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The invention relates to a method for operating a wind farm with a plurality of wind turbines, wherein the wind turbines can be controlled and/or regulated in response to a received target value of a power-related electrical variable for the output of power.

5 The invention additionally relates to a wind farm having a plurality of wind turbines and at least one control unit.

Limiting the total power output by a wind farm by specifying a target value for this wind farm is known in principle. This may be necessary, for example, if the

10 available power should not be fed into the electrical grid due to particular circumstances (e.g. grid restrictions, lack of demand). This type of reduced operation of the wind farm makes it necessary to likewise provide reduced operation for at least some of the wind turbines in the wind farm, or to shut them down completely. Various methods for controlling the output of a wind farm are known from WO

15 2010/028954 A2, EP 2 896 102 B1, EP 2 824 322 A1 and EP 2757250 A1.

A method for operating a wind farm is known from EP 2 028 368 B1, wherein a superordinate controller determines each target value for the individual wind turbines as a function of the current maximum possible value that the wind turbine

20 can generate. The total quantity that is to be provided by the wind farm is thus distributed in accordance with the quantity that each individual wind turbine can currently provide. In order to determine the individual target values for the wind turbines, the maximum possible value of the wind farm is divided by the number of wind turbines in the wind farm and is weighted with the quotient of the current

25 maximum possible value of the wind turbine in question and the mean value of the current maximum possible values of all wind turbines. Because the distribution depends upon the current maximum possible value in the wind farm, the change of just one value of a wind turbine has an effect on the target values of all of the wind turbines. Owing to the influence of the wind turbines of the wind farm on the wind

30 field and the inflow conditions that other wind turbines of the wind farm encounter, which depends upon their respective operating states, the change of the wind

conditions at one wind turbine can influence all other turbines. Depending upon the current wind conditions, this can result in significant fluctuations in the target values of the individual wind turbines and possibly to oscillation behavior in the control system due to interactions between the turbines. Owing to the interaction of an upwind turbine with the wind field, a change may occur in the determined available active power of downwind turbines. Therefore, when a change occurs in the power output, turbulence induced by pitch movements of the rotor blades influences the power available at downstream turbines. The change in power output of a turbine usually causes a change in the thrust force that acts upon the nacelle of said turbine.

5 The turbine can be set into a pitching movement as a result. The relative wind speed and thus the available active power change as a result of this pitching.

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Proceeding from the prior art described above, the object of the invention is to provide a method for operating a wind farm that efficiently and reliably regulates the power output of the wind farm.

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The invention achieves the object with the method according to Claim 1. Advantageous embodiments are the subject matter of the dependent claims, the description and the figures.

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The method of the aforementioned type according to the invention comprises the following steps:

- a) determining a power quantity that can be distributed to the wind turbines as a function of a target power level for the entire wind farm and upon minimum power levels of the individual wind turbines,
- 25 b) establishing a weighted distribution that assigns a proportion of the distributable power quantity to each wind turbine,
- c) determining target values for the wind turbines that, based on their momentarily available power levels, can output less or just as much power as
- 30 was allocated to them by the weighted distribution, wherein the target values

- of the power levels are determined in such a way that each of the wind turbines is driven so as to output their momentarily available outputs but at least to output their minimum outputs,
- d) determining a remaining quantity of power that is still to be distributed,
 - 5 e) establishing a further weighted distribution that allocates a proportion of the remaining quantity of power to each of the remaining wind turbines that, based on their momentarily available outputs, can provide more power than was allocated to them by the previous weighted distribution,
 - f) determining target values for those of the remaining wind turbines that,
10 based on their momentarily available power levels, can output less or just as much power as was allocated to them by the further weighted distribution, wherein the target values of the power levels are determined in such a way that each of the wind turbines is driven so as to output their momentarily available outputs,
 - 15 g) repeating steps d) to f) until a termination condition is satisfied,
 - h) presetting the specified target values to the respective wind turbines of the wind farm.

In the method according to the invention, the output power of the individual wind
20 turbines is controlled as a function of a target power specification for the entire wind farm. It is therefore possible to initially specify a target power level for the wind farm. The target power level for the wind farm and/or the wind farm controller as an external variable can be specified, for example, by the operator of the transmission grid into which the wind farm feeds the active power. The wind farm controller can
25 also determine the variable without an external target specification. For example, the wind farm controller can be configured to determine a power target level as a function of the grid frequency, the grid voltage and/or a power schedule. The target power for the wind farm is specified at less than or equal to the available power and/or is limited to such a value. In terms of control technology, this can be achieved
30 with corresponding limiters. If the wind farm controller is in a bidirectional

exchange with a grid control center that is superordinate to the controller, a limitation is normally provided such that the wind farm controller transmits the momentarily available power of the wind farm to the grid control center at regular intervals, and the grid control center specifies the external target value to the wind farm as a function of the reported level of available power. A limitation can also be set on the target power level as a function of the grid frequency, the grid voltage and/or a power schedule. For example, it is known that a wind farm can be operated below the available power level within a dead band around the grid frequency and/or the grid voltage with a power limitation. If the grid parameter exceeds its dead band, it is possible to respond by providing power from the power reserve to support the grid. The output power of the individual wind turbines is controlled by specifying target values for these wind turbines – in particular for the control units of the wind turbines (wind turbine controllers). The target values are target values for a power-related electrical variable, which may be the power itself, for instance. The target values can thus be target power values, in particular target values for the active power and/or the reactive power. However, the powers do not have to be directly specified as target values, but rather can also be specified indirectly, for example as target values for the current or the voltage. The target values relate to power at least inasmuch as it is possible to induce each wind turbine to output a desired power on the basis of these target values. If power levels are discussed in the following as target values – for the sake of simplicity – this does not refer only to target values for power (values with the unit watt) as such, but also other power-related values.

In summary, the method according to the invention provides that a target power, which differs from the target power specified for the entire wind farm, is distributed among the wind turbines of the wind farm depending upon the minimum power of the individual turbines. The distribution is carried out in particular for a reduced operation of the wind farm. The distribution is weighted, wherein the weighting can occur in accordance with various criteria, as will be explained below. This distribution initially results in intermediate values, which cannot be achieved due to

the amount of power momentarily available from at least some of the wind turbines. This means that the available power of some turbines may not be sufficient to reach the intermediate values. For this reason, the desired target power for the wind farm also cannot be provided. Therefore, the power momentarily available at just these
5 wind turbines, but at least their minimum power, is specified as target values, and the remaining amount of power that cannot be provided by these turbines is reallocated, once again with a weighting, to the wind turbines that do have sufficient available power. The turbines that are able to produce more power than has been provided by the distribution take over the power output that the other turbines are
10 not able to provide. The minimum power of each turbine is specified as the lower limit for the respective turbine-specific target values, which will be explained below and which represents the advantage of the present invention.

According to the invention, this occurs iteratively. Further (new) intermediate values
15 are thus determined for the remaining wind turbines, which in turn might not be achieved based on the powers momentarily available from at least some of the remaining wind turbines. For these remaining turbines, their respective momentarily available powers are then specified again as target values. In this way, additional turbines are driven at their maximum with each iteration of the process, and they
20 thus receive target values that prompt them to output their momentarily available power. This is repeated until a termination condition is reached, in particular until no further turbines can be increased to their maximum levels; in other words, until only those wind turbines remain that can output more power or just as much as the intermediate values more recently determined for them. At that point, the only wind
25 turbines remaining are those that can fulfill their share of the most recent distribution (i.e. achieve their most recently determined intermediate values) or that can provide power that cannot be provided by the turbines that have already been increased to their maximums. The remaining wind turbines can then receive the intermediate value determined for them as the target value. The distributable power quantity that
30 was originally determined is thus distributed in its entirety among the wind turbines,

and the target power level for the wind farm or, in particular, the desired reduced operation is thereby achieved. However, a threshold value for the power can also be provided as a termination condition, for example, as will be discussed below. It is then possible for a differential controller (e.g. PID controller) to compensate for the
5 remaining power difference on the basis of a power level measured at the grid connection point and with the formation of a control difference from the requested wind farm target value.

According to the invention, the target values are also determined in such a way that
10 the wind turbines are controlled to provide at least their minimum power. In particular, the target values provided to the wind turbines by this method can set the minimum power of each wind turbine as a lower limit. The minimum power of a wind turbine is understood in particular to be a turbine-specific current minimum power limit (CMPL). In the following, $CMPL_j$ is defined as the CMPL of wind
15 turbine j . CMPL specifies the minimum active power that should be provided by a wind turbine in its current operating state. External target specifications for the wind turbine are permissible only if they are greater than or equal to CMPL. If a wind turbine receives target values below CMPL, it has previously either been limited to a fraction of its available power, which has resulted in the previously described
20 oscillation behavior in the wind farm, or the wind turbine has been shut down without preference having been given to selected wind turbines. The $CMPL_j$ are continuously transmitted by the individual wind turbines to the wind farm controller.

The term should be understood such that the value basically depends upon the
25 configuration (design) of the wind turbine, but ultimately upon the current operating state as well as the loads and effects that occur in the process. For instance, the gearbox of a wind turbine can be the dimensioning component for the minimum effective power, for example when rolling bearings are used as gearbox bearings within it. Other bearings that are used in the wind turbine, such as for

accommodating the main shaft of the wind turbine, can also have a dimensioning effect.

During nominal operation, rolling elements exhibit a defined behavior in their running zones, wherein a defined radial force acts upon the rolling elements. Critical operating states for this type of bearing, which can result in damage to the bearing, occur, for example, when there is a low torque at high rotational speeds, i.e. only low power is supplied. The high rotational speed with a low load leads to undefined states of the rolling elements in the rolling bearing, referred to as bearing slippage. This can result in a break in the oil film between the rolling elements and the bearing race. As a consequence of the missing lubricant film, there is direct contact between the rolling elements and bearing races, and a transfer of material between the rolling elements and the race occurs, or abrasion takes place, and can result in damage to the bearing over time.

In order to prevent this type of damage as well as the costs associated with replacing defective bearings or gearbox, it is necessary, when the wind turbine is controlled as a function of rotational speed, to ensure that the rolling elements experience a minimal radial force so that undefined slippage can be reliably avoided. Accordingly, the torque transmitted via the bearing must have a lower limit. Requirements regarding the prevention of tooth backlash in the gearbox of the wind turbine can also have a limiting effect. For example, short-term fluctuations in the torque that are brought about by turbulence in the wind acting on the rotor of the wind turbine, for instance, can cause damage to the tooth flanks of gears.

In order to identify critical operating states and to take them into account when controlling the wind turbine, different variables can be selected as limiting for the operation control. It can be useful to limit the torque, and thus the product of the torque and rotational speed, the power, depending upon the rotational speed or wind speed. This accounts for the fact that rotational speed and torque are usually not

freely adjustable, and the adjustable operating range depends upon the current wind speed. For example, the current minimum active power limit can also be specified depending upon the current wind direction or turbulence that is occurring. It is also possible to consider different variables at the same time. For instance, when
5 different curves / look-up tables are specified for the minimum active power limit as a function of the wind speed and as a function of the wind direction, particular alignment ranges of the rotor with respect to the wind direction, for example, can be taken into account when specifying the minimum active power limit within which an increased occurrence of turbulence is to be expected.

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The current minimum active power limit can be specified in the form of a look-up table, for example. Moving averages of such variables, such as the 10-minute average wind speed, can also be utilized. It is also possible that wind speed ranges are given in which averages are taken over time periods of different lengths. Look-
15 up tables can also be predefined in accordance with the operating mode of the wind turbine. For example, for an operating mode in which a spinning reserve should be maintained by individual wind turbines of the wind farm, i.e. the wind turbines are operated at a higher rotational speed compared to an aerodynamically more optimal rotational speed range so that they can supply additional control power for a short
20 time, it can be useful to adapt the current minimum active power limit of the wind turbines involved. Taking the current minimum active power limit into consideration leads to a reduction in the wear of the components of the wind turbine.

The minimum power (CMPL) thus basically depends upon the configuration of the
25 respective wind turbines, i.e. their design, but can also be dynamic variables and can depend, for example, upon the operating state of each turbine, in particular the current wind speed and/or the rotational speed. According to one embodiment, the minimum power (CMPL_j) of the wind turbines can be determined depending upon the wind speed and/or the rotational speed. Especially when wind conditions over
30 the area of a wind farm are very inhomogeneous, the momentarily available power

level of one or more of the wind turbines could be lower than their respective minimum power levels (and lower than the proportion allocated according to the distribution). According to the invention, however, these wind turbines are also controlled so as to provide their minimum power, i.e. they specifically receive their
5 respective minimum power value as a target value, even if they cannot achieve it due to the lower available power. Therefore, even those wind turbines that, based on their momentarily available power, are not only able to provide less than or just as much power as was allocated to them by the weighted distribution but that also fail to achieve their respective minimum power level based on their momentarily
10 available power are controlled so as to deliver their minimum power. Even if these turbines cannot actually produce their minimum power, they nevertheless contribute to the total power output of the wind farm.

If these turbines were no longer considered for the process when they fell below
15 their respective minimum power, then these turbines specifically would not receive production authorization, and this could result in unfavorable control effects. As was discussed above, this could lead to frequent shutdowns of wind turbines and to constantly changing target values for each of the wind turbines within the wind farm, which could set the wind turbines into coupled oscillation when unfavorable
20 wind conditions occur. This is due to the fact that the production authorization would be issued depending upon the wind conditions and thus the available power. However, the wind conditions cannot be precisely predicted, and it would likewise not be possible to predict which turbines of the wind farm that have production authorization at the current moment would still have production authorization at the
25 next moment. By fixing the target values at least at the respective minimum power in accordance with the invention, it is possible to prevent such a situation, and in particular all turbines can remain initially switched on. Any residual power that remains as a result can likewise be allocated to the remaining wind turbines, as will be explained below.

The individual steps of the process according to the invention are explained in detail below, in some cases with possible embodiments.

According to the invention, a quantity of power that is to be distributed to the wind turbines of the wind farm is first determined in step a). This is a target power quantity. This distributable quantity of power takes into account the target power specified for the entire wind farm and the minimum power of the individual wind turbines. According to one embodiment, the quantity of power that can be distributed to the wind turbines (hereafter also called the residual) is determined as the deviation from the target power for the entire wind farm and from the minimum power of all wind turbines, in particular as the difference between the target power and the sum of the minimum powers. In particular, $SP_p - \sum_k CMPL_k$ applies for the deviation, where SP_p is the target power of the wind farm and $\sum_k CMPL_k$ is the sum of the minimum powers $CMPL_j$ of all wind turbines k included in the method. The wind farm consists of $n > 0$ wind turbines, and $j, k \in \{1..n\}$. In other words, the CMPL of k wind turbines of the farm are summed. In particular, it can be summed across all of the turbines, $k = n$. In particular, for the distributable power quantity, only the power quantity that exceeds the minimum power of that turbine is considered for each of the wind turbines. The minimum power of the wind turbines should not be subject to the distribution, but rather is intended to form the minimum for the respective target value for each of the wind turbines included in the process. According to the invention, the determination of the target values, which is still to be explained, is carried out in such a way that each of the wind turbines is controlled so as to produce at least its minimum power. If the sum of all minimum powers of the individual wind turbines is greater than the target value set for the wind farm, i.e. $SP_p < \sum_k CMPL_k$, then wind turbines can be taken out of production operation. These turbines then have no production authorization and are not taken into consideration for the method according to the invention. The issuing and withdrawal of production authorizations is carried out in a separate procedure. Therefore, $SP_p \geq \sum_k CMPL_k$ preferably applies, and so in particular the residual is not negative.

In step b), the calculated distributable quantity of power, i.e. the residual, is then distributed computationally among the wind turbines included in the method. According to one embodiment, the weighted distribution is created by determining

5 intermediate values as the sum of the respective minimum power and the deviation multiplied by a weighting factor. In particular, $V2SP_j = CMPL_j + g_j * (SP_p - \sum_k CMPL_k)$ applies, where g_j denotes the weighting factor, $CMPL_j$ denotes the minimum power and $V2SP_j$ denotes the intermediate value for the turbine $j \in \{1 \dots n\}$. Some suitable weighting factors are discussed in greater detail below. A

10 proportion of the distributable quantity of power is assigned to each of the wind turbines by this weighted distribution. This portion might not necessarily be produced by each of the wind turbines, however. In turn, some of the turbines could possibly produce more power than is allocated.

15 A determination is therefore subsequently made as to which of the wind turbines are able to produce that proportion of the quantity of power that is allocated to them. Those wind turbines that are unable to achieve this quantity of power, or that just manage to do so, should deliver their maximum output. These turbines therefore receive a target value in step c) that results in the output of the momentarily

20 available power. On the other hand, if production authorizations are issued to turbines in which momentarily available power falls below their minimum power, these turbines receive their respective minimum power (CMPL) as the target value. These turbines are thus controlled so as to output their minimum power, even if they are not actually able to output this power. The quantity of power that remains as a

25 result can be taken into account when determining the residual that is to be distributed subsequently. If the remaining residual power quantity is not taken into account to determine the residual that is to be distributed subsequently, the target power for the wind farm will not be achieved (even if the residual eventually disappears). It is then possible to compensate for this residual amount of power by

30 means of a suitable differential controller (such as a PID controller). In other words,

in this step, the wind turbines receive either their momentarily available power or their minimum power as the target value, whichever value is greater. In this instance, the momentarily available power of a wind turbine denotes the maximum possible power value that this turbine is able to produce based on the operating state prevailing at this time. The momentarily available power depends upon the operating state of the turbine, for example the wind speed prevailing at the turbine. For the wind turbines for which the previously determined intermediate value $V2SP_{j^*}$ is greater than or equal to their momentarily available power PA_{j^*} , i.e. for which $V2SP_{j^*} \geq PA_{j^*}$, the power PA_{j^*} momentarily available at each of these wind turbines can be defined in particular as the target value. These turbines then contribute at least what they can to the overall power of the wind farm. Thus there is usually a remaining quantity of power that cannot be produced by them, although it was provided for these turbines in the weighted distribution. However, if all of the wind turbines participating in the method are just able to produce their assigned proportion, or are able to contribute even more, i.e. if $V2SP_{j^*} \leq PA_{j^*}$ applies for all of the turbines, the method can already end here (the termination condition contained in step g), which is explained in greater detail below, has been met). All of the turbines are then set to output their allocated proportion of the weighted distribution by their target values.

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The aforementioned remaining quantity of power that cannot be produced by the wind turbines with momentarily available power of less than or equal to their respective intermediate value is then determined in method step d). The remaining quantity of power is thus a sub-quantity of the quantity of power that was previously determined. In this case, according to one embodiment, the remaining amount of power that is still to be distributed is determined as a further deviation, specifically as the deviation between the momentarily available power and the previously determined intermediate values. The further deviation is thus in particular the sum $\sum_{k^*} (V2SP_{k^*} - PA_{k^*})$ of the differences between the intermediate values $V2SP_{j^*}$ and the momentarily available power PA_{j^*} of the total of k^* of the j^* wind turbines for

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which the previously determined intermediate value is greater than or equal to the momentarily available power PA_{j*} . The remaining quantity of power is also referred to hereafter as the further residual. The asterisk on the indices identifies the fact that it is these wind turbines for which the previously determined intermediate value

5 $V2SP_{j*}$ is greater than or equal to the momentarily available power PA_{j*} . This remaining quantity of power (i.e. the further residual) $\sum_k^* (V2SP_{k*} - PA_{k*})$ is then distributed in weighted form. In particular, this further deviation can be calculated across all of the turbines for which $PA_j \leq V2SP_j$, including the turbines for which $PA_j < CMPL_j$. According to one embodiment, the aforementioned remaining

10 quantity of power that is still to be distributed can then be determined as a deviation $(\sum_k^* (CMPL_{k*} - PA_{k*}))$ calculated as the sum of the differences between the minimum power values ($CMPL_{j*}$) and the respective momentarily available power (PA_{j*}) of the wind turbines in which the momentarily available power (PA_{j*}) is less than the minimum power ($PA_{j*} < CMPL_{j*}$) provided for the respective wind turbine.

15 As has been mentioned, this remaining quantity of power together with the remaining quantity of power (i.e. the residual) for the turbines in which $PA_j > CMPL_j$ can be determined together.

As was mentioned, the remaining quantity of power does not have to be taken into

20 account when subsequently determining the residual to be distributed. This can also be carried out at another point in the method, such as before or after step c), in particular between steps b) and c) or between steps g) and h). According to one embodiment, the distributable amount of power is corrected, in particular by a controller, as a function of the remaining quantity of power. The remaining quantity

25 of power be compensated in particular by a suitable differential controller (such as a PID controller) of the wind farm controller. This controller can be configured such that, for example, if a deviation occurs between the specified target value for the wind farm and the measured, achieved actual value for the output power of the wind farm, an increased target value is specified for the wind farm for the next control

cycle. The turbines that can produce additional power are thus successively brought to their available value, and the wind farm is adjusted to the target value.

In step e), a further weighted distribution is established that allocates a proportion of the remaining quantity of power to each of the remaining wind turbines that, based on their momentarily available power, can provide more power than was allocated to them by the previous weighted distribution. This proportion of the remaining quantity of power accumulates for the remaining wind turbines in addition to the quantity of power already allocated in the previous distribution, i.e. in particular in addition to the previously determined intermediate values. According to one embodiment, the further weighted distribution is accordingly created by determining further intermediate values $V3SP_{j\#}$ as the sum of the respective previous intermediate values $V2SP_{j\#}$ for these remaining turbines and the further deviation $\sum_k^* (V2SP_{k^*} - PA_{k^*})$ multiplied by a further weighting factor f_j .

$V3SP_{j\#} = V2SP_{j\#} + f_j * \sum_k^* (V2SP_{k^*} - PA_{k^*})$ thus applies for the further intermediate values. The hash sign on the indices indicates that these are the remaining wind turbines for which the previously determined intermediate value $V2SP_{j\#}$ is greater than or equal to the momentarily available power $PA_{j\#}$ of these turbines. In particular, the further weighting factor can be the same as the previous weighting factor, i.e. $f_j = g_j$ applies. Some suitable weighting factors are discussed in greater detail below. As a result of this further weighted distribution, a proportion of the remaining quantity of power is assigned to each of the remaining wind turbines. It may occur here, too, that not all of the remaining wind turbines are able to produce their proportion, but other wind turbines may possibly be able to produce more.

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In the following step f), target values are defined for those of the remaining wind turbines that, based on their momentarily available power, are able to output less or just as much power as was assigned to them by the further weighted distribution. These target values are basically defined according to the same condition as the target values defined in step c), but with respect to the further weighted distribution,

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i.e. in particular the further intermediate value. The momentarily available power is thus defined as a target value for those of the remaining wind turbines that are able to output less or just as much power as was assigned to each of them by the further weighted distribution. No target values smaller than the minimum power values are defined in this case, as well. According to one embodiment, for those of the remaining wind turbines for which the previously determined further intermediate value $V3SP_{j\#}$ is greater than or equal to their momentarily available power $PA_{j\#}$, the power $PA_{j\#}$ momentarily available at each of these wind turbines is defined as the target value. Accordingly, some wind turbines remain that have a momentarily available level of power that is greater than the further intermediate value, for which $V3SP_{j\#} < PA_{j\#}$. Therefore, a quantity of power to be distributed still remains.

In this case, in accordance with step g), steps d) to f) are repeated until a termination condition is met. The termination condition can be that the only wind turbines remaining are those that are able to output more power or precisely as much power as was assigned to them by the further weighted distribution, i.e. until there are no remaining turbines that are able to output less power than was allocated to them by the previous weighted distribution. In other words, steps d) to f) can be repeated until $VnSP_j \leq PA_j$ applies for all of the remaining turbines, wherein $VnSP_j$ are the intermediate values of the last iteration. This means that the intermediate values determined in the last iteration can be achieved by all of the turbines still remaining because these turbines have enough available power. In step g), target values can then be defined on the basis of the last of the weighted distributions for just these wind turbines that still remain after the last iteration. This may be the next or the last of multiple further distributions, or else the original distribution (if all of the turbines are able to output just as much power as was allocated to them by the distribution in step c), as explained above). In particular, the intermediate values $VnSP_j$ that were determined after the last iteration are then defined as the target values for these turbines. The entire originally determined distributable quantity of power is thus distributed among the turbines. The originally determined distributable quantity of

power is thereby gradually allocated to all of the wind turbines of the wind farm. The maximum number of repetitions of the aforementioned steps corresponds to the number of wind turbines of the wind farm that are participating in the method, i.e. that have production authorization. That is, even for typical wind farm sizes of a few
5 up to several hundred wind turbines, the proposed weighted target value distribution method does not represent a particular challenge in terms of a computer-aided implementation of the method. However, the method can terminate earlier. If a target value can be assigned to all of the turbines after fewer repetitions, then the method can already terminate here. The distributable quantity of power is then
10 already distributed among the wind turbines.

According to one embodiment, the termination condition is met when the remaining quantity of power is equal to or less than a predefined threshold value. It is therefore possible to specify a threshold power value at which the method is terminated when
15 the remaining quantity of power that is still to be distributed reaches or falls below this value. It may be acceptable to not completely distribute the quantity of power. The termination condition can also be met once the method has passed through a predetermined number of iterations. The predetermined number of iterations can depend in particular upon the wind conditions. For example, if a particular number
20 of iterations is empirically sufficient to completely distribute the quantity of power, i.e. to achieve the target power of the wind farm, then reaching this number of iterations can be defined as a termination condition. As has already been described, it is possible for a suitable differential controller (such as a PID controller) of the wind farm controller to compensate for the remaining quantity of power.
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Subsequently, in step h), these target values are specified for the individual wind turbines, for example, by being transmitted to the control units of the respective wind turbines. The wind turbines implement the specification, and the wind farm is put into reduced operation.

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According to one embodiment, the weighted distribution and the further weighted distribution have the same weighting. According to a corresponding embodiment, the first weighting factor g_j and the further weighting factor f_j are identical. This simplifies the calculations.

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According to one embodiment, the weighting of the weighted distribution and/or of the further weighted distribution depends upon the momentarily available power of the respective wind turbine, wherein wind turbines having more momentarily available power are weighted to a greater extent than wind turbines having less momentarily available power. In particular, the weighting factor can be:
 $g_j = PA_j / (\sum_k PA_k)$. The momentarily available power of each turbine is thus weighted by the entire available power of all of the turbines. As a result, wind turbines with a greater momentarily available power are ultimately weighted to a greater extent than wind turbines with a smaller momentarily available power and are thus allocated a greater proportion of the distributable amount of power or of the remaining amount of power. The method can be accelerated in this way. In addition, the wind conditions at the individual turbines can be taken into account in particular. A disadvantage of using the momentarily available power of each turbine for the weighting is that this can result in interactions with the other wind turbines of the wind farm if the momentarily available power of an individual wind turbine changes.

According to an especially preferred embodiment, the weighting of the weighted distribution and/or of the further weighted distribution depends upon the deviation of the nominal power of the respective wind turbine from its minimum power, wherein wind turbines with a smaller deviation are weighted more heavily than wind turbines with a larger deviation. In particular, the weighting factor can be:
 $g_j = (PN_j - CMPL_j) / \sum_k (PN_k - CMPL_k)$, where PN_j denotes the nominal power of the turbine j and PN_k denotes the nominal power of the other k producing turbines of the wind farm. In this way, wind turbines with a smaller deviation between the

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nominal power and the minimum power are weighted to a greater extent than wind turbines with a larger deviation. Wind turbines having a minimum power that is close to their nominal power are thus less heavily weighted and are allocated a smaller proportion of the distributable quantity of power or of the remaining

5 quantity of power. In particular, this type of weighting results in a steadily decreasing weighting of this turbine as the minimum power increases. This is especially advantageous when the minimum power of the wind turbines is not fixed but is instead specified dynamically and/or determined continuously based on the prevailing operating conditions. By giving less consideration to wind turbines that

10 have a smaller difference $PN_j - CMPL_j$, a greater dynamic can be achieved in wind farm control. Moreover, the requirements relating in particular to the deactivation of the wind turbines at excessively high wind speeds can be taken into account.

According to a further embodiment, the weighting of the weighted distribution

15 and/or of the further weighted distribution depends upon the deviation between the momentarily available power of the respective wind turbine and its minimum power, wherein wind turbines having a smaller deviation are weighted to a greater extent than wind turbines having a larger deviation. In particular, the weighting factor can be: $g_j = \max(0; (PA_j - CMPL_j)) / \sum_k \max(0; (PA_k - CMPL_k))$, where, as before, PA_j

20 denotes the momentarily available power of the turbine j , and PA_k denotes the momentarily available power of the other k producing turbines of the wind farm. The restriction to the non-negative semi-axis takes into account the fact that production authorizations may possibly be issued to turbines that have less power available than their respective CMPL. By virtue of this weighting, wind turbines

25 with a smaller deviation between the momentarily available power and the minimum power (CMPL) are more heavily weighted than wind turbines with a larger deviation. Wind turbines with a minimum power that is close to their momentarily available power are thus less heavily weighted and are allocated a smaller proportion of the distributable quantity of power or of the remaining quantity of power. In

30 particular, this type of weighting results in a steadily decreasing weighting of this

turbine as the minimum power increases and/or as the momentarily available power decreases. By also giving less consideration to the difference $PA_j - CMPL_j$, a higher dynamic in terms of wind farm control, but carrying out the control as a function of the momentarily available power is also a matter of discretion in this case.

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According to one embodiment, the weighting of the weighted distribution and/or of the further weighted distribution depends upon the nominal power of the respective wind turbine, wherein wind turbines with a greater nominal power are weighted more heavily than wind turbines with a lower nominal power. Therefore, more powerful turbines are allocated a greater proportion of the quantity of power to be distributed.

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In the weighting factors described above, it is always only the wind turbines that are involved that are taken into account in the denominator when calculating the respective sums. In other words, with respect to the weighted distribution, only those wind turbines in particular that have production authorization and, with respect to the further weighted distribution, only those wind turbines in particular for which the previous respective intermediate values are smaller than the momentarily available power of these turbines.

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The invention additionally relates to a wind farm comprising a multitude of wind turbines and having at least one control unit, wherein the control unit is configured to carry out the method explained above. The explanations provided with respect to the method thus likewise apply to the wind farm. The at least one control unit can be a control unit that is superordinate to the wind turbines, in particular a wind farm controller. The superordinate control unit can thus determine the target values and transmit them in particular to the control units of the individual turbines. In principle, however, one or more of the control units of the individual wind turbines can also be configured to carry out the method. The variables required to determine the target values are provided in the superordinate control unit in the form of input

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variables for carrying out the method. For example, the wind turbines or their control units can be configured to identify the momentarily available power values and minimum power values at regular intervals and to transmit them to the superordinate control unit. Alternatively, some variables can also be stored or
5 determined in the superordinate control unit. Nominal power values can be stored in the superordinate control unit, for example. However, it is also conceivable for the wind turbines to be configured to transmit the current measured values and state variables to the superordinate control unit in real time, or approximately real time, and for the variables required for the method to be calculated in the superordinate
10 control unit. In this instance, the behavior of the individual wind turbines can be virtualized on the central control unit. Corresponding solutions for this type of model-based or observer-based control are known from the prior art and can readily be combined with the method according to the present invention by a person skilled in the art in the field of control technology.

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Embodiments of the invention are explained below using figures. Schematically:

Figure 1 shows a lateral view of a wind turbine;

20 Figure 2 shows a schematic diagram of the wind turbine according to Fig. 1;

Figure 3 shows a flow chart for the method according to the invention; and

Figure 4 shows a diagram representing possible profiles of the minimum power and
25 the maximum available power of a wind turbine plotted against wind speed.

If not otherwise specified, the same reference numbers indicate the same objects below.

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A wind turbine 100 can be seen in Figure 1, comprising a tower 110, a nacelle 120, a rotor 130, which is rotatably arranged on the nacelle with a rotor hub 140, and rotor blades 150, which extend outward from the rotor hub 140. An anemometer 160 is also illustrated on the nacelle. The wind turbine 100 is suitable for the method
5 according to the invention and, in particular, is part of a wind farm 200, as is illustrated in Figure 2.

Figure 2 schematically shows the electrical structure of the wind turbine 100. Other wind turbines 201, 202, 203, which are all part of the wind farm 200, are
10 additionally visible. The wind turbines 100, 201, 202 and 203 are connected to a three-phase electricity transmission grid 230 via a wind farm-internal three-phase electricity grid and a substation 220, and can feed power into said transmission grid. The substation can have a transformer that is configured to transform the power that is output by the wind farm from medium voltage to high voltage. The wind turbine
15 100 can likewise be provided with a transformer 128 and can be connected through it to the wind farm-internal grid.

The rotor 130 of the wind turbine 100 absorbs a torque from the wind and conveys the torque via a drive train 121, which comprises a gearbox 122, to the rotor of a
20 double-fed asynchronous generator 123 that is configured to convert the absorbed kinetic energy into electrical energy and supply it to the three-phase electricity transmission grid 230. The wind turbine is configured as a double-fed asynchronous machine; the stator of the generator 123 is connected directly to the three-phase electricity supply grid 230 via a three-phase line. The rotor of the generator 123 is
25 connected to an AC converter 124 via a three-phase line. The AC current converter 124 is connected on the grid side to the stator line and the electricity supply grid 230 via a three-phase line. For the sake of improved clarity, electrical lines in the figure are schematically illustrated as single-phased.

The AC converter 124 comprises a rotor-side converter 125 and a grid-side converter 126. A DC link is provided between the converters. A converter controller 127 of the AC converter 124 is configured to set a generator torque on the generator 123 by regulating the rotor currents in the rotor. To this end, the converter controller
5 127 can specify control variables, e.g. for rotor currents, active and reactive power and/or generator torque, for the rotor-side converter 125. Corresponding control methods are known from the prior art. The rotor-side converter 125 sets the rotor currents, and thus the generator torque, by connecting power electronics components, for example. In order to regulate the generator torque, the converter
10 controller 127 communicates with a wind turbine controller 129 and, in particular, receives from it a target value for a generator torque or an active power that is to be output.

Furthermore, the wind turbine 100 comprises a rotational speed sensor 161. The
15 rotational speed sensor can be provided at any location on the drive train 121 that is connected to the rotor of the generator 123, such as on a gearbox output shaft. Rotational speed values that are measured by the rotational speed sensor 161 are provided in the form of input variables at the wind turbine controller 129. Wind speed measurements recorded by the anemometer 160 are also provided in the form
20 of input variables at the wind turbine controller 129.

The wind turbine controller 129 is also connected to a blade pitch control device 151, by means of which the wind turbine controller 129 can set a pitch angle of the rotor blades 150. The wind turbine controller 129 generally serves to regulate the
25 wind turbine 100 during operation. In this exemplary embodiment of variable-speed wind turbines, the control and the relationship between rotational speed, torque, power, rotor blade setting angle and wind speed follow methods that are known from the prior art. For example, the wind turbine controller 129 receives signals and control commands from a wind farm controller 210, with which it communicates via
30 a data line. In the present exemplary embodiment, the wind farm controller 210, as a

superordinate control unit, is configured to carry out the method according to the invention. The wind farm controller 210 is linked to a sensor 221 that is configured to record electrical measured variables at the grid connection point of the wind farm. The measured variables, such as those regarding the active and reactive power output by the wind farm, are provided in the form of input variables at the wind farm controller 210. Measured values regarding currents or voltages at the grid connection point can also be provided in the form of input variables at the wind farm controller 210 for controlling the wind farm. The wind farm controller 210 is connected via a data line to an external control system 211, which is operated by the grid operator of the transmission grid 230, for example. The wind farm controller 210 is configured to receive target values from the external control system 211 and to transmit actual values to it. For example, the wind farm controller 210 can be configured to notify the external control system 211 of the momentarily available active power at regular intervals, such as on a 10-second cycle. The external control system 211 can be configured to transmit a target value for the active power that is to be output by the wind farm as a function of the prevailing available active power. Alternatively or additionally, the target value can also be specified in response to a changed power requirement on the grid side. The reactive power can also be regulated in the same way. For example, a power reserve can be set by establishing a target value below a value reported as available. The external control system 211 can also provide specifications with regard to particular modes of operation and, for example, can instruct the wind farm controller to operate the wind farm with a spinning reserve. Corresponding operating modes can also be specified in the wind farm controller 210 and can be set as a function of measured variables measured in the wind farm or at the grid connection point.

The sequence of the method according to the invention is illustrated in Figure 3. The exemplary embodiment shown there comprises at least seven steps 310-370. The wind farm controller 210 carries out the method, for example, when it receives a target power specification SP_p for the wind farm from the external control system

211. This specification may call for reduced operation of the wind farm, for example. In order to achieve this reduced operation, the wind farm controller specifies target power values for the wind turbines in the following manner.
- 5 First, in step 310, the wind farm controller determines a quantity of power that is to be distributed among the wind turbines (residual) as the difference $SP_p - \sum_k CMPL_k$, where $CMPL_j$ denotes the minimum power of the turbine j and $\sum_k CMPL_k$ denotes the sum of the minimum powers of all of the k wind turbines participating in the method. The wind farm can consist of $n > 0$ wind turbines, with $j, k \in \{1 \dots n\}$. If the
 - 10 sum of all minimum powers of the individual wind turbines is greater than the target value set for the wind farm, i.e. $SP_p < \sum_k CMPL_k$, then wind turbines can be taken out of production operation. These turbines then have no production authorization and are not taken into consideration for the method according to the invention. Therefore, $SP_p \geq \sum_k CMPL_k$ applies, and so in particular the residual is not negative.
 - 15 The residual includes only the quantity of power that the wind turbines are able to produce beyond their minimum power. Thereafter, the residual is distributed among the turbines.

To this end, in step 320, a weighted distribution is established that allocates a

20 proportion of the residual to each of the individual wind turbines. Intermediate values $V2SP_j = CMPL_j + g_j * (SP_p - \sum_k CMPL_k)$, where g_j is a weighting factor, are first established for this purpose.

A first definition of target values subsequently occurs in step 330. For the wind

25 turbines for which the previously determined intermediate value $V2SP_j^*$ is greater than or equal to their momentarily available power PA_j^* , i.e. for which $V2SP_j^* \geq PA_j^*$, the power PA_j^* momentarily available at each of these wind turbines can be defined in particular as the target value. In particular, a determination is made for each of the wind turbines as to whether their respective momentarily available

30 power is below or above, or matches exactly, the intermediate value $V2SP_j$ that is

defined for this turbine. Those turbines that do not achieve their intermediate values receive their respective momentarily available power as the target value. The same applies to the turbines that exactly match their intermediate values – in this case, the intermediate value corresponds precisely to the momentarily available power. Those

5 turbines with available power that exceeds their intermediate value receive the remaining quantity of power by the method steps explained below. However, if all of the turbines achieve or exceed their intermediate values, then these intermediate values are defined as the target values and are specified for the wind turbines. The method jumps to step 370. Each turbine thus receives a target value that is less than

10 or equal to its momentarily available power, and the method can already terminate without an iteration. In this instance, though, none of the wind turbines receives a target value that is less than its minimum power. If the momentarily available power of a turbine is below its minimum power, then the minimum power, rather than the momentarily available power, is specified as the target value. In this way it is

15 possible, as is explained above, to prevent oscillation behavior in the control system.

In step 340, a further residual is determined, specifically the remaining quantity of power that cannot be produced by the turbines that received a target value in the previous step. This further deviation is thus in particular the sum $\sum_{k^*} (V2SP_{k^*} -$

20 $PA_{k^*})$ of the differences between the intermediate values $V2SP_{j^*}$ and the momentarily available power PA_{j^*} of the total of k^* wind turbines for which the previously determined intermediate value is greater than or equal to the momentarily available power PA_{j^*} . A remaining quantity of power $\sum_{k^*} (CMPL_{k^*} - PA_{k^*})$ of the turbines with momentarily available power that is below their minimum power can

25 also be used to represent the residual. Alternatively, it is possible to compensate for this remaining quantity of power on the basis of a measurement at the grid connection point and by calculating a control difference from the required wind farm target value using a differential controller (such as a PID controller).

In step 350, the further residual is then distributed among the remaining turbines with a further weighted distribution, i.e. the turbines where: $V2SP_j^* < PA_j^*$. These remaining turbines should therefore receive their proportion of the further residual in addition to the previously determined intermediate values. Further intermediate

5 values $V3SP_{j\#}$ are thus determined, where $V3SP_{j\#} = V2SP_{j\#} + f_j * \sum_k (V2SP_k^* - PA_k^*)$ with the weighting factor f_j , and where in the present case $g_j = f_j$. The weighting factors are preferably $g_j = f_j = (PN_j - CMPL_j) / \sum_k (PN_k - CMPL_k)$, where PN_j denotes the nominal power of the turbine j and PN_k denotes the nominal power of the other k producing turbines of the wind farm. In this way, wind turbines with a

10 smaller deviation between the nominal power and the minimum power are weighted to a greater extent than wind turbines with a larger deviation. Wind turbines having a minimum power that is close to their nominal power are thus less heavily weighted and are allocated a smaller proportion of the distributable quantity of power or of the remaining quantity of power. In particular, this type of weighting results in a steadily

15 decreasing weighting of this turbine as the minimum power increases. This is especially advantageous when the minimum power of the wind turbines is not fixed but is instead specified dynamically and/or determined continuously based on the prevailing operating conditions. By giving less consideration to wind turbines that have a smaller difference $PN_j - CMPL_j$, a greater dynamic can be achieved in wind

20 farm control. Moreover, the requirements relating in particular to the deactivation of the wind turbines at excessively high wind speeds can be taken into account.

In step 360, for the wind turbines for which the previously determined intermediate value $V3SP_{j\#}$ is greater than or equal to their momentarily available power $PA_{j\#}$, i.e.

25 for which $V3SP_{j\#} \geq PA_{j\#}$, the power $PA_{j\#}$ momentarily available at each of these wind turbines can be defined in particular as the target value. If the previously determined further intermediate value $V3SP_{j\#}$ is not greater than or equal to its momentarily available power $PA_{j\#}$ for any of the remaining wind turbines, i.e. if $V3SP_{j\#} < PA_{j\#}$ applies for all of the remaining turbines, then each of the intermediate

30 values $V3SP_{j\#}$ is defined as the target value for these remaining turbines. The

quantity of power that is still to be distributed can therefore be distributed among the remaining turbines, since their available power is sufficient. According to step 370, all of the target values that were defined in the previous steps are then transmitted to the control units of the individual wind turbines, i.e. including to the wind turbine controller 129 in the present case. Otherwise (that is, if $V3SP_{j\#} \leq PA_{j\#}$ does not apply to all of the turbines), the method resumes with step 340, as is indicated by the backward arrow in Fig. 3. A further residual is then determined, a further weighted distribution is created, and lastly intermediate values are again determined, which are specified as the target values for the turbines that remain, provided that each of the wind turbines then has an intermediate value that is less than or equal to its available power. Otherwise, the method can keep returning to step 340 until this is the case.

The method according to the invention provides a simple and reliable way of controlling the turbines of a wind farm to a predefined target value for the wind farm. The minimum power limits of the individual turbines are taken into account, and in particular they establish minimum values for the target values. Turbines for which the momentarily available power is lower than the minimum power limit receive their minimum power as the target value rather than their momentarily available power. In this way, it is possible to prevent unintended activation and deactivation procedures for wind turbines whose momentarily available power is sometimes above and sometimes below their minimum power. Because the minimum power values are taken into consideration, the aforementioned coupled oscillation in particular can be avoided.

The minimum powers basically depend upon the configuration of the respective wind turbines, i.e. their design. However, the minimum power can also be dynamic variables and can depend, for example, upon the operating state of each turbine, in particular the wind speed. Figure 4 shows the dependency of the current minimum power CMPL upon the wind speed for two different operating modes of a wind

turbine that has a nominal power in the megawatt range. In this instance, the active power P of a wind turbine relative to its nominal power P_N is plotted against the wind speed v . In a standard operating mode (continuous line with circular dots), the minimum power CMPL rises abruptly above the 0% value of the nominal power at a

5 wind speed of 15 m/s. Between 20 m/s and 25 m/s, the minimum power is set to increase linearly with the wind speed. The minimum power does not increase any further between 25 m/s and 30 m/s wind speed.

In an operating mode that retains a spinning reserve (dashed line with diamond-shaped dots), the minimum power CMPL rises linearly starting at a wind speed of 5

10 m/s. Between 20 m/s and 30 m/s, the operating mode that retains a spinning reserve provides the same profile for the minimum power as for the standard operating mode. In this respect, the profiles of the continuous line with circular dots and the dashed line with diamond-shaped dots overlap in this interval. In principle, however,

15 a completely different profile is also conceivable. It may also be possible to operate above 20 m/s while retaining a spinning reserve. At 30 m/s, a vertical line represents the deactivation limit value for the wind turbine, which is deactivated when this value is reached. This is also called the “cut-off limit” or “storm cut-off”. Beginning at a wind speed of 20 m/s up to the deactivation limit value of 30 m/s, a linear

20 decrease occurs in an upper power limit value of the turbine, as can be seen from the dashed line with square dots. By specifying this value, an upward limit is placed on the available power of the wind turbine, even if the wind turbine experiences a wind speed that is above its nominal wind speed, i.e. the wind speed at which the turbine could supply its nominal power. The reduction is also called the “soft cutout” or

25 “storm fadeout”. The reduction can also take place in a stepped or non-linear manner. To do so, a rotational speed of the rotor 130 of the wind turbine 100 can be reduced by changing the pitch angle, for example.

The method according to the invention can take this changeable minimum power

30 into account to control the power output of the wind turbines. It follows that wind

turbines with a momentarily available power of less than their minimum power might possibly not be taken into account for the method at all, since production authorization might not be issued to them beforehand. On the other hand, the method according to the invention does not specify any target values below the minimum

5 power for the turbines.

List of Reference Signs

	100	Wind turbine
	110	Tower
5	120	Nacelle
	130	Rotor
	140	Rotor hub
	150	Rotor blade
	160	Anemometer
10	200	Wind farm
	201, 202, 203	Wind turbine
	210	Central wind farm controller
	211	External control system (grid operator)
	220	Substation
15	221	Sensor unit
	230	Electrical transmission grid
	121	Drive train
	122	Gearbox
	123	Generator
20	124	Converter
	125	Rotor-side converter
	126	Grid-side converter
	127	Converter controller
	128	Transformer
25	129	Wind turbine controller
	151	Rotor blade pitch control system
	161	Rotational speed sensor
	n	Number of wind turbines in the wind farm with production authorization
30	SP _j	Active power setpoint of the wind turbine j
	PA _j	Momentarily available active power of the wind turbine j
	CMPL _j	Current minimum power that can be provided by the wind turbine j
	PN _j	Nominal power of the wind turbine j
35	SP _p	Target value for the active power to be fed in at the grid connection point by the wind farm

PATENTKRAV

1. Fremgangsmåde til drift af en vindmøllepark, omfattende en flerhed af vindmøller (vindturbiner), der kan styres og/eller justeres med henblik på at afgive en
5 effekt som reaktion på en modtaget målværdi for en effektrelateret, elektrisk variabel, hvorved fremgangsmåden omfatter de følgende trin:

- 10 a) bestemmelse af en effektstørrelse, der kan fordeles på vindmøllerne i afhængighed af en måleffekt for hele vindmølleparken og minimumseffekter for de enkelte vindmøller,
- b) skabelse af en vægtet fordeling, der tilordner de respektive enkelte vindturbiner en andel af den fordelbare effektstørrelse,
- c) fastlæggelse af målværdier for vindmøllerne, der på grund af deres momentane rådighedseffekter kan afgive mindre eller netop så meget
15 effekt, som er blevet dem tilordnet på grund af den vægtede fordeling, hvorved deres målværdier fastlægges således, at disse vindmøller hver for sig styres til afgivelse af deres momentane rådighedseffekter, men i det mindste til afgivelse af deres minimumseffekter,
- d) bestemmelse af en forblivende effektstørrelse, som står til at blive di-
20 stribueret,
- e) skabelse af en yderligere, vægtet fordeling, som til hver enkelt resterende vindmølle knytter en del af den resterende effektstørrelse, hvilke vindmøller, baseret på deres momentant til rådighed værende effekter, kan afgive mere effekt, end det var tilordnet dem ved hjælp af den tidli-
25 gere vægtede fordeling,
- f) fastlæggelse af målværdier for dem af de resterende vindmøller, som, baseret på deres for øjeblikket til rådighed værende effekt, kan afgive mindre eller lige så stor effekt, som blev tilordnet dem på grund af den yderligere vægtede fordeling, hvorved deres målværdier er defineret så-
30 ledes, at hver af vindmøllerne styres med henblik på afgivelse af deres for øjeblikket til rådighed værende effekt,
- g) gentagelse af trin d) til f), indtil en termineringstilstand er opnået,

h) specificering af de fastlagte målværdier for de respektive vindmøller i vindmølleparken.

2. Fremgangsmåde ifølge krav 1,

- 5 **kendetegnet ved, at** størrelsen af effekt, der kan fordeles til vindmøllerne, bestemmes i henhold til trin a) som en afvigelse ($SP_p - \sum_k CMPL_k$) mellem måleffekten for hele vindmølleparken (SP_p) og minimumseffekten ($CMPL_j$) for alle vindmøllerne ($\sum_k CMPL_k$).

- 10 3. Fremgangsmåde ifølge krav 1 eller 2,

kendetegnet ved, at den vægtede fordeling skabes i henhold til trin b) ved bestemmelse af mellemliggende værdier ($V2SP_j$) som summen af den respektive minimumseffekt ($CMPL_j$) og afvigelsen ($SP_p - \sum_k CMPL_k$) multipliceret med en vægtningsfaktor (g_j).

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4. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at**, ifølge trin c), for de vindmøller, for hvilke den tidligere bestemte mellemliggende værdi ($V2SP_{j^*}$) er større end eller lig med deres for øjeblikket til rådighed værende effekt (PA_{j^*}), er effekten (PA_{j^*}), som for øjeblikket er til rådighed på disse vindmøller, men i det mindste deres respektive minimumseffekt ($CMPL_{j^*}$), defineret som målværdien.
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5. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at**, ifølge trin d), den resterende effektstørrelse, der endnu skal fordeles, bestemmes som en yderligere afvigelse ($\sum_{k^*} (V2SP_{k^*} - PA_{k^*})$), der er dannet som summen af differencerne mellem de respektive mellemliggende værdier ($V2SP_{j^*}$) og de respektive momentant til rådighed værende effekter (PA_{j^*}) fra vindmøllerne, for hvilke den tidligere bestemte mellemliggende værdi ($V2SP_{j^*}$) er større end eller lig med den momentant til rådighed værende effekt (PA_{j^*}).
- 25

6. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** en resterende størrelse af resteffekt, som stadig skal fordeles, bestemmes som en afvigelse ($\sum_{k^*} (CMPL_{k^*} - PA_{k^*})$), der er dannet som summen af differenserne mellem minimumseffekt-værdierne ($CMPL_{j^*}$) og de respektive
- 30

momentant til rådighed værende effekter (PA_{j*}) fra vindmøllerne, for hvilke de til rådighed værende effekter (PA_{j*}) er mindre end minimumseffekten ($PA_{j*} < CMPL_{j*}$), der er tilvejebragt for den respektive vindturbine.

- 5 7. Fremgangsmåde ifølge krav 6, **kendetegnet ved, at** den fordelbare effekt korrigeres, navnlig ved hjælp af en regulator, i afhængighed af den resterende størrelse effekt.
8. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendeteg-**
- 10 **net ved, at**, ifølge trin e), den yderligere, vægtede fordeling skabes ved bestemmelse af yderligere mellemliggende værdier ($V3SP_{j\#}$) som summen af de respektive tidligere mellemliggende værdier ($V2SP_{j\#}$) og den yderligere afvigelse ($\sum_{k*} (V2SP_{k*} - PA_{k*})$) multipliceret med en yderligere vægtningsfaktor (f_j).
- 15 9. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendeteg-**
- net ved, at**, ifølge trin f) for dem af de resterende vindmøller, for hvilke den tidligere bestemte yderligere mellemliggende værdi ($V3SP_{j\#}$) er større end eller lig med deres momentant til rådighed værende effekt ($PA_{j\#}$), er den respektive effekt ($PA_{j\#}$), som momentant er til rådighed på disse vindmøller, defineret som mål-
- 20 værdien.
10. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kende-**
- tegnet ved, at** termineringsbetingelsen er opfyldt, hvis den resterende effekt er mindre end eller lig med en foruddefineret tærskelværdi, og/eller hvis fremgangs-
- 25 måden er udført gennem et forudbestemt antal iterationer, hvorved det foruddefinerede antal iterationer navnlig afhænger af vindforholdene.
11. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kende-**
- tegnet ved, at** den vægtede fordeling og den yderligere vægtede fordeling har
- 30 samme vægtning, og/eller **ved, at** den første vægtningsfaktor (g_j) og den yderligere vægtningsfaktor (f_j) er den samme.

12. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** vægtningen ved den vægtede fordeling og/eller den yderligere vægtede fordeling sker i afhængighed af den momentant til rådighed værende effekt fra den respektive vindmølle, hvorved vindmøller med en højere momentant til rådighed værende effekt vægtes i højere grad end vindmøller med en lavere momentant til rådighed værende effekt.
13. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** vægtningen af den vægtede fordeling og/eller den yderligere vægtede fordeling sker i afhængighed af afvigelsen mellem den nominelle effekt for den respektive vindmølle og dens minimumseffekt, hvorved vindmøller med en mindre afvigelse vægtes højere end vindmøller med en større afvigelse.
14. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** vægtningen af den vægtede fordeling og/eller den yderligere vægtede fordeling sker i afhængighed af den nominelle effekt for den respektive vindmølle, hvorved vindmøller med en højere nominel effekt vægtes højere end vindmøller med en lavere nominel effekt.
15. Vindmøllepark, omfattende en flerhed af vindmøller samt mindst én kontrol-enhed, hvorved kontrolenheden er konfigureret til at udføre fremgangsmåden ifølge et hvilket som helst af kravene 1 til 14, og hvorved kontrolenheden er en kontrolenhed, der er overordnet i forhold til vindmøllerne.

1/4

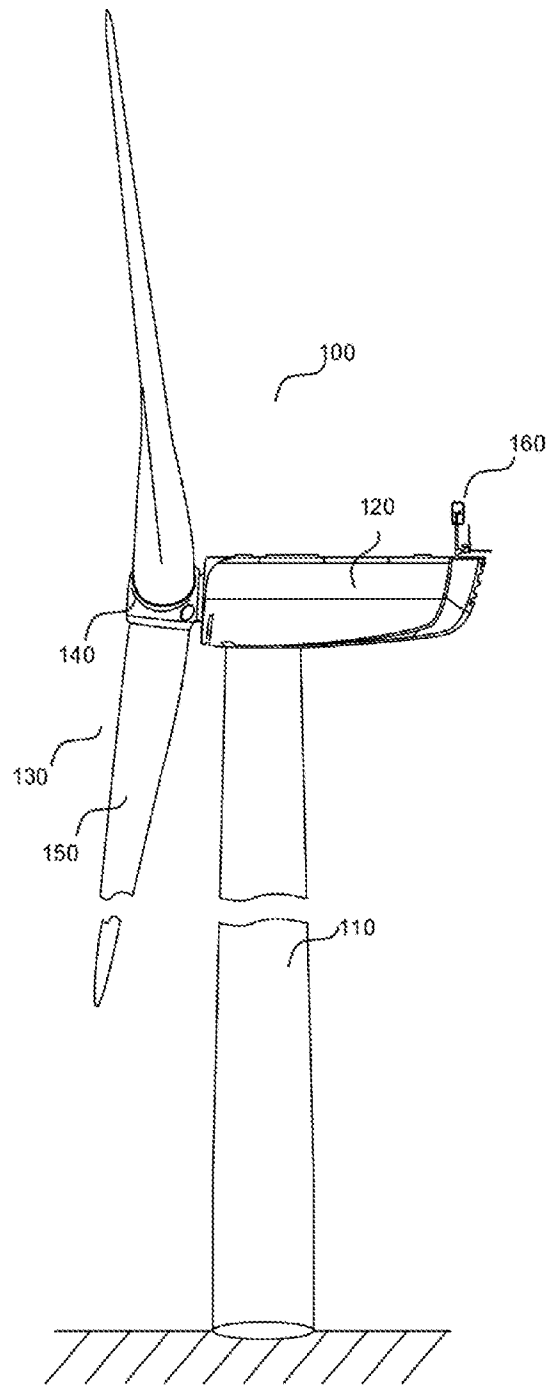


Fig. 1

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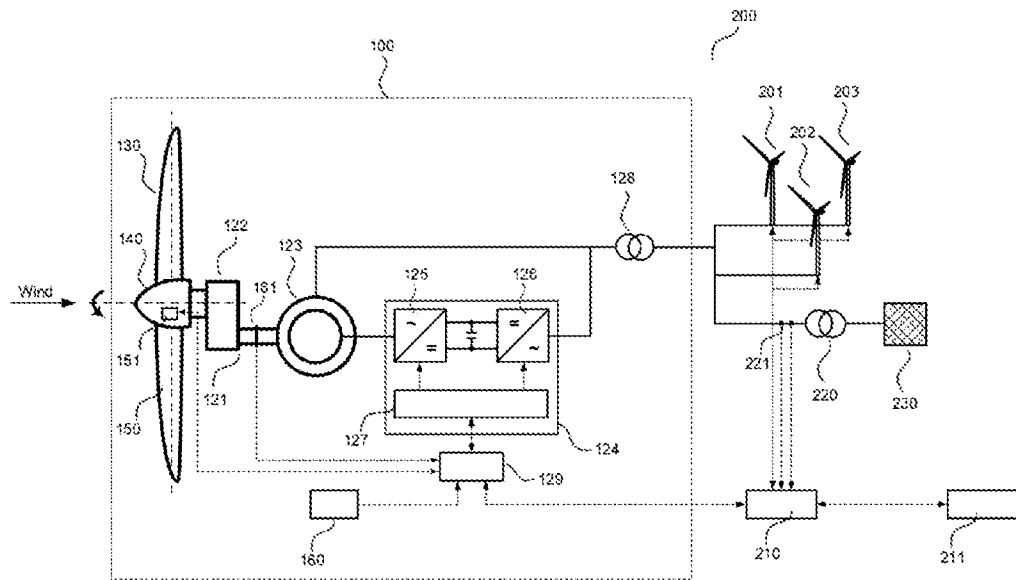


Fig. 2

3/4

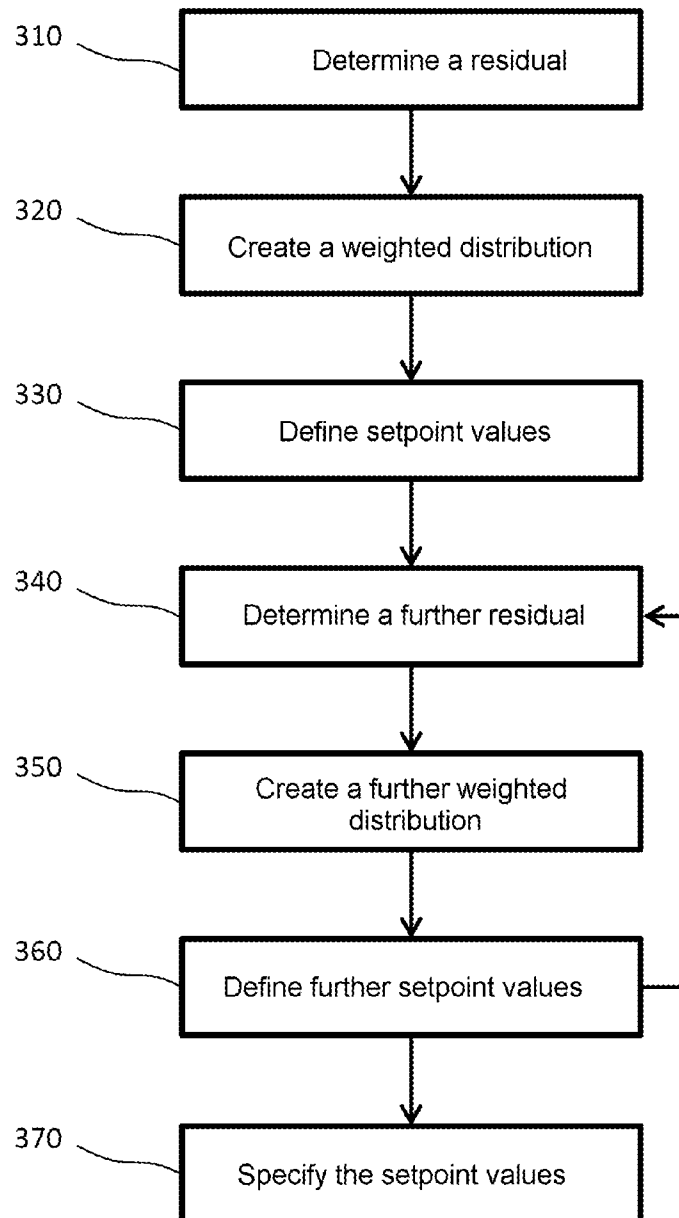


Fig. 3

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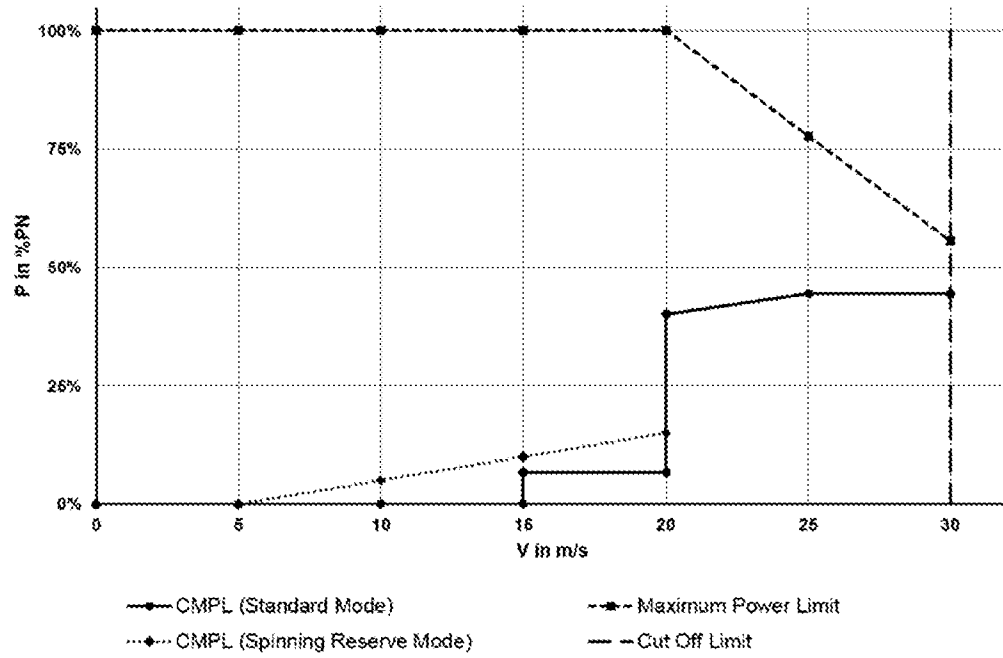


Fig. 4