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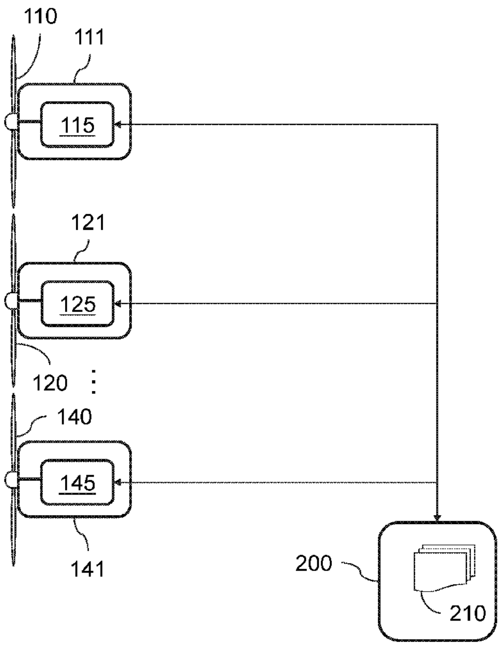

Fig. 2

(57) **Abstract:** A method is disclosed for controlling a multi-rotor wind turbine (100) with at least two rotors (110, 120, 130, 140). The method comprises a step of receiving, from a first one of the at least two rotors (110-140), an error signal, and a step of, in dependence of the error signal, determining respective error responses for the first one and at least a second one of the other rotors (110-140), at least one of the error responses comprising a control signal and the respective error responses for the first and second rotors (110-140) being different. The method further comprises a step of submitting the at least one control signal to a controller (115, 125, 145) of the respective rotor (110).

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ALARM RESPONSE IN A MULTI-ROTOR WIND TURBINE

FIELD OF THE INVENTION

The invention relates to a method for controlling a multi-rotor wind turbine with at least two rotors. The method comprises a step of receiving, from a first one of the at least two rotors, an error signal and a step of, in dependence of the error signal, determining respective error responses for the first one and at least a second one of the other rotors . The method further comprises a step of submitting the error responses for the first and second rotors to their respective controllers. The invention further relates to a computer program product and a multi-rotor wind turbine operable to perform such a method.

BACKGROUND OF THE INVENTION

Today, wind turbines are big, heavy, complex and expensive power plants. In order to operate a wind turbine in a cost-effective manner, it is important to reduce down time periods to a minimum. This is, however, not an easy task at all. Many external and internal factors can influence the ability of a wind turbine to operate in full-power mode. For example, the wind turbine has to be protected from damage, resulting from heavy loads caused by high wind speeds, or from failures of the wind turbine itself. In order to protect a wind turbine in heavy wind conditions it is generally known to shut down the wind turbine in the case that wind speed exceeds a certain limit.

From, e.g., US 7,476,985 B2 it is known to operate a wind turbine in a safe mode in the event that the wind speed exceeds a certain limit. In the safe mode the output power of the wind turbine is reduced. From EP 2 026 160 A1, it is known to decide about the shutdown of a wind turbine, based on an event which is present, such as icing, structural integrity of parts of the wind turbine, etc. EP 1 531 376 B1 discloses a predictive maintenance system, which generates alarms related to failures or malfunctioning of mechanical components of a wind turbine, based on a vibration analysis. In WO 2012/025121 A2, multiple sensor signals representing the state of the wind turbine are analysed to determine whether a specific alarm condition is met as predefined in one of a plurality of different predefined alarm scenarios. Based on the sensor signals and the relevant alarm scenario, it is decided whether the wind turbine is to be put into a predefined safe mode with reduced power output, a shutdown mode or a continued operation mode.

In order to meet the ever growing demand for non-fossil power, rotors and rotor blades have first become bigger and bigger. More recently, also multi-rotor wind turbines have been built, with, e.g., two or four separate rotors mounted to a common support structure. For example, WO 2016/150447 A1 describes a wind turbine with four rotors. Each rotor is operated by a respective local controller. A central controller, connected to the four local controllers, monitors the operation of the complete wind turbine system and based thereon calculates local control objectives for the separate rotors.

When there is an alarm in one of the rotors of a multi-rotor wind turbine, the respective rotor can be shut down or derated in accordance with one of the methods described in the aforementioned patents and patent applications. With one rotor delivering less or no power, while the other rotors on the multi-rotor wind turbine still operating at full capacity, the wind will exert higher thrust forces to some rotors than to others. As a result, the wind turbine would endure excessive tower top displacement and/or tower torsion. In order to prevent this happening, the other rotors have to be stopped or derated in accordance with the alarm scenario for the dysfunctional one. If an alarm scenario is activated too frequently, this will significantly reduce the total amount of electrical power produced by the wind turbine and will diminish the advantages of having multiple rotors on one wind turbine tower.

It is therefore the object of the invention to develop a control method that can minimize the loss of power production due to rotor error response strategies.

SUMMARY OF THE INVENTION

According to the invention this object is achieved by providing a method for controlling a multi-rotor wind turbine with at least two rotors, the method comprising a step of receiving, from a first one of the at least two rotors, an error signal, and a step of, in dependence of the error signal, determining respective error responses for the first one and at least a second one of the other rotors, at least one of the error responses comprising a control signal and the respective error responses for the first and second rotors being different. The method further comprises a step of submitting the at least one control signal to a controller of the respective rotor.

With the method according to the invention, the wind turbine will be able to continue to provide a high output power when only one or a subset of its rotors has to be stopped or derated due to a detected alarm condition (indicated by the error signal). Instead of equally shutting down or derating the still normally functioning rotors, the wind turbine allows the other rotors to provide more power than they would have done in a wind turbine that does not use the method according to the invention. The response strategy determined with the method according to the invention can be implemented by the controllers of the respective rotors using the determined control signal or signals to adjust their operations. It is to be noted that a possible error response may be to not change the operation of one or more of the rotors at all.

In a preferred embodiment of the method according to the invention, the step of determining the respective error responses comprises determining an expected effect of available error responses on at least one operational constraint. The available error response include, but are not limited to, bringing one or more of the rotors to a full stop, putting one or more rotors in a derated power mode or in an idling mode. Of course, combinations of such responses are also available. For putting a rotor in a derated power mode, the control signal may, e.g., provide a maximum allowed power output, a specific power output target, specific pitch and/or yaw angles or limits on the rotational speed or tip speed ratio. The method according to the invention allows the wind turbine to continue to provide more power than with a more classical approach in which nearby rotors have to copy the error response behaviour of the rotor triggering the alarm condition.

Useful operational constraints to take into account are, e.g., a threshold for generator speed, actuator movement, mechanical stress, thrust imbalances, fatigue load and power output. A constraint may be a hard limit, the wind turbine or rotor controllers not allowing the respective parameter to exceed the defined threshold. Alternatively, the constraint may assign a certain cost to exceeding such a threshold and the determined error responses may result from an algorithm weighing all the beneficial and adverse effects of the available error responses.

Important operational constraints are constraints on the structural forces that may act on the wind turbine tower and its rotor carrying arms due to thrust imbalances between different rotors. When applying different error responses to different rotors, the aerodynamic symmetry is broken and the thrust forces on different rotors will be different. This imbalance may lead to increased mechanical stress and fatigue loads or structural displacement of, e.g., a rotor carrying arm or the tower top of the wind turbine. It is important to keep such structural forces within acceptable limits. This may, for example, be achieved by limiting the additional power output each rotor is allowed to deliver above the power output level of the shutdown or derated rotor. Such a limit may, e.g., be implemented as a fixed or relative amount. It is, however, preferred to calculate an expected amount thrust imbalance based on one or more available error response scenarios or to calculate an optimal error response scenario based on one or more predetermined thresholds of maximum allowable structural load.

A further improvement of the method according to the invention is obtained when the step of determining the respective error responses is performed using Model Predictive Control (MPC). MPC algorithms use a holistic model of the wind turbine, combining the aerodynamic characteristics of the rotors with mechanical characteristics of the wind turbine structure. Such an advanced model is well suited for taking multiple inputs (e.g. wind speed, tip speed ratio, rotor speed, generator speed, ...) into account to provide multiple outputs (e.g. pitch angles, yaw angles, individual rotor power outputs, rotor speeds or tip speed ratios, ...) to fulfil a number of objectives (e.g. maximum power output, tolerable structural load, maximum noise levels, ...). MPC allows controlling the multi-rotor wind turbine in a manner which ensures optimized operation of the complete system in relation to predefined criteria. In contrast with ‘old style’ control loops, MPC not only reacts to sensor information, but can also predict how the individual rotors and the complete wind turbine structure will react to and function after implementing a wide range of possible control strategies. Considering a small set of predetermined criteria, the MPC can predict, select and apply the optimal control settings for each rotor of the multi-rotor wind turbine.

When the step of determining the respective error responses is performed using Model Predictive Control (MPC), this will, e.g., allow the wind turbine to keep the other rotors delivering as much power as possible without risking excessive structural load on the wind turbine structure. Already before shutting down or derating the malfunctioning rotor, the MPC can predict the effect that different error response strategies will have on the operation of the individual rotors or the thrust imbalance on different rotors. Accordingly an optimal error response is selected that will combine high power output with safe and efficient operating conditions.

According to further aspects of the invention, also a multi-rotor wind turbine is provided, comprising at least two rotors. Each rotor comprises a respective controller and the wind turbine further comprises a common controller, operatively coupled to the respective controllers and configured to perform the methods according to the invention. The common controller may, e.g. be located in one of the rotors of the multi-rotor wind turbine, somewhere else in or on the wind turbine structure, or on a location further away from the wind turbine itself.

According to a further aspect of the invention, a computer program product is provided comprising computer code for performing, when executed on a computing means, a method according to the invention.

It will be appreciated that preferred and/or optional features of the first aspect of the invention may be combined with the other aspects of the invention. The invention in its various aspects is defined in the independent claims below and advantageous features are defined in the dependent claims below.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, some embodiments of the invention will now be described with reference to the following drawings, in which:

Figures 1A and 1B schematically show two examples of a multi-rotor wind turbine in which the method according to the invention may be implemented.

Figure 2 shows a schematic representation of the most relevant functional parts of the multi-rotor wind turbine.

Figure 3 shows a flow diagram representing the steps in the method according to the invention.

Figure 4 schematically shows the multi-rotor wind turbine and some of the structural loads it may have to bear.

DETAILED DESCRIPTION

Figure 1A schematically shows a multi-rotor wind turbine 100 in which the method according to the invention may be implemented. The currently most common type of wind turbine is the horizontal axis wind turbine (HAWT). It usually has a nacelle placed on top of a high vertical pole, with the rotor blades attached to a horizontal low speed shaft that extends from the nacelle. The nacelle may comprise a gear box for coupling the low speed shaft to an also horizontal high speed shaft that is connected to the generator. Power generated by the generator is transported to the ground by a power line running through the core of the pole, where it can be used or stored immediately or be coupled to a larger power grid. Where, in the past, wind turbines and their rotor blades have grown bigger and bigger to satisfy the increasing demand for wind powered electricity, recently also another strategy has been introduced; the multi-rotor wind turbine 100. Instead of one nacelle with one rotor on the top of the pole, this multi-rotor wind turbine 100 comprises two or more nacelles, here shown with four nacelles 111, 121, 131, 141, each carrying their own rotor 110, 120, 130, 140. In order to avoid the rotor blades of different rotors 110-140 running into each other, the nacelles 111-141 are spaced from each other by attaching them to arms 105, originating from the pole. In this example, all four arms 105 originate from the same top part of the wind turbine 100, but one or more arms may also be attached to a lower part of the pole. Different constructions for installing four rotors 110-140 on one pole are, of course, foreseeable. An example of a multi-rotor wind turbine different from the one shown in Fig. 1A is shown in Fig. 1B, where the four rotors are arranged in two layers, and each layer can be yawed independently. While in the current examples all four rotors 110-140 rotate in the same vertical plane, it is also possible to put one or more rotors in different planes. Alternative configurations are also possible. Twin rotor wind turbines have been designed comprising two poles, organized in a V-shape. In the following exemplary embodiments, the multi-rotor wind turbine has four rotors 110-140. It is, however, to be noted that a multi-rotor wind turbine, may alternatively comprise 2, 3, 5, 6 or more rotors.

Figure 2 shows a schematic representation of some functional parts of the multi-rotor wind turbine 100. For conciseness only, the third rotor 130 is omitted. Parameters being received from and submitted to the fourth rotor 140 are denoted by the subscript n for indicating that the invention also works for wind turbines with more than four rotors. In a similar manner, the wind turbine also works with two, three, five or more rotors. Each rotor 110, 120, 140 is electronically coupled to a respective controller 115, 125, 145. The controller 115-145 is operable to receive sensor readings from all types of sensors useful for the optimized control of the wind turbine 100. Such sensor readings may represent (and are not limited to) wind speed, speed of rotation, gear box settings, pitch angle, yaw angle and power output. Depending on what they are actually measuring, the sensors may, e.g., be installed on the rotor blades, in the rotor hub, in the gearbox or the generator or on a brake or rotor shaft. Wind speed, for example, may be measured centrally with only one wind sensor or at each rotor separately using one or more wind speed sensors installed on each rotor. Alternatively wind speed can be estimated based on a measured power output and the measured values of other relevant parameters.

The controller 115-145 processes, and optionally stores, all the incoming information and adjusts control settings like desired pitch angle, yaw angle and speed of rotation in such a way to control and optimize the power output of the rotor 110-140. A common controller 200 is operably connected to the controllers 115-145 of the individual rotors 110-140. The common controller 200 may, e.g. be located in one of the rotors 110-140 of the multi-rotor wind turbine 100, somewhere else in or on the wind turbine structure 100, or on a location further away from the wind turbine 100 itself. Sensor readings and operational data and parameters from the individual rotors 110-140 are sent to the common controller. Optionally, sensors associated with the individual rotors 110-140 can bypass the individual controllers 115-145 and communicate with the common controller 200 directly. Additionally, the wind turbine 100 may comprise sensors that register parameters that are not rotor specific. Also such global parameters may be communicated to the common controller 200 directly instead of or in addition to sending them to the controllers 115-145 of the individual rotors 110-140. The common controller 200 is used to coordinate the operation of the separate rotors 110-140 in such a way that the wind turbine 100 as a whole can produce the required amount of power in the most efficient way. For example, WO 2016/150447 A1 provides a detailed description of how central and local controllers may together control the operation of the wind turbine 100.

It should be noted that in Figure 2 the rotor controllers 115-145 and the common controller 200 are shown as separate modules or units. Although this implies a physical hardware separation, this need not necessarily be the case. As such, the functionality of the rotor controllers 115-145 and the common controller 200 may be implemented in different physical hardware components with the rotor controllers in communication with and being instructed by the common controller, but may also be implemented on a single hardware component, having associated processing and memory utilities, whilst being functionally separated into appropriate software domains.

Figure 3 shows a flow chart of the method according the invention. In a first, error detection step 31, the local controller 115-145 or a sensor of the rotor 110-140 detects a problem or situation that may interfere with the normal operation of the rotor 110-140. Examples of problems that may be detected are mechanical failures of essential parts of a rotor, overheating of the brakes, the generator, the power converter or control electronics, or software failures in the local controller 115-145. While many possible errors may be identified by a single sensor, an error signal may also be generated by the local controller when a combination of sensor readings suggests that something may be wrong. In, e.g., WO 2012/025121 A2, multiple sensor signals representing the state of the wind turbine are analysed to determine whether a specific alarm condition is met as predefined in one of a plurality of different predefined alarm scenarios.

In error signalling step 32, the common controller 200 receives an error signal from the rotor 110-140 where the problem is detected. This signal will usually come from the local controller 115-145 of the rotor 110-140 having problems, but may alternatively come directly from a sensor of that rotor 110-140. When the common controller 200 receives the error signal, it becomes aware of the alarm condition in the respective rotor 110-140.

Previously, the common controller 200 would then determine the appropriate response to the detected alarm condition and apply that response to all rotors. 110-140. The selected response strategy may. e.g., be to completely stop and/or shut down the rotors 110-140, to put them in an idle mode or to reduce their power output to a certain level. Because of the aerodynamic effect of applying such a response strategy to the malfunctioning rotor only, it used to be essential to apply the same strategy to the other rotors 110-140 too. The thrust imbalance that results from stopping only one rotor may otherwise lead to, e.g., excessive structural displacement of the rotor arms 105, or tower top and/or high torsional loads on the tower structure. Such additional loads may lead to more damage to the wind turbine 100 and its many different parts, or even to rotor arms 105, rotors 110-140 or parts of rotors 110-140 breaking off.

Figure 4 schematically shows some of the effects a thrust imbalance may have on a multi-rotor wind turbine 100. This exemplary wind turbine 100 comprises two rotor arms 105, each having a rotor 110-140 connected at one end. The rotor arms 105 are connected to the wind turbine tower at connection points 101. Usually, the upper and lower rotor arm 105 will be arranged in parallel with all rotors 110-140 being at the same distance from the central axis of the wind turbine tower. If one of the rotors 110-140 is shutdown or derated, the resulting thrust imbalance may cause the respective rotor arm end to be pushed into a fore-aft direction 106 and or in an up-down direction. The effect on the rotor at the other end of the same arm will be largely the same, but in the opposite direction. This will result in torsional loads on the connection point 101 that connects the arm to the wind turbine tower, and via the connection point 101 also the to the wind turbine tower itself. Shutting down or derating only one of the rotors 110-140 also changes the air flow and wind pattern in the area around this one rotor 110-140. This, in turn, can also lead to a thrust imbalance at the other rotor arm 105.

According to the invention, the common controller 200 is configured to apply different responses to different rotors 110-140 of the multi-rotor wind turbine 100. Although it may not always be safe to shut down or derate one of the rotors 110-140 while all other rotors 110-140 keep on operating at full speed, the common controller 200 of this invention is able to balance power output and the resulting aerodynamic asymmetry in order to maintain maximum power output and not further damage the wind turbine 100 at the same time. Instead of equally shutting down or derating the still normally functioning rotors 110-140, the wind turbine 100 allows the other rotors to provide more power than they would have done in a wind turbine that does not use the method according to the invention. So, in response planning step 33, the common controller 200, based on all available relevant information, determines a suitable error response. The error response will comprise control signals for the malfunctioning rotor 110-140 and at least one other rotor 110-140. If the wind turbine 100 only comprises two rotors, positioned at opposite sides of the wind turbine tower, the error response strategy may, e.g., be to shut down the malfunctioning rotor and bring the power output of the other one back to a certain maximum level. The strategy will be such that any aerodynamic asymmetry that may result therefrom will not damage the wind turbine 100 any further. When the wind turbine 100 has more than two rotors, e.g. in the configuration of figures 1b and 4, each rotor 110-140 may be instructed to respond in a different way. It may, e.g., be useful to adapt some control parameters of the still perfectly working rotors to compensate for an aerodynamic situation that changed due to shutting down a rotor 110-140 on the other rotor arm 105. There may also be situations in which it is possible to (partly) compensate for a thrust imbalance in the rotor arm 105 with the malfunctioning rotor 110-140 by introducing a second counteracting thrust imbalance in the other rotor arm 105.

For the response planning step 33, the common controller may take into account an expected effect of available error responses on at least one operational constraint. As already discussed, the available error response include, but are not limited to, bringing one or more of the rotors 110-140 to a full stop, putting one or more rotors 110-140 in a derated power mode or in an idling mode. Of course, combinations of such responses are also available. For putting a rotor 110-140 in a derated power mode, the control signal may, e.g., provide a maximum allowed power output, a specific power output target, specific pitch and/or yaw angles or limits on the rotational speed or tip speed ratio. Useful operational constraints to take into account are, e.g., a threshold for generator speed, actuator movement, mechanical stress, thrust imbalances, fatigue load and power output. A constraint may be a hard limit which the wind turbine 100 or rotor controllers 115-145 not allow to be exceeded. Alternatively, the constraint may assign a certain cost to exceeding such a threshold and the selected error responses may result from an algorithm weighing all the beneficial and adverse effects of the available error responses.

Important operational constraints are constraints on the structural forces that may act on the wind turbine tower and its rotor carrying arms 105 due to thrust imbalances between different rotors 110-140. When applying different error responses to different rotors 110-140, the aerodynamic symmetry is broken and the thrust forces on different rotors 110-140 will be different. This imbalance may lead to increased mechanical stress and fatigue loads or structural displacement of, e.g., a rotor carrying arm 105 or the tower top of the wind turbine 100. It is important to keep such structural forces within acceptable limits. This may, for example, be achieved by limiting the additional power output each rotor 110-140 is allowed to deliver above the power output level of the shutdown or derated rotor 110-140. Such a limit may, e.g., be implemented as a fixed or relative amount. It is, however, preferred to calculate an expected amount thrust imbalance based on one or more available error response scenarios or to calculate an optimal error response scenario based on one or more predetermined thresholds of maximum allowable structural load.

In a preferred embodiment, the response planning step 33 is performed using Model Predictive Control (MPC). MPC algorithms use a holistic model of the wind turbine 100, combining the aerodynamic characteristics of the rotors with mechanical characteristics of the wind turbine structure. Instead of using a large number of related and interconnected control loops, MPC uses one unified objective function in which all relevant constraints are explicitly included. The MPC combines, e.g., a tower model, a blade model, aerodynamics, a drive train model and/or a noise model. Such an advanced model is well suited for taking multiple inputs (e.g. wind speed, tip speed ratio, rotor speed, generator speed, ...) into account to provide multiple outputs (e.g. pitch angles, yaw angles, individual rotor power outputs, rotor speeds or tip speed ratios, ...) to fulfil a number of objectives (e.g. maximum power output, tolerable structural load, allowable rotor speeds, maximum noise levels, ...). MPC allows controlling the multi-rotor wind turbine 100 in a manner which ensures optimized operation of the complete system in relation to predefined criteria. In contrast with ‘old style’ control loops, MPC not only reacts to sensor information, but can also predict how the individual rotors 110-140 and the complete wind turbine structure will react to and function after implementing a wide range of possible control strategies. Considering a small set of predetermined criteria, the MPC can predict, select and apply the optimal control settings for each rotor 110-140 of the multi-rotor wind turbine 100.

When the step of determining the respective error responses is performed using Model Predictive Control (MPC), this will, e.g., allow the wind turbine 100 to keep the other rotors 110-140 delivering as much power as possible without risking excessive structural load on the wind turbine structure. Already before shutting down or derating the malfunctioning rotor, the MPC can predict the effect that different error response strategies will have on the operation of the individual rotors or the thrust imbalance on different rotors. Accordingly an optimal error response is selected that will combine high power output with safe and efficient operating conditions.

When the response strategy is determined, the common controller sends the relevant control signals to the respective controllers 115-145 of the individual rotors 110-140 in a subsequent instruction step 34. If one of the rotors 110-140 does not need to adapt its mode of operation, the common controller 200 may either not generate a control signal at all or provide a control signal indicating that no changes are needed. The response strategy determined by the common controller 200 is then implemented by the controllers 115-145 of the respective rotors 110-140 using the respective control signals in a response implementation step 35.

CLAIMS:

1. A method for controlling a multi-rotor wind turbine (100) with at least two rotors (110, 120, 130, 140), the method comprising the steps of:

receiving, from a first one of the at least two rotors (110, 120, 130, 140), an error signal,

in dependence of the error signal, determining respective error responses for the first one and at least a second one of the other rotors (110, 120, 130, 140), at least one of the error responses comprising a control signal and the respective error responses for the first and second rotors (110, 120, 130, 140) being different, and

submitting the at least one control signal to a controller (115, 125, 145) of the respective rotor (110, 120, 130, 140).

2. A method for controlling a multi-rotor wind turbine (100) as claimed in claim 1, further comprising the step of controlling the respective rotor (110, 120, 130, 140), based on the control signal.

3. A method for controlling a multi-rotor wind turbine (100) as claimed in claim 1 or 2, wherein the step of determining the respective error responses comprises determining an expected effect of available error responses on at least one operational constraint.

4. A method for controlling a multi-rotor wind turbine (100) as claimed in claim 3, wherein the operational constraint defines a threshold for at least one of generator speed, actuator movement, mechanical stress, a thrust imbalance, fatigue load, and power output.

5. A method for controlling a multi-rotor wind turbine (100) as claimed in claim 3 or 4, wherein the step of determining the respective error responses is performed using Model Predictive Control (MPC).

6. A method for controlling a multi-rotor wind turbine (100) as claimed in claim 5, wherein the Model Predictive Control (MPC) is operative to predict a structural displacement of a part of the wind turbine (100) based on estimated thrust imbalances between at least the first and second rotors (110, 120, 130, 140).

7. A method for controlling a multi-rotor wind turbine (100) as claimed in claim 6, wherein the structural displacement comprises a tower top displacement or a displacement of a rotor carrying arm of the wind turbine (100).

8. A method for controlling a multi-rotor wind turbine (100) as claimed in any one of the claims 5-7, wherein the Model Predictive Control (MPC) is operative to predict a tower torsion load of the wind turbine (100) based on estimated thrust imbalances between at least the first and second rotors (110, 120, 130, 140).

9. A method for controlling a multi-rotor wind turbine (100) as claimed in any one of the claims 3-8, wherein the step of determining the respective error responses comprises determining a maximum obtainable power output for the whole multi-rotor wind turbine (100), while satisfying the operational constraint.

10. A method for controlling a multi-rotor wind turbine (100) as claimed in any one of the claims 3-8, wherein the step of determining the respective error responses comprises keeping a total power output for the whole multi-rotor wind turbine (100) at a power output target level.

11. A method for controlling a multi-rotor wind turbine (100) as claimed in any one of the claims 1 to 10, wherein the error response for the first rotor (110, 120, 130, 140) is an instruction to stop the rotor (110, 120, 130, 140) or to put the rotor (110, 120, 130, 140) in an idling mode, and wherein the error response for the second rotor is to put the rotor (110, 120, 130, 140) in a derated power mode.

12. A method for controlling a multi-rotor wind turbine (100) as claimed in any one of the claims 1 to 10, wherein the error response for the first rotor (110, 120, 130, 140) is an instruction to put the rotor (110, 120, 130, 140) in a derated power mode at a first percentage of its maximum power, and wherein the error response for the second rotor is to put the rotor (110, 120, 130, 140) in a derated power mode at a second percentage of its maximum power, the second percentage being higher than the first.

13. A method for controlling a multi-rotor wind turbine (100) as claimed in any one of the claims 1 to 12, wherein the error responses comprise control settings for controlling at least one of:

- respective pitch angles for the first and second rotors (110, 120, 130, 140),

- respective yaw angles for the first and second rotors (110, 120, 130, 140),
- respective rotational speeds for the first and second rotors (110, 120, 130, 140), and
- respective tip speed ratios for the first and second rotors (110, 120, 130, 140).

14. A computer program product comprising computer code for performing, when executed on a computing means, a method as claimed in any one of the claims 1 to 13.

15. A multi-rotor wind turbine (100) comprising:

at least two rotors (110, 120, 130, 140), each rotor comprising a respective controller (115, 125, 145), and

a common controller (200), operatively coupled to the respective controllers (115, 125, 145) and configured to perform a method as claimed in any one of the claims 1 to 13.

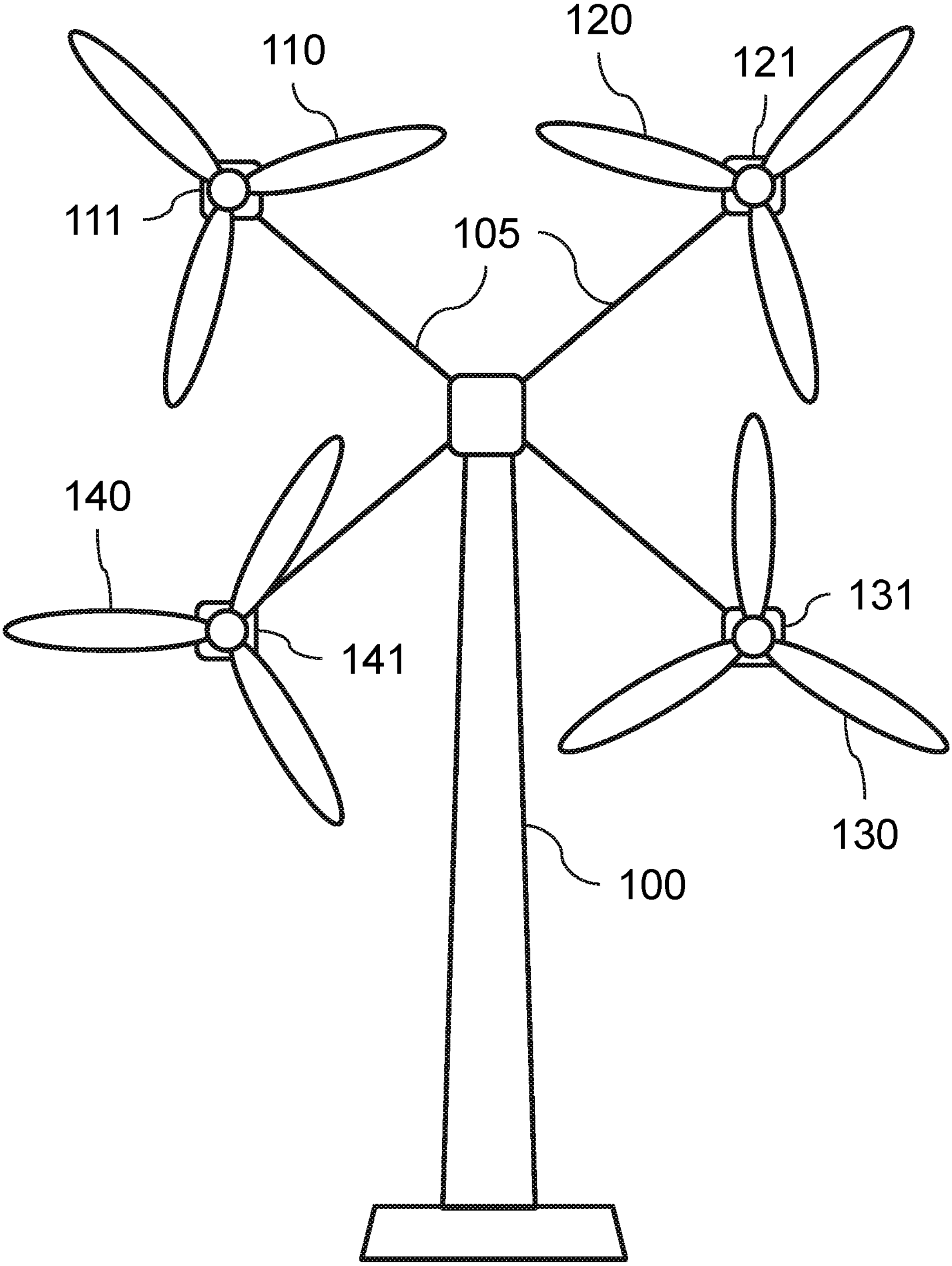

Fig. 1A

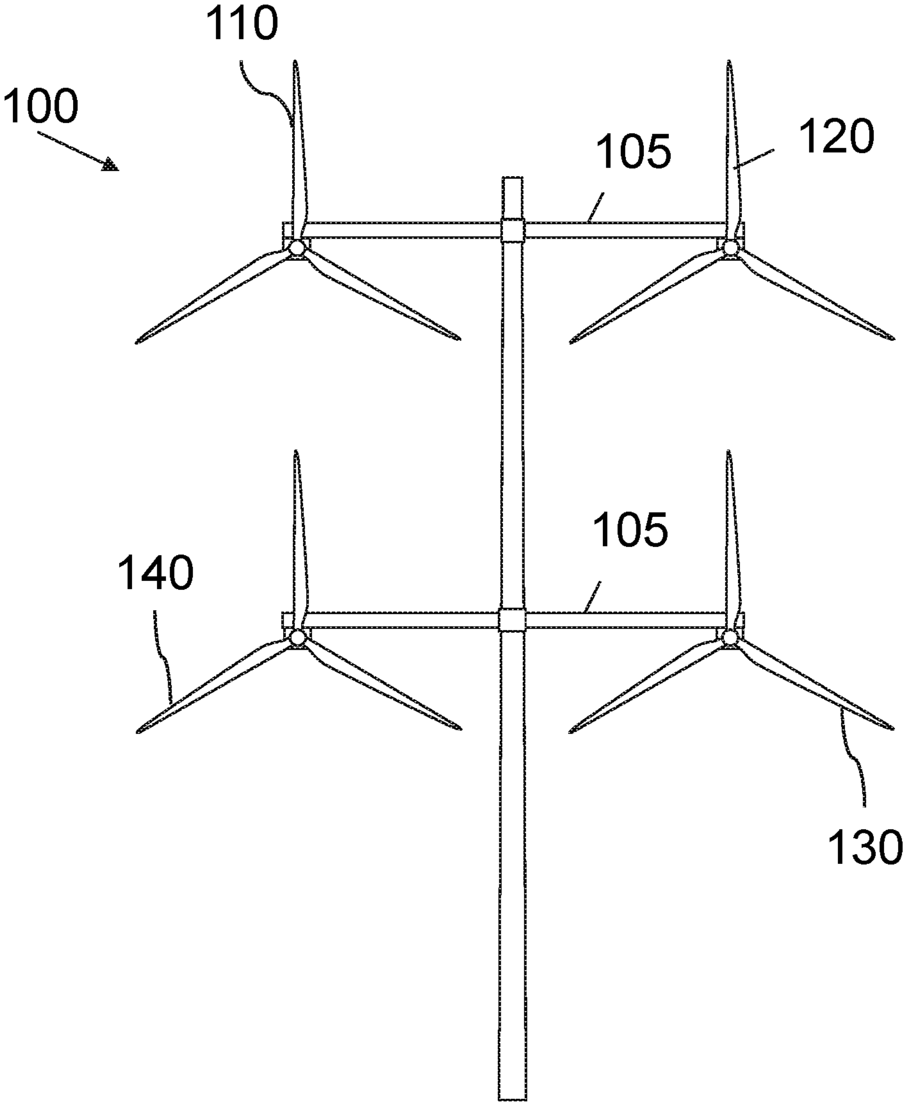

Fig. 1B

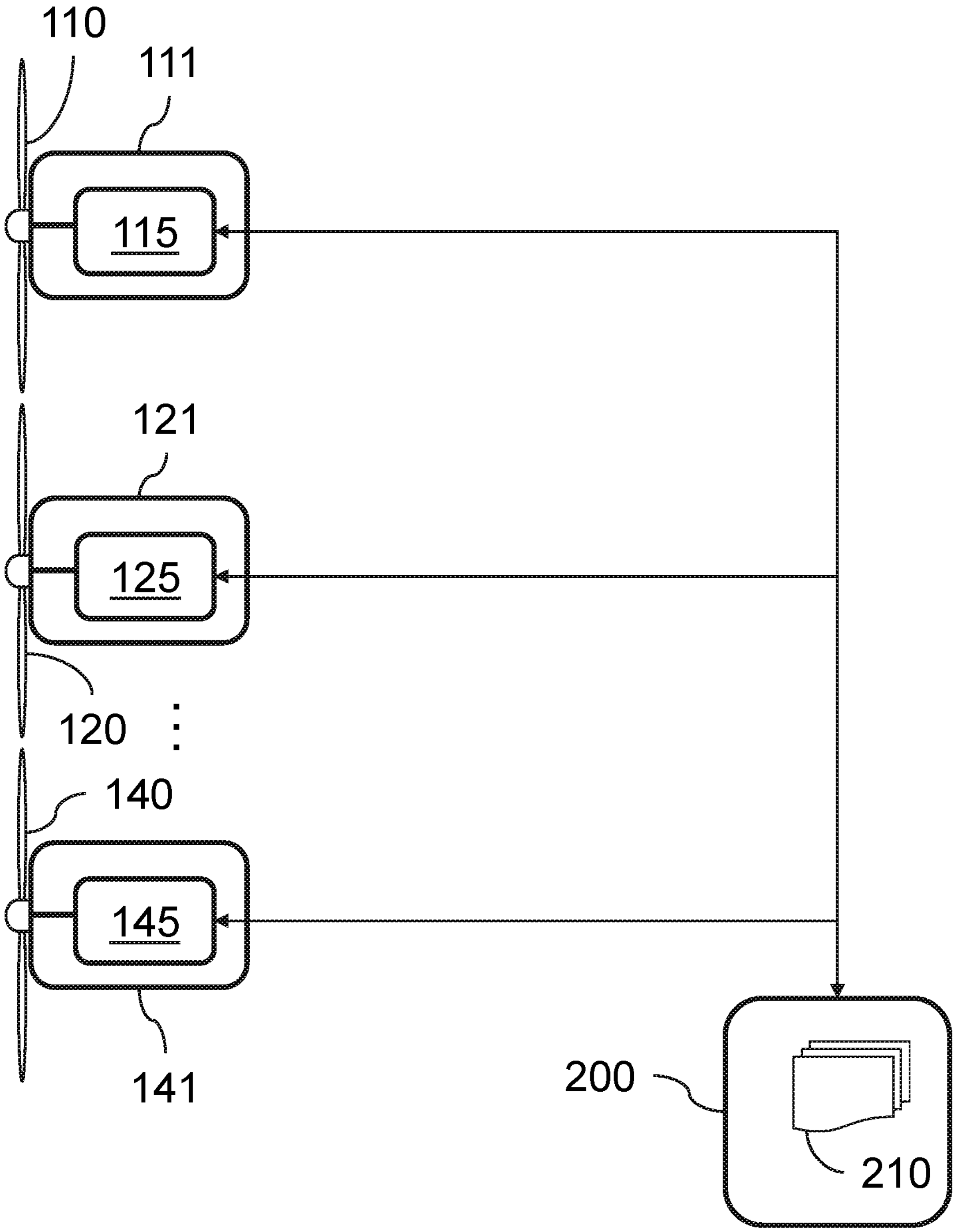

Fig. 2

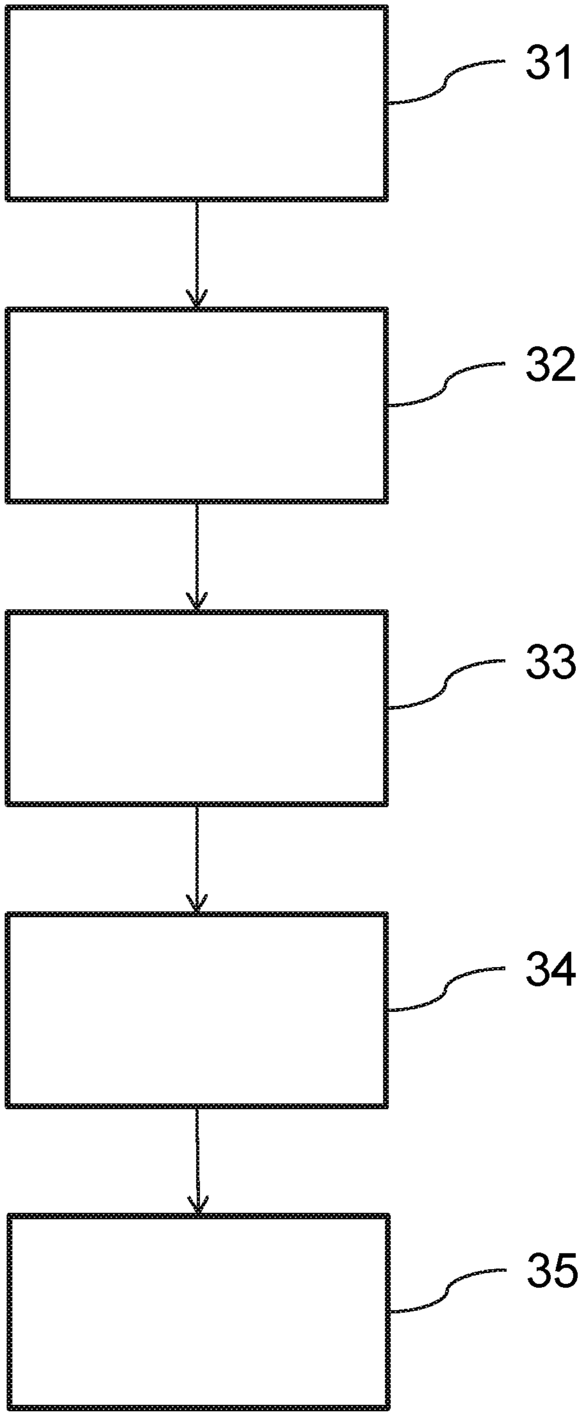

Fig. 3

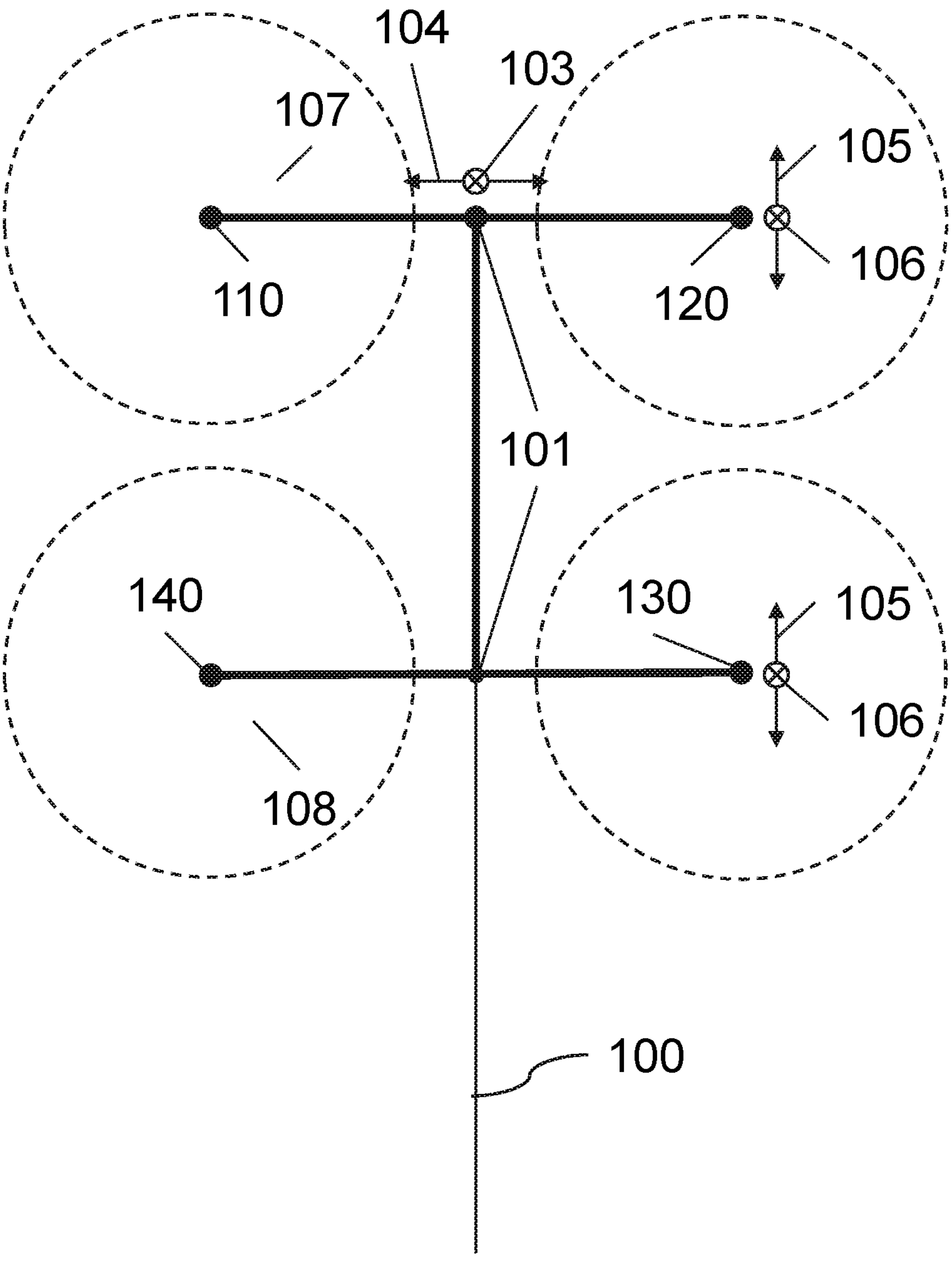

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2018/050319

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D1/02 F03D7/02 F03D17/00
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

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 Y	WO 2016/128002 A1 (VESTAS WIND SYS AS [DK]) 18 August 2016 (2016-08-18) page 1, line 30 - page 2, line 34 page 5, line 34 - page 11, line 2	1-4,9-15 5-8
X	US 2003/170123 A1 (HERONEMUS WILLIAM E [US]) 11 September 2003 (2003-09-11) paragraph [0016]; figure 3	1-3, 13-15
Y	WO 2016/150447 A1 (VESTAS WIND SYS AS [DK]) 29 September 2016 (2016-09-29) the whole document	5-8

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

☒ See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 21 February 2019	Date of mailing of the international search report 27/02/2019
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Libeaut, Laurent

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