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(54) Title: A WIND POWER PLANT

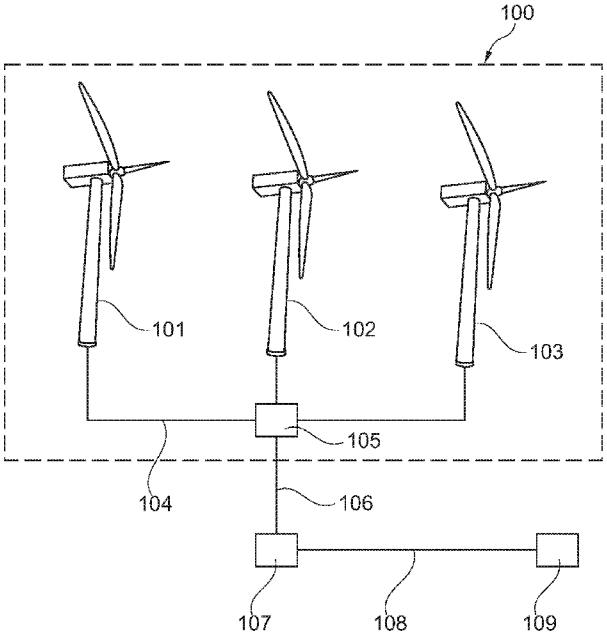

Fig. 1

(57) Abstract: The present invention relates to a wind power plant for feeding power to an external power grid, the wind power plant comprising one or more groups of wind turbine generators, each group comprising a plurality of wind turbine generators operatively connected to a common group switchgear of that group via an internal power grid of that group, and a wind power plant substation operatively connected to the common group switchgear of each of the respective groups, the wind power plant substation further being operatively connected to the external power grid. The present invention also relates to an associated method for operating a wind power plant.

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A WIND POWER PLANT

FIELD OF THE INVENTION

Aspects of the present invention relate to a wind power plant for feeding power to an external power grid, and to a method for operating a wind power plant for feeding power to an external power grid.

BACKGROUND OF THE INVENTION

Wind turbine generators of today are typically equipped with a protecting switchgear whereby the wind turbine generators may be individually connected to or disconnected from a power grid. The switchgear is often positioned in the bottom of the tower of the wind turbine generators.

It is well established knowledge that a plurality of wind turbine generators may be combined to form a wind power plant. In addition to having their own respective switchgears the wind turbine generators are connected to a substation comprising a protecting substation switchgear. The substation switchgear allows connection and/or disconnection of the complete wind power plant to and/or from the main grid. Thus, according to prior art arrangements switchgears are provided at two protecting levels: 1) in the individual wind turbine generators and 2) in the power plant substation. An example of such an arrangement may be found in WO 2012/003835.

SUMMARY OF THE INVENTION

It may be seen as an object of embodiments of the present invention to provide a cost efficient arrangement of wind turbine generators within a wind power plant.

It may be seen as a further object of embodiments of the present invention to provide an arrangement that allows that the wind turbine generators forming a wind power plant do not require a switchgear.

The above-mentioned objects are complied with by providing a wind power plant for feeding power to an external power grid, the wind power plant comprising

- one or more groups of wind turbine generators, each group comprising a plurality of wind turbine generators operatively connected to a common group switchgear of that group via an internal power grid of that group, and

- a wind power plant substation operatively connected to the common group switchgear of each of the respective groups, the wind power plant substation further being operatively connected to the external power grid.

Thus, the present invention aims at grouping wind turbine generators within a wind power plant. For example a wind power plant comprising a total of 100 wind turbine generators may be divided into 20 groups each containing 5 wind turbine generators and a common group switchgear to which common group switchgear the 5 wind turbine generators are connected, i.e. the 5 wind turbine generators share the common group switchgear. The common group switchgear of each of the groups replaces the switchgear of the individual wind turbine generators whereby the number of applied switchgears is reduced. From a cost perspective the reduced number of applied switchgear is advantageous.

In the present context, the common group switchgear of each group is to be understood as a protecting and isolating power electronic device that may connect and/or disconnect a group of wind turbine generators to and/or from a power grid within the wind power plant via its controllable switches, fuses and circuit breakers. Thus, a switchgear of a given group may be adapted to connect and/or disconnect that specific group to and/or from a power grid within the wind power plant.

The common group switchgear may be capable of operating at high-voltage levels, i.e. above 1 kV AC. Typical voltage levels of the internal power grid of the groups may be between 10 kV AC and 75 kV AC. A switchgear should also be capable of handling the total power levels of the wind turbine generators to which it is connected.

The wind power plant substation may comprise a substation switchgear. The substation switchgear is to be understood as a protecting and isolating power electronic device adapted to connect and/or disconnect the complete wind power plant to and/to from an external power distribution grid, such as the main power grid. Thus, a substation switchgear may provide an additional layer of protection in that it allows connection and/or disconnection of the complete wind power plant to and/or from for example the main power grid. The substation switchgear and each group switchgear of the one or more groups of wind turbine generators may be independently controllable from a power plant controller (PPC).

The PPC may be configured to connect and/or disconnect the various groups of wind turbine generators in response to the amount of power (active and reactive) being required. Also, the PPC may be configured to connect and/or disconnect the groups of wind turbine generators in response to for example frequency and/or voltage support on the external power grid. Finally, the PPC may take into account maintenance plans for the various wind turbine generators.

Each of the one or more groups of wind turbine generators may in principle contain any number of wind turbine generators. However, in most scenarios each group of wind turbine generators may comprise less than 20 wind turbine generators, such as less than 15 wind turbine generators, such as less than 10 wind turbine generators, such as less than 8 wind turbine generators, such as less than 5 wind turbine generators. It should be noted however that in case of relatively small wind turbine generators the number of wind turbine generators within a group may exceed 20.

Also, the number of groups within a wind power plant may in principle be selected arbitrary. Thus, the wind power plant may comprise less than 25 groups of wind turbine generators, such as less than 20 groups of wind turbine generators, such as less than 15 groups of wind turbine generators, such as less than 10 groups of wind turbine generators.

Each of the wind turbine generators may be connected to a switchgear, e.g. to the group switchgear, via at least one T-connector, such as three T-connectors, i.e. one T-connector for each phase. T-connectors may be connected to each other and/or they may be connected to the switchgear. Also, a current sensor arrangement for measuring a current from each of the wind turbine generators may be provided. The current may be measured using current transformers.

In a second aspect the present invention relates to a method for operating a wind power plant for feeding power to an external power grid, the method comprising the steps of

- providing a wind power plant comprising one or more groups of wind turbine generators, each group comprising a plurality of wind turbine generators operatively connected to a common group switchgear of that group via an internal power grid of that group, and

- connecting and/or disconnecting a group of wind turbine generators to and/or from the external power grid by activating the group switchgear of that group of wind turbine generators, e.g. by activating only said group switchgear.

The connecting and/or disconnecting of a group of wind turbine generators may be controlled by the PPC. As already addressed the PPC may be configured to connect and/or disconnect the groups of wind turbine generators in response to the amount of power (active and reactive) required by for example a power distributor. Also, the PPC may be configured to connect and/or disconnect the groups of wind turbine generators in response to for example frequency and/or voltage support on the external power grid. Finally, the PPC may take into account maintenance plans for the various wind turbine generators.

In a third aspect the present invention relates to a group of wind turbine generators of a wind power plant, the group comprising a plurality of wind turbine generators operatively connected to a common group switchgear via an internal power grid of that group. The wind power plant may comprise a plurality of groups of wind turbine generators. The common group switchgear may be adapted to connect and/or disconnect that group to and/or from a power grid of the wind power plant. Thus, the common group switchgear may act as a protecting and isolating power electronic device for the wind turbine generators of the group. The group may comprise less than 20 wind turbine generators, such as less than 15 wind turbine generators, such as less than 10 wind turbine generators, such as less than 8 wind turbine generators, such as less than 5 wind turbine generators. However, in case of relatively small wind turbine generators, say for example 750 kW wind turbine generators, the number of wind turbine generators of a group may exceed 20.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in further details with reference to the accompanying figures, wherein

Fig. 1 shows schematically an embodiment of a wind power plant according to the present invention;

Fig. 2 shows schematically a further embodiment of a wind power plant according to the present invention;

Fig. 3 schematically illustrates how the wind turbine generators are connected to the switchgear according to an embodiment; and

Fig. 4 schematically illustrates a method according to an embodiment of the present invention.

While the invention is susceptible to various modifications and alternative forms specific embodiments have been shown by way of examples in the drawings and will be described in details herein. It should be understood, however, that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF EMBODIMENTS

The inventor of the present invention has understood that the total number of switchgears applied in prior art wind power plants is unnecessary high. The reason for this being that switchgears are positioned in both all the wind turbine generators as well as in the wind power plant substation. As switchgears in general are relatively expensive devices it would be advantageous if the number of switchgears within a wind power plant as a whole could be reduced. In one aspect of the present invention, one approach to achieve this is to remove the switchgears from the individual wind turbine generators. An aim of the embodiments of the present invention is to provide a cost efficient arrangement of wind turbine generators within a wind power plant. The cost efficient arrangement allows for that the wind turbine generators forming a wind power plant do not require individual switchgears.

Thus, in one aspect, the embodiments of the present invention provide a cost effective arrangement of a plurality of wind turbine generators. In another aspect, the embodiments of the present invention provide an arrangement of wind turbine generators where the number of applied switchgears is significantly reduced.

In general, the embodiments of the present invention relate to a group of wind turbine generators of a wind power plant, the group comprising a plurality of wind turbine generators operatively connected to a common group switchgear via an internal power grid of that group. By "common" switchgear is meant a shared switchgear, which is shared between the wind turbine generators of that group. The group switchgear is adapted to connect and/or disconnect that group to and/or from a power grid of the wind power plant. The group may comprise less than 20 wind turbine generators, such as less than 15 wind turbine generators, such as less than 10 wind turbine generators, such as less than 8 wind turbine generators, such as less than 5 wind turbine generators.

Referring now to Fig. 1, a group of wind turbine generators 100 according to an embodiment of the present invention is depicted. In the following a group of wind turbine generators will be denoted a mini wind power plant.

As seen in Fig.1 the mini wind power plant 100 comprises a total of three wind turbine generators 101, 102, 103 all connected to the same common group switchgear 105 via an internal power grid 104. It should be noted that the number of wind turbine generators may differ from three. The internal power grid is typically a three-phase high-voltage power grid having a nominal voltage between 10 kV AC and 75 kV AC. The common group switchgear 105 should thus be configured to operate at a similar voltage level.

The wind turbine generators 101, 102, 103 are adapted to convert wind energy into electrical energy. The rated power levels of the wind turbine generators 101, 102, 103 may typically be from a few hundred kW to several MW.

The wind turbine generators 101, 102, 103 share the common group switchgear 105 which is connected to a substation switchgear 107 via the power line 106. The common group switchgear 105 replaces the switchgears normally arranged within each of the wind turbine generators. Thus, none of the wind turbine generators 101, 102, 103 contain a switchgear. The common group switchgear 105 should thus be capable of handling the total power level on the busbar side of the wind turbine generators 101, 102, 103.

In general, a switchgear is a controllable power electronic device which via its controllable switches, fuses and circuit breakers is capable for protecting and isolating power electronic equipment, such as wind turbine generators in case of for example grid faults, maintenance of wind turbine generators etc. Thus, the common group switchgear 105 serves as a protecting and isolating device for all three wind turbine generators 101, 102, 103. For example, the common group switchgear 105 may be prompted to isolate the wind turbine generators 101, 102, 103 in response to a measured current in the internal power grid 104.

The substation switchgear 107 is connected to the external power grid 109 via the power line 108. The external power grid, which may be the main power grid 109, may also be connected to other power generating facilities including other renewable power facilities (wind, solar, wave etc.), nuclear-based power facilities and coal-based power facilities.

The mini wind power plant 100 may be connected to or disconnected from the power line 106, and thereby the external power grid 109, using the common group switchgear 105. By implementing the mini wind power plant 100 as depicted in Fig. 1 the total number of applied

switchgears are reduced from three to one. This reduction of the number of applied devices reduces the associated costs accordingly.

The inventor has estimated that for a mini wind power plant containing five 3.3 MW wind turbine generators the reduction of costs relating to the switchgears and the internal power grid may be as high as 80%.

As depicted in Fig. 2 two mini wind power plants 201, 202 may exist within a wind power plant 200. The wind power plant 200 may in general comprise a plurality of groups of wind turbine generators, i.e. a plurality of mini wind power plants. Thus, the number of mini wind power plants may differ from two. The mini wind power plant 201 comprises wind turbine generators 203, 204, 205 all feeding power to an internal power grid 206 which is connected to the common group switchgear 207. Similarly, the mini wind power plant 202 comprises wind turbine generators 208, 209, 210 all feeding power to internal grid 211 which is connected to the common group switchgear 212. The number of wind turbine generators of each mini wind power plant may differ from the three wind turbine generators shown in Fig. 2. Also, the number of wind turbine generators may differ from one mini wind power plant to another mini wind power plant. The nominal voltage level of the mini wind power plants 201, 202 is between 10 kV AC and 75 kV AC.

Each of the common group switchgears 207 and 212 are connected to the wind power plant substation switchgear 215 which, via power line 216, is connected to the external power grid 217. The switchgears 207, 212, 215 should be capable of handling the relevant power levels. Generally, the group switchgears of the mini wind power plants and the substation switchgear may be controlled independently. Thus, the common group switchgears 207, 212 as well as the substation switchgear 215 may be controlled in an independent manner from for example the PPC.

Similar to Fig. 1 the mini wind power plants 201 and 202 may be connected to or disconnected from the external power grid 217 using the common group switchgears 207 and 212, respectively. The complete power plant 200 may be connected to or disconnected from the external power grid 217 using substation switchgear 215. The common group switchgears 207, 212 serve as protecting and isolating power electronic devices for wind turbine generators 203-205 and 208-210, respectively, in that the common group switchgear 207 is adapted to connect and/or disconnect the mini wind power plant 201 to and/or from the power line 213. Similarly, the common group switchgear 212 is adapted to connect and/or disconnect the mini wind power plant 202 to and/or from power line 214.

Within a wind power plant 200 each of the one or more mini wind power plants 201, 202 may comprise less than 20 wind turbine generators, such as less than 15 wind turbine generators, such as less than 10 wind turbine generators, such as less than 8 wind turbine generators, such as less than 5 wind turbine generators. Also, a wind power plant 200 may comprise less than 25 mini wind power plants, such as less than 20 mini wind power plants, such as less than 15 mini wind power plants, such as less than 10 mini wind power plants.

Within each mini wind power plant a current sensor arrangement may be provide, cf. Fig. 3. The current sensor arrangement may comprise a current transformer for measuring the current from each of the wind turbine generators.

Again, the cost savings achievable by implementing mini wind power plants according to embodiments of the present invention is significant primarily due to the reduced number of switchgears being used.

The wind power generators of a mini wind power plant may be connected to the switchgear in different ways.

Fig. 3 shows one approach 300 where five wind turbine generators are connected to the common group switchgear 301 via power lines 311-315 and T-connectors 302-306. Each of the T-connectors 302-306 comprises three T-connectors. Thus, each wind turbine generator is connected to the common group switchgear 301 via three T-connectors, i.e. one T-connector for each phase. As seen in Fig. 3 the T-connectors 302, 303, 304 are mutually connected and connected to top bushing 307, whereas T-connectors 305, 306 are mutually connected and connected to top bushing 308. It should be noted that the bushings can be positioned differently. Thus, one of the five wind turbine generators is connected to the common group switchgear 301 via power line 311 and T-connectors for each of its phases. A series of current sensors 309, 310 measure the flow of current of power lines 311-315. The flow of current may be measured using current transformers. The common group switchgear 301 is connected to a substation switchgear (not shown) via power line 316.

Fig. 4 shows, in a schematic manner, a method according to an embodiment of the present invention. As depicted in Fig. 4 a new power reference, active (P) and/or reactive (Q), may be provided. This new active and/or reactive power reference is then compared with the actual power reference for the active and/or reactive power. In case the new power reference exceeds the actual power reference, i.e. additional power (active or reactive) is needed, at least one additional group of wind turbine generators, i.e. at least one mini wind power plant, is/are connected to the wind power plant substation switchgear in order to increase the total amount of generated power. Another scenario could be that the new power reference is lower

than the actual power reference, i.e. a smaller amount of power (active or reactive) is required. In this scenario at least one group of wind turbine generators, i.e. at least one mini wind power plant, is/are disconnected from the wind power plant substation switchgear in order to lower the total amount of generated power.

As already addressed, a PPC may be configured to connect and/or disconnect the groups of wind turbine generators in response to the amount of power (active and reactive) required by for example a power distributor. Also, the PPC may be configured to connect and/or disconnect the groups of wind turbine generators in response to for example frequency and/or voltage support on the external power grid. Finally, the PPC may take into account maintenance plans for the various wind turbine generators.

CLAIMS

1. A wind power plant for feeding power to an external power grid, the wind power plant comprising

- one or more groups of wind turbine generators, each group comprising a plurality of wind turbine generators operatively connected to a common group switchgear of that group via an internal power grid of that group, and

- a wind power plant substation operatively connected to the common group switchgear of each of the respective groups, the wind power plant substation further being operatively connected to the external power grid.

2. A wind power plant according to claim 1, wherein a group switchgear of a group of wind turbine generators is adapted to connect and/or disconnect that group to and/or from a power grid of the wind power plant.

3. A wind power plant according to claim 1 or 2, wherein the wind power plant substation comprises a substation switchgear adapted to connect and/or disconnect the wind power plant to and/or from the external power grid.

4. A wind power plant according to any of claims 1-3, wherein the wind power plant comprises a plurality of groups of wind turbine generators.

5. A wind power plant according to any of the preceding claims, wherein the substation switchgear and the group switchgear of the one or more groups of wind turbine generators are independently controllable.

6. A wind power plant according to any of the preceding claims, wherein each of the one or more groups of wind turbine generators comprise less than 20 wind turbine generators, such as less than 15 wind turbine generators, such as less than 10 wind turbine generators, such as less than 8 wind turbine generators, such as less than 5 wind turbine generators.

7. A wind power plant according to any of the preceding claims, wherein the wind power plant comprises less than 25 groups of wind turbine generators, such as less than 20 groups of wind turbine generators, such as less than 15 groups of wind turbine generators, such as less than 10 groups of wind turbine generators.

8. A wind power plant according to any of the preceding claims, wherein each of the wind turbine generators is connected to a group switchgear via at least one T-connector, such as three T-connectors.

9. A wind power plant according to any of the preceding claims, further comprising a current sensor arrangement for measuring a current from each of the wind turbine generators.

10. A wind power plant according to claim 9, wherein the current sensor arrangement comprises a current transformer.

11. A method for operating a wind power plant for feeding power to an external power grid, the method comprising the steps of

- providing a wind power plant comprising one or more groups of wind turbine generators, each group comprising a plurality of wind turbine generators operatively connected to a common group switchgear of that group via an internal power grid of that group, and

- connecting and/or disconnecting a group of wind turbine generators to and/or from the external power grid by activating the group switchgear of that group of wind turbine generators.

12. A group of wind turbine generators of a wind power plant, the group comprising a plurality of wind turbine generators operatively connected to a common group switchgear via an internal power grid of that group.

13. A group of wind turbine generators according to claim 12, wherein the group switchgear is adapted to connect and/or disconnect that group to and/or from a power grid of the wind power plant.

14. A group of wind turbine generators according to claim 12 or 13, wherein the group comprises less than 20 wind turbine generators, such as less than 15 wind turbine generators, such as less than 10 wind turbine generators, such as less than 8 wind turbine generators, such as less than 5 wind turbine generators.

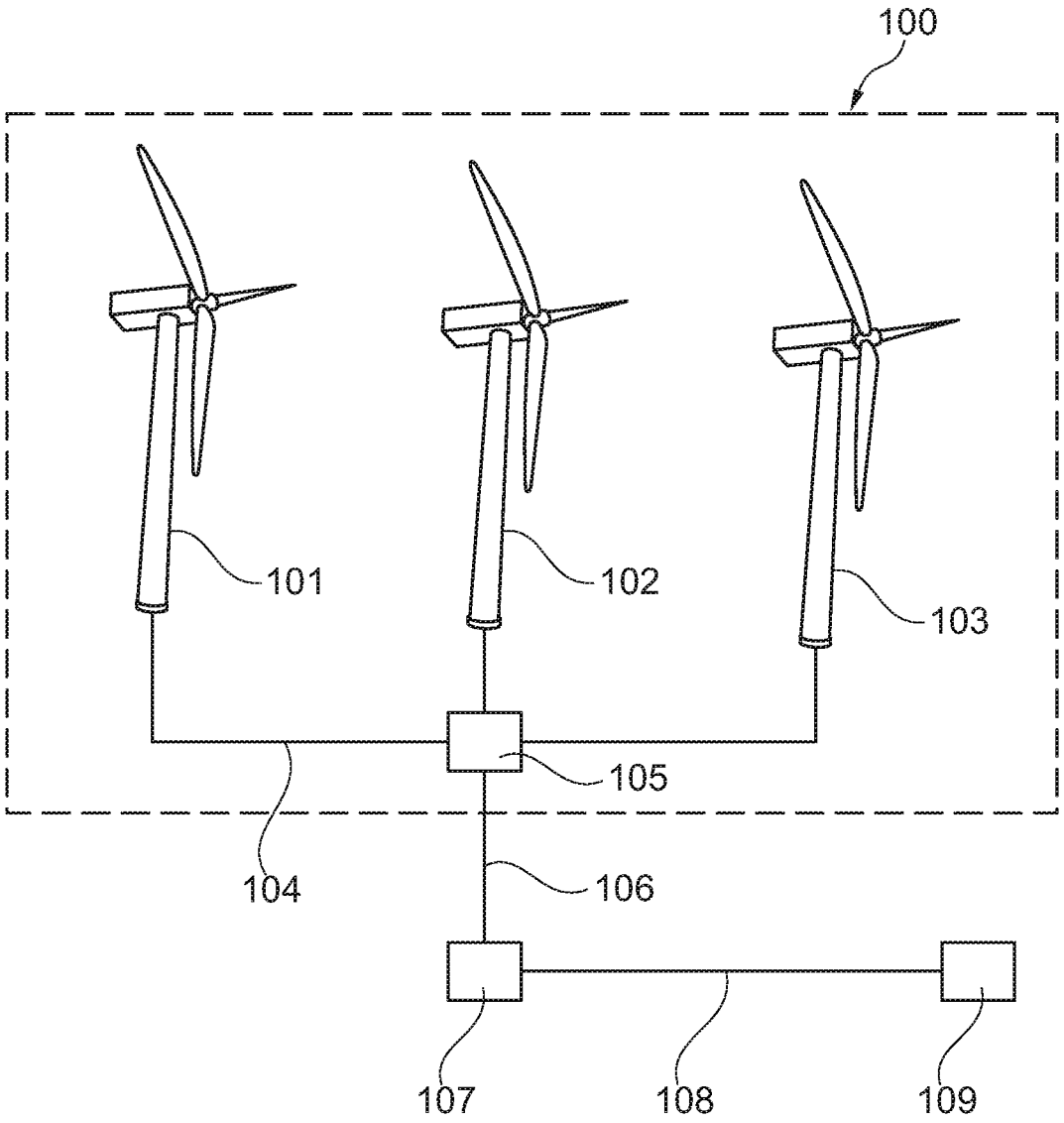

Fig. 1

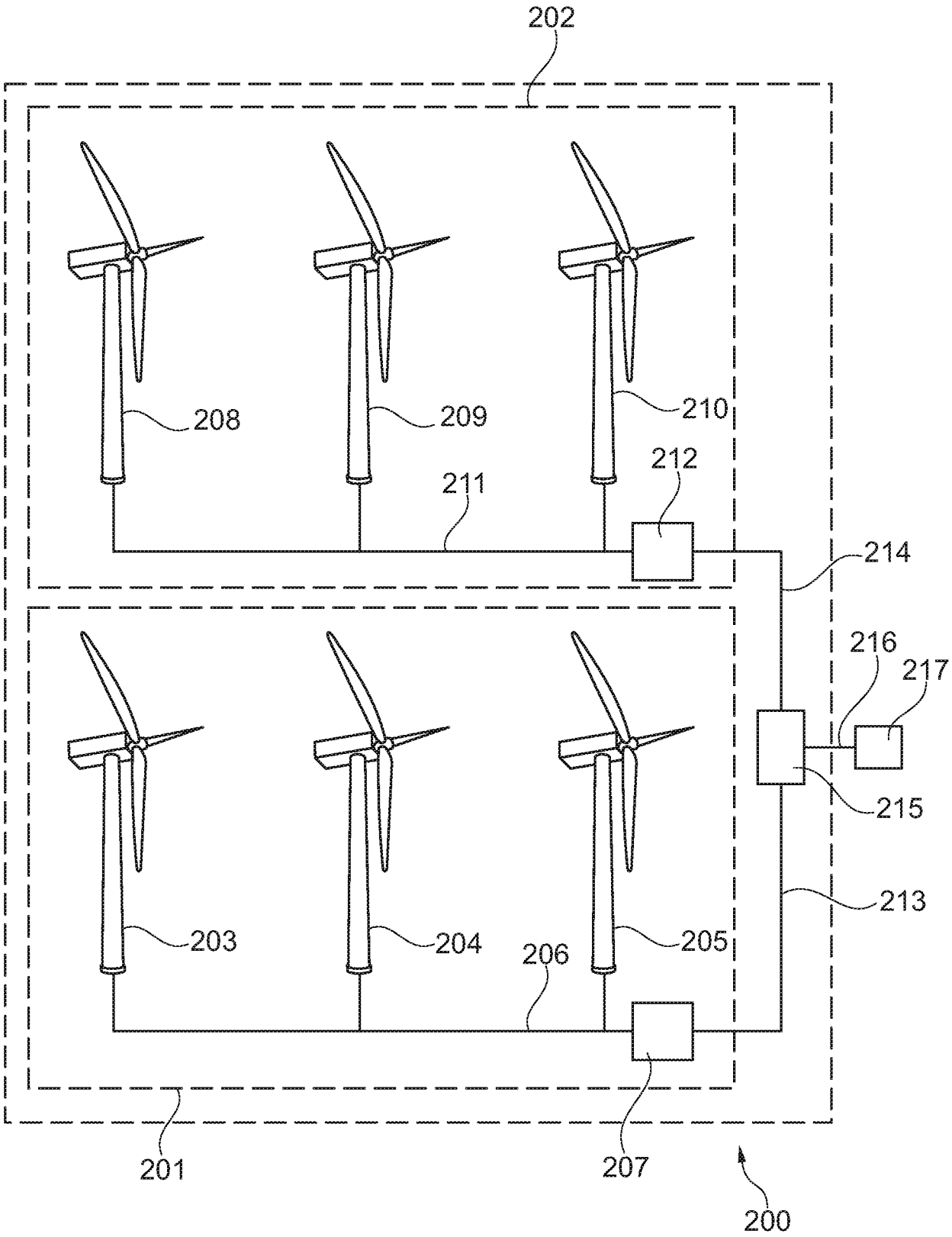
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Fig. 2

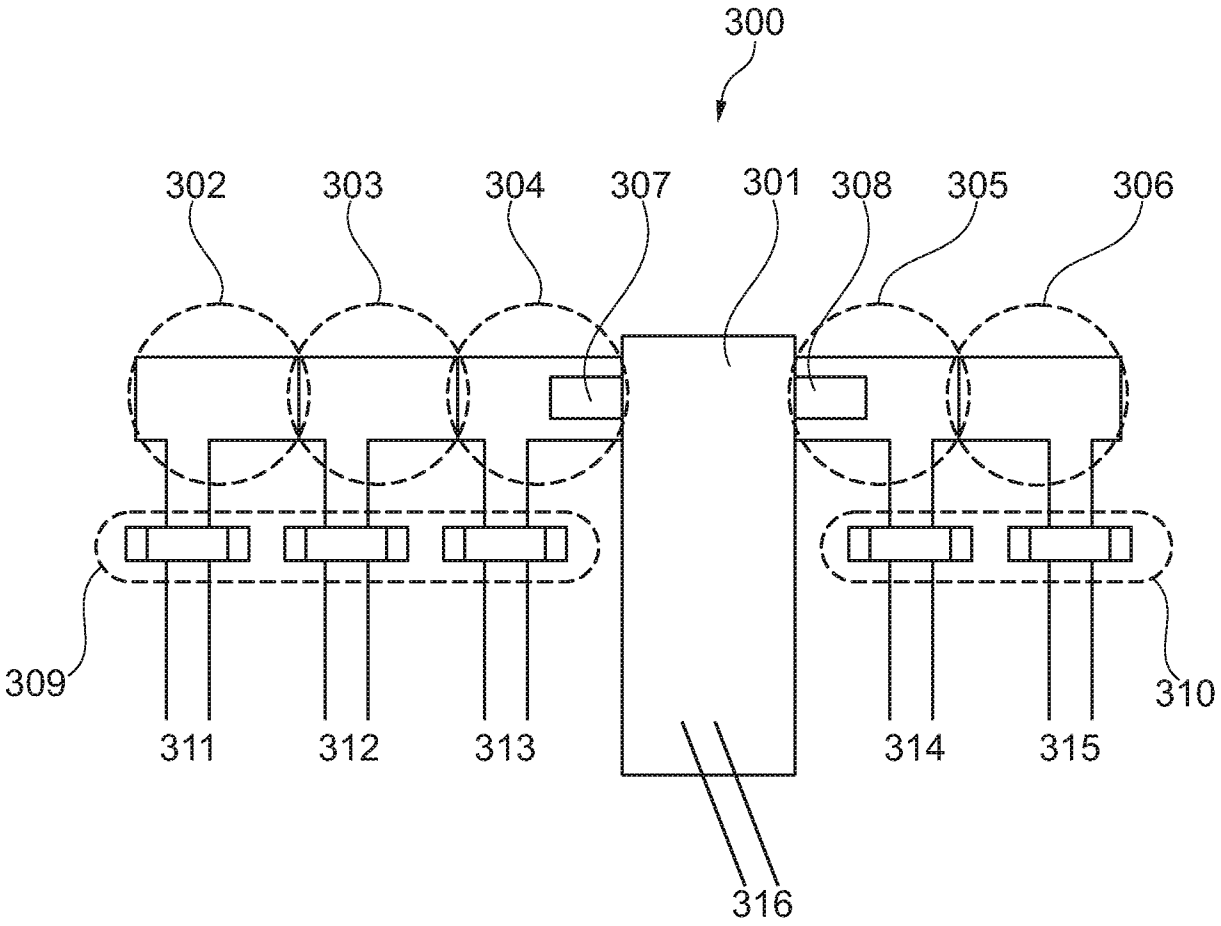
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Fig. 3

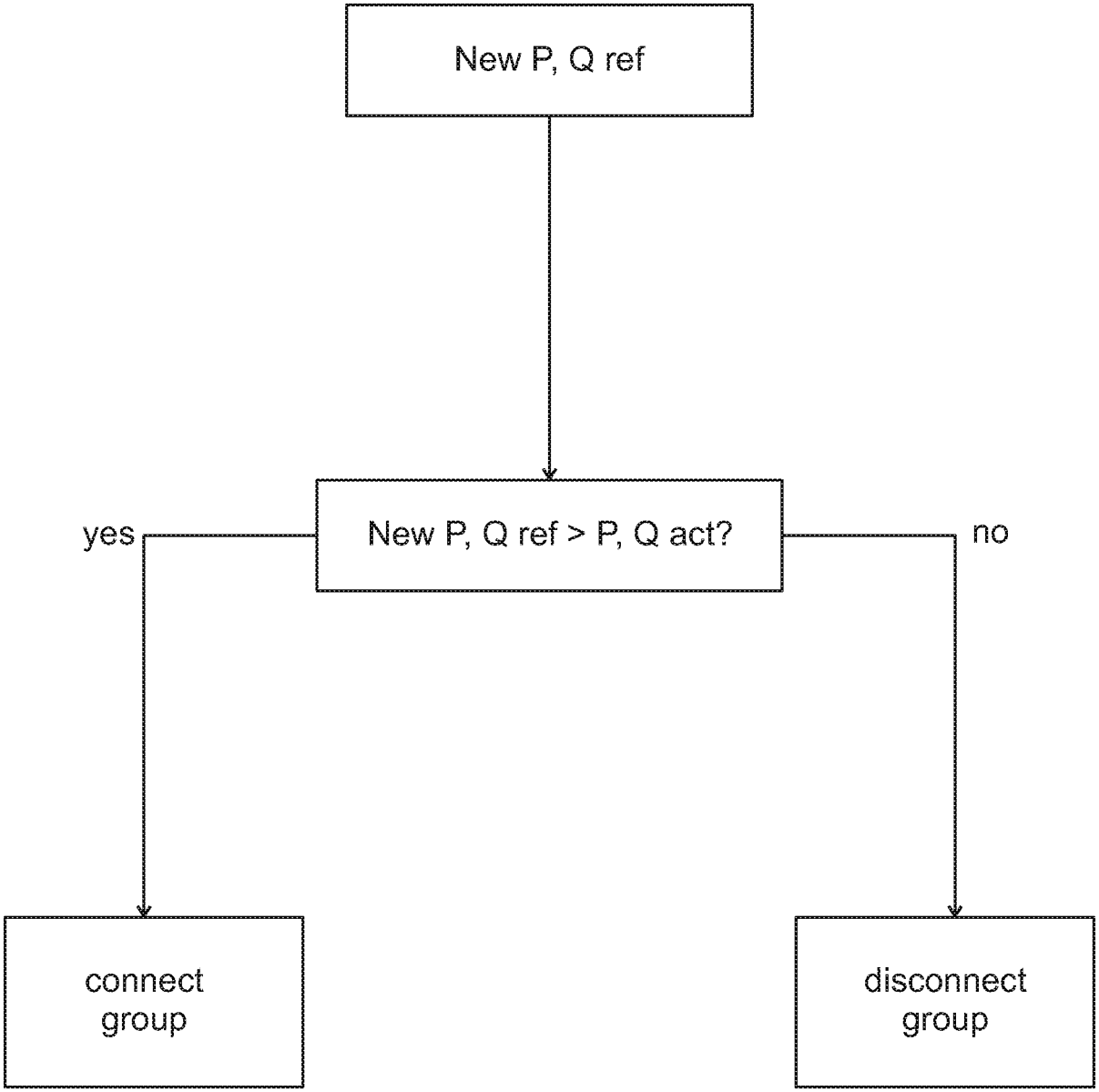
New P, Q ref
New P, Q ref > P, Q act?
yes
no
connect group
disconnect group

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2016/050413

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D9/25 H02J3/38
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03D H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/010350 A1 (LOF PER-ANDERS [US] ET AL) 15 January 2004 (2004-01-15) paragraphs [0026] - [0034], [0068] - [0078], [0094]; figure 3	1-14
X	US 2010/033016 A1 (THORBURN KARIN [SE] ET AL) 11 February 2010 (2010-02-11) paragraphs [0010] - [0061], [0072] - [0091], [0097], [0098]; figures 1-5	1-14
X	EP 2 894 753 A1 (SIEMENS AG [DE]) 15 July 2015 (2015-07-15) paragraphs [0009], [0053] - [0063]; figure 1	1-14
X	EP 1 993 184 A1 (SIEMENS AG [DE]) 19 November 2008 (2008-11-19) paragraphs [0022] - [0046]; figures	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 February 2017	22/02/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Libeaut, Laurent

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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