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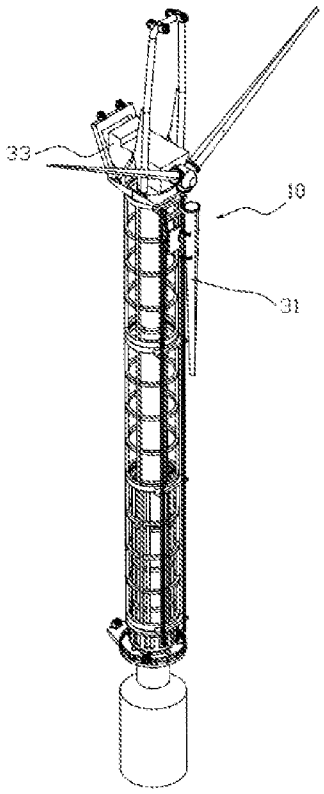
(54) Title **ARRANGEMENT AND METHOD FOR USE IN INSTALLING A WIND TURBINE**

(57) Abstract

The invention relates to an arrangement for use in installing a wind turbine, the arrangement comprising a longitudinal structure at least partially supported on a wind turbine tower, a guide track connected to the longitudinal structure and a dolly arranged to follow the guide track along the longitudinal structure.



ARRANGEMENT AND METHOD FOR USE IN INSTALLING A WIND TURBINE

The present invention relates in particular to an arrangement for use in installing a wind turbine, and related method.

A modern wind turbine generally comprises a tower upon which blades connected to a rotary hub are supported on an upper end. The blades are coupled to a generator through a shaft and bearings arrangement at the top of the tower. In use, the blades are caused to turn by the wind which in turn produces rotation of a shaft and allows electricity to be produced by the generator. In addition to the generator, auxiliary equipment, such as a transformer and control and monitoring systems, is typically provided. The top structure, referred to as a nacelle, is typically supported on the tower with bearings, so that the nacelle can be rotated around a vertical axis of the tower and be adjusted to varying wind directions. The blades are coupled to the nacelle.

Wind turbines have developed from small land-based of far less than 1 MW to wind turbines to today's larger turbines of about 10 MW. Apart from differences of scale, the configuration of wind turbines has largely kept to the same general design over many years. Current developments include floating wind turbines capable of producing installed power of up to 15-20 MW. The blades used can be of a length of 100 meters and more.

In today's wind turbines, the blades are typically installed after the nacelle has been mounted on top of the tower structure. The blades are hoisted up by a crane either external to the turbine tower or supported on the turbine tower. During mounting, a blade is typically lifted by the crane using of a lifting yoke to grip and hold the blade in a horizontal position while the blade is being mounted onto the nacelle. Using a crane supported on the turbine tower may be advantageous for installation of wind turbines offshore especially as it minimizes relative motion between the wind tower and the crane. When

blades are mounted from a horizontal position, the crane head reaches out from the wind turbine tower to hold the blade in the correct position. This causes the mass centre of the crane with the blade lifted to be shifted away from the turbine tower mass centre. This typically requires installation during calm weather as both wind and waves may cause stress to the crane and the wind turbine tower especially as the blade is lifted high and away from the turbine centre.

It is known to mount blades from a substantially vertical position, holding the blades just below the nacelle. Wires attached to a lower end of the blades are typically used to hold the blade in distance apart from the turbine tower preventing the blades from crashing into the crane tower due to wind and/or waves.

The time intervals for acceptable wave conditions offshore are often very short. Furthermore, installation of offshore wind turbines can be technically demanding and costly. There is hence a need for easy and more robust installation methods especially adapted for offshore use.

At least one aim of the invention is to remedy or reduce one or more drawbacks associated with the prior art.

According to a first aspect, the invention relates to an arrangement for use in installing a wind turbine, the arrangement comprising a longitudinal structure at least partially supported on a wind turbine tower, a guide track connected to the longitudinal structure and a dolly arranged to follow the guide track along the longitudinal structure.

The arrangement facilitates elevation of a wind turbine blade or nacelle close to the wind turbine tower. By having the dolly following the guide track, the arrangement prevents relative motion of the wind turbine blade or nacelle during installation. The arrangement furthermore ensures that the mass centre of wind turbine blade or the nacelle is kept close to the wind turbine tower during lifting and mounting. An advantage is that the arrangement extends the time intervals for installation, by enabling installation of wind turbine blades or the nacelle in harsher weather conditions.

The guide track may be arranged to prevent sideways rotation of the dolly. The guide track may comprise two laterally spaced track members to prevent sideways rotation of the dolly. Preventing sideways rotation of the dolly is advantageous in that it increases control of the wind turbine blade during elevation and mounting.

The wind turbine may be a land-based wind turbine or may be an offshore wind turbine. The offshore wind turbine may be a bottom fixed wind turbine or a floating wind turbine.

The longitudinal structure may be fully supported on the wind turbine tower. The longitudinal structure may enclose at least a portion of the wind turbine tower.

The arrangement may comprise an elevation means for elevating the dolly along the longitudinal structure. The elevation means comprises at least one winch and at least one wire. The wire may be suspended from an upper portion of longitudinal structure.

The elevation means may comprise a crane and at least one crane wire for elevating the dolly. The crane may be a crane external to the wind turbine tower. The crane may be a crane supported on the wind turbine tower.

The dolly may comprise a blade holding means for holding a wind turbine blade. An advantage of the blade holding means is that the dolly easily can be used for lifting and supporting a wind turbine blade during a blade installation process.

The blade holding means may be arranged to change between a first position and a second position, wherein the blade holding means in the first position is configured to hold the wind turbine blade in a substantially horizontal orientation and the blade holding means in the second position is configured to hold the wind turbine blade in a substantially vertical orientation.

Holding the wind turbine blade in a substantially vertical orientation reduces exposure to wind thereby minimizing stress to the elevation means and the longitudinal structure. Also, it enables the mass centre of the wind turbine blade to be kept close to the wind turbine tower during installation.

The dolly may comprise tilt means for tilting the blade holding means about a horizontal axis, wherein a mounting portion of the wind turbine blade is moved closer or further away from the wind turbine tower. This enables fine adjustment of the position of the mounting portion with respect to the nacelle.

The longitudinal structure may comprise a crane tower. A crane may be supported on top of the crane tower.

According to a second aspect, the invention relates to a method of elevating at least one wind turbine blade, the method comprising providing the arrangement according to any one of claims 4 to 9, elevating a wind turbine blade along a wind turbine tower by use of the dolly and rotating the blade from the horizontal orientation to a vertical orientation during elevation.

According to a third aspect, the invention relates to a method of elevating a nacelle for mounting to a wind turbine tower, the method comprising providing the arrangement according to any one of the preceding claims, lifting the nacelle by use of crane wires suspended from the crane and supporting the nacelle close to the wind turbine tower by means of support wires fastened to the dolly.

According to a fourth aspect, the invention relates to a method of elevating a wind turbine tower section for mounting to a partially constructed wind turbine tower, the method comprising providing the arrangement according to any one of the preceding claims, elevating the wind turbine tower section by use of crane wires suspended from the crane, and supporting the wind turbine tower section close to the wind turbine tower by means of support wires fastened to the dolly.

There will now be described, by way of example only, embodiments of the invention, with reference to the accompanying drawings, in which:

Fig. 1A shows a floating wind turbine arrangement for mounting of a wind turbine blade;

Fig. 1B shows a detailed view of part of Figure 1A showing a dolly holding the wind

turbine blade;

Fig. 2 shows the dolly in a first position holding a wind turbine blade horizontally;

Fig. 3 shows the dolly approaching a second position holding a wind turbine blade vertically; and

Fig. 4 shows the arrangement when used for installing a nacelle on top of a wind turbine tower.

Figure 1A and 1B show an installation arrangement 100 for an offshore wind turbine 300. The wind turbine 300 comprises a turbine tower 32 and is shown with a crane arrangement 200 comprising a crane tower 21 with a crane 22 attached on top. The crane tower 21 is supported on and surrounds the wind turbine tower 32.

The installation arrangement 100 comprises a vertical support structure, in this example comprising the crane tower 21, and a dolly 10 for carrying the turbine blades 31 upward along the crane tower 21. The installation arrangement 100 further comprises an elevation means 5, in the example comprising the crane 22 with crane wires 25 attached to the dolly 10. The crane tower 21 further comprises a longitudinal guide track 23 on the outside of the crane tower 21, and supported on the crane tower 21, as part of the crane tower 21. The guide track 23 is arranged to guide the dolly 10 along the turbine tower 32 while the dolly 10 is elevated by the elevation means 5, i.e. pulled upward by the crane wire. Furthermore, the dolly 10 comprises blade holding means 2 for holding a wind turbine blade 31.

During installation of the wind turbine blade 31, the dolly 10 is lowered using the elevation means 5 along the turbine tower 32. The dolly 10 is guided by the longitudinal track. The blade holding means 2 is activated to engage and hold the wind turbine blade 31. The dolly 10 with the turbine blade 31 is then elevated by the elevation means 5 along the turbine tower 32. The turbine blade 31 can thereafter be mounted to a nacelle 33 on top of the turbine tower 32 while being supported by the dolly 10. During the mounting operation, advantageously, by way of installation arrangement 100 with the guide track 23, the dolly 10 is secured and positioned close to the crane tower 21.

The installation arrangement 100, the crane arrangement 200 and the wind turbine 300 will now be explained in more detail.

The wind turbine 300 comprises a floating base 39 and a wind turbine tower 32 with a nacelle 33 fixed on top. The nacelle 33 is shown with two blades 31 fixed thereto. The figure further shows a crane arrangement 200 enclosing the wind turbine tower 32.

The crane arrangement 200 is shown supported on the wind turbine tower 32. The crane arrangement 200 comprises a platform 20, the crane tower 21 and the crane 22. The platform 20 is clamped to the wind turbine tower 32 at or near a lower end of the wind turbine tower 32. The crane tower 21 is supported on the platform 20 and comprises a cylindrical structure surrounding a circumference of the turbine tower 32. The crane 22 is fixed to an upper end of the crane tower 21. The dolly 10 supported by the vertical support structure is shown in Figures 1A and 1B holding a blade 31 by use of the blade holding means 2 in a substantially vertical position close to the nacelle 33. The vertical support structure enables the dolly 10 to travel close to the wind turbine tower 21 as it carries the blade 31 up towards the nacelle 33.

In the process of installing several wind turbine blades 31, the dolly 10 moves down along the crane tower 21, engages the blade holding means 2 to a wind turbine blade 31 arranged in a horizontal position, lifts the blade 31 while gradually rotating the blade 31 to a vertical position while moving up towards the nacelle 33. The dolly 10 holds the blade in a substantially vertical position up against the nacelle 33 while the blade 31 is fixedly mounted to the nacelle 33. The dolly 10 can then be released from the blade 31 by disengaging the blade holding means 2 and travel down and to engage to another blade 31.

The dolly 10 will now be described in more detail with reference to Figure 1B.

The dolly 10 comprises a main body 1 and the blade holding means 2 comprising one or more pairs of clamp members 8 (two pairs shown) for gripping and holding a wind turbine blade 31. The blade holding means 2 is coupled to the main body 1 through a rotatable connection 3. The rotatable connection 3 is arranged to rotate the blade holding means 2 about a horizontal axis, so that when holding a blade 31, the blade 31 can be rotated be-

tween a horizontal orientation and a vertical orientation.

The rotatable connection 3 can comprises an axel between the main body 1 and the blade holding means 2. The axel can have a substantially horizontal direction pointing outward from the wind turbine tower 32.

The dolly 10 further comprises a track follower 4 attached to the main body 1 and arranged to follow the guide track 23 on the crane tower 21. The guide track 23 extends vertically along an outside of the crane tower 21 between the platform 20 and the nacelle 33. The track follower 4 provides a sliding or rolling engagement of the dolly 10 to the guide track, thereby allowing the dolly 10 to travel along the crane tower 21 while being secured to the crane tower 21. Crane wires 25 suspended from the crane 22 are engaged to an upper portion of the guide follower 4, so that the dolly 10 can be elevated by use of the crane 22. A power cable (not shown) further connects a power supply (not shown) on the platform 20 to the dolly 10 for e.g., providing power for rotating the blade holding means 2 and operating the blade holding means 2 to grip and hold the blade 31. In other examples separate wire(s) (not shown) suspended from an upper portion of the crane tower 21 may be used to elevate the dolly 10. A winch controlling the wires can be positioned at or close to the platform 20.

Figure 2 shows the dolly 10 in a first position, wherein the blade holding means 2 has a horizontal orientation close to the platform 20. To engage with a turbine blade 31, the clamp members 8 are opened to allow a turbine blade 31 to be horizontally inserted and the clamps to be closed. Insertion of the turbine blades into the blade holding means 2 may be facilitated by an external vessel or a moveable rack (not shown) arranged on the platform 20 for holding and feeding the dolly 10 with turbine blades 31. The dolly 10 with the turbine blade 31 attached is then elevated by use of the crane 22. As the dolly 10 is elevated towards the nacelle 33, the blade holding means 2 is rotated to direct the turbine blade 31 vertically. Figure 3 shows the dolly 10 approaching a second position wherein the turbine blade 31 is held up against the nacelle 33 so that the turbine blade 31 can be mounted thereto.

Referring back to Figure 1B, the dolly 10 comprises eight hinged connections 6 (only five

shown) between the guide follower 4 and the main body 1. Two pistons 7 (one shown) is provided to tilt the main body 1 with the blade holding means 2 fixed thereto. Hence, by use of the pistons 7, the turbine blades 31 may be slightly tilted. This way a mounting portion 31a of the turbine blades 31 may be moved closer or further away from the wind turbine tower 32 so as to facilitate alignment of the mounting portion 31a with the nacelle 33. The number of hinged connections 6 and/or pistons 7 may vary in other examples.

In other examples, the embodiments the arrangement may comprise a rack and pinion drive mechanism for elevation of the dolly 10 along the longitudinal structure.

The arrangement 100 described above, can with a few modifications also be used to facilitate installation of the nacelle 33. An example of this is shown in figure 4, where the nacelle 33 is lifted by the crane 22 by use of the crane wires 25. A lower portion of the nacelle 33 is secured by support wires 26 fastened to the dolly 10. The dolly 10 can be controlled actively by a separate drive mechanism (not shown), such as separate wires suspended from the crane 22, or be elevated passively by means of the support wires 26 attached to the nacelle 33. The support wires 26 prevents uncontrolled movement of the nacelle 33 and hold it close to the wind turbine tower 32 during lifting. During elevation, the nacelle 33 is suspended between the crane 22 and the dolly 10 to minimize relative lateral movement of the nacelle 33 compared to the crane tower 22. Similarly, the arrangement 100 may be used in the process of erecting the wind turbine tower 32, lifting and supporting a wind turbine tower section by means of the crane 22 and the dolly 10 respectively.

The apparatus and methods described herein can be used as a part of an installation, construction, replacement or maintenance process of a wind turbine 300.

C l a i m s

1. An arrangement for use in installing a wind turbine, the arrangement comprising:
   - a longitudinal structure at least partially supported on a wind turbine tower;
   - a guide track connected to the longitudinal structure; and
   - a dolly arranged to follow the guide track along the longitudinal structure.

2. The arrangement according to claim 1, further comprising an elevation means for elevating the dolly along the tower structure.

3. The arrangement according to claim 2, wherein the elevation means comprises at least one winch and at least one wire.

4. The arrangement according to claim 3, wherein the elevation means comprises a crane wire and at least one crane.

5. The arrangement according to any one of the previous claims, wherein the dolly comprises a blade holding means for holding a wind turbine blade.

6. The arrangement according to the previous claim, wherein the blade holding means is arranged to move between a first position and a second position, wherein the blade holding means in the first position is configured to hold the wind turbine blade in a substantially horizontal orientation and the blade holding means in the second position is configured to hold the wind turbine blade in a substantially vertical orientation.

7. The arrangement according to any one of the preceding claims wherein the dolly comprises tilt means for tilting the blade holding means about a horizontal axis, wherein a mounting portion of the wind turbine blade is moved closer or further away from the wind turbine tower.

8. The arrangement according to any one of the preceding claims, wherein the longitudinal structure comprises a crane tower.

9. The arrangement according to the previous claim, wherein a crane is supported on top of the crane tower.

10. A method of elevating at least one wind turbine blade, the method comprising:
- providing the arrangement according to any one of claims 5 to 10;
- elevating a wind turbine blade along a wind turbine tower by use of the dolly; and
- rotating the blade from the horizontal position to a vertical position during elevation of the wind turbine blade.

11. A method of elevating a nacelle for mounting to a wind turbine tower, the method comprising:
- providing the arrangement according to any one of the preceding claims;
- elevating the nacelle by use of crane wires suspended from the crane; and
- supporting the nacelle close to the wind turbine tower by means of support wires fastened to the dolly.

12. A method of elevating a wind turbine tower section for mounting to a partially constructed wind turbine tower, the method comprising:
- providing the arrangement according to any one of the preceding claims;
- elevating the wind turbine tower section by use of crane wires suspended from the crane; and
- supporting the wind turbine tower section close to the wind turbine tower by means of support wires fastened to the dolly.

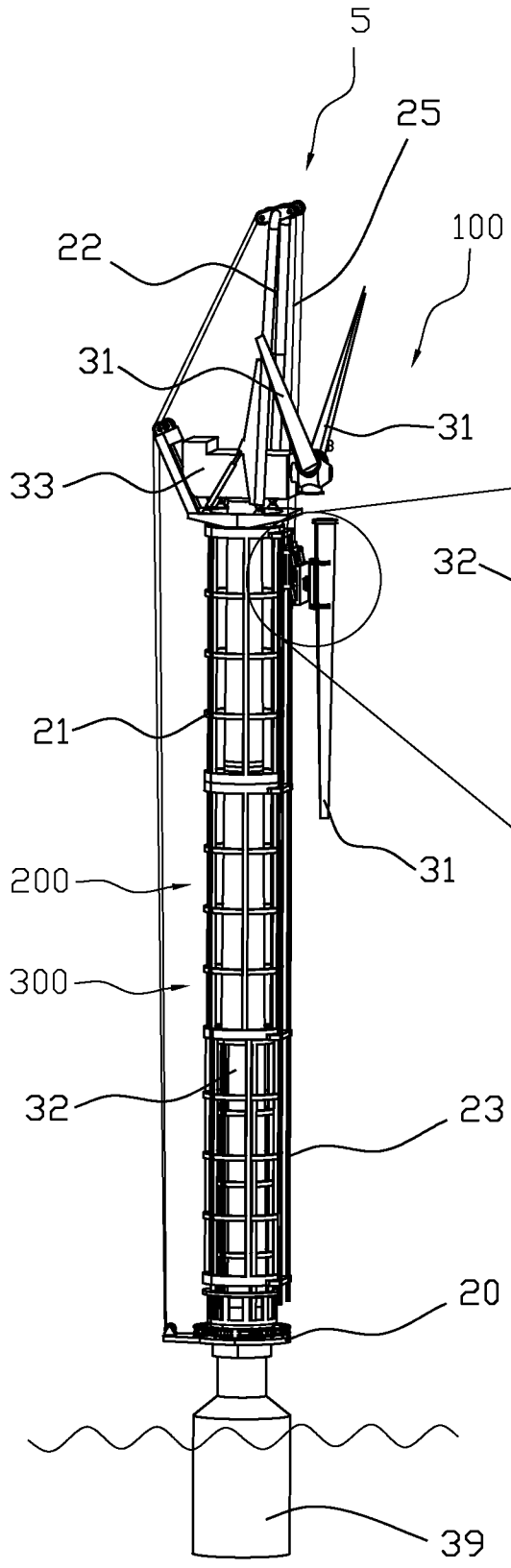

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Fig. 1A

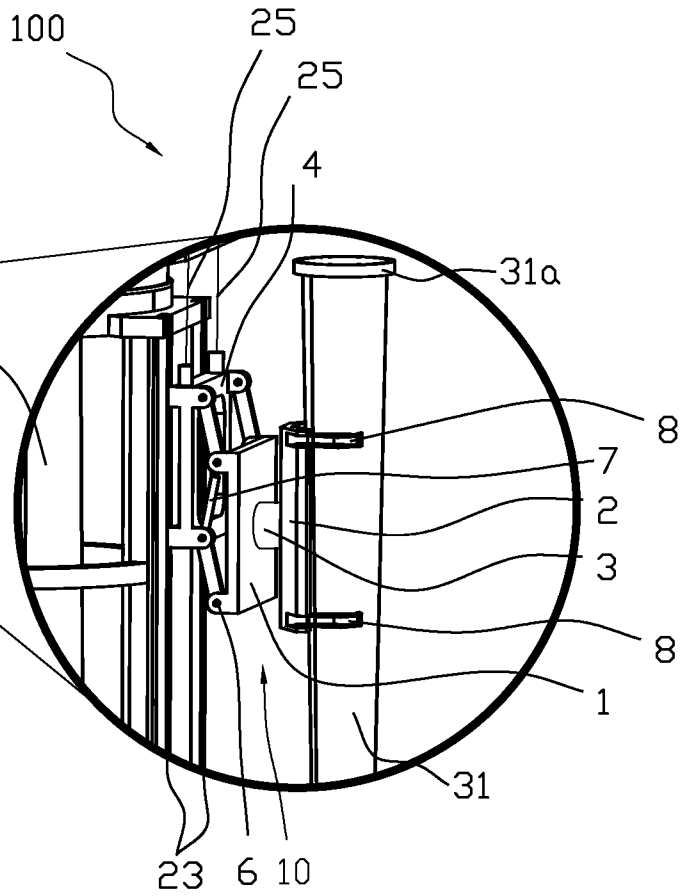
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Fig. 1B

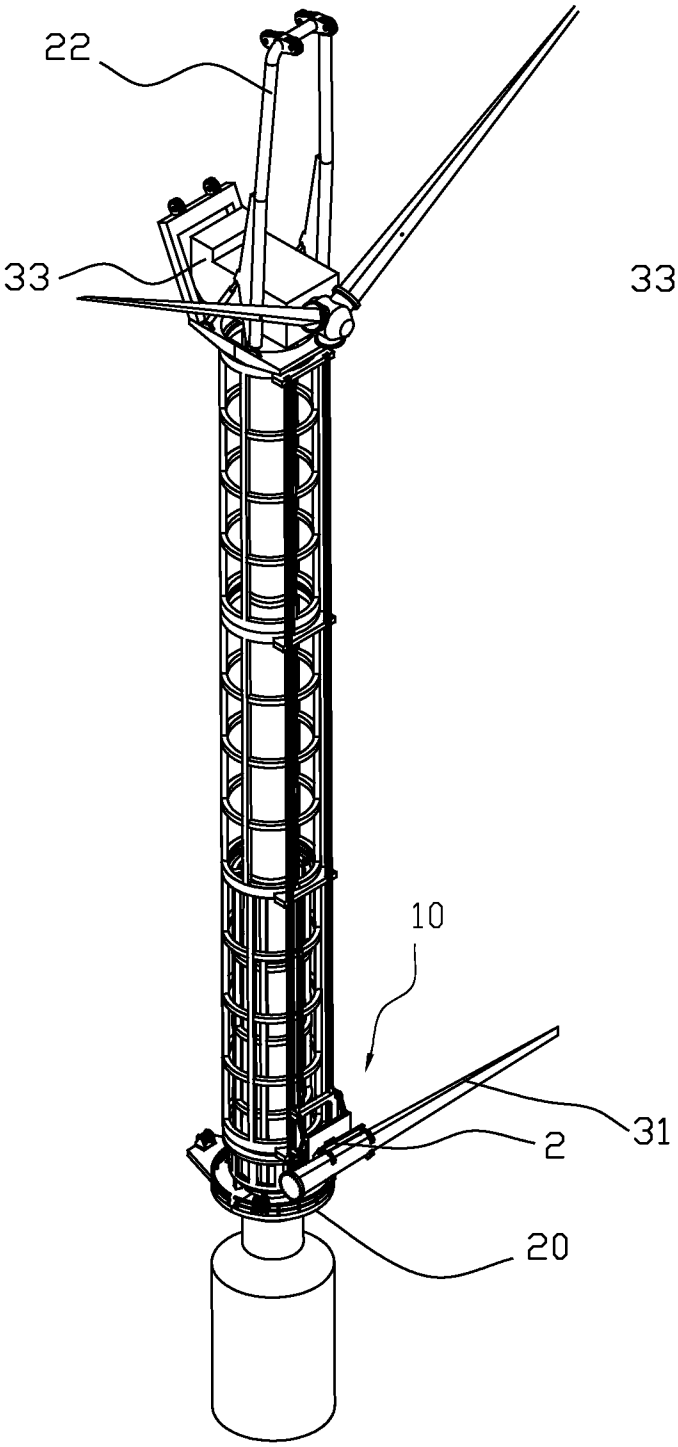

Fig. 2

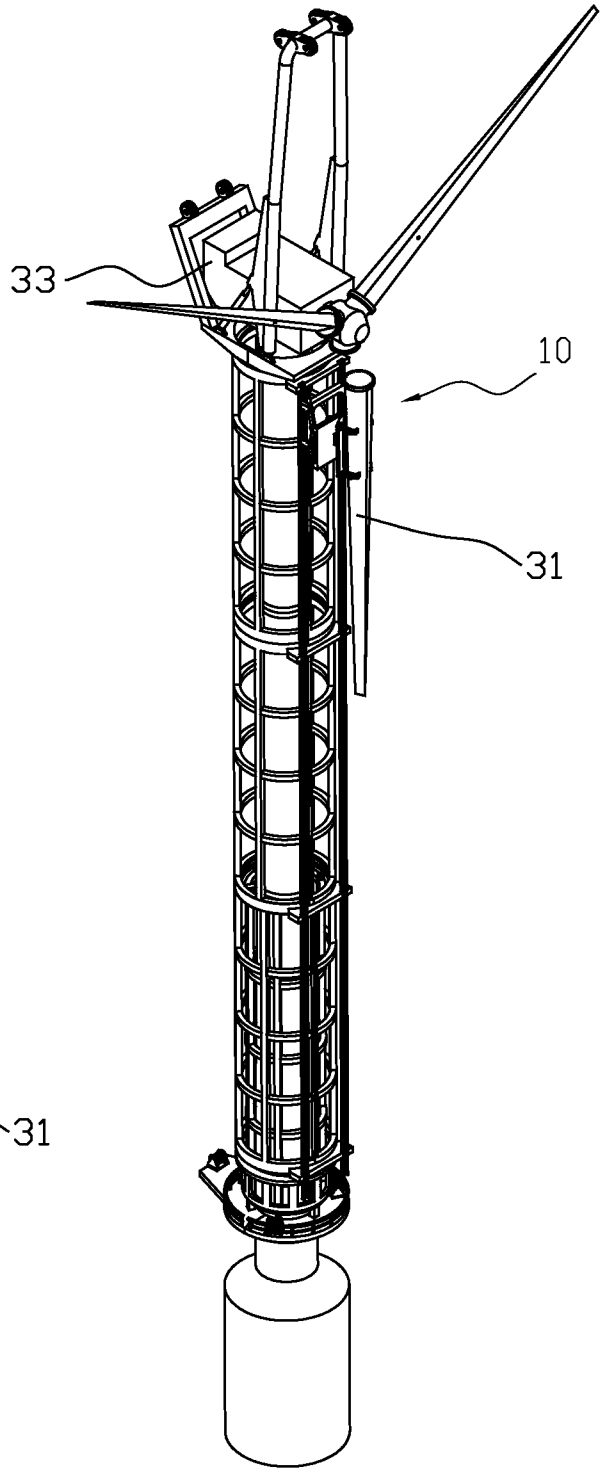

Fig. 3

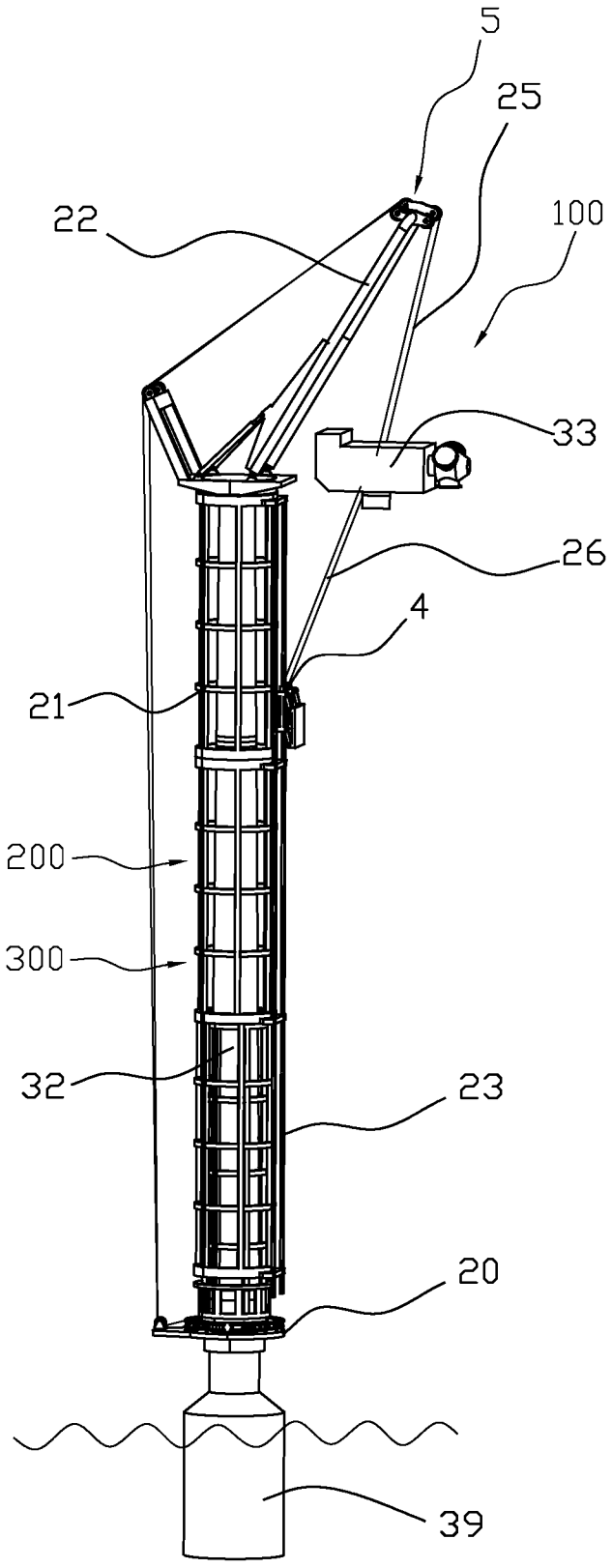

Fig. 4