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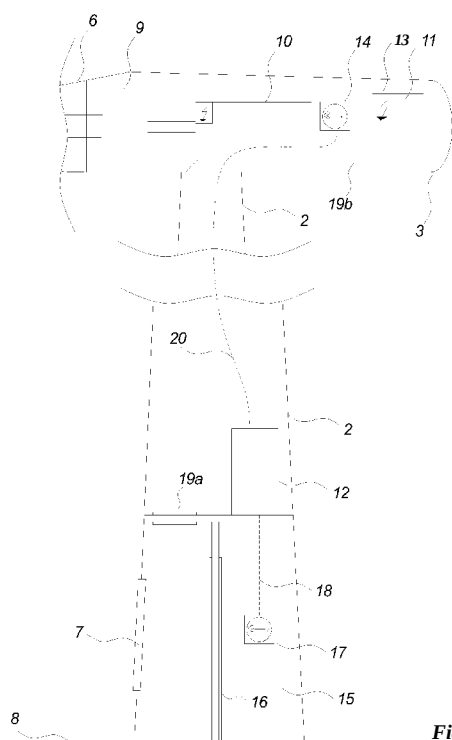


Fig. 3

(57) Abstract: The invention relates to a method for controlling a wind turbine in a non-operational mode, said method comprising the steps of entering the wind turbine via a tower entrance door by personnel, and manually handling at least one interlock device positioned inside the wind turbine in order to gain control of the functionality of the wind turbine switchgear. The invention further relates to a wind turbine (1) for supplying power to a utility grid.

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**A METHOD FOR CONTROLLING A WIND TURBINE IN A NON-OPERATIONAL MODE AND A
WIND TURBINE**

Background of the invention

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The invention relates to a method for controlling a wind turbine in a non-operational mode. The invention further relates to a wind turbine.

Description of the related art

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A wind turbine known in the art comprises a wind turbine tower and a wind turbine nacelle positioned on top of the tower. A wind turbine rotor with three wind turbine blades is connected to an electric generator of the nacelle via a low speed shaft and a gearbox, as illustrated on figures 1 and 2.

15

Modern wind turbines may comprise different high voltage components between the electric generator and a utility grid receiving the generated power such as a power converter, a utility grid transformer and switchgear positioned in the wind turbine nacelle and/or tower.

20

From Japanese patent application JP2006/0009596 it is known to use a storage chamber at the lower part of a wind turbine tower comprising switchgear as well as transformer. With this separation arrangement, the passive and local safety for personnel working in the wind turbine tower is increased but they may still come in
25 contact with high voltage of electric components of the wind turbine.

An object of the invention is therefore to provide technique allowing safe access and work inside a wind turbine in a non-operational mode.

The invention

The invention provides a method for controlling a wind turbine in a non-operational mode, said method comprising the steps of:

- 5 entering the wind turbine via a tower entrance door by personnel, and

manually handling at least one interlock device positioned inside the wind turbine in order to gain control of the functionality of the wind turbine switchgear.

- 10 The interlock device ensures that work inside a wind turbine in a non-operational mode may be performed safely as the switchgear can only function in response to an active handling of the interlock device or devices e.g. allowing reconnection of the switchgear when a worker has handled an interlock device to indicate that the personnel or component safety is ensured at the device location and otherwise
- 15 disallowing the reconnection.

- In an aspect of the invention, said personnel handles at least two interlock devices in different locations of the wind turbine. The use of interlock devices in different locations ensures that reconnection of the switchgear is deliberate. Further, it may
- 20 ensure that reconnection of the switchgear may only be performed when the personnel has activated all the necessary interlock devices.

- In another aspect of the invention, the personnel access a separate interlock compartment for manually handling at least one interlock device. The interlock
- 25 compartment increases the safety awareness of the personnel when having entered the wind turbine. Further, it establishes a well-defined path in accessing a part of the wind turbine by initially guiding the personnel to the compartment instead of e.g. positioning the interlock device freely on a control panel.

In a further aspect of the invention, the personnel operate and/or remove a key or a similar control device in the manually handling of said at least one interlock device.

5 The use of a key may increase the personnel safety as one worker will carry the key around in the wind turbine making it is impossible for any other worker to deactivate the interlock device and the reactivate the switchgear. Further, the method step of turning a key in handling the interlock device also increases the safety in comparison to pushing a button which may more easily be performed unintentionally.

10 In an even further aspect of the invention, said at least one interlock device connects or disconnects an electric blocking of the functionality of said switchgear. Hereby is established an advantageous embodiment of the invention.

15 In an aspect of the invention, operational mode of the wind turbine is re-established when the electric blocking of the functionality of said switchgear is disconnected. Hereby is established an advantageous embodiment of the invention.

20 In an aspect of the invention, said at least one interlock device is positioned in one or more different locations inside the wind turbine in relation to a location of said wind turbine switchgear. Hereby is established an advantageous embodiment of the invention in avoiding switchgear reconnection when other personnel is still present in a separate location of a wind turbine.

25 The invention also provides for a wind turbine for supplying power to a utility grid, said wind turbine comprising

at least one electric generator,

30 at least one electric power component such as a power converter and/or a utility grid transformer,

switchgear for protecting the wind turbine, and

at least one interlock device for controlling the functionality of said switchgear in an
5 non-operational mode of the wind turbine

where said at least one interlock device is positioned inside the wind turbine.

A wind turbine according to the invention provides safe access and work inside a
10 wind turbine in a non-operational mode.

In an aspect of the invention, said wind turbine in the non-operational mode is
controlled with a method according to any of claims 1 to 6. Hereby is established an
advantageous embodiment of the invention.

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In another aspect of the invention, said at least one interlock device comprise more
than one interlock device positioned in different locations of the wind turbine.
Hereby is established an advantageous embodiment of the invention. Hereby is
established an advantageous embodiment of the invention.

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In an aspect of the invention, said wind turbine switchgear includes utility grid
circuit breakers and one or more earthing switches and is established as one or more
modules e.g. on the tower foundation or on a tower floor level near the foundation.
Hereby is established an advantageous embodiment of the invention.

25

In an aspect of the invention, at least one interlock device is located in a separate and
defined interlock compartment e.g. in proximity of said wind turbine switchgear
and/or below or above the switchgear in the tower.

The interlock device compartment may be a separate room for personnel to enter or a minor cabinet for mainly holding the interlock device.

5 In an aspect of the invention, at least one interlock device is located in proximity of a fault detector system of a wind turbine power component such as the arc detector system of the utility grid transformer or the nacelle cabinet. The power components often handle significant power amounts and reconnections before a fault is fully cleared, which may result in arcing and potentially start a fire at the location of the power component.

10

Consequently, it is advantageous to position an interlock device next to the fault detector system and power component as it ensures that the switchgear is electrically blocked until personnel arrive at the location, appreciate the clearance of the fault and handles the interlock device.

15

In an aspect of the invention, at least one interlock device is located in the wind turbine nacelle e.g. in proximity of the arc detector system of the nacelle utility grid transformer. Switchgear may often be positioned in the lower tower part to better facilitate the utility grid connection and the location may hereby increase the risk of misunderstandings between personnel in tower and nacelle resulting in a hastily reconnection of the switchgear.

20

In an aspect of the invention, said wind turbine switchgear comprise blocking means for electrically blocking switchgear functionality in response to a signal from said at least one interlock device. Hereby is achieved an advantageous embodiment of the invention as the electric blocking will overrule any mechanical activation of the switchgear e.g. one worker of the personnel pressing the on-switch of switchgear while other workers still are present in the wind turbine. The electric blocking may be established with electric relay means or any other well-known electric control solutions.

25
30

In further aspects of the invention, said at least one interlock device includes a key or a similar control device in the manually handling the interlock device and may be positioned in one or more different locations inside the wind turbine in relation to a
5 location of said wind turbine switchgear.

Figures

The invention will be described in the following with reference to the figures in
10 which

- | | |
|-----------|--|
| fig. 1 | illustrates a large modern wind turbine as seen from the front, |
| 15 fig. 2 | illustrates the wind turbine as seen from the side with internal components schematically indicated, |
| fig. 3 | illustrates the tower base and nacelle of the wind turbine with internal components schematically indicated including interlock devices, |
| 20 fig. 4 | illustrates an electric layout of the wind turbine with a number of interlock devices, and |
| 25 fig. 5 | illustrates a basic flow diagram in controlling the wind turbine in a non-operational mode. |

Detailed description of related art

Fig. 1 illustrates a wind turbine 1 as seen from the front comprising a tower 2 and a wind turbine nacelle 3 positioned on top of the tower 2. The wind turbine rotor 4, comprising three wind turbine blades 5, is connected to the nacelle 3 through the low speed shaft which extends out of the nacelle 3 front.

The wind turbine 1 is positioned on a site with a wind turbine foundation and tower entrance door 7 at ground level 8.

10

Fig. 2 illustrates the wind turbine 1 as seen from the side and with different wind turbine components illustrated in short-dotted lines inside the nacelle 3 and the tower 2. The wind turbine has the rotor 4 connected via the hub 6 and shaft to a gearbox 9 and an electric generator 10 inside the nacelle. The nacelle is also illustrated as comprising a utility grid transformer 11 at the rear end.

The tower 2 comprises switchgear 12 positioned at a floor level above the tower entrance door 7 at ground level 8 requiring use of a ladder or an elevator to come from the entrance to the switchgear.

20

The door may also be elevated above ground level and accessible from the outside via stairs and hereby allowing the switchgear to be positioned at a level below the entrance door.

25 Detailed description of the invention

Fig. 3 illustrates the wind turbine comprising two interlock devices 14, 17 located in different locations in relation to the switchgear 12.

In this embodiment of the invention the wind turbine switchgear 12 is positioned on a floor level in the tower 2, above a separate compartment 15 from the tower entrance door 7. The separate compartment 15 has a compartment door 16 which is unlocked when the switchgear is initially tripped or when the wind turbine changes
5 from being operational to non-operational by disconnecting from the utility grid e.g. due to a malfunction or to facilitate any form of wind turbine service by personnel accessing the wind turbine.

Tripping of the wind turbine may be caused by a fault occurring in the turbine, which
10 is detected by an arc detector, which is part of the safety system in the turbine. The arc detector is in communication with the switchgear 12, in particular with a circuit breaker or a mechanical trip connection within the switchgear 12, and upon detecting a fault, will send a trip signal to the circuit breaker in the switchgear 12. The circuit breaker will then disconnect the electrical system of the turbine, preventing a fault
15 wherein a fire could break out.

In another embodiment, the fault is detected by a fire detection system, or a smoke detection system, or any other detection system in the turbine safety system. In yet another embodiment, the circuit breaker in the switchgear 12 may be tripped in the
20 event of an overcurrent fault, a short-circuit fault, an earthing fault, or any other fault in the electrical system.

The compartment 15 comprises an interlock device 17 to remotely gain control of the switchgear 12 via the connection 18 (illustrated as a short-dotted line). The interlock
25 device 17 may have a key allowing the personnel to control the switchgear 12 by turning the key and/or removing the key. In an embodiment, when the key is turned and/or removed from the interlock device 17, it is possible to access the location of the switchgear via a hatch 19a being unlocked with the key operation.

In another embodiment, the switchgear 12 may comprise an interlock device 17 which may be a key interlock device. The interlock device requires that an earthing switch on a circuit breaker panel of the switchgear 12 is activated before allowing access via a door 19b to the transformer room in the nacelle of the turbine. When the
5 earthing switch is properly activated and the high voltage main circuit is isolated, a key interlock compartment will be accessible. The key interlock compartment would contain a metal ring carrying the keys for the transformer room and the keys for the switchgear together in a bunch. A security measure for the metal ring provides that the keys cannot be removed without cutting the metal ring.

10

A further security measure provides that when the key is removed from the key interlock compartment, it would not be possible to deactivate the earthing switch.

When the key for the transformer door is used and the transformer door is open, is it
15 not possible to take out the key before the transformer door is locked and secured again. This will ensure that the transformer door is always locked before reconnection of the earthing switch in the switchgear is possible.

In an embodiment, another interlock device 14 is positioned in the nacelle 3 and in
20 proximity of the utility grid transformer 11 and a detector system 13 which detects the presence of arc faults in the transformer. The interlock device 14 is connected to the switchgear 12 via the connection 20 (illustrated as a short-dotted line).

The interlock device 14 may be used by personnel accessing the nacelle to protect
25 them from a premature reconnection of the switchgear.

Further, the interlock device 14 may be used in confirming that a component fault in the turbine resulting in tripping of the switchgear has been investigated and cleared and hereby ensuring that the reconnection of the switchgear will not result in
30 component damage e.g. in form of arcs.

In an embodiment, the interlock device 14 may comprise an electrical blocking apparatus which is activated after a trip in the wind turbine 1 triggers a disconnection of the circuit breaker. The trip may be caused and/or detected by any of the faults
5 and/or detectors mentioned above.

The electrical blocking apparatus prevents a reconnection of the circuit breaker, which brings about the electrical reconnection of the wind turbine electrical system, until the fault in the turbine has been acknowledged. The acknowledgement is done
10 by means of an acknowledgement button on the interlock device 14, which sends a signal to the switchgear which deactivates the electrical blocking apparatus, making it possible for reconnection of the circuit breaker.

The electrical blocking apparatus may be a blocking coil located at the circuit
15 breaker in the switchgear 12, which prevents the circuit breaker from electrically connecting even if the normal operating switch on the circuit breaker itself is actuated.

Fig. 4 illustrates an electric layout of the wind turbine 1 with a number of interlock
20 devices 14, 17, 21.

In one embodiment, the electrical system of wind turbine 1 is illustrated as a double fed type comprising an electric generator 10 with stator and rotor connected directly and indirectly via a power converter 22 to the utility grid 23. Other electrical system
25 configurations are also possible. The connection also comprises the utility grid transformer 11 and the switchgear 12 including circuit breakers.

A number of interlock devices 14, 17, 21 may gain control of the switchgear functionality when the wind turbine is in a non-operational mode e.g. allowing or
30 disallowing the switchgear 12 to reconnect the wind turbine 1 to the utility grid 23.

The interlock devices 14, 17, 21 are positioned in different location in relation to the location of the switchgear (as schematically illustrated with the short-dotted boxes).

5 The interlock devices 14, 17, 21 are illustrated as one interlock device in each location but may also be several interlock devices in the same location e.g. more than one interlock device in the nacelle.

Fig. 5 illustrates a basic flow diagram in controlling the wind turbine in a non-operational mode with an embodiment of the invention.

10

The flow diagram illustrates how the wind turbine enters the non-operational mode by tripping of the switchgear e.g. due to a fault in the wind turbine or the utility grid or to perform some form of service requiring personnel entering in the wind turbine.

15 Secondly, the personnel handle the interlock device(s) in order to gain control of the switchgear e.g. in order to block any unintently and premature reconnection of the switchgear which may danger the safety of personnel present inside the wind turbine.

20 Thirdly, the control method detects any handling of the local interlock device(s) indicating that the reason for blocking the switchgear is no longer present e.g. the personnel has left the locations or any fault situation has locally been inspected and cleared.

25 Finally, the switchgear is reactivated and the wind turbine may be reconnected to the utility grid and as such ending the non-operational mode of the wind turbine.

The invention has been exemplified above with reference to specific examples of designs and embodiments of a wind turbine 1 with interlock devices 14, 17 in different but specific locations 3, 15 inside the wind turbine. However, it should be
30 understood that the invention is not limited to the particular examples described

above but may be designed and altered in a multitude of varieties within the scope of the invention as specified in the claims.

List

1. Wind turbine
2. Tower
- 5 3. Nacelle
4. Rotor
5. Blade
6. Hub
7. Tower entrance door
- 10 8. Ground level
9. Gearbox
10. Electric generator
11. Utility grid transformer
12. Wind turbine switchgear
- 15 13. Detector such as arc detector
14. Interlock device in location of the nacelle
15. Compartment location for interlock device
16. Compartment door
17. Interlock device in compartment location
- 20 18. Connection between interlock device in compartment location and switchgear
- 19a. Floor level access such as a floor hatch
- 19b. Transformer door access
20. Connection between interlock device in nacelle location and switchgear
21. Further interlock device(s) in different location of the switchgear
- 25 22. Power converter
23. Utility grid
- ID. Interlock Device
- Loc. Location

Claims

1. Method for controlling a wind turbine in a non-operational mode, said method comprising the steps of:

5

entering the wind turbine via a tower entrance door by personnel, and

manually handling at least one interlock device positioned inside the wind turbine in order to gain control of the functionality of the wind turbine switchgear.

10

2. Method for controlling a wind turbine according to claim 1 where said personnel handle at least two interlock devices in different locations of the wind turbine.

3. Method for controlling a wind turbine according to claim 1 or 2 where the personnel access a separate interlock compartment for manually handling at least one interlock device.

15

4. Method for controlling a wind turbine according to any of claims 1 to 3 where the personnel operate and/or remove a key or a similar control device in the manually handling of said at least one interlock device.

20

5. Method for controlling a wind turbine according to any of claims 1 to 4 where said at least one interlock device connects or disconnects an electric blocking of the functionality of said switchgear.

25

6. Method for controlling a wind turbine according to claim 5 where operational mode of the wind turbine is re-established when the electric blocking of the functionality of said switchgear is disconnected.

7. Method for controlling a wind turbine according to any of claims 1 to 6 where said at least one interlock device is positioned in one or more different locations inside the wind turbine in relation to a location of said wind turbine switchgear.

5 8. A wind turbine (1) for supplying power to a utility grid (23), said wind turbine comprising

at least one electric generator (10),

10 at least one electric power component such as a power converter (22) and/or a utility grid transformer (11)

switchgear (12) for protecting the wind turbine (1), and

15 at least one interlock device (14, 17, 21) for controlling the functionality of said switchgear (12) in an non-operational mode of the wind turbine

where said at least one interlock device (14, 17, 21) is positioned inside the wind turbine.

20

9. A wind turbine according to claim 8, where said wind turbine in the non-operational mode is controlled with a method according to any of claims 1 to 7.

10. A wind turbine according to claim 8 or 9, where said at least one interlock device
25 (14, 17, 21) comprise more than one interlock device positioned in different locations of the wind turbine.

11. A wind turbine according to any of claims 8 to 10, where said wind turbine switchgear (12) includes utility grid circuit breakers and one or more earthing

switches and is established as one or more modules e.g. on the tower foundation or on a tower floor level near the foundation..

12. A wind turbine according to any of claims 8 to 11 , where at least one interlock
5 device (17) is located in a separate and defined interlock compartment (15) e.g. in proximity of said wind turbine switchgear (12) and/or below or above the switchgear (12) in the tower.

13. A wind turbine according to any of claims 8 to 12, where at least one interlock
10 device (14, 17, 21) is located in proximity of a fault detector system of a wind turbine power component such as the arc detector system (13) of the utility grid transformer (11).

14. A wind turbine according to any of claims 8 to 13, where at least one interlock
15 device (14) is located in the wind turbine nacelle (3) e.g. in proximity of the arc detector system (13) of the nacelle utility grid transformer (11) or the nacelle cabinet.

15. A wind turbine according to any of claims 8 to 14, where said wind turbine
20 switchgear (12) comprise blocking means for electrically blocking switchgear functionality in response to a signal from said at least one interlock device (14, 17, 21).

16. A wind turbine according to any of claims 8 to 15, where said at least one
25 interlock device (14, 17, 21) includes a key or a similar control device in the manually handling the interlock device.

17. A wind turbine according to any of claims 8 to 16, where said at least one
interlock device (14, 17, 21) is positioned in one or more different locations inside the wind turbine in relation to a location of said wind turbine switchgear.

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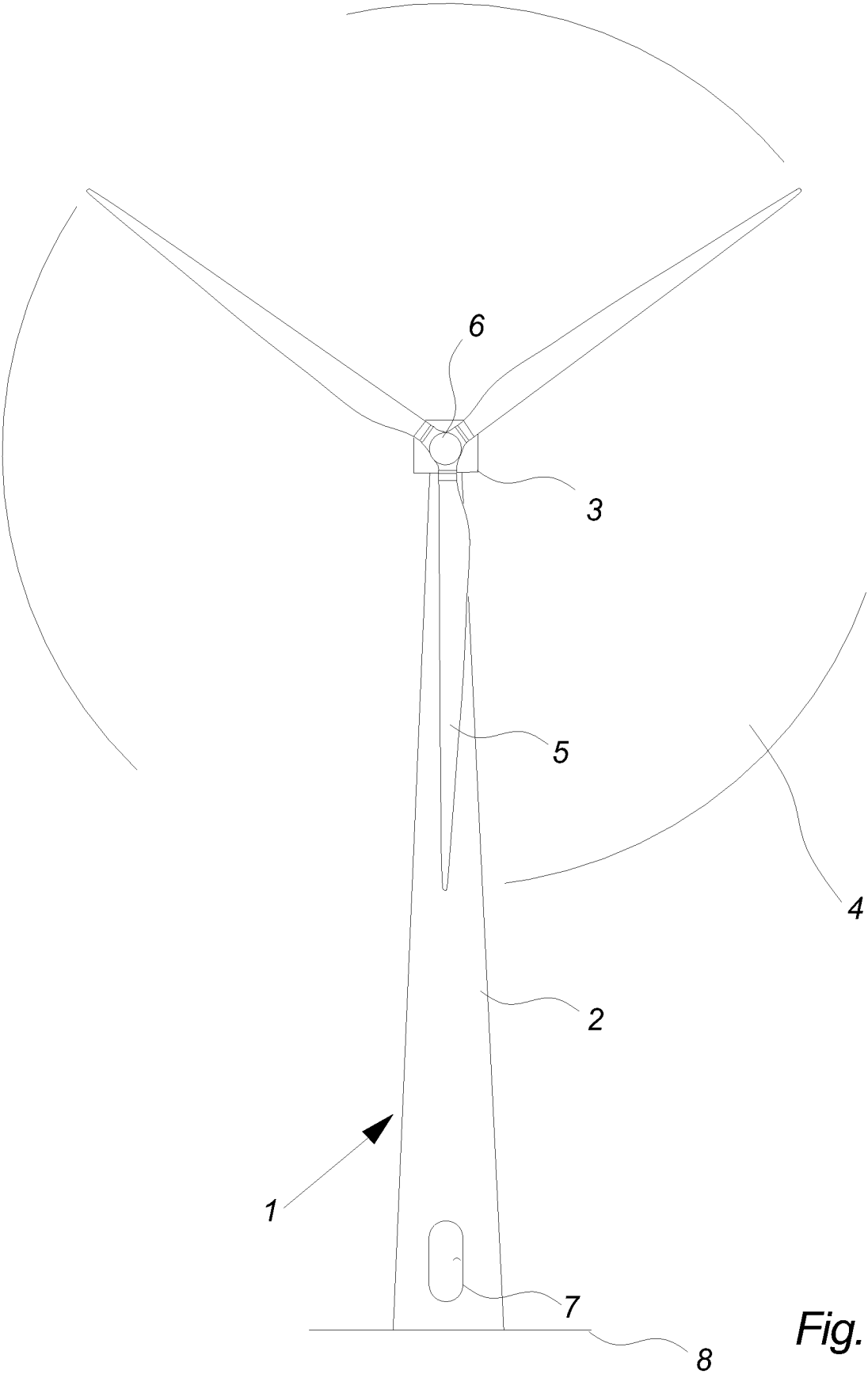


Fig. 1

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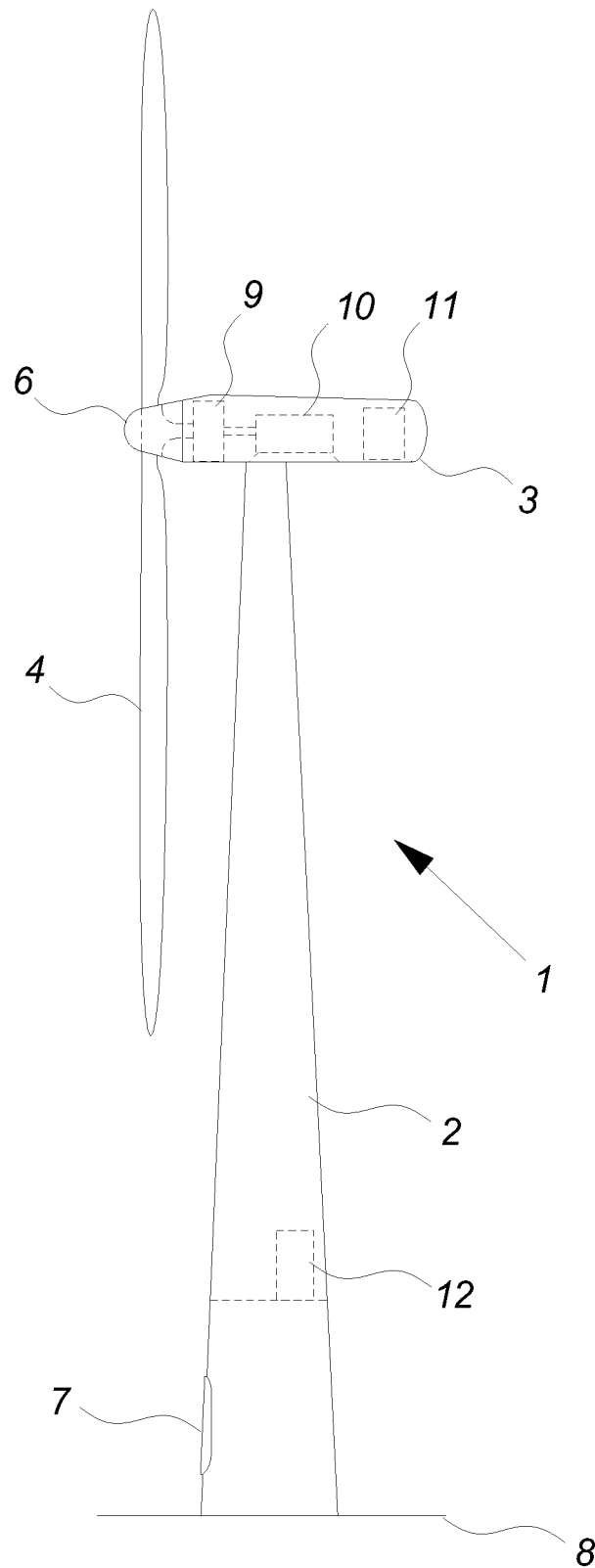


Fig. 2

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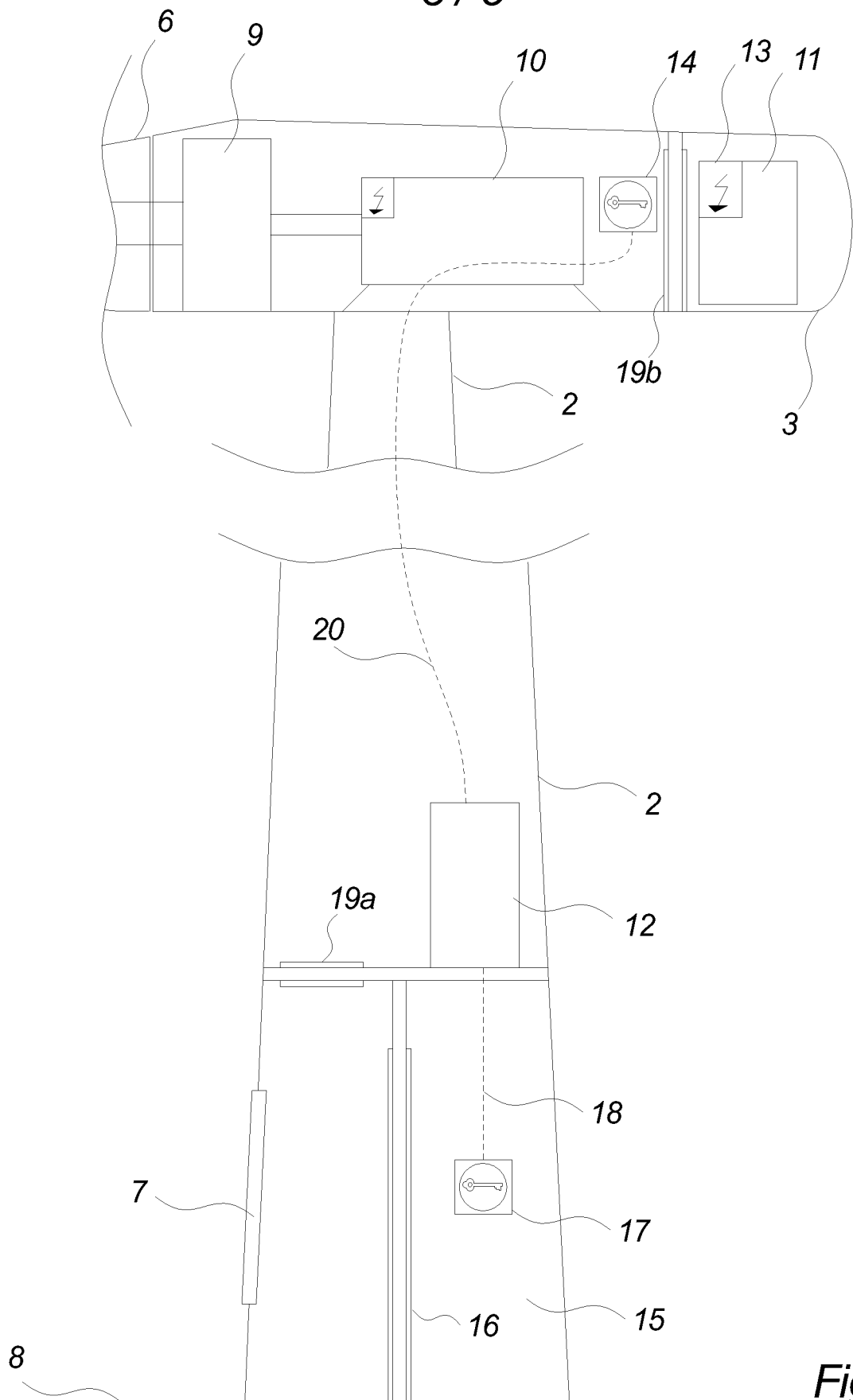


Fig. 3

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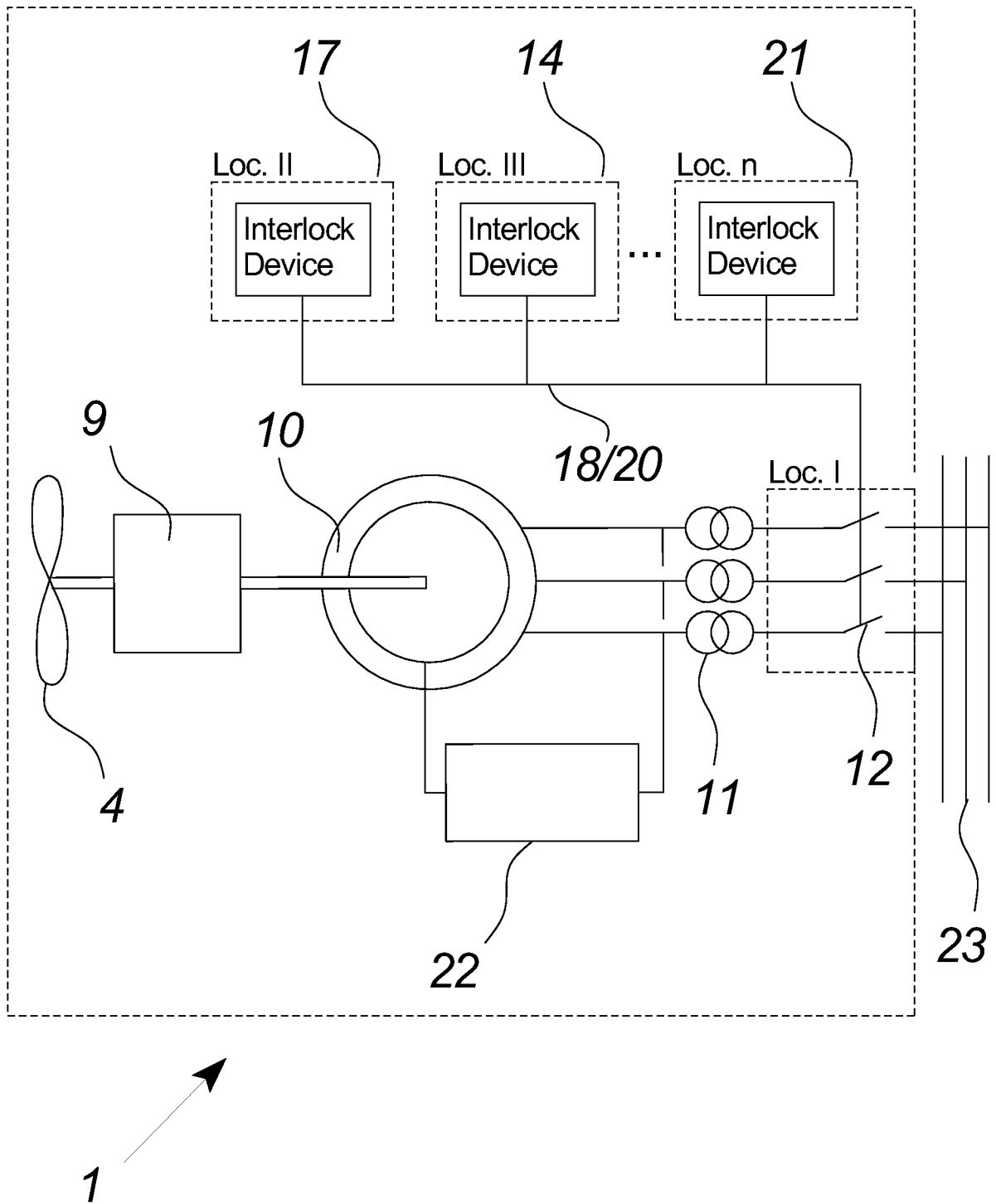


Fig. 4

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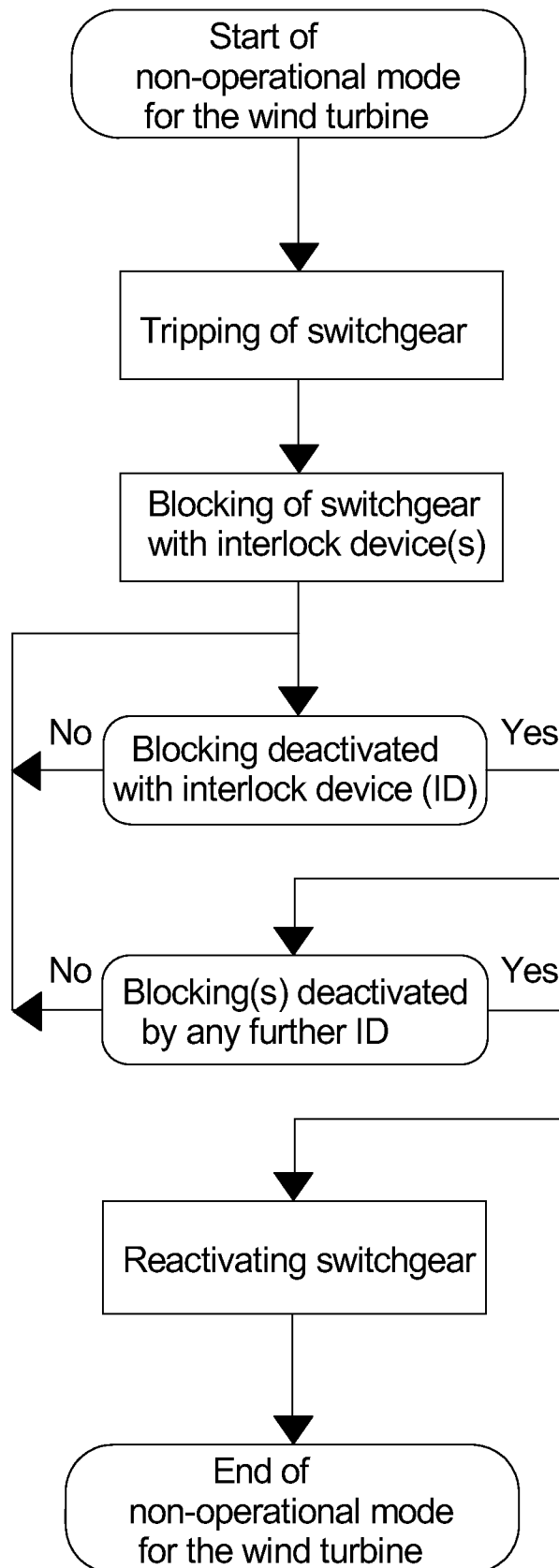


Fig. 5