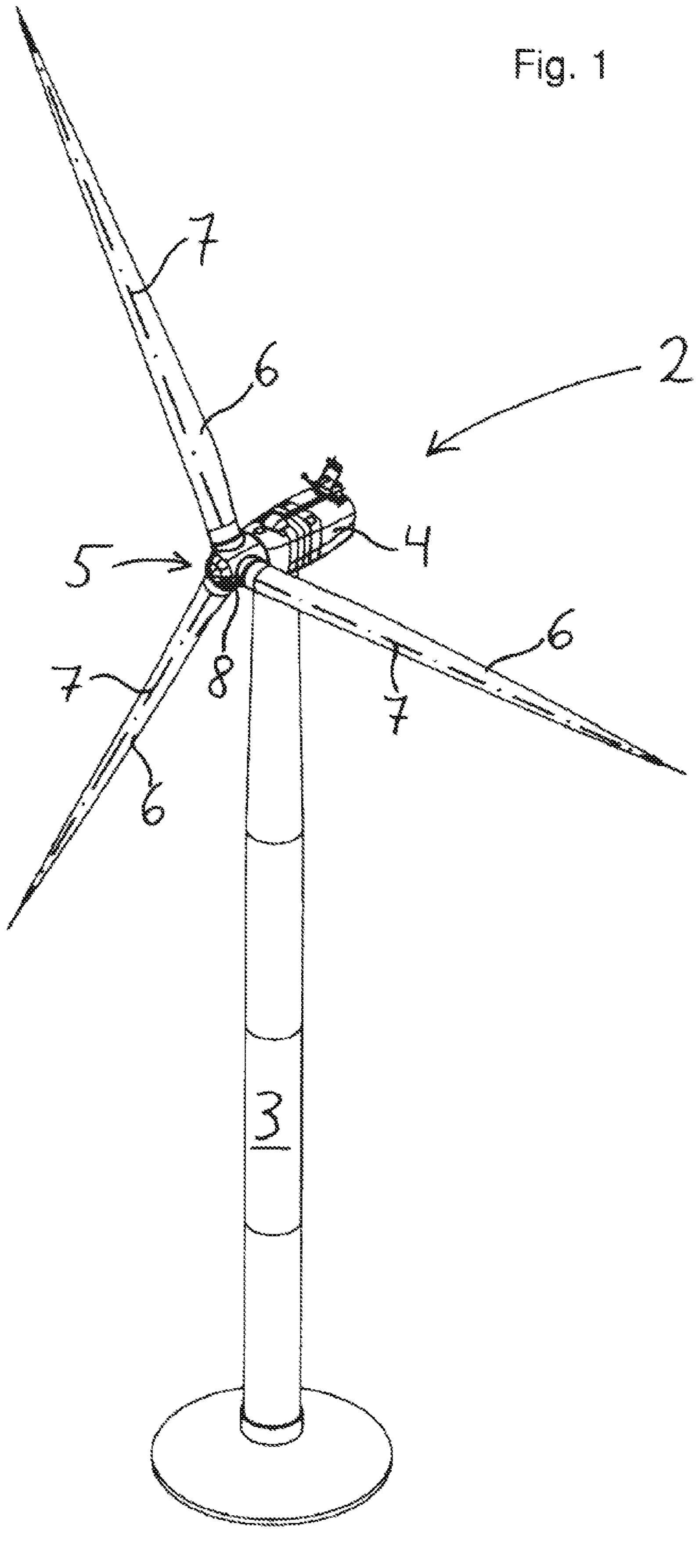

Fig. 2

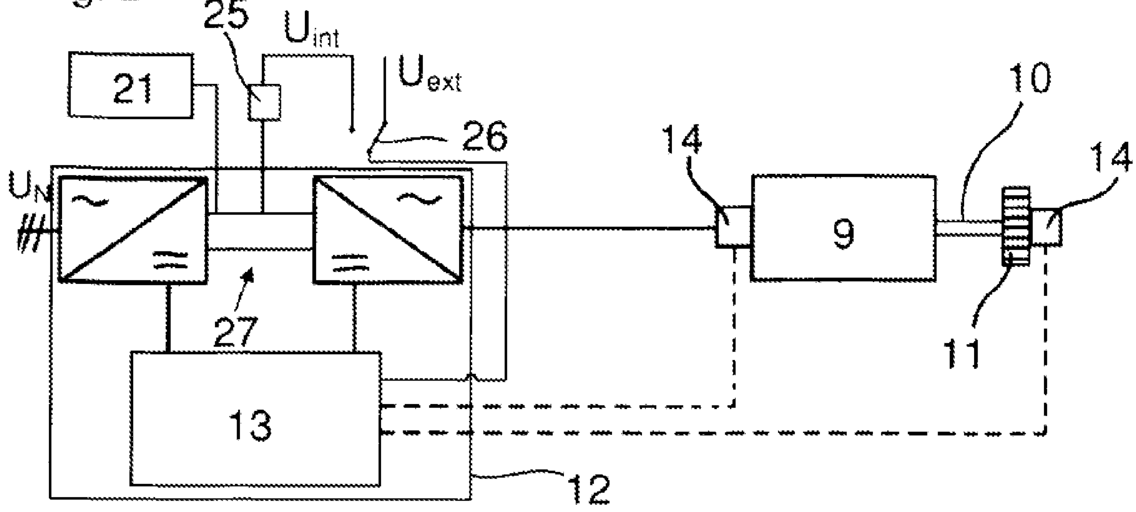
25
U_{int}
21
U_{ext}
26
10
14
14
U_N
9
27
11
13
12

Fig. 3

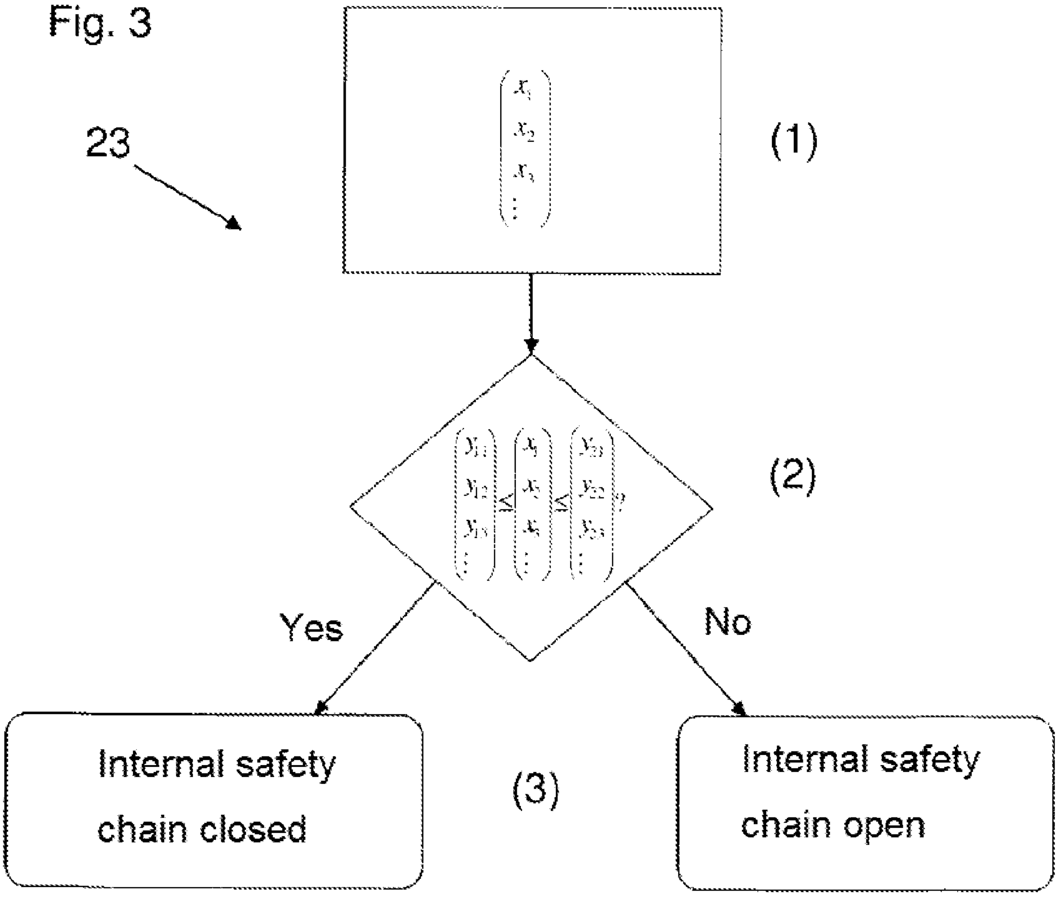
23
(1)
(2)
Yes
No
Internal safety chain closed
(3)
Internal safety chain open

Fig. 4