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(54) Benævnelse: **VINDENERGIANLÆG MED STANDARDVÆRDI FOR REAKTIV EFFEKT**

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MARIUSZ MALINOWSKI ET AL: "Control of Variable-Speed Type Wind Turbines Using Direct Power Control Space Vector Modulated 3-Level PWM Converter" INDUSTRIAL TECHNOLOGY, 2006. ICIT 2006. IEEE INTERNATIONAL CONFERENCE ON, IEEE, PI, 1. Dezember 2006 (2006-12-01), Seiten 1516-1521, XP031178073 ISBN: 978-1-4244-0725-5
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Description

The invention relates to a wind energy plant having a rotor, a generator which is driven by the latter and has a converter for feeding electrical power into a network via a connecting line, and a control device, the control device comprising a converter controller which is designed to control a reactive power component of the power according to a specified value.

To expand the production of electrical energy by means of wind energy, wind energy plants and wind farms with ever greater power are being erected. They are preferably located at sites with high wind availability, such as in particular on elevations, at coasts or offshore in the sea. What these sites have in common is that they are usually located in regions of little or no population, where the electrical network has a low capacity. In order nevertheless to maintain an adequately high quality of supply, tightened requirements are placed on the wind energy plants and/or the wind farms in terms of their network compatibility.

One important criterion for secure and regular operation relates to the supply of reactive power. The connection criteria of many network operators place tight specifications on the power factor. This concerns the relationships at the connection to the network. Wind energy plants are usually connected to the network through a medium-voltage transformer, a connecting line and in some cases a high-voltage transformer. All of these components form reactances, and thus affect the power factor. In order to satisfy the connection criteria, the power factor must be kept within specified limits, and must not change in an uncontrolled manner.

Controlling the power factor can be achieved in that it is measured at the point of connection to the network, and the wind energy plant and/or the wind park is adjusted suitably in response to deviations. Fitting wind energy plants that have synchronous generators with fully controllable converters is known for this purpose (US-A-5,225,712 and Mariusz Malinowski et al.: "Control of Variable-Speed Type Wind Turbines Using Direct Power Control Space Vector Modulated 3-Level PWM Converter"). A converter controller is provided which, through specific switching of the active elements of the converter, determines the phase angle of the power output, and thus specifies the power factor of the power delivered to the network. Relatively complex sensors which determine both the current and the voltage, together with their phases, are provided to determine the power factor at the point of connection.

A monitoring of the reactive power in a wind farm is known from EP 1 512 869 A1.

Measuring the reactive component of the power supplied by the wind plant and comparing it with a specified value is also known (US-A-2006/0012181). A reactive power error is determined from the difference, and from this, taking the voltage at the connecting terminals also into account, modified control parameters are determined for the generator. The reactive power is decoupled from the real power in this concept, and the maintenance of a specific power factor can therefore not be guaranteed.

The invention is based on the object of providing, on the basis of the prior art just mentioned, an improved wind energy plant or a wind farm and a method for their operation.

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

In a wind energy plant having a rotor, a generator which is driven by the latter and which has a converter for feeding electrical power into a network via a connecting line, and a control device, the control device comprising a converter controller which is designed to control a reactive power component of the power according to a specified value, a primary control module is provided according to the invention for the purpose of outputting a signal for a desired reactive power and is designed to determine the desired reactive power in a current-led manner on the basis of a degree of current flow.

Some terms used are explained below:

"Current-led" means that the determination of the desired reactive power is based solely or at least mainly on the current. A determination that makes equal use of the current and the voltage is not considered "current-led".

"Primary control module" refers to a device that functions as the actual controller. It is this that combines a reference variable (flow of current) with the desired manipulated variable (reactive power). The primary control module is to be distinguished from optional secondary control modules that modify the manipulated variable as required on the basis of additional parameters.

The invention is based on the idea of providing a simple control method with the current-dependent specification of reactive power, with which nevertheless a good adjustment of the reactive power is achieved. The invention has recognized that in settling on the flow of current as the reference variable, not only is an easily handled reference variable provided, but that also it is possible in addition to achieve an adjustment of the reactive power to the real power. Expensive apparatus for the determination of the power factor, as is used in the prior art, can be omitted thanks to the invention. It is true that if the apparent current is used as the degree of current flow the adjustment is not necessarily perfect, particularly since, when the reactive power changes, it also changes immediately. Surprisingly, however, this is not disadvantageous for the achieved result. This is because the invention here exploits the fact that, particularly in the important higher power ranges, the apparent current and the effective current only differ slightly, so that according to the invention a very good approximation to the required reactive power is enabled using the apparent current.

A further advantage of the invention is that it enables reactances in the connecting line, particularly of transformers for medium and/or high voltage, to be taken into account with little effort. Using the known electrical parameters of the connecting line, it is possible to determine how the generator is to be set in order, at the particular current flow, to provide the desired reactive power at the point of connection to the network. The invention thus permits a faster and more accurate compensation for reactances then a conventional control based on the power factor. It combines advantages in terms of precision with simple applicability. It is suitable not only for reactances connected in series, such as transformer, stray or line inductances, but also for reactances connected in parallel, such as the main transformer inductance or the line capacitance.

Advantageously the primary control module comprises a section model of the connecting line between the wind energy plant and the point of connection to the network. The operating equipment with which the wind energy plant is connected to the network can be taken into account in the section model. The operating equipment reduces the real power as a result of the power losses occurring in it; reactive losses also regularly occur in it, shifting the reactive power fed into the network in the "inductive" or in the "capacitive" direction. A different power factor thus results in the network than in the wind energy plant itself. The section model is designed to determine an estimated value for the reactive power from the degree of current flow. Not all the operating equipment has to be included in the section model - it is sufficient to include the predominant equipment. The invention has recognized that these are a medium-voltage transformer (usually arranged at the wind energy plant) and, optionally, a high-voltage transformer (arranged at the connection of the connecting line to the network). Their reactances are X_T and X_H respectively. If, for example, the voltage drop is

$$U_1 = X * I \quad (1)$$

then, with a reactance of

$$X = X_T \quad (2)$$

for the medium-voltage transformer or, optionally, for the medium-voltage and high-voltage transformer, neglecting the line itself

$$X = X_T + X_H = C * X_T \quad (3),$$

a desired reactive power of

$$Q = 3 * U_1 * I = 3 * C * X_T * I^2 \quad (4),$$

results in a three-phase system, where

$$C = 1 + \frac{X_H}{X_T} \quad (5)$$

By taking the section model into account, it becomes possible to determine how the power factor changes on the basis of the wind energy plant itself, through the operating equipment to the network. The section model makes it possible to calculate the reactive power to which the wind energy plant must be set in order to achieve a target power factor that is desired (and required by the connection guidelines). The section model thus permits an effective feed-forward control, meaning that the power factor at the network can be determined from the current flow of the wind energy plant alone. In this way, the reactive losses of the operating equipment along the connecting line can be compensated for in an astonishingly simple and effective manner.

It is particularly expedient if this section model comprises a second-order functional member (containing at least one quadratic term and, if relevant, a linear and a constant term). The second-order functional member models the above-mentioned relationship. It permits a simple and accurate feed-forward compensation in which, through a measurement of current that can be made at the wind energy plant, the reactive power at the point of connection of the connecting line to the network can be determined.

In many cases, the determination of the current flow value is most easily made by direct measurement. The current flow value can, however, be determined in other ways. It can also be provided that an observer for determining the degree of current flow is provided, which determines an equivalent degree for the degree of current flow from one, preferably at least two, other parameters. The observer also makes it possible to determine a value that is not directly measured or measurable. The observer makes it possible to omit the measurement of the current. Thanks to the observer, dedicated measurement sensors for the current are superfluous, which is in particular advantageous for the wind energy plants of higher power classes that are being used with increasing frequency, or in the case of large wind farms. In one particularly advantageous embodiment, which may be worthy of independent protection, the observer and the primary control module are implemented in integrated form. The integration makes it possible to determine the wanted desired reactive power directly from the parameters used for the observer without the calculation of intermediate values. Numerically efficient calculation methods can be chosen, thanks to omitting intermediate magnitudes. The observer can, for example, be so constructed that a degree of current flow is determined from parameters that are in any case present in the converter controller, such as, for example, the speed of rotation of the wind rotor, the shaft torque and/or the network voltage delivered. This is not, however, essential, and it is also possible to use an intermediate magnitude that does not have a physical significance of its own. With such an observer, the invention combines low instrumentation complexity with efficient calculation, which is ideally suited for implementation on a numerically operating processor.

In addition to the primary control module, a correction module can be provided in the converter controller. It is constructed to determine a correction value for the desired reactive power on the basis of the voltage. It is, in principle, possible that in the case of excessively high voltage without compensation, a desired value of reactive power that is too high is output; conversely, when the voltage is too low, that a desired value of reactive power that is too low is output. The voltage is preferably measured at the wind energy plant, specifically at the medium-voltage level; a measurement prior to the medium-voltage transformer, or at the high-voltage transformer, should not however be ruled out. With this it is possible to correct the value of the current flow in such a way that the primary control module compensates the current determined at an arbitrary voltage as if the rated voltage, or another selected reference voltage, were present. It can be provided for this purpose that the correction module acts on an exponent in the primary control module in order, for example, in the case of the second-order functional member, to deviate from the nominal value of "two" for the exponents. The determination of the desired value of reactive power according to the invention from a value of current flow is thus independent of the voltage that is actually present. The correction module can further advantageously be developed further such that it compensates for line capacitances and/or main transformer inductances. Their reactances act in a voltage-dependent manner on the power factor. Through appropriately adjusted changes to the specified reactive power it is in this way also possible to achieve a compensation for this operating equipment.

A partial load correction model can also be provided. It has been found that an improvement in the stability of the reactive power behaviour under partial load can be achieved through a controlled reduction in the desired value of the reactive power with respect to a base value calculated purely on the basis of the current. Expediently this is achieved in that, as was already explained above, the exponent of the primary control module is changed, this preferably being done in the range between one and two.

Advantageously a limiting module is provided for the desired reactive power. It follows the primary control module, and is designed to limit the desired reactive power within a predeterminable range. A value of zero can, for example, be provided as the lower limit, so restricting the desired reactive power to the range of over-excited operation. It has been found that a change between positive and negative desired reactive power can have unfavourable effects on the system stability of the wind energy plant. A constant value can, for example, be provided as the upper limit, corresponding to a wanted power factor when the wind energy plant is approximately half-loaded. At high loading and correspondingly greater real power supplied by the wind energy plant, the desired reactive power then remains restricted constantly to the value of the upper limit, meaning that the power factor changes. The invention has recognized that this counters the risk of unstable operating points of the wind energy plant. It offers, moreover, the advantage that, through the restriction of the desired reactive power to an upper limit, the components involved can be designed with lower size, particularly in view of an operation at under-voltage. Through the limitation, therefore, surprising advantages in terms of operational security and cost-effectiveness are combined together.

The invention accordingly relates to a wind farm with a plurality of wind energy plants, and a farm master, wherein the values for the desired reactive power are determined by the farm master, and transmitted to the wind energy plants. For this purpose, the farm master comprises a reactive power control device that incorporates a primary control module. This is designed to determine, depending on a degree of current flow, values for the respective desired reactive power in a current-led manner for the various wind energy plants of the wind farm. The values are transmitted to the wind energy plants, and the respective local control device of the wind energy plant adjusts the converter appropriately.

The invention furthermore covers a corresponding method for operating a wind energy plant or a wind farm. Reference is made to the above embodiments for a closer description.

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

Fig. 1 shows a schematic view of a wind energy plant according to the invention;

Fig. 2 shows a schematic view of a converter and its controller;

Fig. 3 shows an equivalent circuit diagram of a connecting line;

Fig. 4 shows a detailed view of the converter controller according to a first exemplary embodiment;

Fig. 5 shows a detailed view of the converter controller according to a second exemplary embodiment;

Fig. 6 shows a detailed view of the converter controller according to a third exemplary embodiment;

Fig. 7 shows a schematic view of a wind farm according to the invention;

Fig. 8 shows various characteristic curves of supplied reactive power.

An exemplary embodiment of a wind energy plant according to the invention is illustrated in Fig. 1. It comprises a tower 10 on which a pivoting machine cabin 11 is arranged. A wind rotor 12 is arranged rotatably on its front face, and connected via a drive shaft to a generator 3. The generator 3 is preferably a double-fed asynchronous machine, but other structural types such as synchronous, asynchronous, or permanently excited machines can however also be used. The generator 3 is connected electrically to a converter 4 and also to a line 15. The converter 4 can be implemented and connected as a full or partial converter. A control device 5 is provided for operational control of the wind energy plant. It is designed to carry out the operational management of the wind energy plant. It comprises a converter controller 6 for this purpose. It is designed to operate the converter 4 - put more precisely, its active switching elements - on the basis of adjustable specifications. This will be explained in more detail further below. The electrical power produced by the generator 3 is passed over the line 15 to the foot of the tower 11. A connecting line 7 is connected there, the other end of which is connected to a high-voltage energy transmission network 9. The connecting line 7 comprises, as components, a medium-voltage transformer 71, a medium-voltage line system 72, and a high-voltage transformer 73.

Further wind energy plants 1', which have the same or similar construction to the wind energy plant 1, can be connected to the medium-voltage line system. If a plurality of wind energy plants 1, 1' are grouped together, a wind farm can thus be formed with a farm master 8 (see Fig. 7). The interaction of the farm master 8 with the wind energy plants 1, 1' will be explained later in more detail.

The control device 5 and its interaction with other components of the wind energy plant are illustrated in Fig. 2, where, for reasons of clarity, a single-phase representation has been chosen. The generator 3 is implemented as a double-fed asynchronous machine, and comprises a stator 31 and a rotor 32. The first-mentioned is connected directly to the line 15 and the connecting line 7, while the latter is connected to it via a converter 4. The converter 4 comprises a machine-side inverter 41, an intermediate circuit 42, and a network-side inverter 43. The construction of such converters is known per se, and does not need to be explained in more detail. What is important is that at least one of the inverters 41, 43 comprises controllable, active switching elements (not illustrated) such as, in particular GTOs or IGBTs. The network-side inverter is connected to the line 15 coming from the stator. A current sensor 51 is provided between this point and the medium-voltage transformer 71. It measures the total current produced by the generator 3 and delivered to the network 9, and outputs it as a current flow value I. The current flow value I is connected to the input 56 of the converter controller 6. Their structure and mode of operation is explained in more detail below. The converter controller outputs a desired reactive current signal Q at an output 61, which is applied to the converter 4 via the control device 5.

In its basic form, as illustrated in Fig. 4, the converter controller 6 comprises a primary control module 61. It is designed to determine a value for a desired reactive current from a degree of current flow applied to the input 56, which is output at the output 61 and set by the converter 4. For this purpose the primary control module 61 comprises a simple section model that consists of a second-order functional member as the squaring member 621 and a proportional member 622 that effects a multiplication with an adjustable value C. The simplified section model is based on the following considerations: the medium-voltage transformers 71 (and short medium-voltage line system 72) can be considered, with sufficient precision, in the simplified form of an R-X equivalent circuit diagram (see the left-hand part of Fig. 3). With a current I, real losses

$$P_V = 3 * R * I^2 \quad (6)$$

and reactive losses

$$Q_V = 3 * X * I^2 \quad (7)$$

occur in this element. The reactive losses actually produced in operation are determined practically directly by the current, and depend on it quadratically. In the place of a complicated consideration of reactive power, or the calculation of power factor, the invention therefore proposes to determine the desired reactive power value in a current-led manner, and to do so in accordance with the formula

$$Q = C*3*X*I^2 \quad (8),$$

with C as a supplementary factor for determining the adjustment. The degree of current flow is the current I measured by the current sensor 34. A power measure is formed from this by squaring, which is appropriately scaled through multiplication with the value 3*C*X. The following applies to the value C: if only the medium-voltage transformer is to be compensated, then C = 1; if only partial compensation is employed, C lies in the range between 0 and 1; and if additional impedances such as the high-voltage transformer require compensation (see right-hand part of Fig. 3), then C lies in the range between 1 and 3. If reactive power is to be provided in under-excited operation, C may be chosen in the range between 0 and -3. The last option permits application of the invention also to weak networks with long lines to the wind energy plant.

Fig. 8a shows a graph illustrating the curve of the power factor cos ϕ (COSPHI) achieved with the reactive power specification obtained in a current-led manner according to the invention against the real power (0 to 4000 kW) at various voltages; this is shown both for the rated voltage (690 V) and also for a 10% over-voltage (759 V) and correspondingly a 10% under-voltage (621 V). The graph is based on a design for a target power factor of 0.975 at a real power of 2000 kW and a rated voltage of 690 V (in the line 15). It can clearly be seen that, particularly in the region of the rated voltage, the target power factor is achieved well over a wide range, with an entirely desirable reduction at very high power.

The apparent current is used for the degree of current flow I in the exemplary embodiment illustrated. The current sensor 51 used for this purpose can have a relatively simple construction. In most applications, the required power factor does not different greatly from 1 (e.g. 0.95 or 0.9), so that the reactive power component can be small in comparison with the real power component. The apparent current I therefore does not differ greatly from the real current, so that the more-easily determined apparent current can be used as the current flow value for the invention. The use of the real current as the current flow value should not, however, be excluded.

It is true that a simple measuring sensor 51 for determining the degree of current flow is sufficient for the invention, although all of the current from the wind energy plant flows through it. The measuring sensor must therefore have large dimensions, and is correspondingly expensive. As an alternative to direct measurement, it can be provided that the degree of current flow is determined indirectly from at least one other parameter. An observer that determines the degree of current flow indirectly from the other parameter can be provided for this purpose (see Fig. 5). Such parameters as are in any case present in the control device 5 of the wind energy plant 1, or of the converter controller 6, are preferably used for this purpose. It has been found in particular that the speed of rotation N of the wind rotor 12 is a suitable parameter. In modern pitch-controlled wind energy plants, the speed of rotation N at partial load is held with a constant ratio to the wind speed, which is in turn the determining factor for the power produced by the wind energy plant. An observer 63, to which the speed of rotation N is applied as a parameter, can therefore optionally be provided to determine the degree of current flow. The observer 63 can be designed in such a way as to determine a power through multiplication of the speed of rotation N with the torque M in a multiplication member 631, and from this, taking into account a voltage signal according to a voltage reference 413, to determine a value for the degree of current flow through division 632. The observer 63 thus determines the degree of current flow from desired values.

A partial load correction model 60 can also be provided. It is designed to reduce the desired reactive power value calculated in a current-led manner when under partial load. A characteristic curve member can be provided for this purpose which, depending on the load, provides a reduction of the reactive power by a specific percentage factor. A direct action on the primary control module 62, as illustrated in Fig. 5, is more expedient. Here the section model 621 is modified by a connecting line 602, depending on the load. For example, reduced exponents (in the range between 1 and 2) are contained in a characteristic curve member 601 of the partial load correction module 60 for a squaring module 621 of the section module. Under full load then, calculation is carried out normally with an exponent of 2, whereas under partial load calculation is performed with exponents of, for example, 1.9 or even 1.8. A harmonious and controlled reduction in the desired reactive power value with respect to the plain basic value, which results in an improvement to the stability in particular in terms of the dynamic behaviour, can be achieved with this. The reduction under partial load is illustrated in the graph of Fig. 8b over the entire range of powers for various voltages.

In a particularly preferred embodiment, which may be worthy of independent protection, the primary control module and the observer are implemented in integrated form 64. A more direct and thus more efficient calculation of the desired reactive power Q is enabled by the integrated unit 64. For a three-phase system, the foundation for this is provided by the relationships

$$S^2 = P^2 + Q^2$$

$$I = \frac{S}{\sqrt{3} * U} \qquad (9)$$

$$Q = C * 3 * X_T * I^2$$

from which, through mutual substitution, the quadratic equation

$$Q^2 - \frac{U^2}{C * X_T} * Q - P^2 = 0 \quad (10)$$

results. This has two solutions, a stable solution

$$Q_1 = P_{stab} - sign(C) * \sqrt{P_{stab}{}^2 - P^2} \quad (11)$$

and unstable solution

$$Q_2 = P_{stab} + sign(C) * \sqrt{P_{stab}{}^2 - P^2} \quad (12)$$

where

$$P_{stab} = \frac{U^2}{2*C*X_T} \quad (13)$$

as the stability limit value for the real power. The integrated implementation makes it possible to calculate directly the stability limit value, and then a stable value for the desired reactive power. Such an integrated embodiment is illustrated in Fig. 6. The speed of rotation N and the desired torque M are applied as input signals. The observer further comprises a section model 643 to which a voltage value, i.e. the desired voltage value, or a value recorded by a voltage sensor for the actual voltage, is connected through a selection switch 641. The section model 643 takes the reactance Xt of the medium-voltage transformer and the supplementary factor C into account. The stability limit Pstab is calculated from this. By means of a multiplication member 645, a value for the actual power P is obtained from the input signals for the speed of rotation N and the desired torque M, and this is combined with the value for the stability limit Pstab and the algebraic sign of the factor C by the members 646 to 652 according to the above equation (13), and the stable solution for the desired reactive power is thus determined according to equation (11). A limiter 66, which restricts the values for the desired reactive power to a range between a selectable lower limit Q_{min_I} and a selectable upper limit Q_{max_I}, is further provided. This limited signal is output, and can be applied to the converter. Thanks to the direct calculation, intermediate values do not have to be calculated separately. An independent current sensor 51 can be dispensed with here, since the equivalent information for the degree of current flow - as explained above - can be obtained from the integrated observer. The direct calculation is fast, since iterations do not have to be carried out. It furthermore ensures the stability of the calculated desired reactive power.

A correction module 67 can be provided in order to improve the precision further. Its purpose is to change the desired reactive power determined in one of the ways described above so as to compensate for voltage deviations. A signal for the actual voltage, taken from a voltage sensor 52 at the connecting line 7, is applied to an input of the correction module 67. The correction module 67 comprises a section model 673 that is designed to determine correction values for the current depending on the actual voltage. The section model member 63 models the reactances X_{mag} and X_C caused by the main inductance of the medium-voltage transformer and the line capacitance of the connecting line, and outputs a correction value for the reactive power. A downstream delimiter 68 limits the correction value to a range between an adjustable lower limit Q_{min_U} and an adjustable upper limit Q_{max_U}. The correction value limited in this way is added in a summation member 69 to the desired reactive power determined by the integrated unit 64. The graph of Fig. 8c shows the power factor COSPHI against the real power P (over the range from 0 to 4000 kW) at reduced voltage. The reduction in the power factor, and thereby the increase in the reactive power compared to the corresponding under-voltage characteristic curve of Fig. 8a, can clearly be seen

Finally, an optional mode selector 65 can also be provided. The desired reactive power determined by the primary control module, the correction value determined by the correction device 67, and the desired reactive power formed by the summation member 69, are applied to its inputs. The mode selector 65 is operated by its control input in such a way that one of the applied signals is provided at the output 61 to the converter 4. The possibility is thus additionally opened up of switching over to a different control regime, for example to a specification of reactive power in a voltage-led manner.

The voltage correction module 67, the limiter 66 and/or the mode switch 67 can also optionally be provided in the other forms of embodiment (Fig. 4, 5). Equally, the partial load correction module 60 can be provided in the other forms of embodiment (Fig. 4, 6).

When a plurality of wind energy plants 1, 1' are grouped together to form a wind farm, the determination of the desired reactive power in a current-led manner according to the invention can be performed centrally by the farm master 8, instead of non-centrally in the individual wind energy plants 1, 1'. The farm master 8 is provided for this purpose with a power control device 85 which determines the desired reactive power centrally for the wind energy plants 1, 1' of the wind farm. Sensors 83, 84 for the current and voltage are connected to the farm master 8, with which the electrical power produced by the wind energy plants 1, 1' is fed over the network of connecting lines 7 internal to the farm, through the high-voltage transformer 73 into the network 9. The structure and mode of operation of the power control device 85 correspond to the above explanation related to the individual wind energy plants. The wind park further comprises a communication network 87, over which signals are exchanged between the farm master 8 and the wind energy plants 1, 1'. The communication network can be built as a dedicated wired network, or, as illustrated in Fig. 7, as a radio network. The farm master 8 and the wind energy plants 1, 1' each have a radio module 88 which is connected to the respective control device 5, 85. The wind energy plants 1, 1' each obtain their desired value for the reactive power from the farm master 8 over the communication network, and this is then appropriately set in the individual wind energy plants by the local control device 5 by means of the converter 4.

Patentkrav

1. Vindenergianlæg med en rotor (12), en dermed fremdrevet generator (3) med en omformer (4) til tilførsel af elektrisk effekt til et net (9) via en forbindelsesledning (7) og en styreindretning (5), hvor styreindretningen (5) omfatter en omformerstyring (6), der er udformet til kontrol af en reaktiv effektandel af effekten i henhold til en standardværdi,
kendetegnet ved, at
der er indrettet et primært styremodul (62, 64) til udlæsning af et signal for et setpunkt for reaktiv effekt (Q), hvilket styremodul er udformet til strømført bestemmelse af setpunktet for reaktiv effekt i afhængighed af et mål for strømgennemløbet, hvor der ved strømført forstås, at bestemmelsen af setpunktet for reaktiv effekt alene eller i det mindste hovedsageligt er baseret på strømmen.

2. Vindenergianlæg ifølge krav 1,
kendetegnet ved, at
det primære styremodul (62, 64) har en strækningsmodel (621, 622) til bestemmelse af en anslået værdi for den reaktive effekt ud fra målet for strømgennemløbet.

3. Vindenergianlæg ifølge et af de foregående krav,
kendetegnet ved, at
der er indrettet en måleindretning (51) til måling af den strøm, der flyder gennem forbindelsesledningen (7), fortrinsvis den tilsyneladende strøm.

4. Vindenergianlæg ifølge et af de foregående krav,
kendetegnet ved, at
der er indrettet en iagttager (63) til bestemmelse af målet for strømgennemløbet, hvilken iagttager ud fra en, fortrinsvis i det mindste to andre parametre bestemmer et erstatningsmål for målet for strømgennemløbet.

5. Vindenergianlæg ifølge et af de foregående krav,
kendetegnet ved, at

omformerstyringen (6) endvidere omfatter et korrektionsmodul (67), som i afhængighed af spændingen bestemmer en korrektionsværdi for setpunktet for reaktiv effekt.

6. Vindenergianlæg ifølge krav 5,
kendetegnet ved, at
der er indrettet en modeselektor (65), som valgfrit udlæser setpunktet for reaktiv effekt med eller uden korrektionsværdien eller kun korrektionsværdien som udgangssignal.

7. Vindenergianlæg ifølge et af de foregående krav,
kendetegnet ved, at
et begrænsningsmodul (66) er koblet efter det primære styremodul.

8. Vindpark med et flertal af vindenergianlæg (1, 1'), som genererer elektrisk energi til afgivelse til et net (9), og en parkmaster (8) til styring af vindenergianlægget (1, 1'), hvor vindenergianlægget (1, 1') har en rotor (12), en dermed fremdrevet generator (3) med en omformer (4) til indførsel af elektrisk effekt i en parkintern forbindelsesledning (7), og parkmasteren (8) har en styreindretning for reaktiv effekt (85),
kendetegnet ved, at
styreindretningen for reaktiv effekt (85) har et primært styremodul (62, 64) til udlæsning af et signal for et setpunkt for reaktiv effekt (Q), hvilket styremodul er udformet til strømført bestemmelse af setpunktet for reaktiv effekt i vindenergianlæggene (1, 1') i afhængighed af et mål for strømgennemløbet, hvor der ved strømført forstås, at bestemmelsen af setpunktet for reaktiv effekt alene eller i det mindste hovedsageligt er baseret på strømmen.

9. Vindpark ifølge krav 8,
kendetegnet ved, at
styreindretningen for den reaktive effekt (85) er udformet ifølge kravene 2 til 7.

10. Fremgangsmåde til drift af et vindenergianlæg (1, 1') med en rotor (12), en dermed fremdrevet generator (3) med en omformer (4) til tilførsel af elektrisk effekt til et net (9) via en forbindelsesledning (7) og en styreindretning (5), hvor styreindretningen (5) omfatter en omformerstyring (6), der kontrollerer en reaktiv effektandel af effekten i henhold til en standardværdi, kendetegnet ved
bestemmelse af et mål for strømgennemløbet,
strømført bestemmelse af et setpunkt for reaktiv effekt i afhængighed af målet for strømgennemløbet, hvor der ved strømført forstås, at bestemmelsen af setpunktet for reaktiv effekt alene eller i det mindste hovedsageligt er baseret på strømmen.

11. Fremgangsmåde ifølge krav 10,
kendetegnet ved
anvendelse af en strækningsmodel (621, 622) til beregning af en grundværdi for setpunktet for reaktiv effekt ud fra målet for strømgennemløbet.

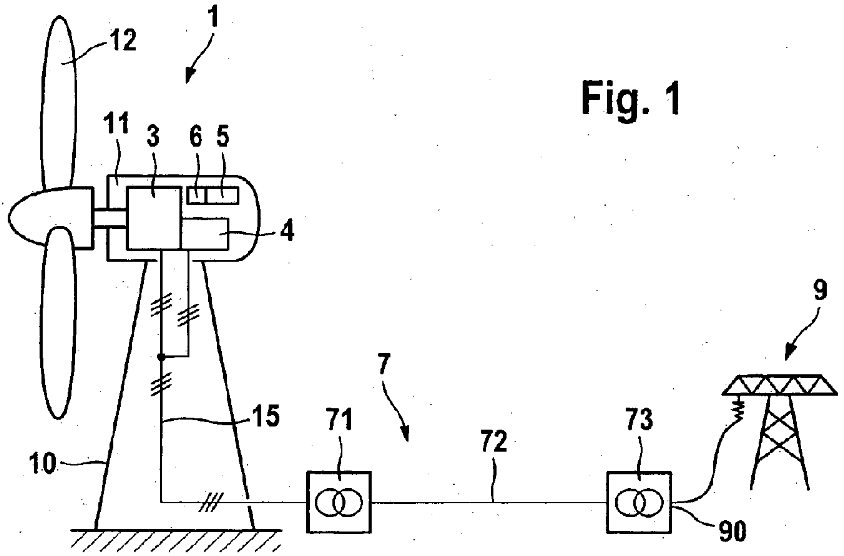
12. Fremgangsmåde ifølge et af kravene 10 til 11,
kendetegnet ved
bestemmelse af et erstatningsmål for målet for strømgennemløbet ud fra en, fortrinsvis i det mindste to andre parametre ved hjælp af en iagttager (63).

13. Fremgangsmåde ifølge et af kravene 10 til 12,
kendetegnet ved
bestemmelse af en korrektionsværdi for setpunktet for reaktiv effekt i afhængighed af spændingen.

14. Fremgangsmåde til drift af en vindpark med et flertal af vindenergianlæg (1, 1'), som genererer elektrisk energi til afgivelse til et net (9), med en rotor (12), en dermed fremdrevet generator (3) med en omformer (4) til indførsel af elektrisk effekt i en parkintern forbindelsesledning (7), hvor parkmasteren (8) har en effektstyreindretning (85), som

kontrollerer en reaktiv effektandel af effekten i henhold til en standardværdi,
kendetegnet ved
bestemmelse af et mål for strømgennemløbet,
stømført bestemmelse af et setpunkt for reaktiv effekt i afhængighed af målet for strømgennemløbet for vindenergianlæggene (1, 1'), hvor der ved strømført forstås, at bestemmelsen af setpunktet for reaktiv effekt alene eller i det mindste hovedsageligt er baseret på strømmen.

15. Fremgangsmåde ifølge krav 25,
kendetegnet ved
bestemmelse af setpunktet for reaktiv effekt ifølge kravene 11 til 13.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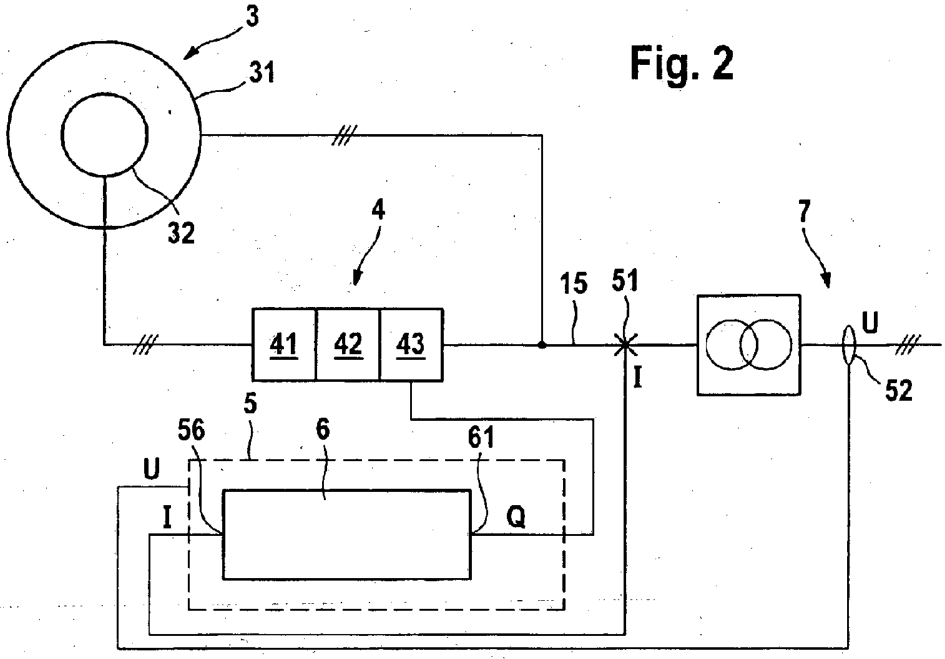
73
9
90

Fig. 1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56
6
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I
Q

Fig. 2

Fig. 3

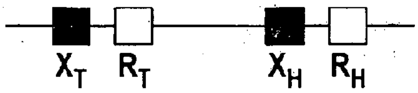


Fig. 4

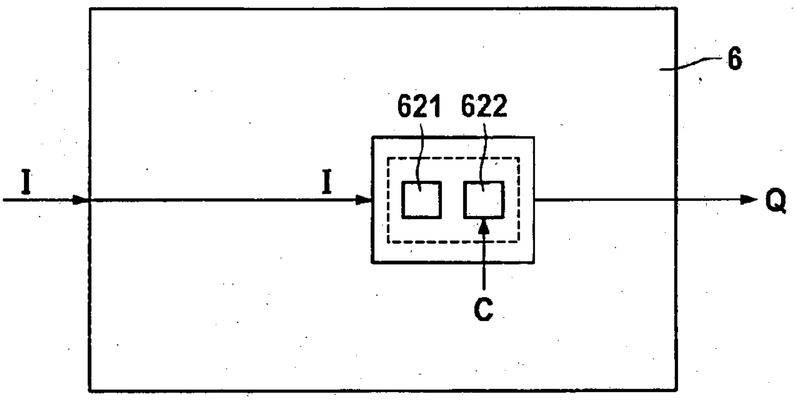


Fig. 5

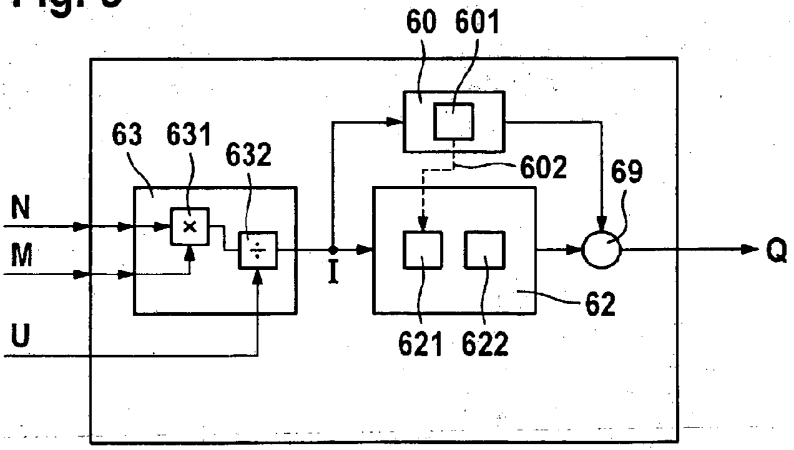
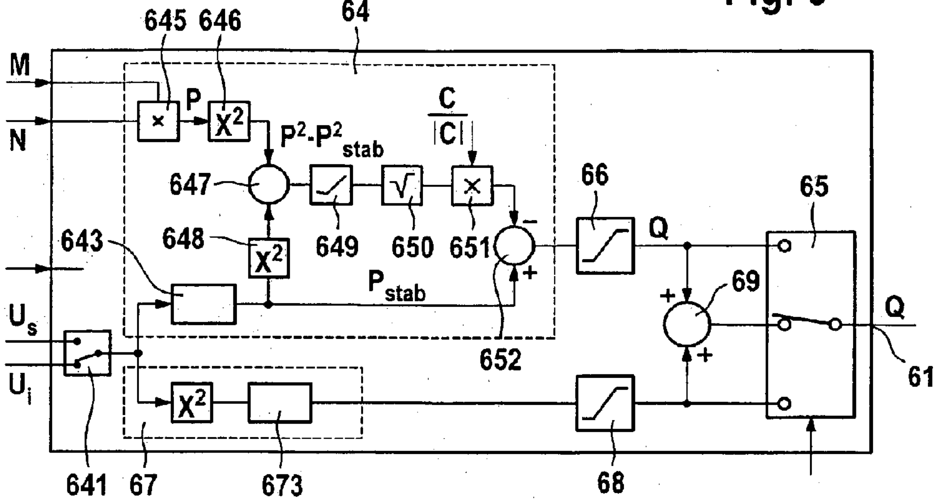


Fig. 6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Pstab
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Fig. 7

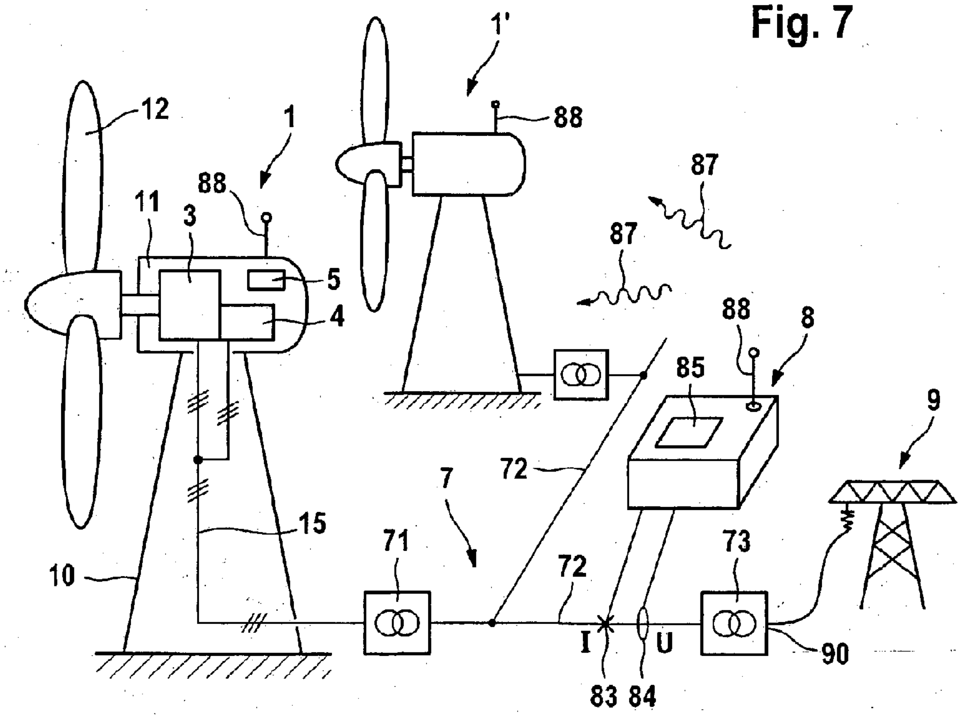
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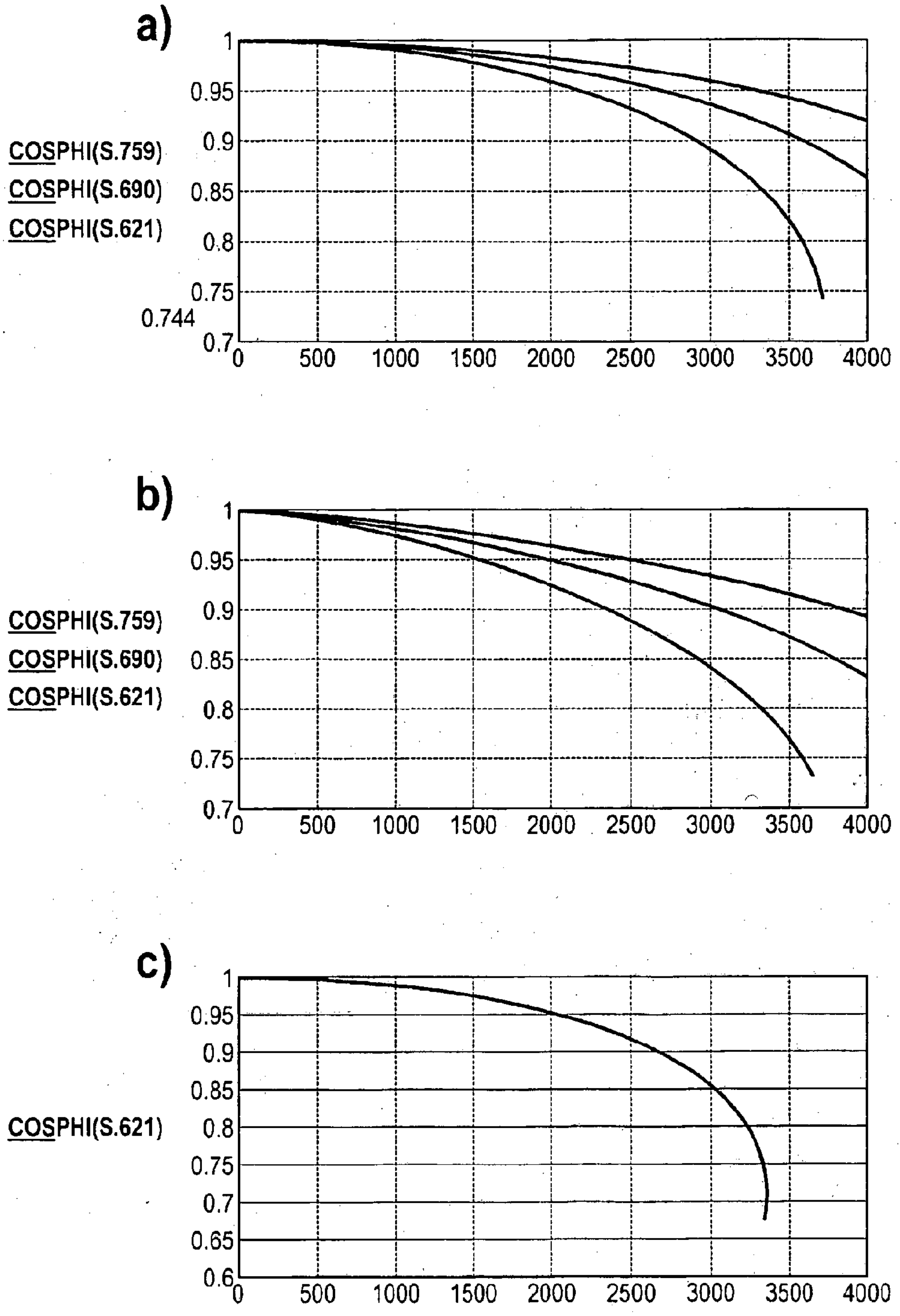
Fig. 8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COSPHI(S.690)
COSPHI(S.621)
b)
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COSPHI(S.759)
COSPHI(S.690)
COSPHI(S.621)
c)
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4000
COSPHI(S.621)