(19) DANMARK

(10) DK/EP 2636893 T3

(12) Oversættelse af europæisk patentskrift

Patent- og Varemærkestyrelsen

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

(45) Oversættelsen bekendtgjort den: **2016-11-28**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2016-08-31**

(86) Europæisk ansøgning nr.: **12158421.3**

(86) Europæisk indleveringsdag: **2012-03-07**

(87) Den europæiske ansøgnings publiceringsdag: **2013-09-11**

(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**

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(54) Benævnelse: **Fremgangsmåde til styring af driften af en vindmølle**

(56) Fremdragne publikationer:
EP-A2- 2 233 736
WO-A2-2008/131775
WO-A2-2008/131778
US-A1- 2007 018 457

DESCRIPTION

[0001] The invention relates to a method to control the operation of a wind turbine above a certain wind speed threshold value. The invention even relates to a wind turbine, which is prepared and designed to execute this method.

[0002] A wind turbine and its components are designed to withstand and to cope with high wind speeds. The wind turbine might be exposed to a wind speed, which is higher than 25 m/s for example. This wind speed is known by wind turbine manufacturers as a typical "wind speed threshold value".

[0003] Quite high mechanical loads are acting on the wind turbines components if a given wind speed threshold value is reached and even topped.

[0004] It is known to change the pitch angle of the rotating wind turbine blades until a so called "feathered position" of the blades is reached if the measured and averaged wind speed reaches the threshold value. Thus the wind load, which is acting on the blades, is reduced and thus a (fatigue) load is avoided.

[0005] It is even known to disconnect the wind turbine from the electrical grid if a so called "high wind situation" with a high wind speed is reached at the site of the wind turbine.

[0006] As a drawback electrical energy and thus money is lost for the wind turbine operator if the wind turbine is close to this limiting operational range.

[0007] Document EP 0 847 496 B1 describes another solution if the "high wind situation" is reached.

[0008] According to the method described the nominal output power of the wind turbine as well as the rotational speed of the rotor are continuously reduced if a certain wind velocity is reached. Thus an overload of the wind turbine and its components are avoided. The continuous reduction of the output power and of the rotational speed of the rotor is done in dependency of the rise in the wind velocity. During the procedure the wind turbine stays connected with the grid. Thus the disconnection of the wind turbine is avoided or is at least delayed. As electrical power is still fed into the grid financial losses are minimized or even avoided.

[0009] There is a drawback, which is related to this method as described in EP 0 847 496 A. There always will be situations with a wind speed threshold being reached, while the wind turbine and its components are not endangered by fatigue loads at the same time.

[0010] According to the EP 0 847 496 A the wind turbine would reduce the rotational speed and even the electrical output power thus potential produced output power is lost for the operator unnecessarily. Thus in those situation the method is not cost-effective.

[0011] Document EP 1497556 B1 discloses another control method, where the power output of the turbine is regulated. The rotor speed is regulated within a predefined wind speed range by varying the rotor blade angle. The output power is reduced in excess of a defined wind-speed-dependent threshold value, while a defined rotor blade limiting angle is used as threshold value.

[0012] Other attempts to operate wind turbines in high wind speed situations are described in WO2008131775 A, WO2008131776 A and WO 2008131778A.

[0013] Document US 2007/0018457 A1 discloses a method of operating a wind turbine. The method comprises a step of reducing the rotor speed and/or the generator power in response to one or more variables exceeding predetermined value(s). That said variable(s) belong(s) to the group consisting of the wind direction relative to the horizontal direction of the main shaft of the turbine and the turbulence of the wind, as sensed by external sensors, as well as any other variable(s) as sensed by one or more sensors mounted on components of the turbine and sensing a condition of that component.

[0014] It is the aim of the invention, to provide an improved method and to provide an improved wind turbine in view to the prior art documents thus the operation of the wind turbine above a certain wind speed threshold value is allowed in an improved manner.

[0015] This aim is solved by the features of claim 1 and of claim 12. Preferred configurations are addressed by the dependent claims.

[0016] The wind turbine comprises at least a rotor, a pitch-system and a generator. Wind turbine blades of the rotor are driven by the wind, thus the rotor rotates with a specific rotational speed.

[0017] The rotor is coupled with the generator by a rotating shaft for example. Thus the generator is even driven by the wind generating electrical power in dependency of the rotating blades of the rotor.

[0018] The electrical power of the generator is adjusted in its electrical values (i.e. frequency, amplitude, phase angle) and is fed into a grid, which is connected with the wind turbine.

[0019] In a preferred configuration the generator is connected with a converter, while the converter is used to adjust the output power of the generator in view to the requirements of the grid connected.
In another preferred configuration the generator used is a torque controlled generator.

[0020] The rotating blades of the rotor are connected with a pitch system. The pitch system is used to adjust the pitch angle of the blades to the direction of the incoming wind. The pitch angle is adjusted in a way that an optimized amount of wind energy is transformed into rotational speed and generated electrical power.

[0021] According to the invention the wind turbine in view to its overall performance is controlled by a first control loop and by a second control loop.

[0022] The output power of the wind turbine, which is fed into the grid, is controlled by the first control loop.

[0023] The rotational speed of the wind turbine rotor and thus the rotational speed of the rotating wind turbine blades are controlled by the second control loop.

[0024] The first control loop and the second control loop are activated, if predefined certain wind speed threshold values are reached or even exceeded.

[0025] In a preferred configuration the first control loop is activated if a first predefined certain wind speed threshold value is reached or is even exceeded. The second control loop is activated if a second predefined certain wind speed threshold value is reached or is even exceeded, accordingly.

[0026] In a preferred configuration the first predefined certain wind speed threshold value and the second predefined certain wind speed threshold value are the same, they are equal in its value.

[0027] In a preferred configuration the certain wind speed threshold value is defined and well known as those wind speed value, which might lead to damaged wind turbine components of the wind speed value is exceeded.

[0028] For example wind speeds, which are higher than 25 m/s might lead to damaged components. Thus this 25 m/s value might be used as wind speed threshold value.

[0029] The first control loop and the second control loop are activated and operated independently to each other.

[0030] The first control loop is prepared and arranged to influence the output power of the wind turbine, which is fed in the grid.

[0031] The output power, which is fed in the grid, is reduced from a nominal value to a lower value if the wind speed threshold value is reached or even exceeded.

[0032] In a preferred configuration the output power is reduced in dependency of the increasing wind speed. Thus the power reduction might be done in a continuous and proportional manner in view to the continuous and proportional increase of the wind speed.

[0033] In a preferred configuration the pitch position of the blades or an allocated pitch reference value might be used to determine the wind speed. The pitch position as well as the pitch reference value is a function of the wind speed, thus this knowledge, which is already implemented in the wind turbine, might be used for this purpose.

[0034] In a preferred configuration the wind speed is measured by a cup anemometer or by a so called "FT sensor", which

measures the wind speed by an acoustic resonance measurement for example.
The cup anemometer or the sensor might be arranged at the wind turbine or at a meteorological mast, which is allocated to the wind turbine.

[0035] In a preferred configuration the measured wind speed is averaged over a certain predefined time period. Thus the averaged wind speed is used to activate both loops or to operate and control the first control loop.

[0036] The output power of the wind turbine is preferably reduced by the converter, which is arranged between the generator of the wind turbine and the grid.

[0037] The output power of the wind turbine is preferably reduced by the torque controlled generator, if there is one used in the wind turbine.

[0038] In a preferred configuration the wind speed might be determined by monitoring the rotational speed of the turning shaft, which drives the generator.

[0039] The second control loop is prepared and arranged to control the rotational speed of the rotor or of the rotating wind turbine blades.

[0040] The rotational speed is reduced from a nominal value to a lower value if a wind turbulence threshold value is reached or even exceeded.

[0041] The certain wind turbulence threshold value is defined and well known as it is those wind turbulence value, which might lead to damaged components of the wind turbine if it is exceeded.

[0042] In a preferred configuration the rotational speed is reduced in dependency of increasing wind turbulences. Thus the rotational speed reduction might be done in a continuous and proportional manner in view to a continuous and proportional increase of the wind turbulences.

[0043] In a preferred configuration the rotor speed acceleration is monitored, as it is a function of the wind turbulences. Thus this knowledge, which is already implemented in the wind turbine, might be used for this purpose.

[0044] In a preferred configuration wind turbulence values are monitored and averaged over a certain predefined time period. Thus the averaged values are used for the reduction of the rotational speed.

[0045] Now there are different operational modes of the wind turbine according to preferred configurations of the invention:

If the wind speed is below the wind speed threshold value the wind turbine is operated in its known "normal" mode. The first control loop and the second control loop are not activated. The output power of the wind turbine, which is fed in the grid, is optimized in regard to a nominal output power value. The optimization is done in view to the incoming wind and in view to a stable grid and its conditions.

[0046] If the wind speed reaches the wind speed threshold value or even exceeds this threshold value, the first control loop and the second control loop of the wind turbine are activated.

[0047] In this case the output power of the wind turbine is reduced by the first control loop from a nominal value to a lower value as described above.

[0048] If the wind turbulences are below the wind turbulence threshold value the rotational speed of the rotor is kept constant even if the wind speed further increases. This is preferably done by an adjustment of the pitch angles of the blades.

[0049] If the wind turbulences reaches or exceeds the wind turbulence threshold value the rotational speed of the rotor is reduced. This is preferably done by an adjustment of the pitch angles of the blades.

[0050] Thus if a critical wind speed is reached the output power of the wind turbine, which is fed in the grid, is reduced before the rotational speed of the rotor is reduced.

[0051] The invention allows the control of the produced power as well as the control of the rotational speed of the rotor. Both controls are performed in an independent manner thus the usable time period for feeding power in the grid is prolonged.

[0052] The invention allows the wind turbine to stay connected with the grid even during high-wind situations in an advantageous manner.

[0053] The invention ensures that wind turbine components are held below their fatigue load limits. Thus the lifetime of the components is not limited by the operation of the wind turbine in high wind situations.

[0054] The invention allows keeping a nominal rotational speed of the rotor and to reduce at the same time the output power of the wind turbine. Thus fewer loads are induced on the wind turbine components (i.e. the blades, the drive-train, the shaft, etc.).

[0055] The invention is shown in more detail by help of FIG 1.

[0056] In a first step S1 the wind speed WS is determined.

[0057] In a second step S2 the wind speed is compared with the wind speed threshold value WST.

[0058] If the wind speed WS is below the wind speed threshold value WST the wind turbine is operated in a normal mode NM as shown in step S3. Thus the output power Pout of the wind turbine, which is fed in the grid GR, is optimized in regard to a nominal output power value of the wind turbine.
The optimization is done in view to the incoming wind and in view to a stable grid and its conditions. The determination of the wind speed WS is continued.

[0059] If the wind speed WS reaches the wind speed threshold value WST or even exceeds this threshold value WST, the first control loop CL1 and the second control loop CL2 of the wind turbine are activated as shown in the step S4.

[0060] As shown in step S5 the output power Pout of the wind turbine, which is fed in the grid GR, is reduced by the first control loop CL1 from a nominal value to a lower value. This is preferably done in dependency to the dynamic behavior or increase of the wind speed WS.

[0061] In step S6 the wind turbulences WT are determined and are compared with the wind turbulence threshold value WTT.

[0062] If the wind turbulences WT are below the wind turbulence threshold value WTT the rotational speed RS of the rotor is kept at a predefined value as shown in step S7.
Thus the rotational speed RS stays constant even if the wind speed WS should increase further. The value of the rotational speed RS is kept constant by an adjustment of the pitch angles of the blades preferably.

[0063] If the wind turbulences WT reaches or exceeds the wind turbulence threshold value WTT the rotational speed RS of the rotor is reduced by the second loop CL2.
This is shown in step S8. This reduction is preferably done by an adjustment of the pitch angles of the blades.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP0847496B1 [0007]
- EP0847496A [0009] [0010]
- EP1497556B1 [0011]

- WO2008131775A [0012]
- WO2008131776A [0012]
- WO2008131778A [0012]
- US20070018457A1 [0013]

Patentkrav

1. Fremgangsmåde til styring af driften af en vindmølle over en vis vindhastighedstærskelværdi,

- hvor der produceres en elektrisk udgangseffekt ved roterende vinger af vindmøllen, og hvor den producerede udgangseffekt tilføres til et net, som er forbundet med vindmøllen,
- hvor vindhastigheden bestemmes og sammenlignes med en vis foruddefineret vindhastighedstærskelværdi,
- hvor vindmøllen styres af et første styre-loop og af et andet styre-loop, som aktiveres, hvis vindhastigheden når eller overstiger vindhastighedstærskelværdien,
- hvor begge styringer udføres på en uafhængig måde,
- hvor det aktiverede første styre-loop styrer udgangseffekten afhængigt af vindhastigheden,
- hvor udgangseffekten af vindmøllen reduceres fra en nominel værdi til en lavere værdi, hvis den bestemte vindhastighed når eller overstiger vindhastighedstærskelværdien,
- hvor det aktiverede andet styre-loop styrer omdrejningshastigheden af de roterende vinger afhængigt af vindturbulenserne,
- hvor vindturbulenser bestemmes og sammenlighes med en vis foruddefineret vindturbulenstærskelværdi,
- hvor rotationshastigheden af de roterende vinger reduceres fra en nominel værdi til en lavere værdi, hvis vindturbulenstærskelværdien nås eller overstiges.

2. Fremgangsmåde ifølge krav 1, hvor udgangseffekten reduceres afhængigt af den stigende vindhastighed.

3. Fremgangsmåde ifølge krav 2, hvor reduktionen af udgangseffekten foretages på en kontinuerlig og forholdsmæssig måde, hvis vindhastigheden stiger på en kontinuerlig og forholdsmæssig måde.

4. Fremgangsmåde ifølge krav 1,

- hvor en pitchposition af vingerne eller en allokeret pitchreferenceværdi anvendes til at bestemme vindhastigheden, eller

- hvor vindhastigheden måles med et skålanemometer eller en FT-sensor, eller
- hvor vindhastigheden bestemmes ved overvågning af rotationshastigheden af en aksel, der driver vindmøllegeneratoren.

5. Fremgangsmåde ifølge krav 1, hvor der beregnes et gennemsnit af vindhastigheden over et vist foruddefineret tidsrum, før den anvendes til at aktivere både det første og det andet styre-loop.

6. Fremgangsmåde ifølge krav 1, hvor vindturbulenstærskelværdien defineres som den vindturbulensværdi, der fører til beskadigede komponenter i vindmøllen, hvis den overskrides.

7. Fremgangsmåde ifølge krav 1, hvor rotationshastigheden reduceres afhængigt af stigende vindturbulenser.

8. Fremgangsmåde ifølge krav 7, hvor rotationshastigheden reduceres på en kontinuerlig og forholdsmæssig måde, hvis vindturbulenserne stiger på en kontinuerlig og forholdsmæssig måde.

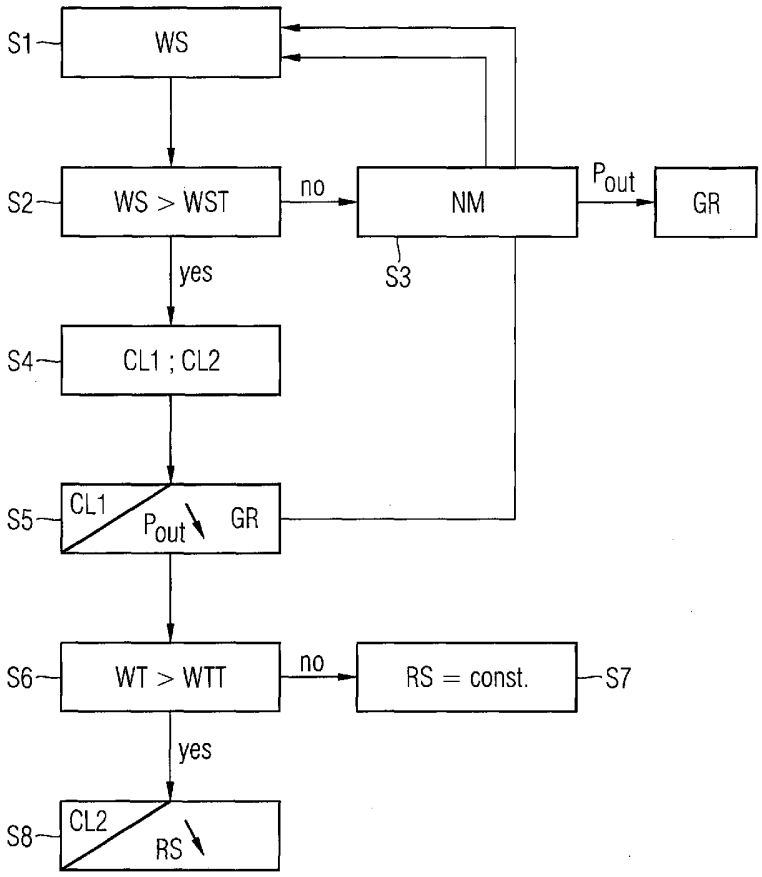
9. Fremgangsmåde ifølge krav 1, hvor accelerationen af de roterende vinger eller rotorhastigheden overvåges som en funktion af vindturbulenserne.

10. Fremgangsmåde ifølge krav 1, hvor vindturbulensværdierne overvåges, og der beregnes et gennemsnit af vindturbulensværdierne over et vist foruddefineret tidsrum, før de anvendes af det andet styre-loop.

11. Fremgangsmåde ifølge krav 1,
- hvor rotationshastigheden holdes konstant, hvis vindturbulenserne er under vindturbulenstærskelværdien, og
- hvor rotationshastigheden reduceres, hvis vindturbulenserne når eller overstiger vindturbulenstærskelværdien.

12. Vindmølle, som er klargjort til styring af driften af vindmøllen over en vis vindhastighedstærskelværdi, omfattende midler, der er indrettet og klargjort til at udføre fremgangsmåden ifølge et af kravene 1 til 11.

DRAWINGS


S1
WS
S2
WS > WST
no
NM
Pout
GR
S3
yes
S4
CL1 ; CL2
S5
CL1
Pout
GR
S6
WT > WTT
no
RS = const.
S7
yes
S8
CL2
RS