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(54) Benævnelse: **VINDENERGIANLÆG MED FORBEDRET TILRÅDIGHEDSSTILLELSE AF EFFEKTRESERVE**

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Description

The invention relates to a wind turbine and a method for providing a power reserve. A generator of the wind turbine driven by a wind rotor delivers electrical power. Its operation is monitored by a controller which comprises an input for a desired power reduction.

With the rising significance of wind turbines in the generation of electrical power in an electric network, the requirements of the wind turbines to provide system services for the power network are also rising. In addition to a provision of reactive power, the system services also include the provision of reserve power in order to be able to feed additional energy into the network at short notice when requested by the network operator. Two particular difficulties occur here with wind turbines. Wind turbines are, namely, usually operated in such a way that they generate the maximum possible power from the available wind. On the other hand, the power generated by the wind turbine depends from the adventitious strength of the wind, and can thus not be deliberately changed or increased. The dependency on the wind strength is particularly marked when the wind turbine is operating under partial load, since in this case all of the available wind is already being converted into electric power - an increase is not possible if the wind conditions are unchanged.

In full-load operation, on the other hand, wind is blowing that is sufficiently strong to potentially allow more power, but the wind turbine is already delivering its rated power, and can therefore not increase the power output.

Different approaches have become known in order nevertheless to call on wind turbines also for the provision of additional reserve power. A first approach is that of using the kinetic energy stored in the wind rotor and the rotating part of the drive train to provide a so-called control power, active for a very short time. Specifically, this slows the rotor, so that the kinetic energy released here can be delivered as additional electric power (WO 2005/025026 A1). This concept, however, only functions for the very short-term provision of additional power, since the wind rotor quickly loses speed and the wind turbine consequently delivers less power than before.

Enabling wind turbines to deliver sustained additional power by operating them regularly with a suboptimal setting is furthermore known (Prillwitz, F. et al.: Primärregelung mit Windkraftanlagen, ITG-Workshop "Neue dezentrale Versorgungsstrukturen", February 2003, Frankfurt/Main). It is thus proposed, particularly when operating at partial load where conventionally, to generate maximum power, the wind turbine is operated with an optimal blade angle, that the blade angle is given an offset so that the optimal value is abandoned. The wind turbine thus generates less power than it could in principle under the given wind conditions (reduced operation). When, in case of need, additional reserve power should be delivered, the offset is reduced and the blade angle returned to its optimal value. This concept offers the advantage that, in principle, it is suitable for continuous operation, and the wind turbine can thus provide reserve power continuously. An extension of this concept is that of implementing a unique characteristic for different planned reserved powers (DE 10 2011 081 795 A1). The concept described, however, provides no indications as to how the transition behaviour, which is important to stable operation, between reduced and non-reduced operation can be configured favourably.

A further concept for the sustained provision of reserve power by means of a suboptimal blade angle is described in WO 2010/000648 A2. The power delivered by the wind turbine can be restricted by a selectable amount. The selectable amount can be a fixed power value or a percentage proportion. The document does not concern itself with the aspect of improving the transition behaviour. If, starting from an available power determined at runtime, a pitch angle is to be determined for the deliberate reduction of the power delivered, then the problem first arises of determining the available power with enough precision. The "reduction pitch angle" determined in this way will, furthermore, vary continuously. This, however, would result in a continuous activity of the pitch actuator. A significantly increased wear of the results A further example from the prior art is known from EP2270332.

On the basis of the last-mentioned prior art, the invention is based on the object of providing a wind turbine and a method for its operation that achieves an improvement in the provision of reserve power, to be precise in particular with regard to conserving the wind turbine.

The solution according to the invention is found in the features of the independent claims. Advantageous developments are the objects of the dependent claims.

A method is provided for providing a power reserve when operating wind turbines, which have a generator, which is driven by a wind rotor and is intended for delivering electrical power, and also a controller for it, which has a first characteristic for a relationship between the tip-speed ratio of the wind rotor and the blade angle of the rotor blades and also an input for a desired power reduction, wherein an implementation of a second characteristic with different blade angles for suboptimal operation, so that a predetermined power reduction is achieved, using the second characteristic for the control of when reserve power (standby operation) is to be provided, and a calculation of the pitch angle by means of a mixture of the first characteristic of the second characteristic when reserve power is requested (active operation) are provided. The cross-fading is provided here in that the calculated values are weighted nonlinearly in relation to one another, the weighting depending nonlinearly on the reserve power requested.

Advantages going far beyond a simple, gradual cross-fading are achieved in this way. This is because the non-linear dependency of the weighting on the requested reserve power takes into account the fact that the power coefficient of the rotor also depends nonlinearly on the blade angle. Preferably, the relationship between reserve power and weighting is, as accurately as possible, the inverse of the relationship between blade angle and rotor power. In this way it is even made possible that arbitrary points in the non-linear characteristic of the rotor power can only be approached with the aid of two characteristics and a weighting function. The invention also entails advantages in terms of a reduction of the required memory space and the computing time. This can, furthermore, be provided with a rapid provision of reserve power.

This is based on the idea that the wind turbine can be designed optimally for the reserve operation by means of the second characteristic, and further that by means of a special mixing of characteristics, the cross-fading behaviour between reduced and non-reduced operation is improved, in order to ensure an operation of the wind turbine that protects material. As a result, no attention needs to be paid to the cross-fading behaviour when designing the second characteristic, and it can be optimized purely for continuous operation. The invention provides a mixing of both characteristics for a smooth transition behaviour in the event, for example, of a request for reserve power in the active range. A gradual cross-fading can be achieved with this, resulting in a harmonic, step-less transition.

The improved transition behaviour leads to smoother running, whereby a reduction in the pitch activity, in particular when changing from reduced to non-reduced operation, can result. The gentler operation of the drive train resulting from the improved transition behaviour is particularly advantageous for high-power turbines, as are typically provided for offshore operation. This is because on the one hand these turbines, due to their high power, are susceptible to additional, parasitic loads, and on the other hand these turbines are expensive to maintain due to the difficult access. A protection thanks to the improved behaviour according to the invention is of particular significance for precisely such turbines.

It is a further advantage of the invention that it achieves the advantageous effect with little expense, while in particular there is no requirement for either additional hardware or computing models that are complicated to parameterize. In the majority of cases it is sufficient to appropriately supplement the program controller that is already present. The invention thus also opens the way to the retrofitting of older wind turbines that are already installed.

A particularly expedient form of embodiment for the non-linear cross-fading is found in a root function, in particular a square root function. This can be explained with reference to an example: If, for example, a provision of 50% of the reserve power that is held ready is requested, the pitch angle to be set for this purpose is calculated from the square root of 0.5, corresponding to the 0.707 times the second characteristic (reserve operation) and the complementary value of 1 - (square root of 0.5), corresponding to 0.293 times the first characteristic (non-reduced operation).

The value for the power reduction can be conveyed as a quota, in particular in the form of a percentage value of the delivered power. This ensures that the power reserve is a controlled and appropriate ratio of the available wind power of the wind turbine. The risk of overloading through the specification of too high a power reserve when the wind conditions are only weak is thus counteracted. Alternatively, a fixed value can be stated for the power reserve.

It is further expediently provided that an oversized desired power reduction is established, wherein, "oversized" refers to a value of at least 50% of the rated power of the wind turbine. This makes it possible to regulate the wind turbine down through a corresponding oversized power reduction, in particular in the case in which overfrequency occurs.

It is fundamentally the case that the second characteristic is specified depending on the size of the power reserve provided. It can happen in this way that, for each power reserve that is set, an own, further characteristic of its own is determined. It is, however, simpler and entirely adequate if, for a plurality of different power reserves, a characteristic is determined for only one of them, and an interpolation is carried out appropriately for the other power reserves. The effort when setting the second characteristic for the reduced operation can be reduced in this way, and an adequately smooth operating behaviour and harmonic transition behaviour is nevertheless achieved with the method according to the invention thanks to the non-linear cross-fading.

The characteristics are advantageously implemented in the form of a lookup table. Only a few fixed points may be sufficient in some cases to model the non-linear weighting function provided according to the invention. If necessary, linear interpolation can be performed between the fixed points without the non-linear relationship of the weighting being entirely lost as a result. It is, however, also possible for a direct calculation from functions to be provided instead of the lookup table.

The method advantageously provides that a signal for the request for reserve power is applied from outside, in particular from a farm master. A central control of the reserve power can be achieved in this way. This is particularly advantageous for the operation of the wind turbines in a windfarm. Since, however, a communication failure is also possible, so that no parameters from outside are then applied for the requested reserve power, a local value storage is advantageously provided. Thus even in the event of a communication failure, it is possible to continue the method on the basis of the last value. A plurality of the past values is expediently stored, so that a mean value signal can advantageously be formed from them. Thanks to the averaging, this enables a smoother mode of operation in the event of a communication failure.

The control for the delivery of reserve power can be performed centrally, so that a corresponding signal - as already explained - is applied to the wind turbine from outside. This is particularly advantageous for the operation of the wind turbines in a windfarm. It has been found beneficial, particularly in the case of a windfarm, if only some of the wind turbines in the farm are adjusted for the output of the reserve power rather than all of them.

A value for a maximum power is, furthermore, advantageously applied to the controller. This value can, in particular, be such a value for a power limit, as is prescribed within the windfarm. In addition to the reduction, such a power limit is expediently taken into account for the power reserve to be held ready. The setpoint value for the power resulting from the power limitation can in appropriate cases be compared with a setpoint value applied from outside, wherein the minimum of the two values is then used.

Alternatively or in addition it can, however, also be provided that the maximum value is prescribed from outside, in particular at the higher-level control centre or network control centre. This is, in particular, a so-called "reduced farm setpoint value", with which the external centre (in particular the network control centre) prescribes a power limitation to the farm. The prescription of a power reserve is unaffected by this, so that it can nevertheless be called up if needed. In this case, the setpoint value for the farm power is also to be correspondingly reduced by the value for the power reserve to be held ready, so that additional reserve power can be fed in if necessary. The power reduction prescribed from outside is normally retained here. The possibility that in case of need the external power reduction is removed in order thus to further increase the reserve power to be made available should not, however, be ruled out. Expediently, in the case of a power reduction, only a proportion of the wind turbines of the windfarm are preferably correspondingly operated in a reduced manner, preferably those that or already in full-load operation. An unnecessary loading of the wind turbines that are operating at partial load is thus avoided with this regulation function.

A static module which determines the value for the power reserved to be held ready on the basis of a network frequency is preferably provided. A value for the power reserved to be held ready at the nominal net frequency provides the starting point. At underfrequency this value is continuously reduced if the frequency falls below the lower limit of tolerance band around the nominal net frequency, to be precise until the power reserve is zero. At overfrequency, that is to say at a frequency above the upper threshold value for the tolerance band, the power reserve to be held ready is significantly increased, to be precise to values of more than 50% of the rated power of the wind turbines, so that an effective power reduction is achieved in the event of the occurrence of overfrequencies. If, in spite of the significant power reduction, the frequency rises further, the wind turbine is expediently disconnected from the network.

The invention furthermore extends to a method for operating a windfarm comprising a plurality of wind turbines, as described above. Refer to more detailed explanations or the description above.

The invention further relates to a wind turbine or to a windfarm provided with corresponding wind turbines. For a more detailed explanation, refer to the description of the method.

The invention is explained in more detail below with reference to the attached drawing in which an advantageous exemplary embodiment is illustrated. Here:

Fig. 1 shows a schematic view of a wind turbine according to one exemplary embodiment of the invention;

Fig. 2 shows a block diagram of a power reduction module for the wind turbine according to Figure 1;

Fig. 3 shows a detailed view of a cross-fading module of the power reduction module according to Figure 2;

Fig. 4 shows a diagram with two characteristics for pitch adjustment;

Fig. 5 shows a diagram for visualizing the potentials of the power reduction; and

Fig. 6 shows a diagram that represents a segment of a practical case of the power reduction.

A wind turbine, which as a whole is given reference 1, according to an exemplary embodiment of the invention comprises a tower 10 at the upper end of which a nacelle 13 is arranged such that it can pivot in the azimuth direction. A wind rotor 11 on which a plurality of rotor blades 12 are arranged is provided rotatably at a front face of the nacelle 13. It drives a generator 14 with a converter 15 for the generation of electric power via a rotor shaft. A controller 2 for the operation of the wind turbine 1 is further provided in the nacelle 13. The wind turbine 1 is preferably arranged in a windfarm with a plurality of other wind turbines 1, 1′, 1" that are connected to one another and to a farm master 5 via a network 9 internal to the farm. The individual wind turbine 1 is linked here via a connection power 19 into the internal farm network 9. The electric power is delivered and communication signals are also passed from and to the wind turbine 1 or the farm master 5 along this.

The wind rotor 11 comprises a plurality of rotor blades 12. They are arranged adjustably on a hub of the wind rotor 11, so that their blade angle ϕ can be adjusted. The adjustment takes place through turning the rotor blades 12 around the longitudinal axis (shown dashed in Fig. 1) by means of a pitch system 21.

The controller 2 is used for the operation of the wind turbine on the basis of prescribed parameters that are applied directly to the wind turbine 1 or by the farm master 5 or from a higher authority, for example an operator (not illustrated) of a transmission network, connected to the wind turbine 1 or to the windfarm. A limiting unit 3 is provided for the controller 2 according to the invention. As an alternative to the non-central arrangement at the wind turbine 1, the limiting unit 3 can also be provided at the farm master 5 (see the dashed representation of the limiting unit 3’).

Reference is now made to Figure 2 to explain the structure and mode of operation of the limiting unit 3. A prescription element 31, which specifies a power reserve on the basis of particular input parameters, is provided. In the exemplary embodiment illustrated, the reserve is determined depending on a network frequency in the network 9. A value for the frequency actually obtaining in the network 9 is supplied here as the parameter f_i, as is a value for the nominal frequency f_N as a reference parameter. A value for a power reserve (reduction value R_0) to be held available for a nominal frequency f_N is also applied. In the exemplary embodiment illustrated, this is implemented as a lookup table. It includes a plurality of modes that are identified by their respective benchmark figures. A first mode consists of a linear reduction down to a reduction value R_0, and starts at a frequency value significantly below the nominal frequency f_N (fixed point A), with still no reduction, i.e. full power (fixed point A), dropping to a reduction value R_0 that can be set in advance which is achieved at a low underfrequency (fixed point B). The fixed point B marks the lower limit of a tolerance band which extends as far as the frequency value somewhat above the nominal frequency at f_N with an unchanged degree of reduction (fixed point C). At frequencies lying above that, an overfrequency range starts in which the wind turbine 1 further significantly reduces the power delivered down to the reduction value R_1 (fixed point D). If this value is reached, an overfrequency is present that is so significant that the wind turbine is finally switched off.

A value for the reduction power R_P determined in this way by the prescription element 31 is finally output and supplied to a summation node 32. A signal for a power limitation R_D desired (by the farm master 5 or externally) is further applied to the summation node 32, to be precise by a signal line 30. Through combining both values, a value for the current reserve power is output by the summation node 32, and is identified as a degree of reduction r. This value r is not used directly for reducing the mechanical power obtained from the wind by means of the wind rotor 11, but is supplied, according to the invention, to a non-linear mixing module 4.

The mixing module 4 has the purpose of determining a setpoint value for a blade angle ϕ of the rotor blades 12 on the basis of a plurality, illustrated in the exemplary embodiment as two, input signals along with a control signal. It is usually the case that a blade angle ϕ of the rotor blades 12 to be set by the pitch adjusting device is determined depending on a tip-speed ratio λ. The tip-speed ratio λ is defined as the ratio between the circulation speed of the rotor blades 12 (measured at the blade tip) to the speed of the wind acting on the wind rotor 11. Typically, starting from switching the wind turbine on at relatively low wind speeds up to a certain rotor rotation speed (rated rotation speed) the blade angle ϕ is held constant, so that as a result the rotation speed of the wind rotor 11 remains proportional to the wind speed v. Above the rated rotation speed, the blade angle ϕ is continuously adjusted so that the rotation speed n of the wind rotor 11 remains essentially constant (namely at the rated rotation speed). The rotation speed of the wind rotor 11 thus no longer rises in proportion to the wind speed v. The tip-speed ratio λ thus falls as the wind strength increases.

The corresponding characteristic for the relationship between the pitch angle ϕ and the tip-speed ratio λ is illustrated in Fig. 4 (with the solid line) and is implemented in the block 36 (Fig. 2). An estimation element 33 for the tip-speed ratio λ precedes the block 36. It determines a smoothed value for the tip-speed ratio λ, for example on the basis of parameters for the delivered power P, the rotation speed n of the wind rotor 11 and a measure for the currently set blade angle ϕ. From the smoothed tip-speed λ ratio determined in this way by the estimation element 33, which is applied to an input 34 of the characteristic block 36, a setpoint value ϕ' for the blade angle of the rotor blades 12 is determined in a manner known per se. This is made available at an output 38 of the characteristic block 36 and is applied to an input of the mixing module 4.

According to the invention, the same value λ for the smoothed tip-speed ratio is used to determine a second setpoint value ϕ*, to be precise on the basis of a second characteristic. The second characteristic is a reduction characteristic at which a lower power is delivered than with the first characteristic, to be precise lower by the amount of the desired power reserve (expressed by the degree of reduction R_0). The second characteristic, reduced by the degree of reduction R_0, is illustrated with a dashed line in Figure 4. On the basis of this value for the tip-speed ratio λ a second setpoint value ϕ* is determined by means of the block 37 on the basis of the second characteristic, shown dashed, is output at its output 39 and applied to the second input of the mixing module 4. The characteristic implemented in the block 37 is illustrated (with a dashed line) in Fig. 4. The setpoint values ϕ' and ϕ* according to the first and second characteristics respectively are the two values between which the mixing module 4 mixes, to be precise on the basis of the value r for the current degree of reduction applied to it. From this, the mixing module 4 A determines a setpoint value ϕ_S line between the two values ϕ' and ϕ^* for the blade angle.

The mixing module 4 is as illustrated in more detail in Figure 3. The value for the degree of reduction r, which determines the mixing ratio, is applied to its control input 40. Here - as already explained - the two line profiles (according to Fig. 4) are mixed, as shown for the first characteristic in block 36 for normal operation and for the reduced operation with power reserve according to the second characteristic in block 37. The mixing module 4 is designed here such that the two characteristic curves are mixed together in a non-linear ratio. A square root block 41 that determines a square root for the degree of reduction r is provided for this purpose. This square root value is applied by a first signal line 45 to a multiplier acting as a first weighting module 47, at the other input of which the setpoint value, provided by the characteristic block 37, for the reduced pitch angle ϕ^* according to the second, reduced characteristic is applied. This setpoint value is weighted with the factor applied via the signal line 45. This desired value is applied to an input of the summation element 48. The square root value of the reduction ratio r determined by the block 41 is further applied to a compliment element 42 which forms a compliment value by means of calculation of the difference from 1. This complement value is applied via a signal line 44 to a further multiplier that acts as the second weighting element 46. This weights the value made available by the first characteristic block 36 for a pitch angle ϕ' according to the first characteristic. This value weighted in this way is applied to another input of the summation element 48. The summed value $\phi_S(r)$ formed by the summation element 45 is output at an output 49 of the mixing module 4, and finally applied to the pitch controller 21 of the wind rotor 11 as a setpoint value to be set.

The mixing module 4 thus brings about a non-linear cross-fading, i.e. one following a root function, between the characteristic for the normal operation with full power (without reserve) on the one hand and the second characteristic for operation at reduced power, i.e. with reserve made available, on the other hand. If, for example, a reduction value R_0 of 4% is provided for the power reserve (defined by fixed point B in the prescription element 31), then the characteristic is appropriately configured for that in the characteristic block 37. If the frequency in the network 9 lies in the range of the tolerance band (between the fixed points B and C in the prescription element 31), then the degree of reduction for the power delivered by the wind turbine is 4%, so the full reserve is made available. In this case the degree of reduction r is 1, and the pitch angle according to the second characteristic is used alone to determine the setpoint value ϕ_S. If, however, a situation now arises in which a partial mobilization of the reserve is required, for example an underfrequency precisely between the two fixed points A and B, the reduction is halved according to the prescription element 31. The degree of reduction r is thus 0.5. According to the invention, a cross-fade is performed from now on between the two characteristics implemented in the blocks 36 and 37, to be precise in the form of embodiment illustrated, by means of the root function. The pitch angle is determined here according to the reduction characteristic implemented in block 37 of $\sqrt{0.5} = 0.707$ from the reduction characteristic according to block 37, and accordingly, in a complementary manner, $1 - \sqrt{0.5} = 0.293$ from the first characteristic according to block 36. A soft cross-fading is achieved with this non-linear cross-fading using the root function, which particularly takes into account the knowledge that the wind turbine reacts less sensitively at small set angles.

The setpoint value for the pitch angle ϕ_S, determined through the cross-fading according to the invention using the mixing module 4, is applied to the pitch controller 21, which accordingly adjusts the pitch angle ϕ of the rotor blades 12 in the manner known per se.

The operating behaviour achieved with the invention is illustrated in Figures 5 and 6. A requested reduction value R_0 is illustrated in Figure 6 with a solid line. This, however, changes over time, starting from 0% at T = 50 s, and rising up to 2.5% at around T = 320 s, falling again at T = 400 s from this value, dropping again to 0 at T = 700 s. The degree of reduction r actually reached is displayed by means of the dashed line. It can be seen how while there are indeed certain deviations, the degree of reduction actually set nevertheless on average closely follows the set degree of reduction. It is noticeable in particular that the deviations are particularly small at small degrees of reduction. The desired improvement in the transition behaviour is thus achieved, in particular when operating at full-load.

The fundamental concept of the power reduction for the provision of reserve power is shown in Figure 5. A power feed P, which depends on the wind and cannot be planned, of a wind turbine over time t is shown here. It can be seen how the power that can be drawn from the wind and fed in (illustrated with a solid line) varies strongly over time. The provision of reserve power is wanted during each of two time segments, which are indicated by dashed lines in Figure 5. This means that the wind turbine delivers less power (see the dashed line) than it could in principle on the basis of the wind conditions (solid line). The (hatched) region lying between is available as reserve power, and can be made available at any time on demand or on the occurrence of specific parameters (an underfrequency, for example), independently, to be precise, of whether the wind at the time is blowing strongly or weakly.

An input for a requested reduction in the farm power R_E is furthermore provided at the farm master 5. A higher authority, for example an operator of the transmission network, can in this way assign a power reduction to the windfarm from outside. The farm master 5 can accordingly operate the individual wind turbines 1, 1', 1" of the windfarm in a reduced manner, or simply output corresponding, internal reduction signals to the wind turbines 1, 1', 1", to be precise via their input R_D 30. The power reduction is then carried out in the manner described above.

Patentkrav

1. Fremgangsmåde til tilrådighedsstillelse af en effektreserve ved drift af vindenergianlæg (1, 1', 1"), der har en af en vindrotor (11) fremdrevet generator (14) til afgivelse af elektrisk effekt samt en styring (2) derfor, der har en første karakteristik (36) for en sammenhæng mellem vindrotorens (11) hurtigløbetal og dens rotorblades (12) bladvinkel samt en indgang (30) for en ønsket effektreduktion, med trinene

- implementering af en anden karakteristik (37) med afvigende bladvinkler for en suboptimal drift, således at der er nået en forudbestemt effektreduktion, og
- anvendelse af den anden karakteristik (37) for styringen (2), når der skal stilles reserveeffekt til rådighed (tilrådighedsstillelsesdrift),

kendetegnet ved, at

- ved anmodning om reserveeffekt (aktiv drift) beregnes bladvinklen ved hjælp af en blanding af den anden karakteristik (37) og den første karakteristik (36), nærmere bestemt ved hjælp af et blandemodul (4),
- hvor blandingen sker ved en overblænding mellem de to værdier for bladvinklerne på den måde, at de beregnede værdier for bladvinklerne vægtes ikke-lineært i forhold til hinanden, hvor vægtningen afhænger ikke-lineært af den anmodede reserveeffekt.

2. Fremgangsmåde ifølge krav 1, kendetegnet ved, at den ikke-lineære vægtning af de to bladvinkler sker ved hjælp af en rodfunktion, især ved hjælp af en kvadratrodsfunktion.

3. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at den anden karakteristik (37) bestemmes afhængigt af en indstillelig effektreserve.

4. Fremgangsmåde ifølge krav 3, kendetegnet ved, at der for hver indstillet effektreserve bestemmes en særskilt yderligere karakteristik.

5. Fremgangsmåde ifølge krav 3, kendetegnet ved, at der for flere effektreserver kun er bestemt en karakteristik for en af effektreserverne, og der for de øvrige effektreserver interpoleres.

6. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at der ved en overfrekvens sker en ekstra stor effektreduktion.

7. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at effektreserven er bestemt som en andel af vindenergianlæggets (1) aktuelt afgivne effekt.

8. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at bestemmelsen af effektreserven og overblændingen sker centralt for flere vindenergianlæg (1, 1', 1"), fortrinsvis ved en parkmaster (5).

9. Fremgangsmåde ifølge krav 8, kendetegnet ved, at kun en del af vindenergianlæggene (1, 1', 1'') i en vindpark styres tilsvarende af parkmasteren (5).

10. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved hensynstagen til en øvre grænse for den afgivne effekt.

11. Fremgangsmåde ifølge krav 10, kendetegnet ved forudfastsættelse af den øvre grænse fra ekstern side.

12. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at karakteristikkerne er implementeret i form af lookup-tabeller.

13. Fremgangsmåde til drift af en vindpark omfattende en parkmaster (5) og et antal af vindenergianlæg (1, 1', 1''), der har en af en vindrotor (11) fremdrevet generator (14) til afgivelse af elektrisk effekt samt en styring (2) derfor, som

har en første karakteristik (36) for en sammenhæng mellem vindrotorens (11) hurtigløbetal og dens rotorblades (12) bladvinkel samt en indgang (30) for en ønsket effektreduktion, med trinene

- implementering af en anden karakteristik (37) med afvigende bladvinkler for en suboptimal drift, således at der er nået en forudbestemt effektreduktion, og
- anvendelse af den anden karakteristik (37) for styringen (2), når reserveeffekten skal stilles til rådighed (tilrådighedsstillelsesdrift),

kendetegnet ved, at

- ved anmodning om reserveeffekt (aktiv drift) beregnes bladvinklen ved hjælp af en blanding af den anden karakteristik (37) og den første karakteristik (36), nærmere bestemt ved hjælp af et blandemodul,
- hvor blandingen sker ved en overblænding mellem de to værdier for bladvinklerne på den måde, at de beregnede værdier for bladvinklerne vægtes ikke-lineært i forhold til hinanden, hvor vægtningen afhænger ikke-lineært af den anmodede reserveeffekt.

14. Fremgangsmåde ifølge krav 13, kendetegnet ved, at den er videreudviklet ifølge et af kravene 2 til 12.

15. Vindenergianlæg med en af en vindrotor (11) fremdrevet generator (14) til afgivelse af elektrisk effekt samt en styring (2), der har en første karakteristikblok (36) med en første karakteristik for en sammenhæng mellem vindrotorens (11) hurtigløbetal og dens rotorblades (12) bladvinkel samt en indgang for en ønsket effektreduktion,
styringen (2) har yderligere en blok (37) for en anden karakteristik, der har implementeret afvigende bladvinkler for en suboptimal drift,
kendetegnet ved, at
det omfatter et blandemodul (4), til hvilket den første karakteristikblok (36) samt den anden karakteristikblok (37) er tilsluttet, og som er udformet til ved anmodning om reserveeffekt at beregne bladvinklerne ved hjælp af en

overblænding mellem den anden karakteristik og den første karakteristik, hvor overblændingen er implementeret på den måde, at de ifølge de første og anden karakteristikker bestemte værdier for bladvinklerne er vægtet ikke-lineært i forhold til hinanden, hvor vægtningen afhænger ikke-lineært af den anmodede reserveeffekt.

16. Vindenergianlæg ifølge krav 15, kendetegnet ved, at styringen (2) er videreudviklet ifølge et af kravene 2 til 12.

17. Vindpark omfattende en parkmaster (5) samt et antal af vindenergianlæg (1, 1', 1"), kendetegnet ved, at vindenergianlæggene (1, 1', 1") er udformet ifølge et af kravene 15 eller 16.

Patentkrav

1. Fremgangsmåde til tilrådighedsstillelse af en effektreserve ved drift af vindenergianlæg (1, 1', 1"), der har en af en vindrotor (11) fremdrevet generator (14) til afgivelse af elektrisk effekt samt en styring (2) derfor, der har en første karakteristik (36) for en sammenhæng mellem vindrotorens (11) hurtigløbetal og dens rotorblades (12) bladvinkel samt en indgang (30) for en ønsket effektreduktion, med trinene
- implementering af en anden karakteristik (37) med afvigende bladvinkler for en suboptimal drift, således at der er nået en forudbestemt effektreduktion, og
- anvendelse af den anden karakteristik (37) for styringen (2), når der skal stilles reserveeffekt til rådighed (tilrådighedsstillelsesdrift),
kendetegnet ved, at
- ved anmodning om reserveeffekt (aktiv drift) beregnes bladvinklen ved hjælp af en blanding af den anden karakteristik (37) og den første karakteristik (36), nærmere bestemt ved hjælp af et blandemodul (4),
- hvor blandingen sker ved en overblænding mellem de to værdier for bladvinklerne på den måde, at de beregnede værdier for bladvinklerne vægtes ikke-lineært i forhold til hinanden, hvor vægtningen afhænger ikke-lineært af den anmodede reserveeffekt.

2. Fremgangsmåde ifølge krav 1, kendetegnet ved, at den ikke-lineære vægtning af de to bladvinkler sker ved hjælp af en rodfunktion, især ved hjælp af en kvadratrodsfunktion.

3. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at den anden karakteristik (37) bestemmes afhængigt af en indstillelig effektreserve.

4. Fremgangsmåde ifølge krav 3, kendetegnet ved, at der for hver indstillet effektreserve bestemmes en særskilt yderligere karakteristik.

5. Fremgangsmåde ifølge krav 3, kendetegnet ved, at der for flere effektreserver kun er bestemt en karakteristik for en af effektreserverne, og der for de øvrige effektreserver interpoleres.

6. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at der ved en overfrekvens sker en ekstra stor effektreduktion.

7. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at effektreserven er bestemt som en andel af vindenergianlæggets (1) aktuelt afgivne effekt.

8. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at bestemmelsen af effektreserven og overblændingen sker centralt for flere vindenergianlæg (1, 1', 1"), fortrinsvis ved en parkmaster (5).

9. Fremgangsmåde ifølge krav 8, kendetegnet ved, at kun en del af vindenergianlæggene (1, 1', 1'') i en vindpark styres tilsvarende af parkmasteren (5).

10. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved hensynstagen til en øvre grænse for den afgivne effekt.

11. Fremgangsmåde ifølge krav 10, kendetegnet ved forudfastsættelse af den øvre grænse fra ekstern side.

12. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at karakteristikkerne er implementeret i form af lookup-tabeller.

13. Fremgangsmåde til drift af en vindpark omfattende en parkmaster (5) og et antal af vindenergianlæg (1, 1', 1''), der har en af en vindrotor (11) fremdrevet generator (14) til afgivelse af elektrisk effekt samt en styring (2) derfor, som

har en første karakteristik (36) for en sammenhæng mellem vindrotorens (11) hurtigløbetal og dens rotorblades (12) bladvinkel samt en indgang (30) for en ønsket effektreduktion, med trinene

- implementering af en anden karakteristik (37) med afvigende bladvinkler for en suboptimal drift, således at der er nået en forudbestemt effektreduktion, og
- anvendelse af den anden karakteristik (37) for styringen (2), når reserveeffekten skal stilles til rådighed (tilrådighedsstillelsesdrift),

kendetegnet ved, at

- ved anmodning om reserveeffekt (aktiv drift) beregnes bladvinklen ved hjælp af en blanding af den anden karakteristik (37) og den første karakteristik (36), nærmere bestemt ved hjælp af et blandemodul,
- hvor blandingen sker ved en overblænding mellem de to værdier for bladvinklerne på den måde, at de beregnede værdier for bladvinklerne vægtes ikke-lineært i forhold til hinanden, hvor vægtningen afhænger ikke-lineært af den anmodede reserveeffekt.

14. Fremgangsmåde ifølge krav 13, kendetegnet ved, at den er videreudviklet ifølge et af kravene 2 til 12.

15. Vindenergianlæg med en af en vindrotor (11) fremdrevet generator (14) til afgivelse af elektrisk effekt samt en styring (2), der har en første karakteristikblok (36) med en første karakteristik for en sammenhæng mellem vindrotorens (11) hurtigløbetal og dens rotorblades (12) bladvinkel samt en indgang for en ønsket effektreduktion,

styringen (2) har yderligere en blok (37) for en anden karakteristik, der har implementeret afvigende bladvinkler for en suboptimal drift,

kendetegnet ved, at

det omfatter et blandemodul (4), til hvilket den første karakteristikblok (36) samt den anden karakteristikblok (37) er tilsluttet, og som er udformet til ved anmodning om reserveeffekt at beregne bladvinklerne ved hjælp af en overblænding mellem den anden karakteristik og den første karakteristik, hvor overblændingen er implementeret på den måde, at de ifølge de første og anden karakteristikker bestemte værdier for bladvinklerne er vægtet ikke-lineært i forhold til hinanden, hvor vægtningen afhænger ikke-lineært af den anmodede reserveeffekt.

16. Vindenergianlæg ifølge krav 15, kendetegnet ved, at styringen (2) er videreudviklet ifølge et af kravene 2 til 12.

17. Vindpark omfattende en parkmaster (5) samt et antal af vindenergianlæg (1, 1', 1"), kendetegnet ved, at vindenergianlæggene (1, 1', 1") er udformet ifølge et af kravene 15 eller 16.