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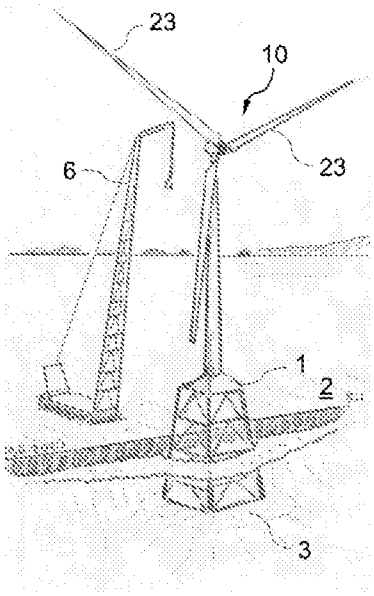
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(54) Title **CONSTRUCTION OF OFFSHORE WIND POWER PLANTS**

(57) Abstract

A method of constructing a wind power plant (10), the method comprising: providing a mast support structure (1); positioning the mast support structure (1) on an underwater base (3) adjacent a shoreside (2); with the mast support structure (1) positioned on the base (3), mounting a wind turbine generator (4) onto the mast support structure (1) to form a wind power plant (10); picking up the wind power plant (10) with a barge or vessel (5); transporting the wind power plant (10) from the base (3) to an installation site (11); and landing and fixing the mast support structure (1) to a sea floor (12) at the installation site (11).



CONSTRUCTION OF OFFSHORE WIND POWER PLANTS

The present invention relates to a method for construction of wind power plants, and particularly to a method for constructing offshore, bottom-fixed wind power plants.

BACKGROUND

Offshore wind power is growing in importance worldwide, with the recent years having seen a number of large development projects being commissioned, among other places in the North Sea. At present, such development projects mainly utilize bottom-fixed wind turbine generators, i.e. wind turbine generators which are mounted on a bottom-fixed structure such as a piled or gravity-base foundation to form a power plant. While floating wind turbine generators are being investigated by various groups worldwide, bottom-fixed technology is currently the most competitive at shallower water depths. Bottom-fixed wind turbine generators are currently feasible at water depths of up to about 60 m, and with future advances in technology, it is likely that bottom-fixed systems will be suitable for even larger water depths.

Publications which may be useful to understand the field of technology include: WO11102738, WO03066427, WO11028102, EP2251254, EP3170730, GB2580103, EP2505484, GB2479232, US2009217852, EP2307269, US2004262926, WO2006080850, WO2006076920.

With a projected continued increase in the investments into wind power in the future, there is a need for further improved technology in this area. The present disclosure has the objective to provide such improvements, or at least alternatives, to the current state of the art.

SUMMARY

In an embodiment, there is provided a method of constructing a wind power plant, the method comprising: providing a mast support structure; positioning the mast support structure on an underwater base adjacent a shoreside; with the mast support structure positioned on the base, mounting a wind turbine generator onto the mast support structure to form a wind power plant; picking up the wind power

plant with a barge or vessel; transporting the wind power plant from the base to an installation site; and landing and fixing the mast support structure to a sea floor at the installation site.

The detailed description, figures and claims outline further inventive aspects and embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other characteristics will become clear from the following description of illustrative embodiments, given as non-restrictive examples, with reference to the attached drawings, in which

Figs 1-6 show various steps of a method of constructing and installing a wind power plant according to an embodiment.

Figs 7-12 illustrate an example of the construction of a wind power plant at and near a shoreside.

Figs 13-16 illustrate an example of transporting and landing a wind power plant using a barge.

Figs 17 and 18 illustrate steps of a method using a vessel for transport and landing a wind power plant.

Fig. 19 illustrates an example of a vessel suitable for carrying out method steps relating to transporting and landing a wind power plant.

Figs 20 and 21 illustrate an example of a vessel suitable for carrying out method steps relating to transporting and landing a wind power plant.

DETAILED DESCRIPTION

The following description may use terms such as “horizontal”, “vertical”, “lateral”, “back and forth”, “up and down”, ”upper”, “lower”, “inner”, “outer”, “forward”, “rear”, etc. These terms generally refer to the views and orientations as shown in the

drawings and that are associated with a normal use of the invention. The terms are used for the reader's convenience only and shall not be limiting.

Figures 1-6 illustrate a method of constructing a wind power plant 10 according to an embodiment. The method comprises providing a mast support structure 1 and positioning the mast support structure 1 on an underwater base 3 adjacent a shoreside 2. The mast support structure 1 may, for example, be a jacket or truss structure, which can provide advantageous handling capability, structural strength and constructability.

The underwater base 3 may, for example, be a concrete underwater foundation, a pre-piled seabed foundation or similar, prepared for supporting the mast support structure 1 thereon. The underwater base 3 may, for example, be arranged at a water depth of more than 20m, more than 30m or more than 40m. The underwater base 3 is advantageously arranged so that a shoreside, land-based crane 6 can reach a position above the base 3. A long-reach crane 6 may be employed for this purpose, as required. (Optionally, a floating or jack-up vessel crane may be used, as described below.) Preferably, the shoreside 2 comprises a quay so that a horizontal distance between the land-based crane 6 or other shoreside equipment and the base 3 can be minimised.

Providing the mast support structure 1 may comprises building the mast support structure 1 at least partly on the shoreside 2. Advantageously, the mast support structure 1 can be built fully, i.e. in its entirety, on the shoreside 2 and subsequently positioned on the underwater base 3 by moving the mast support structure 1 from the shoreside 2 to the base 3. This is illustrated in Figs 1 and 2, where a complete or close-to-complete mast support structure 1 is moved from the shoreside 2 and positioned on the base 3. Moving and positioning the mast support structure 1 onto the underwater base 3 can be carried out by use of the land-based crane 6, another crane, and/or other shoreside equipment, as appropriate.

Alternatively, the mast support structure 1 can be built partially on the shoreside 2 and partially on the base 3. For example, a first section of the mast support structure 1 can be built on the shoreside 2 and positioned on the base 3, and thereafter a second section of the mast support structure 1 can be built or connected onto the first section while the mast support structure 1 is on the base 3.

Building the mast support structure 1 at the shoreside 2 may comprise building the mast support structure 1 by use of the land-based crane 6 and other shoreside equipment, as appropriate.

Alternatively, the mast support structure 1 can be provided from a remote location and positioned on the underwater base 3. For example, if the mast support structure 1 is built elsewhere, for example at a remote yard, it can be provided to the shoreside 2 or the base 3 from the yard, for example by ship. In such a case, the mast support structure 1 can be provided directly onto the base 3 without being placed at the shoreside 2 at all, or it can be provided to the shoreside 2 and thereafter be positioned on the base 3, for example by the crane 6. The latter case may be most suitable if, for example, a number of mast support structures are provided in one shipment to the shoreside 2 and temporarily stored.

With the mast support structure 1 positioned on the base 3, the method further comprises mounting a wind turbine generator 4 onto the mast support structure 1 to form a wind power plant 10, as illustrated in Fig. 3. As used herein, the term wind power plant 10 thus comprises both the mast support structure 1 and a wind turbine generator 4, the latter comprising a tower 21, a nacelle section 22 and a plurality of blades 23 (see Fig. 6). Forming the wind power plant 10 may comprise mounting the wind turbine generator 4 onto the mast support structure 1 using the land-based crane 6. This may include mounting at least one tower section 21, at least one nacelle section 22 and at least one turbine blade 23 onto the mast support structure 1. These components may be mounted individually and sequentially, or with more than one of these mounted together in one operation. At least one of the tower section 21, nacelle section 22 and turbine blade 23, or optionally all these, can be mounted by use of a land-based crane 6.

Mounting the wind turbine generator 4 or one or more of its components on the mast support structure 1 while the mast support structure 1 is positioned on the base 3 and using of the land-based crane 6 may simplify the construction and mounting operations. For example, lifting of heavy components from a floating barge or vessel is avoided, and/or it is more practicable to carry out the mounting operations in several steps in an efficient manner. By carrying out these operations at or near the shoreside 2, weather impacts are also reduced.

Further, by having the mast support structure 1 arranged on the underwater base 3 while mounting the wind turbine generator 4 or one or more of its components reduces the required lifting height for installation and mounting operations.

Optionally, or additionally, some or several of the operations described above as carried out by the land-based crane 6 can be carried out by a barge or vessel-based crane 24 arranged on a barge or vessel 25, illustrated in Fig. 8. The barge or vessel 25 may be floating or for example a jack-up vessel which can be fixed to the sea floor for these operations. Even with a floating barge or vessel for carrying out these operations, the advantages mentioned above of avoiding heavy lifts and installation operations offshore can be realized, in that the conditions at or near the shoreside 2 will usually be more advantageous and weather impacts lesser. Using a crane barge or vessel 25 for this purpose may, for example, be relevant where suitable shoreside equipment cannot be provided or shoreside structural conditions don't allow for crane operations. In such a case, a barge or vessel-based crane 24 may, for example, pick up or otherwise be provided with components to be installed from the shoreside 2.

When the wind power plant 10 is substantially complete, illustrated in Fig. 3, the method comprises picking up the wind power plant 10 with a barge or vessel 5 and transporting the wind power plant 10 from the shoreside 2 to an installation site 11. This is illustrated in Figs 4-6. At the installation site 11, the mast support structure 1 is landed and fixed to the sea floor 12, thereby installing the wind power plant 10 and making it ready for electrical hook-up and operation.

Transporting the wind power plant 10 from the base 3 to the installation site 11 is advantageously carried out with at least a part of the mast support structure 1 submerged. This can be the case during the entire transport operation, thus, if water depth conditions along the transport route allow it, obviating the need for lifting the wind power plant 10 to a higher level than that required to lift it off the base 3.

Advantageously, at least a part of the transport operation may including transporting the wind power plant 10 with the mast support structure 1 submerged to a water depth which is lower than that at the base 3. This may allow the centre of gravity to be further lowered for the transport operation. This step may include lowering the wind power plant 10 a pre-defined amount from the barge or vessel 5 after the barge or vessel 5 has picked up the wind power plant 10 from the base 3 but before it is

lowered onto the sea floor 12, such that a part of the transport operation is done with the mast support structure 1 being submerged to a larger depth than when positioned on the base 3. Hence, in this example, the barge or vessel 5 may lift the wind power plant 10 off the base 3, commence the transport operation, and, when the barge or vessel 5 has moved away from the base 3 and water depth conditions allow, further lower the wind power plant 10 to lower the centre of gravity for example by a few or several meters.

The submerged part of the mast support structure 1, during transport and/or when positioned on the base 3, can make up at least half of the height of the mast support structure 1, at least 60% of the height of the mast support structure 1, or at least 75% of the height of the mast support structure 1.

The step of picking up the wind power plant 10 with the barge or vessel 5 may comprise lifting the wind power plant 10 off the base 3 with a handling assembly 30 arranged on the barge or vessel 5. An example of such a handling assembly is illustrated in Fig. 19, described in further detail below.

Alternatively, or additionally, the step of picking up the wind power plant 10 with a barge or vessel 5 may comprise fixing the wind power plant 10 in relation to the barge or vessel 5 and adjusting the draught of the barge or vessel 5 to lift the wind power plant 10 off the base 3. The barge or vessel 5 may, for example, be a barge specifically designed for this purpose, for example as described below.

Figs 7-12 illustrate another example of the construction of a wind power plant 10. Illustrated in Fig. 7, a mast support structure 1 is constructed at a shoreside 2 by means of a crane 6. In this example, a second crane 24 arranged on a barge or vessel 25 as described above is used to assist the construction of the mast support structure 1. In this case, the barge or vessel 25 is a floating crane barge. Other equipment on the shoreside 2 and/or on the barge or vessel 25 may be employed, as required.

In Figs 8 and 9, the complete or substantially complete mast support structure 1 is moved from the shoreside 2 onto an underwater base 3 adjacent the shoreside 2. In this example, moving the mast support structure 1 is carried out by both cranes 6,24, however using one of these cranes may also be possible. Additionally or alternatively, other equipment, such as other cranes or other lifting or handling equipment, could be employed for this purpose.

Illustrated in Figs 10-12, with the mast support structure 1 positioned on the base 3, a mast 21, a nacelle 22, and a plurality of blades 23 are mounted on the mast support structure 1 to form the wind power plant 10 (see Fig. 12).

Figs 13-16 illustrate a pick up, transport and installation sequence according to one example, using a barge 5. A tug 35 can be used for moving the barge 5 with the wind power plant 10 from the base 3 and to an installation site offshore, as shown in Figs 13 and 14. Fig. 15 illustrates the barge 5 carrying the mast support structure 1 and thereby the wind power plant 10 for the transport operation.

Fig. 16 illustrates the barge 5 having arrived at and positioned above the installation site 11. Landing the mast support structure 1 to the sea floor 12 at the installation site 11 may be done by lowering the wind power plant 10 from the barge 5, e.g. by winches or a handling assembly 30 as described in relation to Fig. 19 below, and/or by de-ballasting the barge 5 to lower the barge 5 and the wind power plant 10 together towards the sea bed 12.

Illustrated in Fig. 16, the installation site 11 may have a prepared foundation or foundations 31, such as a piled foundation arranged to engage a lower part of the mast support structure 1 and fix it to the sea floor 12. The foundations 31 may, for example, comprise receptacles arranged to receive legs of the mast support structure 1.

Figs 17 and 18 illustrate another embodiment, in which a vessel 5 is arranged to carry two wind power plants 10 for installation. The method may otherwise be similar to that described elsewhere in this disclosure.

Fig. 19 illustrates another example where a special purpose vessel 5 is employed to transport the wind power plant 10 from the base 3 to the installation site 11. The special purpose vessel 5 may, for example, be a purpose-built vessel for this operation or a converted vessel such as a semi-submersible rig or construction vessel. Fig. 19 also illustrates a handling assembly 30 for engaging and carrying the wind power plant 10. Such handling assembly 30 may be arranged on the other examples for the vessel or barge 5 described herein. The handling assembly 30 may be arranged to fix, grip or otherwise hold the mast support structure 1 and/or the tower 21 for the purpose of lifting the wind power plant 10 off the base 3, holding it during transport, and for lowering and installing it at the installation site 11.

Figs 20 and 21 illustrate another example for a vessel 5 suitable to carry out the methods described herein. The vessel has a receptacle 34 arranged to receive the mast support structure 10 therein. Suitable equipment can be arranged on the vessel 5 to engage and hold the wind power plant 10 in the receptacle 34. Such a receptacle 34 can also be used with a barge 5 as shown in Figs 13-16. This can provide advantages of improved stability and handling capability for the vessel or barge 5 when picking up, transporting and/or landing the wind power plant 10. For example, with such an arrangement, when picking up the wind power plant 10 from the base 3, the vessel or barge 5 can be positioned such that the vessel or barge 5 supports the mast support structure 1 on at least at two horizontally opposing sides for the purpose of lifting it off the base 3 and fixing it to the vessel or barge 5 for transport.

Advantageously, with methods according to the examples described herein, it may be possible to carry out various operations relating to the construction and installation of bottom-fixed, offshore wind power plants in a safer, more efficient and/or simpler manner. For example, lifting operations offshore and at the installation site 11, such as lifting of heavy wind turbine components, can be reduced or eliminated.

By constructing the wind power plant 10 on an underwater base 3, handling the wind power plant 10 for transport offshore may be simplified. A challenge in such operations can be the high weight of the wind turbine parts such as the nacelle, and the high centre of gravity, making transport of complete wind power plants 10 challenging. By providing the wind power plant 10 on the base 3, it can be picked up by a barge or vessel 5 with the centre of gravity of the wind power plant 10 lowered compared to for example handling it completely assembled from the shoreside 2.

As will be appreciated when reading the disclosure herein, advantages of the methods described may be realised individually and by the use of only some of the method steps described above. The invention is not limited by the embodiments described above; reference should be had to the appended claims.

CLAIMS

1. A method of constructing a wind power plant (10), the method comprising:
providing a mast support structure (1);
positioning the mast support structure (1) on an underwater base (3) adjacent a shoreside (2);
with the mast support structure (1) positioned on the base (3), mounting a wind turbine generator (4) onto the mast support structure (1) to form a wind power plant (10);
picking up the wind power plant (10) with a barge or vessel (5);
transporting the wind power plant (10) from the base (3) to an installation site (11); and
landing and fixing the mast support structure (1) to a sea floor (12) at the installation site (11).

2. A method according to any preceding claim, wherein the step of providing a mast support structure (1) comprises building the mast support structure (1) at least partly on the shoreside (2).

3. A method according to any preceding claim, wherein the step of providing a mast support structure (1) comprises building the mast support structure (1) fully on the shoreside (2) and subsequently positioning the mast support structure (1) on the underwater base (3) by moving the mast support structure (1) from the shoreside (2) to the base (3).

4. A method according to any preceding claim, wherein the step of providing a mast support structure (1) comprises building the mast support structure (1) partially on the shoreside (2) and partially on the base (3).

5. A method according to any preceding claim, wherein the step of providing a mast support structure (1) comprises providing the mast support structure (1) from a remote location and positioning the mast support structure (1) on an underwater base (3).

6. A method according to any preceding claim, wherein the step of transporting the wind power plant (10) from the shoreside (2) to an installation site (11) is carried out with at least a part of the mast support structure (1) submerged.

7. A method according to the preceding claim, wherein the submerged part makes up at least half of the height of the mast support structure (1), at least 60% of the height of the mast support structure (1), or at least 75% of the height of the mast support structure (1).

8. A method according to any preceding claim, wherein the step of transporting the wind power plant (10) comprises transporting the wind power plant (10) with the mast support structure (1) submerged to a water depth which is lower than its depth when positioned on the base (3).

9. A method according to any preceding claim, wherein the step of picking up the wind power plant (10) with a barge or vessel (5) comprises lifting the wind power plant (10) off the base (3) with the barge or vessel (5).

10. A method according to any preceding claim, wherein the step of picking up the wind power plant (10) with a barge or vessel (5) comprises fixing the wind power plant (10) in relation to the barge or vessel (5) and adjusting the draught of the barge or vessel (5) to lift the wind power plant (10) off the base (3).

11. A method according to any preceding claim, wherein the step of building a mast support structure (1) at the shoreside (2) comprises building the mast support structure (1) by use of a land-based crane (6).

12. A method according to any preceding claim, wherein the step of positioning the mast support structure (1) on the underwater base (3) is carried out by use of a land-based crane (6).

13. A method according to any preceding claim, wherein the step of mounting a wind turbine generator (4) onto the mast support structure (1) to form a wind power plant (10) comprises mounting the wind turbine generator (4) onto the mast support structure (1) using a land-based crane (6).

14. A method according to any preceding claim, wherein the step of mounting a wind turbine generator (4) onto the mast support structure (1) to form a wind power plant (10) comprises mounting at least one tower section (21), at least one nacelle section (22) and at least one turbine blade (23) onto the mast support structure (1).

15. A method according to any preceding claim, wherein at least one of the steps of mounting at least one tower section (21), at least one nacelle section (22) and at least one turbine blade (23) is carried out by use of a land-based crane (6).

16. A method according to any preceding claim, wherein all the steps of mounting at least one tower section (21), at least one nacelle section (22) and at least one turbine blade (23) is carried out by use of a land-based crane (6).

17. A method according to any preceding claim, wherein the step of landing and fixing the mast support structure (1) on and to the sea floor (12) at the installation site (11) comprises landing and fixing the mast support structure (1) on and to a prepared foundation (31).

18. A method according to any preceding claim, wherein the prepared foundation (31) comprises a piled foundation arranged to engage a lower part of the mast support structure (1).

19. A method according to any preceding claim, wherein the step of landing and fixing the mast support structure (1) on and to the sea floor (12) at the installation site (11) comprises lowering the wind power plant (10) from the barge or vessel (5).

20. A method according to any preceding claim, wherein the step of landing and fixing the mast support structure (1) on and to the sea floor (12) at the installation site (11) comprises adjusting the draught of the barge or vessel

(5) to lower the wind power plant (10) together with the barge or vessel (5) to land the mast support structure (1) on the sea floor (12).

21. A method according to any preceding claim, wherein the submerged part of the mast support structure (1), when positioned on the base (3), makes up at least half of the height of the mast support structure (1), at least 60% of the height of the mast support structure (1), or at least 75% of the height of the mast support structure (1).

22. A method according to any preceding claim, wherein the underwater base (3) is arranged at a water depth of more than 20m, more than 30m or more than 40m.

23. A method according to any preceding claim, wherein the step of picking up the wind power plant (10) with a barge or vessel (5) comprises positioning the mast support structure (1) in a receptacle (34) on the barge or vessel (5).

24. A method according to the preceding claim, wherein the receptacle (34) is arranged to support the mast support structure (1) at least at two horizontally opposing sides.

25. A method according to any preceding claim, wherein the step of transporting the wind power plant (10) from the base (3) to the installation site (11) comprises supporting the mast support structure (1) in the receptacle (34) while transporting the wind power plant (10).

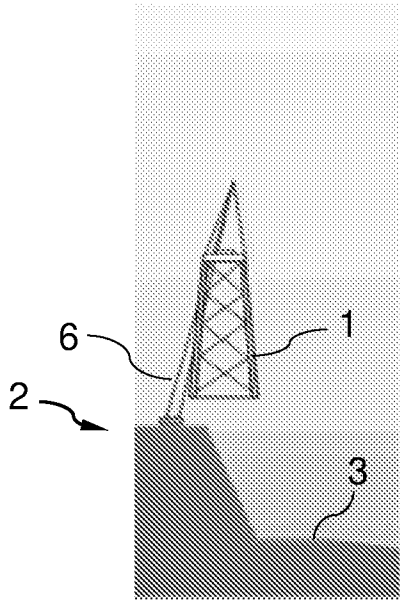


Fig. 1

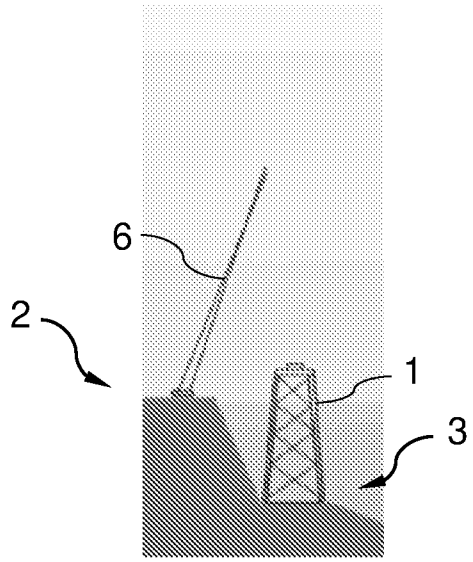


Fig. 2

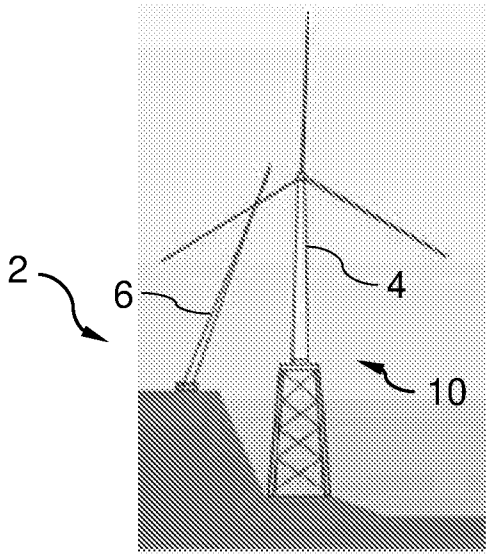


Fig. 3

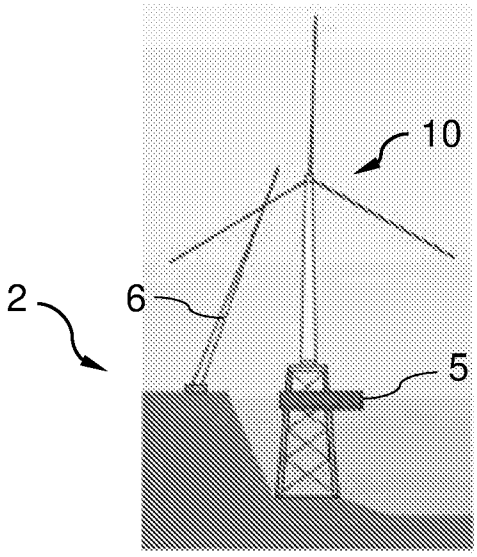


Fig. 4

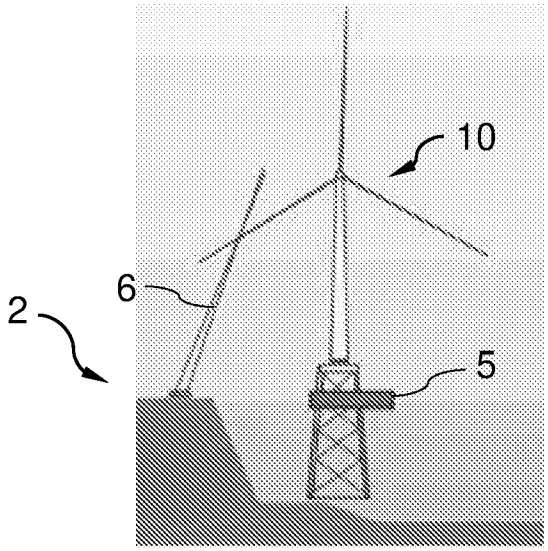


Fig. 5

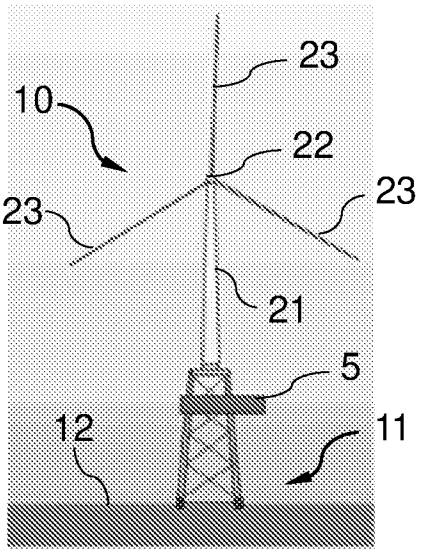


Fig. 6

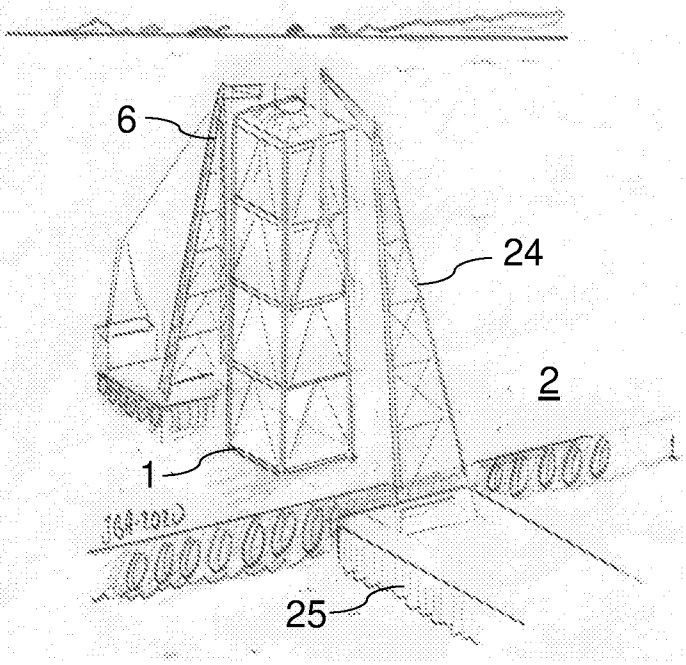


Fig. 7

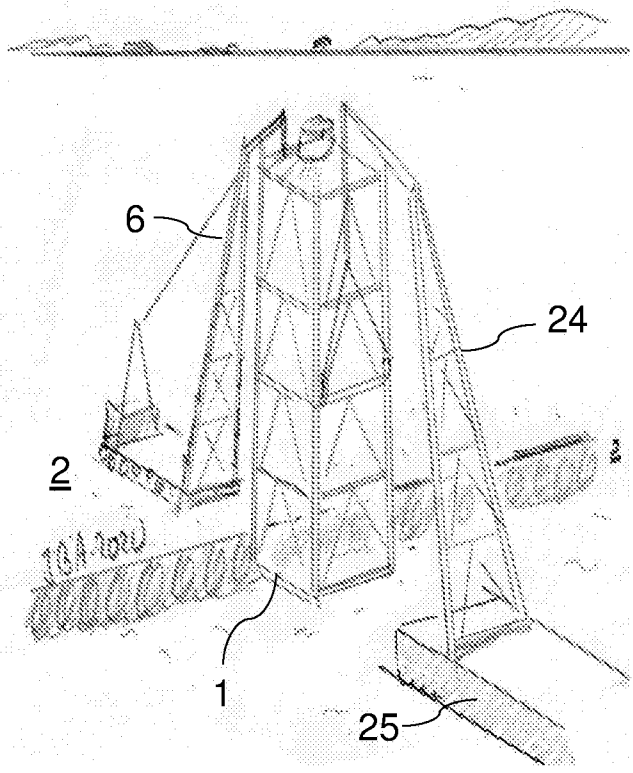


Fig. 8

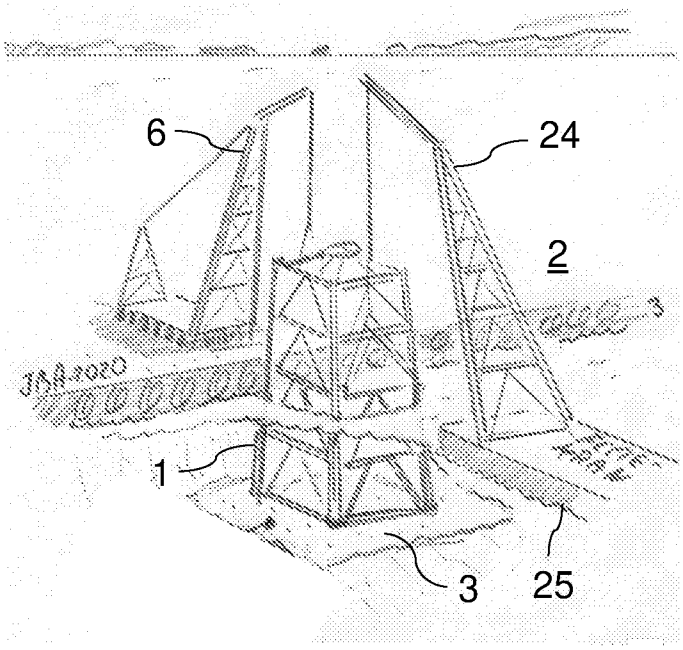


Fig. 9

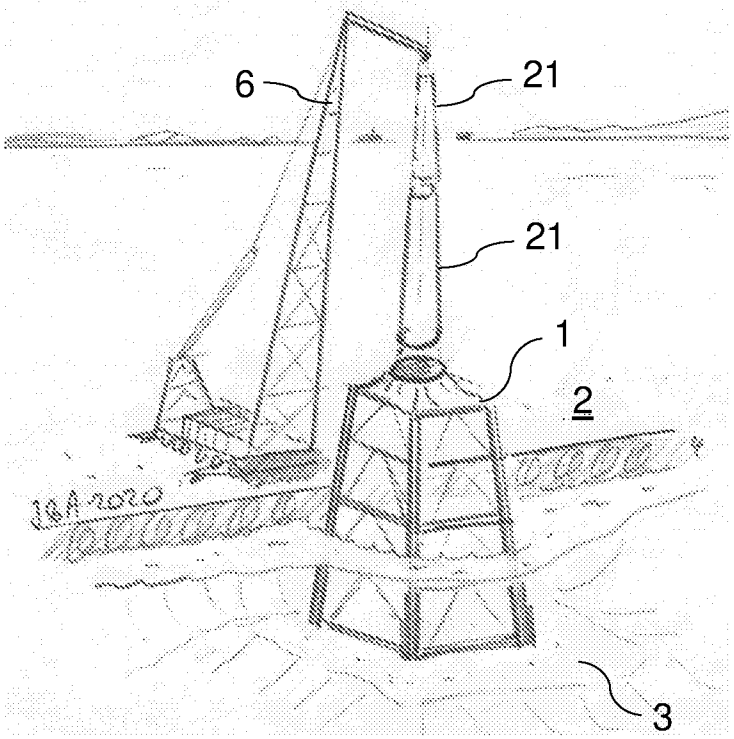


Fig. 10

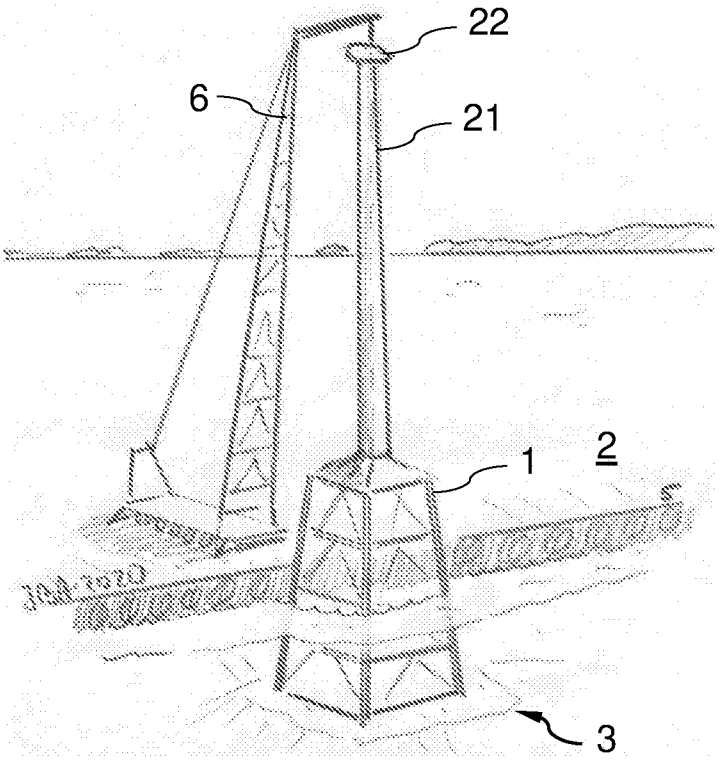


Fig. 11

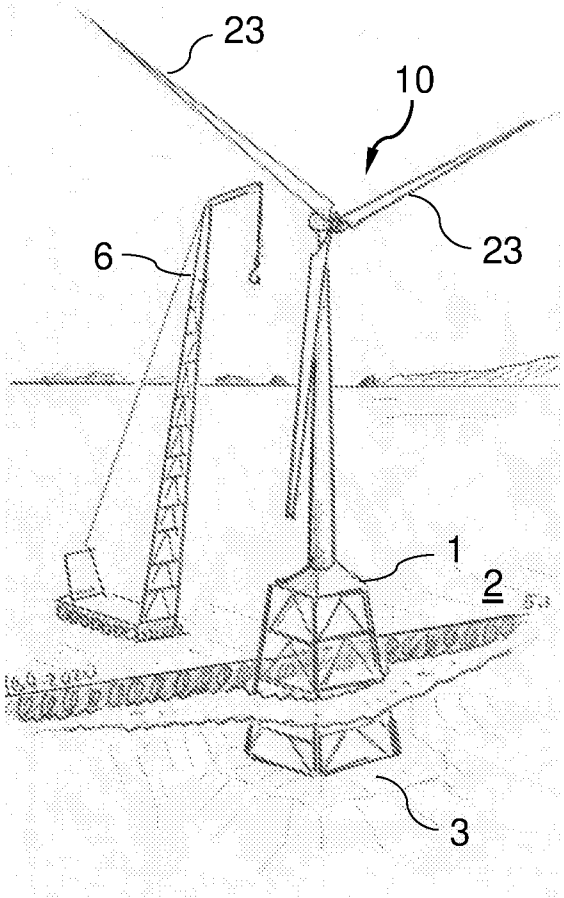


Fig. 12

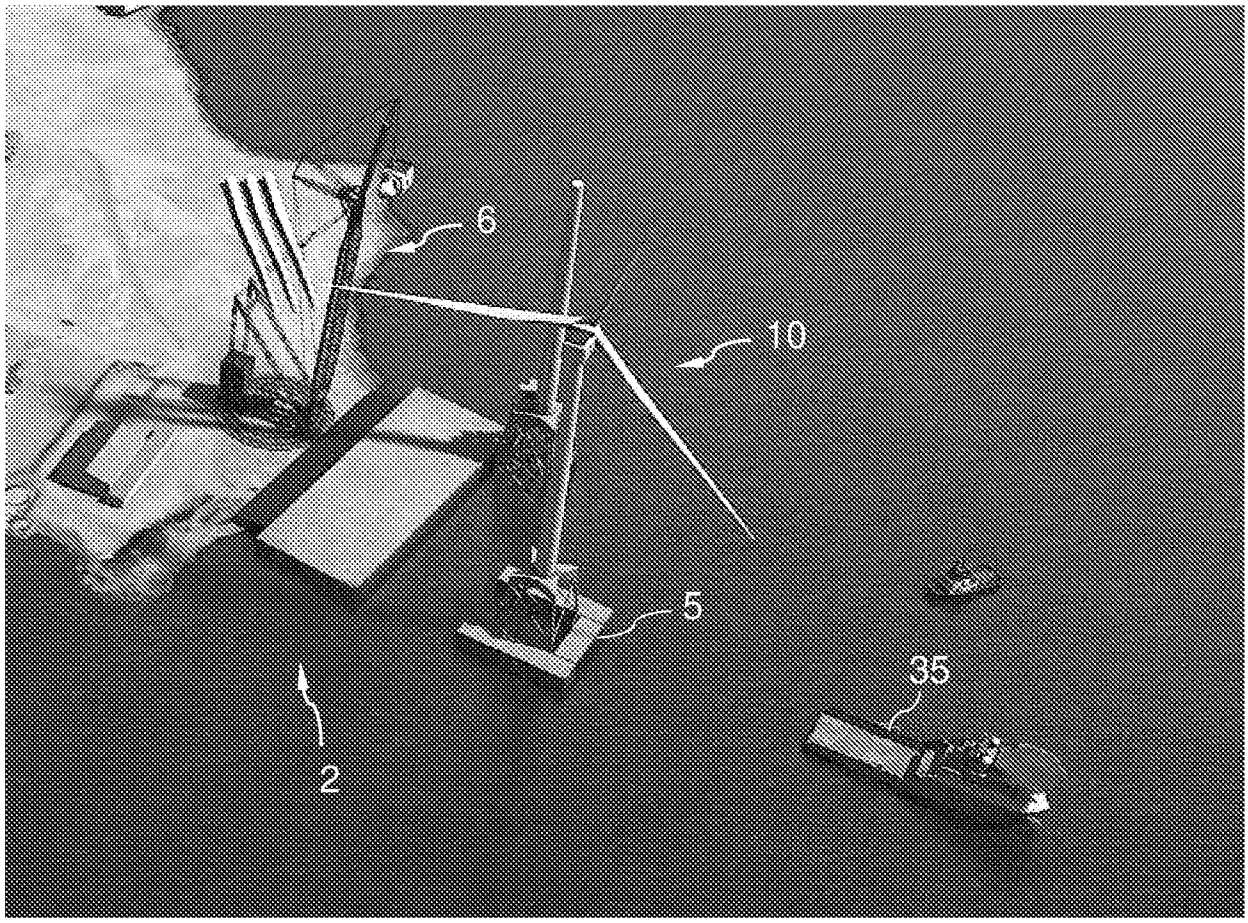


Fig. 13

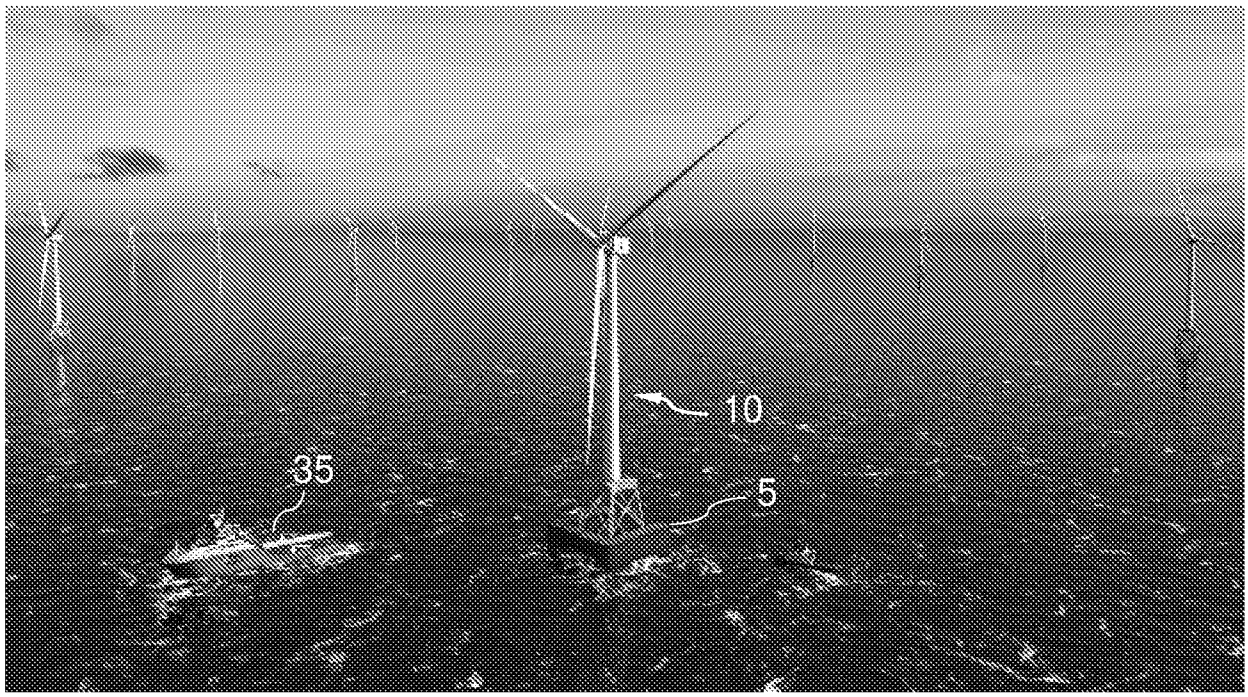


Fig. 14

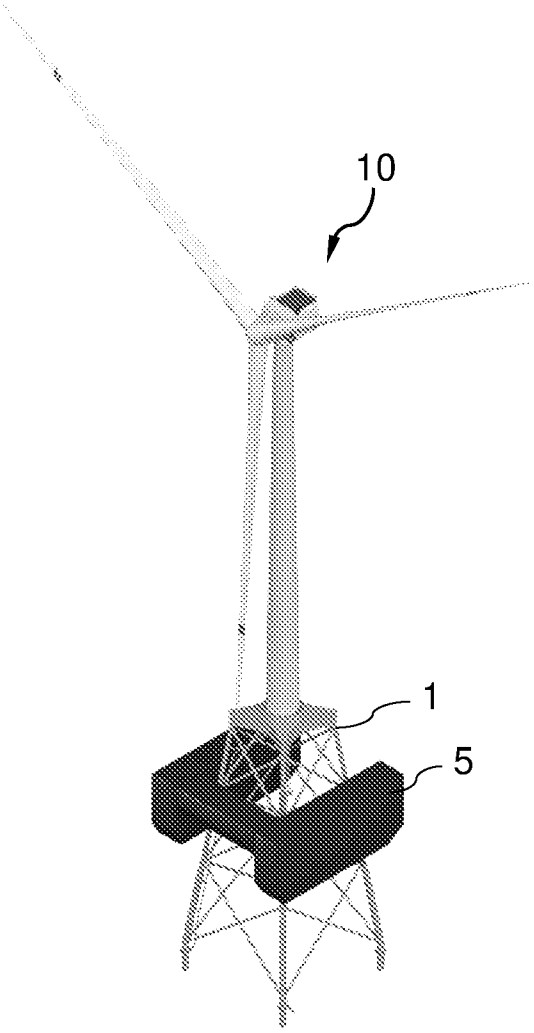


Fig. 15

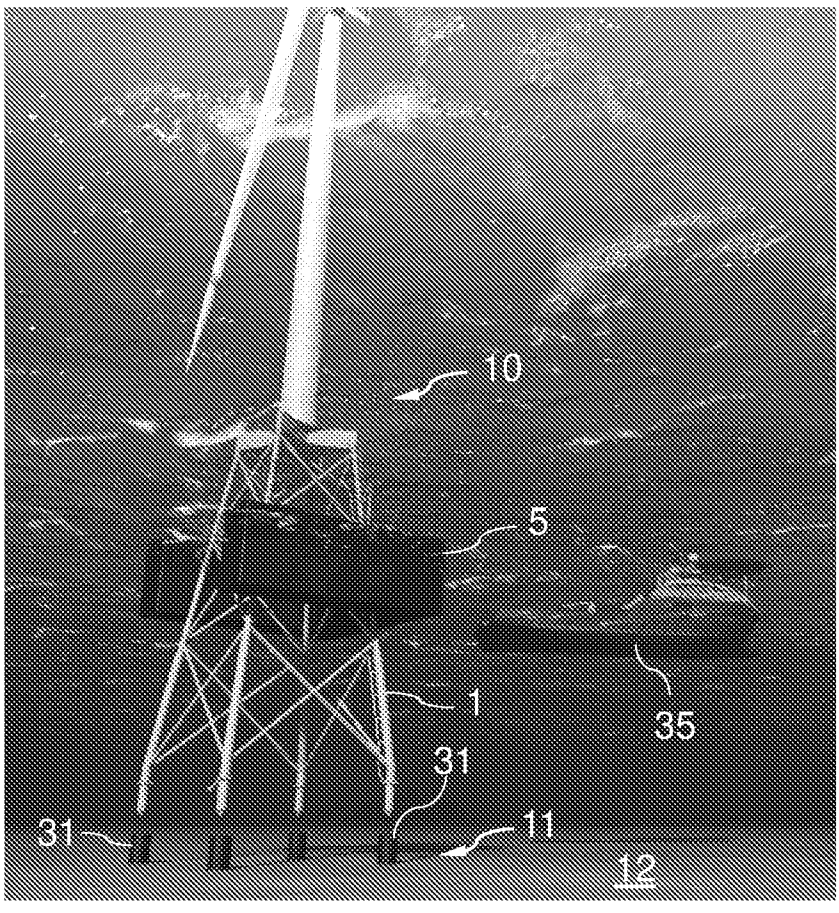


Fig. 16

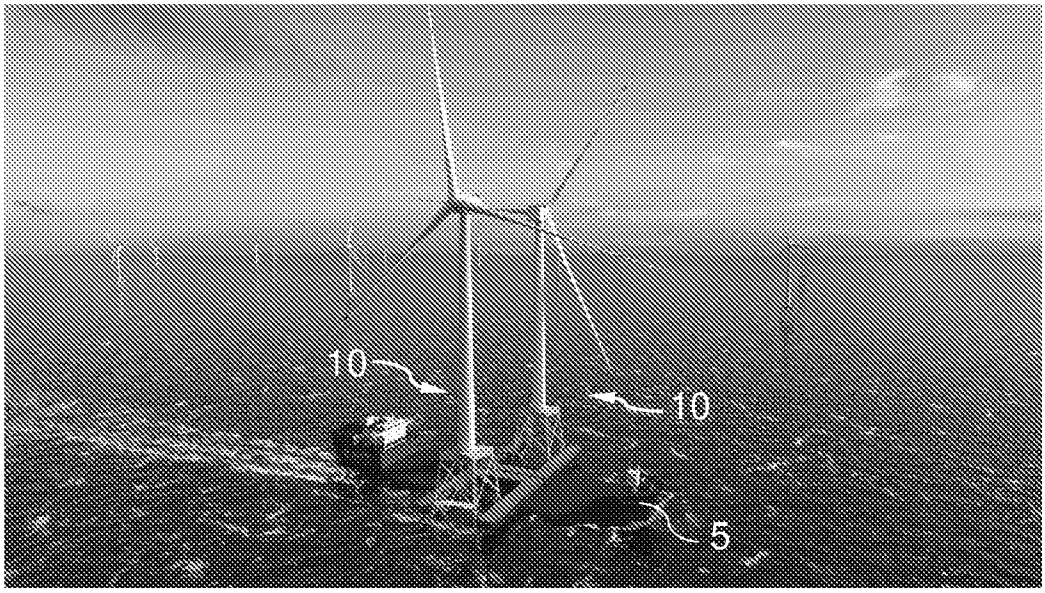


Fig. 17

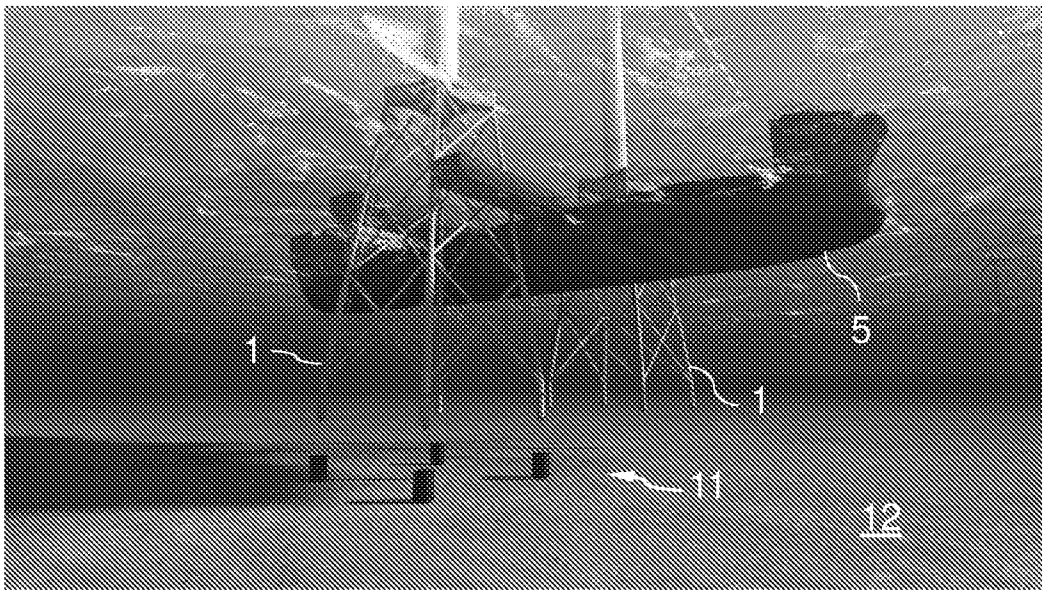


Fig. 18

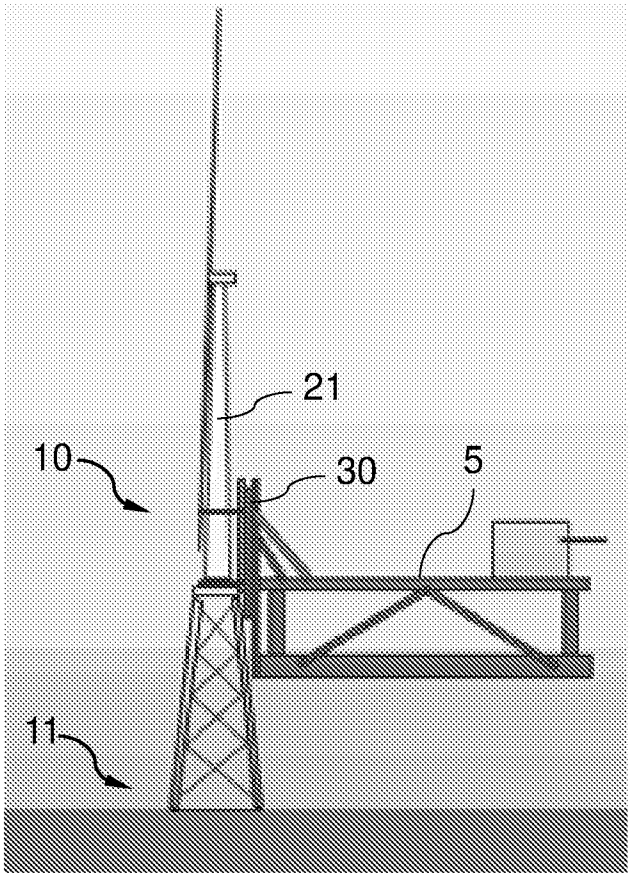


Fig. 19

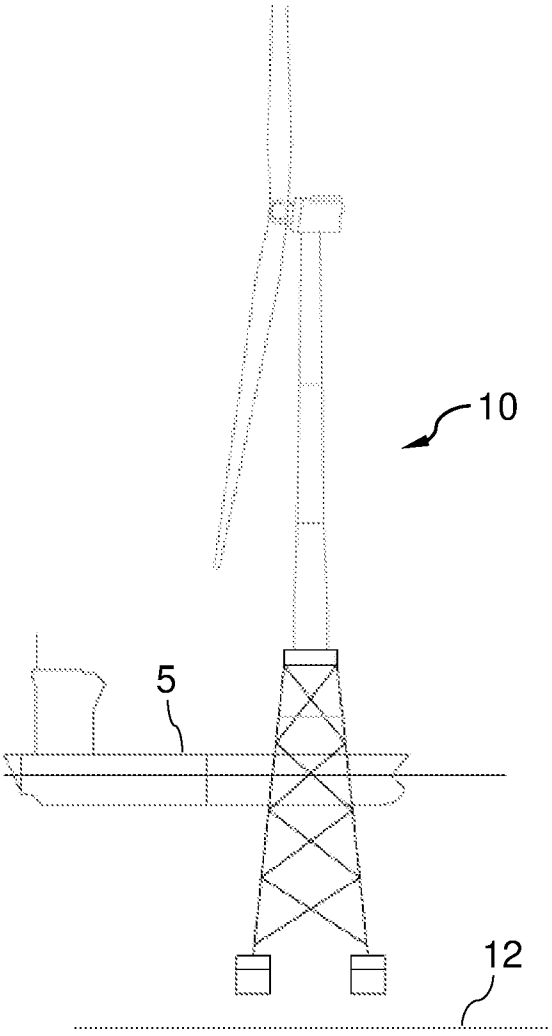


Fig. 20

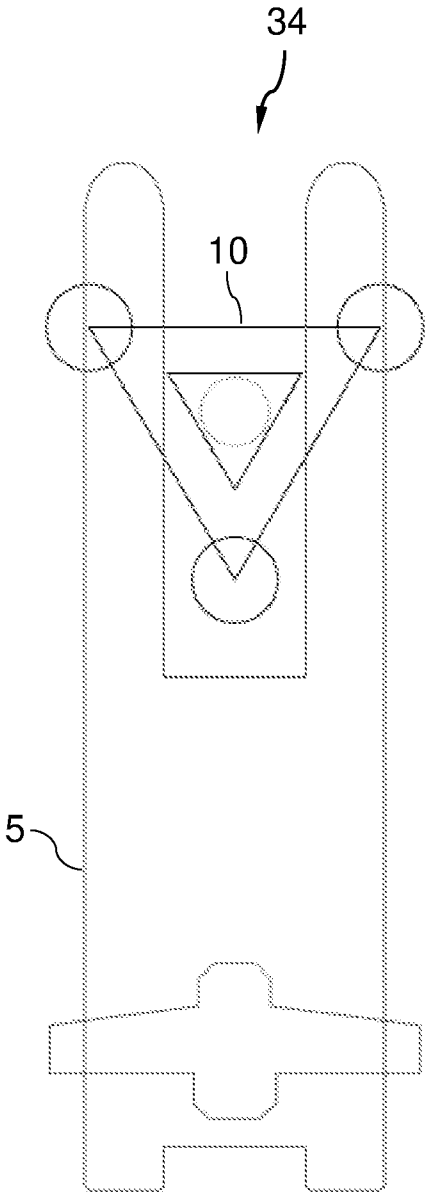


Fig. 21