(19) DANMARK

(10) **DK/EP 3721083 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: ***F 03 D 80/40 (2016.01)*** ***F 03 D 7/02 (2006.01)*** ***F 03 D 17/00 (2016.01)***

(45) Oversættelsen bekendtgjort den: **2022-11-14**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2022-10-26**

(86) Europæisk ansøgning nr.: **18811487.0**

(86) Europæisk indleveringsdag: **2018-11-27**

(87) Den europæiske ansøgnings publiceringsdag: **2020-10-14**

(86) International ansøgning nr.: **EP2018082643**

(87) Internationalt publikationsnr.: **WO2019110364**

(30) Prioritet: **2017-12-07 DE 102017129112**

(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: **Wobben Properties GmbH, Borsigstrasse 26, 26607 Aurich, Tyskland**

(72) Opfinder: **SCHAPER, Ulf, Dorfstraße 26, 27254 Staffhorst, Tyskland**

(74) Fuldmægtig i Danmark: **Zacco Denmark A/S, Arne Jacobsens Allé 15, 2300 København S, Danmark**

(54) Benævnelse: **Fremgangsmåde til drift af et vindenergianlæg**

(56) Fremdragne publikationer:
WO-A1-2004/104412
US-A1- 2014 091 572
US-A1- 2015 035 548

Description

The present invention concerns a method of operating a wind turbine and a corresponding wind turbine.

Below certain temperatures it can happen that icing occurs on the rotor blades of a wind turbine. Such icing or ice accretion is unwanted because that can result in people and buildings in the surroundings of the wind turbine being endangered. In addition icing or ice accretion on the rotor blades of the wind turbine leads to a modified aerodynamic behaviour so that the wind turbine can no longer be operated in the optimum fashion.

WO 2004/104412 A1 describes a method of operating a wind turbine, wherein the temperature in the surroundings of the wind turbine is detected. Operating parameters of the wind turbine are also detected. The outside temperature is checked in the event of a deviation in the detected operating parameters from stored operating parameters. If the outside temperature is below a limit value operation of the wind turbine can be influenced. If the temperature in the region of the wind turbine is above the limit value the stored parameter values can be adapted to the detected parameter values.

Known methods of ice accretion detection on rotor blades of a wind turbine are however inaccurate so that premature shutdown of the wind turbine can occur although the rotor blades of the wind turbine are not coated with ice.

On the German patent application from which priority is claimed the German Patent and Trade Mark Office searched the following documents: DE 10 2005 016 514 A1, DE 10 2016 124 554 A1, US 2011/0 089 692 A1, EP 2 828 161 B1 and WO 2004/104412 A1.Further prior art is disclosed in document US 2014/091572 A1.

An object of the present invention is to provide a method of operating a wind turbine which overcomes the above-described disadvantages. A further object of the present invention is to provide a method of operating a wind turbine which permits effective operation of the wind turbine and effective activation of a rotor blade heating means.

In particular an object of the invention is to ensure reliable restarting of the wind turbine when freedom from ice has been detected.

That object is attained by a method of operating a wind turbine according to claim 1 and by a wind turbine according to claim 8.

According to the invention two different ice detection methods for detecting ice on the rotor blades of the wind turbine are used in parallel. The two ice detection methods can respectively output separate warning signals, by way of which the wind turbine can be stopped in the event of critical icing. When that has occurred the wind turbine can be optionally deiced (if there is a rotor blade heating means) and re-started.

If the second ice detection method is suitable for establishing freedom from ice on the rotor blades then automatic restarting of the wind turbine can be triggered on the basis thereof. That can be necessary in particular with wind turbines which cannot be thawed by a rotor blade heating means. Automatic restarting of the wind turbine by the second ice detection method can also be triggered if the first ice detection method has initially detected or not detected the preceding icing. Restarting however is only possible if the second ice detection method has also previously detected icing. At the same time in accordance with the invention in the event of failure of the second ice detection method operational safety which is provided by the first ice detection method is not restricted. Accordingly ice detection is made possible, which permits stopping and restarting of the wind turbine without endangering the operational safety of the wind turbine.

According to the invention there is provided a method of operating a wind turbine having at least two rotor blades. An outside temperature in the surroundings of the wind turbine is detected. Operating parameters of the wind turbine are detected and the detected operating parameters are compared to stored operating parameter values. A first warning signal or stop signal is output if the detected operating parameters differ from the stored operating parameters and the detected outside temperature falls below a first icing threshold. At least one ice thickness, ice mass and/or surface temperature at at least one location on a surface of the rotor blade is detected and the detected ice thickness, ice mass

and/or surface temperature is compared to a second icing threshold value. A second warning signal is output if the measured ice thickness or ice mass is above the second icing threshold value. Intervention into operation of the wind turbine and/or activation of a rotor blade heating means is effected if the first or second warning signal has been detected. Deactivation of the rotor blade heating means or deactivation of the intervention in the operation of the wind turbine is effected if the at least one detected ice thickness or ice mass is below the second icing threshold value or the surface temperature is above the second icing threshold value and the second warning signal has been previously registered.

Optionally the rotor blade heating means can be activated if the output power falls below a limit value (at a corresponding wind speed). Furthermore the wind turbine can be stopped if the power (at a corresponding wind speed) falls below a second limit value. Optionally the rotor blade heating means can be activated if the ice thickness or ice mass or surface temperature exceed or fall below limit values or established combinations of those criteria are involved.

According to an aspect of the invention deactivation of the rotor blade heating means can be effected in time-displaced relationship after the last occurrence of one of the activation conditions (first or second heating signal).

The invention also concerns a wind turbine having at least two rotor blades. The wind turbine has a first ice accretion detection unit adapted to compare operating parameters of the wind turbine with stored operating parameters and to output a first warning signal if the detected operating parameters deviate from the stored operating parameters and an outside temperature in the region of the wind turbine falls below a first icing threshold value and a second ice accretion detection unit having a plurality of sensors at the rotor blades, wherein surface temperatures and/or ice masses and/or ice thicknesses at the surface of the rotor blade are respectively detected by the sensors. The second ice accretion detection unit has a base station adapted to compare the detected ice masses or ice thicknesses or surface temperatures to a second icing threshold value and to output a second warning signal

if the measured ice masses or ice thicknesses or surface temperatures are respectively above or below a second icing threshold value.

In addition there is provided a control unit adapted in dependence on the first and/or second warning signal to intervene in operation of the wind turbine and/or to activate a rotor blade heating means, wherein the control unit is adapted to deactivate the rotor blade heating means or deactivate intervention in operation of the wind turbine if the ice masses or ice thicknesses or surface temperatures measured by the sensors are respectively below or above the second icing threshold value and the control unit has previously received a second warning signal from the second ice accretion detection unit.

The invention concerns the notion of implementing ice accretion detection redundantly based on two separate ice detection methods. For that purpose according to a first ice detection method an outside temperature in the region of the wind turbine and operating parameters of the wind turbine are detected. The detected operating parameters are compared to stored operating parameters. If the detected operating parameters differ by a predetermined amount from the stored operating parameters and the detected outside temperature in the region of the wind turbine is below a first icing threshold value then a first warning signal can be output. That first warning signal indicates ice accretion at the rotor blades. Independently thereof in accordance with a second ice detection method a surface temperature of the rotor blade, an ice thickness and/or an ice mass is detected at at least one location on the rotor blade. The detected surface temperature, the detected ice thickness and/or the detected ice mass is compared to a second icing threshold value. If the detected temperature is below or the detected ice thickness and/or the detected ice mass is above the second icing threshold value then a second warning signal is output, which can point to icing of the rotor blade. If the first and/or the second warning signal has been detected then intervention in operation of the wind turbine is effected and/or the rotor blade heating means is activated. Intervention in operation of the wind turbine can for example represent a reduction in the speed of rotation of the wind turbine. Deactivation of the intervention in

operation of the wind turbine is effected if the measured surface temperature is above the second icing threshold value and the second warning signal has been previously recorded.

According to an aspect of the invention upon stopping of the installation the first ice detection method can no longer operate. That results in the 'redundancy problem', more specifically the wind turbine cannot unconditionally listen to a restart command by the second ice detection method as the first ice detection method, by virtue of stoppage of the installation, could not contradict that information, that is to say in the event of unconditional restarting there would no longer be redundant ice detection.

Deactivation of the rotor blade heating means or restarting of the wind turbine can thus occur in dependence on the detected surface temperature and/or ice mass and/or ice thickness, only if the detected surface temperature and/or ice mass and/or ice thickness has previously respectively exceeded or fallen below the second icing threshold value. In that way it is possible to ensure that the first monitoring effect based on an icing characteristic cannot be cancelled by monitoring of the surface temperature and/or ice mass and/or ice thickness. This therefore provides a redundant method of detecting ice accretion on the rotor blades of the wind turbine. No redundancy problems occur in regard to control of the rotor blade heating means in normal operation so that the two ice detection methods can simply operate in parallel. The rotor blade heating means is activated if at least one of the systems requires that. The redundancy problem however occurs upon stoppage of the wind turbine as the characteristic-curve method (first ice accretion detection) then fails and can no longer detect icing. In that situation upon a malfunction the second ice accretion detection could trigger restarting without the first system being able to prevent that.

According to an aspect of the present invention there is provided a first detection unit which monitors the operating parameters of the wind turbine and the outside temperature of the wind turbine and can output a first warning signal. A second detection unit detects the surface temperature of the rotor blades and compares that to the second icing

threshold value. The second detection unit can output with the first warning signal a plurality of parameters of the wind turbine and the outside temperature of the wind turbine and can output a first warning signal. A second detection unit detects the surface temperature of the rotor blades and compares that to the second icing threshold value. The second detection unit can output with the first warning signal a plurality of icing levels like for example no icing, minimum icing, moderate icing or severe icing.

Redundant ice accretion detection can be provided with the method according to the invention. According to an aspect of the present invention the second detection unit could output for example four icing levels or stages.

The sensors for detecting the surface temperature of the at least one rotor blade can represent sensors which have been described in EP 2 828 264 B1. The sensors thus have a temperature detection unit, a wireless communication unit, at least one solar cell and an energy storage means. The measured temperatures are then wirelessly transmitted. The photovoltaic cell ensures the power supply for the sensor and the energy storage means ensures that the sensor can be operated even without light. The sensor can output the surface state of the rotor blade for example by four surface states, namely free surface (no icing), a very thin layer of ice or moisture on the rotor blade, a layer of ice of between 1 and 2 mm and a layer of ice of greater than 10 mm.

The invention further concerns the notion of permitting effective ice accretion detection and effective restarting or resumption of operation of the wind turbine if freedom from ice has been detected. In addition rotor blade deicing can be started for example by means of a heating unit. If there is too much ice on the rotor blades the wind turbine can then be stopped. In addition the wind turbine can optionally be shut down if the ice accretion detection units have failed and for example the temperature is negative or in the range in which ice accretion can occur.

The method of operating a wind turbine according to the invention ensures that, if two different ice detection methods are used, a situation does not occur in which an ice detection method detects ice but the other

does not, and the result of that is that the wind turbine is not shut down or the rotor blade heating means is not activated. That applies in particular if one of the ice detection methods can determine freedom from ice.

If freedom from ice can be detected then that can be used to provide that the wind turbine automatically starts up again as soon as the freedom from ice has been signaled.

According to a further aspect of the present invention an ice detection method can be implemented internally in the wind turbine while a further one can be implemented externally. According to the invention this then takes account of what happens if the external ice detection method is defective or defectively signals freedom from ice.

According to an aspect of the present invention the first ice detection method is based on a characteristic-curve method, that is to say a deviation from the normal power curve of the wind turbine is detected and at a corresponding outside temperature ice accretion is assumed to apply. If for example the second ice detection method is defective and signals freedom from ice while according to the first ice detection method it was detected that there is ice accretion, then the first ice detection method can have priority, that is to say signaling of the freedom from ice by the second ice detection method can be ignored. In particular that is achieved by a signal indicating freedom from ice by the second ice detection method being deemed to be permissible only if the second ice detection method has previously detected an ice accretion. If that is not the case it is then to be assumed that the second ice detection method is defective and thus restarting is to be avoided as ice accretion is probably still present on the rotor blades.

According to an aspect of the present invention the second ice accretion detection unit which has a plurality of sensors on a surface of the rotor blades can determine not only the surface temperature but also an ice thickness. That can be effected in particular by capacitive measurement or a change in the frequency of oscillation of the rotor blade. In other words the ice thickness is determined by a change in capacitance.

According to an alternative aspect of the present invention the second ice accretion detection unit can have a plurality of oscillation sensors detecting the oscillations of the rotor blade. Based on those detected oscillations it is possible for example by a comparison with a threshold value to detect a differing oscillation which in turn can indicate an ice accretion.

According to an aspect of the present invention for controlling the blade heating means it is possible to have recourse to the information from the sensors of the second ice accretion detection unit, more specifically the surface temperature and the ice thickness.

According to the invention rotor blade heating can be effected on the basis of the detected surface temperature and/or based on the detected ice thickness.

According to a further aspect of the present invention the detected surface temperatures and/or the detected ice thicknesses can be stored in order possibly to evaluate them later.

Further configurations of the invention are subject-matter of the appendant claims.

Advantages and embodiments by way of example of the invention are described in greater detail hereinafter with reference to the drawing.

Figure 1 shows a diagrammatic view of a wind turbine according to an embodiment of the invention,

Figure 2 shows a block circuit diagram of the ice accretion detection units and the control unit of the wind turbine, and

Figure 3 shows a block circuit diagram of the second ice accretion detection unit.

Figure 1 shows a diagrammatic view of a wind turbine according to an embodiment of the invention. The wind turbine 100 has a tower 110, a pod 120 and a plurality of rotor blades 130. The rotor blades 130 are connected to the rotor 190 and drive the aerodynamic rotor 190 in rotation if there is sufficient wind. The rotor 190 is coupled to an electric generator, the rotor of which is driven in rotation by rotation of the aerodynamic rotor so that electric power is generated. The wind turbine has a blade adjustment unit 140, by means of which the blade angles or

pitch angles of the rotor blades 130 can be adjusted. In addition there can optionally be a pod control cabinet 150 in the pod 120, by means of which the components of the wind turbine in the region of the pod can be controlled. A control cabinet 170 can be provided in the region of the base of the tower 110, the cabinet 170 having electronic power components in order to deliver the electric power generated by the generator 180 to an external power supply network.

According to the invention two different ice detection methods for detection of ice on the rotor blades 130 of the wind turbine 100 are used in parallel. The two ice detection methods can respectively output separate warning or stop signals, by way of which the wind power can be stopped in the case of critical icing. When that has occurred the wind turbine can be optionally de-iced (if there is a rotor blade heating means) and re-started.

If the second ice detection method is suitable for establishing freedom from ice on the rotor blades automatic re-starting of the wind turbine can be triggered based on an 'ice-free signal'. That may be necessary in particular in the case of wind turbines which cannot be thawed out by a rotor blade heating means. Automatic re-starting of the wind turbine by the second ice detection method can also be triggered if the first ice detection method has first detected the preceding icing. At the same time according to the invention in the event of failure of the second ice detection method the safety factor afforded by the first ice detection method is not nullified. This therefore permits ice detection which enables stoppage and re-starting of the wind turbine without endangering operational safety of the wind turbine.

According to the invention the wind turbine has a first ice accretion detection unit 300 which detects the outside temperature in the region of the wind turbine and operating parameters of the wind turbine and compares the detected operating parameters to stored operating parameters. If the detected operating parameters differ from the stored operating parameters by a predetermined amount and the outside temperature falls below an icing threshold value then a first warning signal can be output. That first ice detection method can only be used when

the rotor is rotating. When the wind turbine is stationary the first ice detection method does not give any results. The function of the first ice detection unit 300 is described in greater detail in WO 2004/104412 A1.

The wind turbine has a second ice accretion detection unit 200 having a plurality of sensors 210 on the rotor blades 130. Those sensors detect a surface temperature of the rotor blade and/or the ice mass and/or the ice thickness and transmit those values to a base station. The function of those sensors is described in detail in EP 2 828 164 B1.

The ice detection accretion unit 200 has a base station 220 and a plurality of antennas or transmission units 230 for detection of the signals transmitted by the sensors 210. In the base station 220 the detected temperature signals are compared to an icing threshold value and a second warning signal can be output if the detected temperature is below the icing threshold value and/or an ice mass and/or ice thickness is above the icing threshold value.

Optionally the sensors 210 can output four different stages or levels indicating differing ice accretion. Those stages or levels can represent no ice accretion, slight ice accretion, moderate ice accretion or severe ice accretion or icing.

The first and second warning signals or the stop signal can be output to the pod control cabinet 150. As soon as the pod control cabinet receives the first or second warning signal it can limit operation of the wind turbine, for example by the rotary speed being reduced or by a rotor blade heating means 160 being activated to heat and thus de-ice the rotor blades.

A redundant ice accretion detection effect can thus be provided with the system according to the invention. Re-starting of the wind turbine or de-activation of the rotor blade heating means can be effected based on the measurement values of the ice accretion detection unit 200 only if that has previously established ice accretion.

Rotor blade heating can also be preventatively actuated to avoid an ice build-up. Such a blade heating effect is also triggered by the ice detection method, in which case lower threshold values and/or other

decision algorithms are used. The signals of the two ice detection methods for activation of the rotor blade heating means during operation of the turbine can represent a first heating signal and a second heating signal.

The second ice detection method can be based on spot-wise ice thickness measurements at one or more locations on the rotor blade. In that case the measurements can be based on measurement of a capacitance or a capacitance change. Furthermore measurements can optionally be effected in respect of the blade surface temperature. Icing can be established if a high ice thickness threshold value is exceeded at a few locations on the rotor blade or an average ice thickness threshold value is exceeded at many locations on the rotor blade. Freedom from ice can optionally be established if there are a sufficient number of measurement points and the average ice thickness threshold value is nowhere exceeded on the rotor blade.

The blade heating means can be activated if the lowest measured blade surface temperature falls below a threshold value and at the same time a certain proportion of the rotor blade surface exceeds a given ice thickness.

As an alternative thereto ice thickness can also be ascertained based on the change in the rotor blade oscillation characteristic. Acceleration sensors in the rotor blades can measure the rotor blade vibration frequencies. It is possible to conclude that there is an increase in mass (and thus icing) by a comparison of the measured frequencies with stored vibration frequencies in the ice-free state and suitable corrections. An increase in mass ascertained in that way (= ice mass) is compared to different limit values, from which icing signals (warning signals), ice-freedom signals (re-starting signals) and rotor blade heating signals can be produced.

Figure 2 shows a block circuit diagram of the ice accretion detection units and the control unit of the wind turbine. In particular the first and second ice detection accretion units 300, 200, the control unit 150 of the wind turbine and the rotor blade heating means 160 are shown.

The first ice accretion detection unit 300 receives for example the currently prevailing power of the wind turbine, the wind speed and for example a temperature in the region of the wind turbine. The first ice accretion detection unit 300 can output either critical icing 301 or a beginning of icing 302. The signal of critical icing 301 is output to the control unit 150 and the signal of a beginning of icing 302 is output to the rotor blade heating means 160.

Figure 3 shows a block circuit diagram of the second ice accretion detection unit. The second ice accretion detection unit 200 optionally delivers three different output signals, namely critical icing 201, freedom from ice 203 and the beginning of icing 202. The critical icing 201 and the freedom from ice 203 are output to the control unit 150 and the signal in respect of the beginning of icing 202 is output to the rotor blade heating means 160. The control unit 150 serves to control the wind turbine and in particular can start or stop the wind turbine. It further serves to control the rotor blade heating means. Starting of the wind turbine is enabled by the control unit 150 if a signal 203 in respect of freedom from ice is received.

The second ice accretion detection unit 200 has a first detection unit for detecting critical icing 204, a second detection unit for detecting freedom from ice 205 and a third detection unit 206 for determining a beginning of icing. The first detection unit 204 receives the ice thickness signals D1-D3 from the sensors S1-S3 and on the basis of those data ascertains whether there is or is not critical icing. If thick layers have been detected on the sensors that can only represent a thick layer of ice so that the signal 201 is output.

The second detection unit 205 also acquires the ice thickness signals of the sensors. When there are no layers or if the ice thickness is slight or is below a threshold value then it can be assumed that there is freedom from ice and an ice freedom signal 203 is output.

The third detection unit 206 serves for control of the rotor blade heating means. In that respect in particular the ice thickness measure-

ment and temperature measurement are taken into consideration. Furthermore the position of the sensors can optionally also be taken into account.

In particular only those sensors which are at a mounting position which can be influenced by the rotor blade heating means can be evaluated.

The second ice accretion detection unit 200 can be activated if the mode of operation of the first ice accretion detection unit 300 is restricted by virtue of meteorological conditions, for example on the basis of excessively low or excessively high wind speed, in particular situations like great wind shear or slope flow.

Patentkrav

1. Fremgangsmåde til drift af et vindenergianlæg, der har mindst to rotorvinger, med trinnene:

at udføre en første isdetekteringsfremgangsmåde ved hjælp af en første isbelægningsdetekteringsenhed (300),

at afgive et første advarselssignal, når der ved hjælp af den første isdetekteringsfremgangsmåde detekteres en isbelægning på en af rotorvingerne (130), der overskrider en første tærskelværdi,

at udføre en anden isdetekteringsfremgangsmåde ved hjælp af en anden isbelægningsdetekteringsenhed (200),

at afgive et andet advarselssignal, når der ved hjælp af den anden isdetekteringsfremgangsmåde detekteres en isbelægning på en af rotorvingerne (130), der overskrider en anden tærskelværdi,

at afgive et frigivelsessignal, når der ved hjælp af den anden isdetekteringsfremgangsmåde detekteres isfrihed på de mindst to rotorvinger (130),

at intervenere i driften af vindenergianlægget ved hjælp af en styreenhed (150), når det første eller andet advarselssignal er registreret; og

at deaktivere interventionen i driften af vindenergianlægget ved hjælp af styreenheden (150), når styreenheden (150) modtager frigivelsessignalet og forinden har modtaget det andet advarselssignal.

2. Fremgangsmåde til drift af et vindenergianlæg ifølge krav 1, hvor:

udførelsen af den første isdetekteringsfremgangsmåde omfatter følgende trin:

at registrere en udetemperatur i vindenergianlæggets omgivelser ved hjælp af den første isbelægningsdetekteringsenhed (300),

at registrere driftsparametre af vindenergianlægget ved hjælp af den første isbelægningsdetekteringsenhed (300),

at sammenligne de registrerede driftsparametre med gemte værdier af driftsparametrene ved hjælp af den første isbelægningsdetekteringsenhed (300), og

at afgive et første advarselssignal, når de registrerede driftsparametre afviger fra de gemte driftsparametre, og den registrerede udetemperatur falder til under en første tilisningstærskelværdi.

3. Fremgangsmåde til drift af et vindenergianlæg ifølge krav 1 eller 2, hvor udførelsen af den anden isdetekteringsfremgangsmåde omfatter følgende trin:
at registrere en istykkelse eller ismasse af en isbelægning på de mindst to rotorvinger (130) på mindst et sted på en overflade af rotorvingen ved hjælp af den anden isbelægningsdetekteringsenhed (200),
at sammenligne den mindst ene registrerede istykkelse eller ismasse med en anden tilisningstærskelværdi ved hjælp af den anden isbelægningsdetekteringsenhed (200),
at afgive et andet advarselssignal, når den registrerede istykkelse eller ismasse ligger over den anden tilisningstærskelværdi, og
at afgive frigivelsessignalet, når der ikke er registreret nogen istykkelse, eller når den registrerede istykkelse eller ismasse ligger under en tærskelværdi.

4. Fremgangsmåde til drift af et vindenergianlæg ifølge et af kravene 1 til 3, med trinnene:
at registrere mindst en overfladetemperatur ved hjælp af den anden isbelægningsdetekteringsenhed (200) på de steder på rotorvingens overflade, hvorpå en rotorvingeopvarmning kan medføre en opvarmning af overfladen på disse steder.

5. Fremgangsmåde til drift af et vindenergianlæg ifølge krav 3, hvor
den første isbelægningsdetekteringsenheds (300) første advarselssignal påpeger en kritisk tilisning af rotorvingen eller en begyndende tilisning af rotorvingen,
hvor den anden isbelægningsdetekteringsenheds (200) andet advarselssignal påpeger en kritisk tilisning, og
hvor frigivelsessignalet påpeger isfrihed af de mindst to rotorvinger.

6. Fremgangsmåde til drift af et vindenergianlæg ifølge et af kravene 1 til 5, hvor
der aktiveres en rotorvingeopvarmning, når det første og/eller andet advarselssignal påpeger en begyndende tilisning.

7. Fremgangsmåde til drift af et vindenergianlæg ifølge et af kravene 1 til 6, med trinnene:
at aktivere den anden isbelægningsdetekteringsenhed (200), når den første isbelægningsdetekteringsenheds (300) funktionsmåde indskrænkes på grund af meteorologiske betingelser.

8. Vindenergianlæg med
mindst to rotorvinger (130),
en første isbelægningsdetekteringsenhed (300), der er udformet til at udføre en første isdetekteringsfremgangsmåde og afgive et første advarselssignal, når der registreres en isbelægning på en af rotorvingerne (130), der overskrider en første tærskelværdi,
en anden isbelægningsdetekteringsenhed (200), der er udformet til at udføre en anden isdetekteringsfremgangsmåde, afgive et andet advarselssignal, når der ved hjælp af den anden isdetekteringsfremgangsmåde detekteres en isbelægning på en af rotorvingerne (130), der overskrider en anden tærskelværd, og afgive et frigivelsessignal, når der detekteres isfrihed på de mindst to rotorvinger (130), og
en styreenhed (150), der er udformet til afhængigt af det første og/eller andet advarselssignal at intervenere i driften af vindenergianlægget, og at deaktivere interventionen i driften af vindenergianlægget ved hjælp af styreenheden (150), når styreenheden (150) modtager frigivelsessignalet og forinden har modtaget det andet advarselssignal.

9. Vindenergianlæg ifølge krav 8, hvor
den anden isbelægningsdetekteringsenhed (200) omfatter en flerhed af sensorer (210) på rotorvingernes (130) overflade, der ved hjælp af en kapacitiv målefremgangsmåde registrerer en istykkelse på rotorvingerne (130).

10. Vindenergianlæg ifølge krav 8, hvor
den anden isbelægningsdetekteringsenhed (200) omfatter mindst en svingningssensor, der registrerer en svingning af en rotorvinge,

hvor den anden isbelægningsdetekteringsenhed (200) er udformet til baseret på den registrerede svingning af rotorvingen eller på en svingningsændring af rotorvingen et bestemme en istykkelse af isbelægningen eller isfrihed.

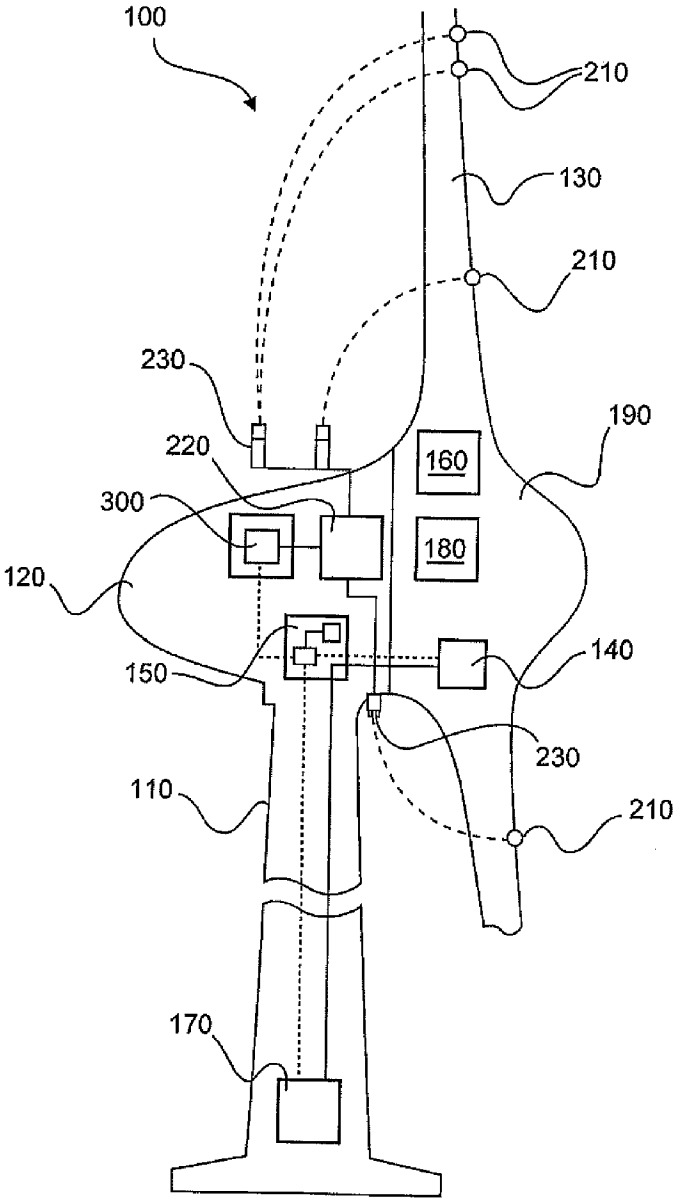

100
210
130
210
230
190
220
160
300
180
120
140
150
230
110
210
170

Fig. 1

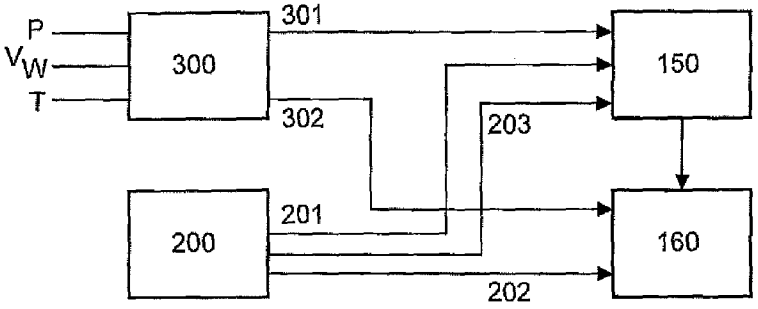

P
V_W
T
300
301
302
150
203
200
201
202
160

Fig. 2

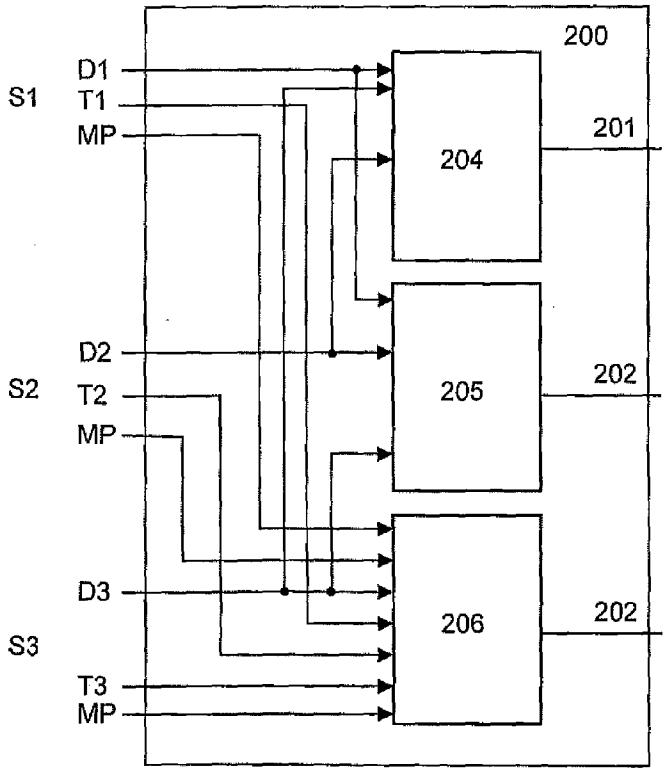

200
D1
S1
T1
MP
204
201
D2
S2
T2
MP
205
202
D3
S3
T3
MP
206
202

Fig. 3