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DESCRIPTION

FIELD OF THE INVENTION

[0001] The present invention relates to an anchoring arrangement for anchoring a floatable unit in water. The anchoring arrangement comprises a floatable wind power unit, and an anchoring element comprising an elongated fundament firmly attached in a bottom sediment so that a longitudinal axis of the fundament is oriented from the bottom sediment towards the surface of the water.

[0002] The present invention further relates to a method for anchoring a floatable unit in water by means of an anchoring arrangement and use of anchoring arrangement.

PRIOR ART

[0003] Prior art anchoring arrangements for anchoring a floatable unit in water comprising wires, chains, ropes to a fundament, such as an anchor, attached in the bottom sediment. The wires are either attached directly to the floatable unit or to a buoy. The buoy enables the floatable unit to pivot around the fundament or the buoy.

[0004] A problem with prior art anchoring arrangements is that the floatable unit, in particular when anchored in shallow water, may entangle in the wires connected to the fundament or the buoy. This may result in that the floatable unit is prevented from pivoting around the fundament or the buoy, which may prevent the use of the floatable unit. For example, when the floatable unit comprises a wind power unit, the production of electric energy may be reduced or terminated due to that floatable unit is prevented from pivoting around the fundament or the buoy. Furthermore, the entanglement of the wires may result in damage to the connection or attachment arrangement between the fundament/buoy and the floatable unit.

[0005] A further problem with prior art anchoring arrangements is relative movement of the cables to the buoy. In shallow waters the movements of a buoy, both vertically and horizontal offset, could be of the same magnitude as the water depth. This would require special arrangement to offload the cable from severe strain and stress.

[0006] A further problem with prior art anchoring arrangements is that the fundament, such as the anchor or anchors, is subjected to bending forces directed along the longitudinal axis of the fundament, wherein the fundament has to be designed to withstand such vertical forces. Alternative catenary anchoring system is used which require long wires to avoid vertical forces. For non floating wind power units arranged in water, fundaments are used to maintain its position. They are either lattices towers or monopoles. These fundaments are subjected to substantial bending forces, since the horizontal forces from wind and water are quite at a

distance from the bottom sediment.

[0007] SE532886 C2 discloses a floatable unit comprising a wind power unit. The floatable unit is anchored in the bottom sediment according to above described prior art arrangements.

[0008] Moreover, document DE 10 2009 040648 A1 discloses an anchoring arrangement for anchoring a floatable wind power unit comprising the features of the preamble of claim 1.

OBJECTS AND SUMMARY OF THE INVENTION

[0009] The object of the present invention is to provide an improved anchoring arrangement that in particular solves the previously mentioned problems of prior art.

[0010] A first object of the invention is to provide an anchoring arrangement that reduces the risk of entanglement between the floatable unit and the fundament. A second object of the invention is to provide an anchoring arrangement that requires a less rigid attachment of the fundament in the bottom sediment for anchoring the floatable unit in comparison to prior art. The above objects are also obtained by means of a method for anchoring a floatable unit and use of an anchoring arrangement.

[0011] These objects are obtained by an anchoring arrangement anchoring a floatable unit in water as defined by claim 1. The anchoring arrangement is characterized in that the anchoring element further comprises a displacement member rotary arranged on the fundament and a connection member adapted to form a connection between the displacement member and a first part of the floatable unit.

[0012] The connection member forms a rigid connection between the displacement member and the first part of the floatable unit. Preferably, the connection member is configured substantial inflexible and unbendable to the forces it is being subjected to. The displacement member enables the floatable unit to rotate around the fundament without risk of entanglement in that the connection is arranged in vicinity of the displacement member without the uses of wires or similar.

[0013] According to the invention, the displacement member is arranged displaceable along said longitudinal axis between a first position and a second position, which first position is located further away from the bottom sediment than the second position, wherein the connection member is adapted to form a rigid connection between the displacement member and a first part of the floatable unit when the displacement member is in the first position and the displacement member is adapted, while being connected to the first part of the floatable unit, to be brought from the first position to the second position.

[0014] The anchoring element enables the first part of the floatable unit to be connected to the displacement member in the first position by means of the connection member that forms the

rigid connection between the displacement member and the first part of the floatable unit. The first position of the displacement member is located so to allow the floatable unit to float at the surface of the water when the first part of the floatable unit is connected to the displacement member.

[0015] After that the connection has been formed between the displacement member and the first part of the floatable unit, the displacement member is adapted to be displaced from the first position to the second position while the floatable unit is maintained connected to the displacement member. Accordingly, the first part of the floatable unit is sunk together with the displacement member from the first position to the second position. The second position of the displacement member provides an anchored state for the floatable unit.

[0016] The first part of the floatable unit is anchored to the fundament at a level of the second position of the displacement member that is located closer to the bottom sediment than the first position of the displacement member. Accordingly, bending forces on the fundament will be reduced in comparison to prior art Thereby, the fundament will mainly be subjected to shear forced directed away from the longitudinal axis. This allows the requirements on the attachment of the fundament in the bottom sediment to be reduced in comparison to prior art attachment of anchoring elements for anchoring of the corresponding size floatable units. Accordingly, the cost of the providing the anchoring of the floatable unit is reduced in comparison to prior art anchoring.

[0017] According to one aspect of the invention, the first position is located at or in vicinity of the surface of the water. This enables the connection between the first part of the floatable unit and the displacement member to be established while the floatable unit is floating at the surface of the water.

[0018] According to another aspect of the invention, the second position is located at or in vicinity of the bottom sediment. Thereby, the possible bending forces on the fundament is minimized, wherein the requirements on the attachment of the fundament is minimized.

[0019] According to a further aspect of the invention, the displacement member is adapted to be displaced from the first position to the second position by means of reducing the buoyancy of the first part of the floatable unit while a second part of the floatable unit is maintained floating. Accordingly, only the first part of the floatable unit is sunk to the second position of the displacement member. The remaining part of the floatable unit is maintained floating.

[0020] According to one embodiment of the invention, the anchoring element further comprises a locking member adapted to form a fastening of the displacement member to the second position while the first part of the floatable unit is connected to the displacement member.

[0021] When the displacement member is located in the second position with the first part of the floatable unit connected to the displacement member, the displacement member is

fastened in the second position by means of the locking member. Accordingly, the first part of the floatable unit is fastened together with the displacement member at the second position of the displacement member. Thereby, the displacement member and the floatable unit is prevented from being displaced in the vertical direction away from the bottom sediment.

[0022] According to one embodiment of the invention, the anchoring element comprises a stop member adapted to define the second position of the displacement member.

[0023] According to one embodiment of the invention, the connection member provides a releasable connection between the displacement member and the first part of the floatable unit when the displacement member is in the first position. According to one embodiment of the invention, the locking member provides a releasable fastening of the displacement member to the second position.

[0024] The displacement member is adapted, while being connected to the first part of the floatable unit, to be unfastened from the second position and be brought from the second position to the first position and in the first position be disconnected from the first part of the floatable unit.

[0025] The connection member and the locking member are configured to enable a releasable connection of the first part of the floatable unit to the displacement member respectively a releasable fastening of the displacement member to the second position. Accordingly, the floatable unit is adapted to be released from the anchoring element by means of reversing the process of anchoring the floatable unit. Thereby, the anchoring element enables the floatable unit to be released from the anchoring at the anchoring element. Such release of the floatable unit is necessary, for example, to allow the floatable unit to be towed to service facilities for maintenance of the floatable unit.

[0026] According to one embodiment of the invention, the fundament comprises an outer envelope surface and the displacement member comprises a body arranged around the outer envelope surface, which body comprises an inner envelope surface directed towards the outer envelope surface, wherein the outer envelope surface is adapted to guide the displacement of the displacement member between the first and the second position by contacting the inner envelope surface.

[0027] The outer envelope surface is extending along the longitudinal axis and is directed away from a center of the fundament. Preferably, the inner envelope surface and outer envelope surface are cylindrical surfaces. The fundament acts as a guide member that guides the displacement between the first and the second position of the displacement member. Of particular importance is that the displacement is guided to the second position so to enable the locking member to form the fastening of the displacement member to the second position. According to a preferably embodiment of the invention, the body of the displacement member is ring-formed.

[0028] According to one embodiment of the invention, the anchoring element comprises a first pivot that enables the displacement member to be pivoted in relation to the fundament and which first pivot comprises a first rotation axis that is arranged parallel with the longitudinal axis of the fundament.

[0029] The first pivot enables the floatable unit to pivot around the fundament. This enables the floatable unit to be pivoted during use, such as by wind and waves. Thereby, the strain on the connection between the first part of the floatable unit and the displacement member is reduced in comparison without the pivoting movement around the fundament.

[0030] According to one embodiment of the invention, the first pivot comprises the outer envelope surface and the inner envelope surface that are arranged so to enable the displacement member to rotate in relation to the fundament. The embodiment provides a simple and cost effective first pivot, wherein the outer envelope surface and the inner envelope surface cooperates in guiding the displacement member between the first and the second position, and to pivot the floatable unit around the fundament.

[0031] According to one embodiment of the invention, at least one of the displacement member and the connection member comprises a second pivot that enables the floatable unit to rotate in relation to the displacement member and which second pivot comprises a second rotation axis that is arranged perpendicular to the longitudinal axis of the fundament.

[0032] The second pivot enables the first part of the floatable unit to, while being connected to the displacement member, to pivot around the second rotation axis. Thereby, the second pivot enables the first part of the floatable unit to move up and down when subjected to underwater waves and streams.

[0033] According to one embodiment of the invention, at least one of the displacement member and the connection member comprises a third pivot that enables the floatable unit to be pivoted in relation to the displacement member and which third pivot comprises a third rotation axis that is arranged perpendicular to the first rotation axis and the second rotation axis.

[0034] The third pivot enables the first part of the floatable unit, while being connected to the displacement member, to pivot around the third rotation axis. Thereby, the third pivot enables the floatable unit to rotate in relation to the surface of the water when subjected to underwater waves and streams.

[0035] According to one embodiment of the invention, the fundament has a length that allows the fundament to, when attached in the bottom sediment, extend from the bottom sediment to at least the surface of the water. Preferably, the anchoring element is arranged so that the fundament extends from the bottom sediment to above the surface of the water. Thereby, the first part of the floatable unit is easily connected to the displacement member while the floatable unit is floating at the surface of the water.

[0036] According to one embodiment of the invention, the floatable unit comprises a first pontoon member at a first part of the floatable unit, which first pontoon member comprises a first state in which the pontoon member provides a first buoyancy that enables the first part of the floatable unit to float and a second state in which the pontoon member provides a second buoyancy that sinks the first part of the floatable unit towards the bottom sediment, wherein the displacement member is adapted to be displace, while a second part of the floatable unit is floating, from the first position to the second position by means of changing the first pontoon member from the first state to the second state and from the second position to the first position by means of changing the first pontoon member from the second state to the first state.

[0037] The displacement member is adapted to be displaced from the first position to the second position by means of changing the first pontoon member from the first state to the second state. Thereby, the first part of the floatable unit sinks towards the bottom sediment while the second part of the floatable unit is maintained floating.

[0038] The first part of the floatable unit is sunk to the second position of the displacement member, wherein the floatable unit is arranged between the first part at the second position of the displacement member and the second part of the floatable unit that is floating above the second position, preferably above the surface of the water. Thereby, the fundament will mainly be subjected to bending forced. This allows the requirements on the attachment of fundament in the bottom sediment to be reduced in comparison to prior art attachment of anchoring elements for anchoring of the corresponding size of floatable unit.

[0039] According to one embodiment of the invention, the displacement member is adapted to be adjusted to any position between the first and the second position by means of regulating the buoyancy of the first pontoon member.

[0040] According to one embodiment of the invention, the distance between the first and the second part is longer than the distance between the first and the second position of the displacement member.

[0041] According to one embodiment of the invention, the distance between the first and the second part is longer than the depth between the bottom sediment and the surface of the water.

[0042] The anchoring arrangement is in particular suitable for anchoring in shallow water. The term "shallow water" refers to that the length between the first and the second part is longer than the depth between the bottom sediment and the surface of the water. Thereby, the anchoring arrangement enables the first part of the floatable unit to be held at the displacement member located close to the bottom sediment, which results in a substantial reduction of the bending forces subjected to the fundament.

[0043] According to one embodiment of the invention, the first pontoon member comprises wall sections that form a space, wherein the first pontoon member is adapted to be changed between the first state and the second state by means of introducing and removing water to/from said space. By means of allowing water to be introduced into the space and regulating the amount of water in the space, the buoyancy of the first pontoon member is adjustable between the first and the second state.

[0044] According to one embodiment of the invention, the arrangement comprises means for introducing and removing water from the space of the first pontoon member. The means for introducing and removing water comprises for example a pump, a valve, for controlling the level of water in the space. Thereby, the relation between air and water in the space is regulated in order to change the first pontoon member between the first and the second state.

[0045] According to one embodiment of the invention, the floatable unit comprises a frame work providing a buoyancy and a second pontoon member at a second part of the floatable unit, wherein the second pontoon member comprises a third state in which the second pontoon member has a first mass and a fourth state in which the second pontoon member has a second mass, which second mass is larger than the first mass, wherein the second pontoon member is adjustable between the third state and the fourth state.

[0046] The buoyancy of the frame work assures that the second part of the floatable unit floats at the surface of the water when the first part of the floatable unit has been sunk to the second position of the displacement member.

[0047] The second pontoon member is adapted to be arranged in the third state when the floatable unit is transported to and from its anchoring position, wherein the second pontoon member provides additional stability to the floatable unit. The second pontoon member is adapted to be arranged in the fourth state when the first part of the floatable unit is arranged at the second position of the displacement member. By means the larger mass of the second pontoon member in the fourth state in comparison to the third state, the movement of the floatable unit in the water will be reduced in that the natural frequency of the floatable unit is reduced. The addition of mass at a distance from the connection between the displacement member and the first part of the floatable unit results in a larger reduction of the natural frequency of the floatable unit in comparison to if a corresponding mass was added to the first pontoon member.

[0048] According to one embodiment of the invention, the second pontoon member is adapted to be located above the surface of the water when the first part of the floatable unit is at the second position of the displacement member. Accordingly, in the anchored position the second pontoon member does not contribute to the buoyancy of the floatable unit but stabilize the floatable unit.

[0049] According to one embodiment of the invention, the second pontoon member comprises the corresponding features of the first pontoon member. Accordingly, the second pontoon

member is regulated between the third and the fourth state by means of introducing and removing water to/from the space of the second pontoon member. According to one embodiment of the invention, the means for introducing and removing water is configured to regulate the level of water in the second pontoon member.

[0050] According to one embodiment of the invention, the fundament comprises a hollow space extending along the longitudinal axis and the anchoring arrangement comprises a power cable extending from the bottom sediment through said hollow space and to above the surface of the water.

[0051] The power cable is positioned on the bottom of the sea and extends through the hollow space of the fundament. The power cable is for example used for connecting a wind power plant to the grid. The connection of the power cable is established above the surface of the water after the connection of the floatable unit to the fundament. An advantage with this is that the power cable does not move in the water due to movements of the framework, as compared to the solution when the floating unit is anchored to a buoy.

[0052] According to one embodiment of the invention, the first pontoon member comprises an opening in the wall sections for introduction/removal of water to/from the space and a valve for controlling said introduction and removal of water. Preferably, water is introduced by opening the valve and water is removed through the opening.

[0053] According to one embodiment of the invention, the first buoyancy enables the first part of the floatable unit to float so to enable a connection to the displacement member when the displacement member is in the first position and the second buoyancy enables the first part of the floatable unit to sink together with the displacement member to the second position of the displacement member.

[0054] According to one embodiment of the invention, the floatable unit comprises a wind power unit for generating electric energy. The wind power unit on the floatable unit is subjected to wind and therefore the improved anchoring arrangement provided by the anchoring arrangement is suitable for holding the wind power unit in place at its anchored position.

[0055] The previously mentioned object of the invention is further obtained by a method for anchoring a floatable unit in water according to claim 15. The method involves the use of an anchoring element comprising an elongated fundament firmly attached in a bottom sediment so that a longitudinal axis of the fundament is oriented from the bottom sediment towards the surface of the water and a displacement member displaceable along said longitudinal axis between a first position and a second position, which first position is located further away from the bottom sediment than the second position. The method comprises the steps:

- connecting a first part of the floatable unit to the displacement member,
- displacing the displacement member with the first part of the floatable unit from the first position to the second position.

[0056] By means of the method, the floatable unit is anchored so to reduce the bending moment on the fundament. Thereby, the fundament will mainly be subjected to shear forced directed away from the longitudinal axis. This allows the requirements on the attachment of fundament in the bottom sediment to be reduced in comparison to prior art attachment of anchoring elements for anchoring of the corresponding size of floatable unit.

[0057] According to one embodiment of the invention, the floatable unit comprises a first pontoon member at the first part of the floatable unit, which first pontoon member comprises a first state with a first buoyancy and a second state with a second buoyancy, which second buoyancy is lower than the first buoyancy, wherein the method comprises - displacing the displaceable member from the first position to the second position by means of changing the first pontoon member from the first state to the second state.

[0058] The displacement of the displacement member from the first position to the second position is realized by means of changing the first pontoon member form the first state to the second state. Thereby, the first part of the floatable unit acts on the displacement member and induces the displacement of the displacement member to the second position.

[0059] According to one embodiment of the invention, the first pontoon member is changed from the first state to the second state by means of at least partly introducing water into the first pontoon member.

[0060] According to one embodiment of the invention, the method further comprises:

- fastening the displacement member to the second position.

[0061] The previously mentioned object of the invention is further obtained by a method for de-anchoring a floatable unit in water according to claim 19. The method comprises the steps:

- displacing the displacement member with the first part of the floatable unit connected to the displacement member from the second position to the first position, and
- disconnecting the first part of the floatable unit from the displacement member.

[0062] By means of the method, the floatable unit is allowed to be released from the anchoring in a reversed manner to the establishment of anchoring the floatable unit. Thereby, the floatable unit is allowed to be released and towed to service facilities for maintenance.

[0063] According to one embodiment of the invention, the method comprises

- displacing the displaceable member from the second position to the first position by

means of changing the first pontoon member from the second state to the first state.

[0064] The displacement of the displacement member from the first position to the second position is realized by means of changing the first pontoon member form the second state to the first state. Thereby, the first part of the floatable unit acts on the displacement member and induces the displacement of the displacement member to the first position.

[0065] According to one embodiment of the invention, the first pontoon member is changed from the second state to the first state by means of at least partly removing water from the first pontoon member.

[0066] According to one embodiment of the invention, the method comprises

- unfastening the displacement member from the second position.

[0067] According to one embodiment of the invention, the floatable unit comprises a second pontoon member at a second part of the floatable unit, wherein the second pontoon member comprises a third state in which the second pontoon member has a first mass and a fourth state in which the second pontoon member has a second mass, which second mass is larger than the first mass, wherein the further method comprises

- changing the second pontoon member from the third state to the fourth state when anchoring the floatable unit to the anchoring element.

[0068] According to one embodiment of the invention, the method comprises:

- changing the second pontoon member from the fourth state to the third state when removing the floatable unit from the anchoring element.

[0069] According to one embodiment of the invention, the second pontoon member is changed between the third and the fourth state by means of introducing/removing water from the second pontoon member.

[0070] The previously mentioned object of the invention is further obtained by use of an anchoring arrangement according to claim 1-13 for anchoring a floatable unit in water.

BRIEF DESCRIPTION OF THE DRAWINGS

[0071] The invention will now be explained more closely by the description of different embodiments of the invention and with reference to the appended figures.

Fig. 1
shows a perspective view of a floatable unit comprising a wind power plant.

Fig. 2
shows a side view of an anchoring arrangement comprising the floatable unit connected to a displacement member of an anchoring element in a first position.

Fig. 3
shows a side view of the anchoring arrangement in fig. 2 comprising the floatable unit connected to a displacement member of an anchoring element in a second position

Fig. 4
shows a side view of an anchoring element attached in a bottom sediment.

Fig. 5a
shows a flow chart of a method for anchoring the floatable unit to the anchoring element.

Fig. 5b
shows a flow chart of a method for releasing the floatable unit from the anchoring element.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0072] The invention will now be explained with reference to fig. 1-5. Figures 1 - 3 shows a floatable unit 1 comprising a wind power plant 2. The floatable unit 1 is adapted to be anchored at sea where the wind power plant 2 converts wind energy to electrical energy. The wind power plant 2 includes a plurality of wind turbines 2a, 2b. In this embodiment the wind power plant 2 includes two wind turbines 2a, 2b. However, in another embodiment of the invention, the wind power plant 2 may include three or more wind turbines.

[0073] The wind power plant 2 comprises a framework comprising at least two support elements 3a, 3b adapted to support the wind turbines 2a, 2b. The support elements 3a, 3b are elongated. In this embodiment, the support elements 3a, 3b are two hollow tubes arranged at a distance from each other. The wind turbines 2a, 2b are mechanically connected to upper ends of the support elements. The wind power plant 2 is designed so that the support elements 3a, 3b are vertically arranged when the plant 2 is in operation.

[0074] The floatable unit 1 further includes an elongated unit 4 arranged between the support elements 3a-b. The elongated unit 4 is also tube shaped. The elongated unit 4 is mechanically connected to lower ends of the support elements. In another embodiment it is possible to have three or more support elements to support three or more wind turbines. For example, the support elements 3a-b and the elongated units 4 are made by tubes. The tubes contribute to a certain floating power and stabilizing in roll direction.

[0075] The framework further includes a diagonal brace 5 connected to the support elements 3a-b in order to guy the support elements. It is advantageous to use a diagonal brace to stabilize the support elements and to reduce the stresses in the framework. Of course, it is possible to use other type of arrangement to guy the support elements.

[0076] The floatable unit 1 comprises an elongated beam 9, in the following named support beam. The elongated beam 9 is arranged so that it extends from a first part 22a of the floatable unit 1, between the support elements 3a-b, and to a second part 22b of the floatable unit 1. The support elements 3a-b and the elongated unit 4 form a plane. The beam 9 is arranged angular with respect to the plane. The support beam 9 is neither perpendicular to the plane nor parallel with the plane. Preferably, the beam is arranged with an angle α relative the plane which is within the interval of 30° - 80°, preferably 50°-70°

[0077] The framework further comprises a plurality of wire cables 14ah, preferably made of stainless steel arranged between the support beam 9 and the framework in order to mechanically connect the beam to the framework. The beam 9 and the support elements are provided with a plurality of cable attachments for facilitating the attachment of the wire cables. The cable attachment is, for example, a loop or a ring. The ends of the cable wire are also provided with corresponding attachments, for example hooks. The arrangement with wire cables achieves an optimal utilization of material and accordingly reduces the weight of the wind power plant 2.

[0078] In the embodiment shown in figure 1 - 3, eight wire cables are arranged between the beam and the framework. Four of the wire cables 14a-d are arranged between the framework and the end of the beam 9, and four of the wire cables 14e-h are arranged between the framework and the opposite end of the beam 9. In this embodiment, cable wires 14a and 14c are connected between a first end of the beam 9 and the support element 3a, cable wires 14b and 14d are connected between the first end of the beam 9 and the support element 3b. Cable wires 14e and 14g are connected between a second end of the beam 9 and the support element 3a, cable wires 14f and 14h are connected between the second end of the beam 9 and the support element 3b. As seen from figures 1, the support beam 9 is free from the framework, i.e. is not in contact with the framework, and is only connected to the framework through the wire cables 14a-h. Since the support beam 9 has no connection to the framework except through the wire cables 14a-h no movement is introduced in the ends of the cable wires, which reduces the stress in the beam and the framework.

[0079] Figure 2 shows the floatable unit 1 connected to an anchoring element 30. The floatable unit 1 and the anchoring element 30 further constitute an anchoring arrangement 40.

[0080] The floatable unit 1 is in a transportation position, in which it is possible, after disconnecting the floatable unit 1 from the anchoring element 30, to tow the floatable unit 1 away from its anchoring position. The floatable unit 1 comprises a first pontoon member 20a at a first part 22a of the floatable unit 1 and a second pontoon member 20b at a second part 22b

of the floatable unit 1. By means of the first pontoon member 22a and the second pontoon member 22b the floatable unit 1 floats at the surface of the water when the floatable unit is transported to and from the anchoring position.

[0081] In fig. 3 the floatable unit 1 is anchored to the anchoring element 30. In fig. 2 and 3 the floatable member is connected to a displacement member 50 of the anchoring element 30, wherein the displacement member 50 in fig. 2 is in a first position and in fig. 3 in a second position. Fig. 2 and 3 will be discussed further in detail in connection to fig. 4 and the method of anchoring the floatable unit 1.

[0082] Figure 4 shows a side view of a cross section of the anchoring element 30 according to an embodiment of the invention. The anchoring element 30 comprises an elongated fundament 42 adapted to be firmly attached in the bottom sediment 44 so that a longitudinal axis L1 of the fundament 42 is oriented extending essentially perpendicular from the bottom sediment 44 to the surface of the water.

[0083] The fundament 42 comprises an outer envelope surface that is arranged cylindrical. The fundament 42 is for example a homogeneous rod or a pipe. The fundament 42 is made of a material with high strength, in particular to shear stress. The material of the fundament 42 is for example reinforced concrete, steel, stainless steel. The fundament 42 is for example a hollow tube.

[0084] A first end 46 of the fundament 42 is adapted to be arranged within the bottom sediment 44 and together with the bottom sediment 44 form an attachment that firmly holds the fundament 42 in place. The first end 46 of the fundament 42 is arranged with a part that is thicker in comparison the remaining part of the fundament 42. A second end 48 of the fundament 42 is adapted to be in vicinity of the surface of the water. In fig. 4, the second end 48 of the fundament 42 is located above the surface of the water.

[0085] The anchoring element 30 comprises a displacement member 50 that is displaceable along the first longitudinal axis L1 between a first position and a second position. The first position of the displacement member 50 is located further away from the bottom sediment 44 than the second position. In fig. 4 the first position is indicated by depicting the displacement member 50 with full lines and the second position with dotted lines. The second position of the displacement member 50 is defined by a stop member 51.

[0086] The displacement member 50 comprises a ring formed body that comprises an inner envelope surface. The body of the displacement member 50 is arranged so that the displacement member 50 is guided between the first and the second position by means of that the outer envelope surface of the fundament 42 and the inner envelope surface of the displacement member 50 contact each other.

[0087] The anchoring element 30 further comprises a connection member 52 adapted to form a rigid connection between the displacement member 50 and the first part 22a of the floatable

unit 1. For example, the connection member 52 enables the beam 9 of the floatable unit 1 to be connected to the displacement member 50.

[0088] The connection member 52 provides a releasable connection between the first part 22a of the floatable unit 1 and the displacement member 50. According to an embodiment of the invention the connection member 52 comprises a locking pin adapted engage with a respective opening in the connection member 52 and the first part 22a of the floatable unit 1, and thereby enabling the releasable connection.

[0089] The anchoring element 30 further comprises a locking member 54 adapted form a fastening of the displacement member 50 to the second position. The locking member 54 comprises an engaging state where the locking member 54 assures that the displacement member 50 is maintained in the second position and a disengaging state where the locking member 54 allows the displacement member 50 to be displaced between the first and the second position.

[0090] In fig. 4, the locking member 54 is illustrated in the engaging state when the displacement member 50 is in the second position and in the disengaging state when the displacement member 50 is in the first position.

[0091] By means of the locking member 54 it is assured that the displacement member 50 is maintained in the second position during anchoring the floatable unit 1. The locking member 54 provides a releasable fastening of the displacement member 50 to the second position. Accordingly, the locking member 54 allows the displacement member 50 to be fastened to the second position and unfastened from the second position.

[0092] The locking member 54 is for example a locking ring that in the engaging state engages with the envelope surface of the fundament 42 and thereby prevents the displacement member 50 from being displaced away from the second position and in the disengaging state lacks contact with the envelope surface and thereby allows the displacement member 50 to be displaced between the first and the second position.

[0093] The anchoring element 30 comprises a first pivot 60 that allows the displacement member 50 to be pivoted around the outer envelope surface of the fundament 42 with a first axis of rotation R1. The first axis of rotation R1 is thus parallel with the longitudinal axis L1 of the fundament 42.

[0094] By means of the ring-formed body of the displacement member 50 the outer envelope surface of the fundament 42 abuts the inner envelope surface of the displacement member 50 in such a way that allows the displacement member 50 to be pivoted with the first axis of rotation R1. The first pivot 60 assures that the floatable unit 1 is arranged pivotable around the anchoring element 30 without the risk of entanglement with any wires between the anchoring element 30 and the floatable unit 1.

[0095] The anchoring element 30 further comprises a second pivot 62 that allows the connection member 52 to be pivoted in relation to the displacement member 50 with a second rotation axis R2 that is arranged perpendicular to the longitudinal axis L1. The second pivot 62 assures that the floatable unit 1 is arranged pivotable around the displacement member 50 and thereby allows the floatable unit 1 freedom to move as the floatable unit 1 is affected by waves and wind.

[0096] The anchoring element 30 further comprises a third pivot 64 that allows the connection member 52 to be pivoted in relation to the displacement member 50 with a third rotation axis R3 that is arranged perpendicular to the first rotation R1 and the second rotation R2.

[0097] The invention also relates also to a method for anchoring the floatable unit 1 to the anchoring element 30 and releasing the floatable unit 1 from an anchoring element 30. The steps of the method will be described with reference to fig. 5a disclosing a flow chart for anchoring the floatable unit 1 to the anchoring element 30 and fig. 5b disclosing a flow chart for releasing the floatable unit 1 from the anchoring element 30.

[0098] The method for anchoring the floatable unit 1 to the anchoring element 30 comprises, in a step 100, connecting the first part 22a of the floatable unit 1 to the displacement member 50. The connection is established by means of the connection member 52 when the displacement member 50 is in the first position and the floatable unit 1 is floating at the surface on the frame work of the floatable unit 1, the first pontoon member 20a and the second pontoon member 20b. Thereby, the first part 22a of the floatable unit 1 is firmly attached to the displacement member 50. The situation of step 100 is illustrated by fig. 2.

[0099] In a step 110, the method comprises displacing the displacement member 50 from the first position to the second position. The displacement member 50 is displaced along the longitudinal axis L1 of the fundament 42 to the stop member 51 that defines the second position.

[0100] In an embodiment of the invention, the displacement member 50 is displaced from the first position to the second position by means of changing the buoyancy of the first pontoon member 20a from the a first state to a second state while second part 22b of the floatable unit 1 is floating on the frame work of the floatable unit 1. The buoyancy of the first pontoon member 20a is changed by introducing water into the first pontoon member 20a. Thereby, the first part 22a of the floatable unit 1 sinks together with the displacement member 50 to the second position of the displacement member 50 while the second part 22b of the floatable unit 1 is maintained floating at the surface.

[0101] According to the embodiment shown in fig. 3, the second pontoon member 20b is positioned above the surface of the water when the first part 22a of the floatable unit 1 is in the second position of the displacement member 50. By means of changing the second pontoon member 20b from the third state to the fourth state the stability of the floatable unit 1 is improved. In the fourth state the second pontoon member 20b has a higher mass than in the

third state. Thereby, the natural frequency of the floating unit 1 is reduced.

[0102] In a step 120, the method comprises fastening the displacement member 50 to the second position. The fastening is established by means of the locking member 54 that is changed from the disengaging state to the engaging state. Thereby, the displacement member 50 is locked to the second position while the first part 22a is held to the displacement member 50 at the second position. The situation of step 120 is illustrated by fig. 3 and represents the anchored state of the floatable unit 1.

[0103] Due to the fact that the anchoring point is close to the bottom sediment 44, bending stresses on the anchoring element 30 is significantly reduced, and therefore the post only has to be dimensioned mainly for sheer forces with small bending movement.

[0104] The framework and the beam 9 are designed so that the support elements 3a-b are essentially vertical and the plane of the turbines are parallel with the vertical plane when the plant is anchored.

[0105] In a step 130, the method comprises changing the second pontoon member 20b from the third state to the fourth state when anchoring the floatable unit 1 to the anchoring element 30. The change from the third state to the fourth state is realized by introducing water into a space of the second pontoon member 20b. The change results in that the mass of the second pontoon member 20b is increased so that the natural frequency of the floatable unit 1 is reduced.

[0106] The method for releasing the floatable unit 1 from the anchoring element 30 comprises, in a step 200, unfastening the displacement member 50 from the second position. The unfastening of the displacement member 50 is realized by means of changing the locking member 54 form the engaging state to the disengaging state. Thereby, the displacement member 50 is free to be displaced between the first and second position along the longitudinal axis L1 of the fundament 42. The situation is illustrated by fig. 3.

[0107] In a step 210, the method comprises displacing the displacement member 50 from the second position to the first position. The displacement member 50 is displaced along the longitudinal axis L1 of the fundament 42 to the first position located at or in vicinity of the surface of the water.

[0108] In an embodiment of the invention, the displacement member 50 is displaced from the second position to the first position by means of changing the buoyancy of the first pontoon member 20a from the second state to the first state while the buoyancy of the second pontoon member 20b is maintain. Preferably, the buoyancy of the first pontoon member 20a is changed by removing water from the first pontoon member 20a. Thereby, the first part 22a of the floatable unit 1 is lifted towards the surface together with the displacement member 50 to the first position of the displacement member 50 while the second part 22b of the floatable unit 1 is maintained floating at the surface.

[0109] In a step 220, the method comprises disconnecting the floatable unit 1 from the displacement member 50 when the displacement member 50 is in the first position. The connection between the first part 22a of the floatable unit 1 and the displacement member 50 is released by means of the connection member 52. Thereby, the floatable unit 1 is in a transportation position, in which it is possible to tow the floatable unit 1 away from its anchoring position, such as for maintenance. The situation of step 220 is illustrated by fig. 2.

[0110] In a step 230, the method comprises changing the second pontoon member 20b from the fourth state to the third state when releasing the floatable unit 1 from the anchoring element 30. The change from the fourth state to the third state is realized by removing water from the space of the second pontoon member 20b. The change results in that the mass of the second pontoon member 20b is reduced and the second pontoon member 20b again provides buoyancy.

[0111] A power cable 16 is positioned on the bottom sediment 44 and extends through the anchoring element 30. The power cable 16 is connected to the wind power plant above the surface of the water after the connection to the post. An advantage with this is that the power cable 16 does not move in the water due to movements of the framework.

[0112] In an embodiment of the invention, the floatable unit 1 is large, for example, the length of the beam 9 is about 150m. The part of the beam 9 extending in a direction towards the anchoring element 30 is, for example, about 100m and the part of the beam extending in the opposite direction is, for example, about 50m.

[0113] An advantage with the floatable unit 1 comprising the wind power plant 2 according to the present invention is that it is possible to anchor the floatable unit 1 in shallow water. Another advantage compared to the prior art power plants is that the wind turbines only has one support element to the centre of a rotor of the wind turbine. This arrangement reduces disturbances and problems with dynamic dimensioning of the framework.

[0114] The present invention is not limited to the embodiments disclosed but may be varied and modified within the scope of the following claims.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- SE532886C2 **[0007]**
- DE102009040648A1 **[0008]**

Patentkrav

1. Forankringsanordning (40) til at forankre en flydbar vindenergienhed (1) i vand, hvor forandringsanordningen (40) omfatter:

- den flydbare vindenergienhed (1), der har en første del (22a) og en anden del (22b) mellem hvilke støtteelementer (3a, 3b) indrettet til at støtte mindst to vindmøller (2a, 2b) er anbragt, og
- et forankringselement (30) omfattende et langstrakt fundament (42) konfigureret til at blive fast fastgjort i et bundsediment (44), så en langsgående akse (L1) af fundamentet (42) er orienteret fra bundsedimentet (44) mod overfladen af vandet,

hvor forankringselementet (30) yderligere omfatter et forskydningselement (50) roterbart anbragt på fundamentet (42) og et forbindelseselement (52) indrettet til at danne en forbindelse mellem forskydningselementet (50) og den første del (22a) af den flydbare vindenergienhed (1),

hvor forskydningselementet (50) er anbragt forskydeligt langs nævnte langsgående akse (L1) mellem en første position og en anden position, hvilken første position er placeret længere væk fra bundsedimentet (44) end den anden position,

hvor forbindelseselementet (52) er indrettet til at danne en stiv forbindelse mellem forskydningselementet (50) og den første del (22a) af den flydbare vindenergienhed (1), når forskydningselementet (50) er i den første position, og forskydningselementet (50) er indrettet, mens det er forbundet til den første del (22a) af den flydbare vindenergienhed (1), til at bringes fra den første position til den anden position,

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forskydningselementet (50) er indrettet til at forskydes fra den første position, konfigureret til at placeres ved eller i nærhed af overfladen af vandet, til den anden position, konfigureret til at blive placeret ved eller i nærhed af bundsedimentet, ved at reducere opdriften af den første del (22a) af den flydbare vindenergienhed (1), mens den anden del (22b) af den flydbare vindenergienhed (1) fatholdes flydende.

2. Forankringsanordning (40) ifølge krav 1, hvor forankringselementet (30) yderligere omfatter et låseelement (54) indrettet til at danne en fastgørelse af forskydningselementet (50) til den anden position, mens den første del (22a) af

den flydbare vindenergienhed (1) er forbundet til forskydningselementet (50).

3. Forankringsanordning (40) ifølge krav 1 eller 2, hvor forbindelseselementet (52) tilvejebringer en frigivelig forbindelse mellem forskydningselementet (50) og den første del (22a) af den flydbare vindenergienhed (1), når forskydningselementet (50) er i den første position.

4. Forankringsanordning (40) ifølge et hvilket som helst af kravene 1-3, hvor fundamentet (42) omfatter en ydre indhyllingsoverflade og forskydningselementet (50) omfatter et legeme anbragt rundt om den ydre indhyllingsoverflade, hvilket legeme omfatter en indre indhyllingsoverflade rettet mod den ydre indhyllingsoverflade, hvor den ydre indhyllingsoverflade er indrettet til at føre forskydningen af forskydningselementet (50) mellem den første og den anden position ved at kontakte den indre indhyllingsoverflade.

5. Forankringsanordning (40) ifølge et hvilket som helst af de foregående krav, hvor forankringselementet (30) omfatter et første hængselled (60), der roterbart anbringer forskydningselementet (50) i forhold til fundamentet (42) og hvilket første hængselled (60) omfatter en første rotationsakse (R1), der er anbragt parallelt med den langsgående akse (L1) af fundamentet (42).

6. Forankringsanordning (40) ifølge krav 5, hvor mindst en af forskydningselementet (50) og forbindelseselementet (52) omfatter et andet hængselled (62), der gør det muligt for den flydbare vindenergienhed (1) at drejes i forhold til forskydningselementet (50), og hvilket andet hængselled (62) omfatter en anden rotationsakse (R2), der er anbragt vinkelret på den langsgående akse (L1) af fundamentet (42).

7. Forankringsanordning (40) ifølge krav 6, hvor mindst en af forskydningselementet (50) og forbindelseselementet (52) omfatter et tredje hængselled (64), der gør det muligt for den flydbare vindenergienhed (1) at blive drejet i forhold til forskydningselementet (50), og hvilket tredje hængselled (64) omfatter en tredje rotationsakse (R3), der er anbragt vinkelret på den første rotationsakse (R1) og den anden rotationsakse (R2).

8. Forankringsanordning (40) ifølge et hvilket som helst af de foregående krav, hvor fundamentet (42) har en længde, der tillader fundamentet (42) at, når fastgjort i bundsedimentet (44), strække sig fra bundsedimentet (44) til mindst overfladen af vandet.

9. Forankringsanordning (40) ifølge et hvilket som helst af de foregående krav, hvor den flydbare vindenergienhed (1) omfatter et første pontonelement (20a) ved den første del (22a) af den flydbare vindenergienhed (1), hvilket første pontonelement (20a) omfatter en første tilstand, hvori pontonelementet tilvejebringer en første opdrift, der gør det muligt for den første del (22a) af den flydbare vindenergienhed (1) at flyde og en anden tilstand, hvori pontonelementet tilvejebringer en anden opdrift, der synker den første del (22a) af den flydbare vindenergienhed (1) mod bundsedimentet (44),
hvor forskydningselementet (50) er indrettet til at forskydes, mens den anden del (22b) af den flydbare vindenergienhed (1) er flydende, fra den første position til den anden position ved at ændre det første pontonelement (20a) fra den første tilstand til den anden tilstand og fra den anden position til den første position ved at ændre det første pontonelement (20a) fra den anden tilstand til den første tilstand.

10. Forankringsanordning (40) ifølge krav 9, hvor det første pontonelement (20a) omfatter vægafsnit, der danner et rum, hvor det første pontonelement (20a) er indrettet til at ændres mellem den første tilstand og den anden tilstand ved at introducere og fjerne vand til/fra nævnte rum.

11. Forankringsanordning (40) ifølge krav 9-10, hvor den første opdrift gør det muligt for den første del (22a) af den flydbare vindenergienhed (1) at flyde, for at muliggøre en forbindelse til forskydningselementet (50), når forskydningselementet (50) er i den første position og den anden opdrift gør det muligt for den første del (22a) af den flydbare vindenergienhed (1) at synke sammen med forskydningselementet (50) til den anden position af forskydningselementet (50).

12. Forankringsanordning (40) ifølge krav 9-11, hvor den flydbare vindenergienhed (1) omfatter et rammestel, der tilvejebringer en opdrift og et

andet pontonelement (20b) ved den anden del af den flydbare vindenergienhed (22b), hvor det andet pontonelement (20b) omfatter en tredje tilstand, hvori det andet pontonelement (20b) har en første masse og en fjerde tilstand, hvori det andet pontonelement (20b) har en anden masse, hvilken anden masse er større end den første masse, hvor det andet pontonelement (20b) er justerbart mellem den tredje tilstand og den fjerde tilstand.

13. Forankringsanordning (40) ifølge krav 9-12, hvor fundamentet (42) omfatter et hulrum, der strækker sig langs den langsgående akse (L1) og forandringsanordningen (40) omfatter et strømkabel (16), der strækker sig fra bundsedimentet (44) gennem nævnte hulrum og til over overfladen af vandet.

14. Fremgangsmåde til at forankre en flydbar vindenergienhed (1) i vand ved hjælp af et forankringselement (30) omfattende et langstrakt fundament (42) fast fastgjort i et bundsediment (44), så en langsgående akse (L1) af fundamentet (42) er orienteret fra bundsedimentet (44) mod overfladen af vandet og et forskydningselement (50) forskydeligt langs nævnte langsgående akse (L1) mellem en første position og en anden position, hvilken første position er placeret længere væk fra bundsedimentet (44) end den anden position, idet nævnte flydbare vindenergienhed (1) har en første del (22a) og en anden del (22b) mellem hvilke støtteelementer (3a, 3b) indrettet til at støtte mindst to vindmøller (2a, 2b) er anbragt,
hvor fremgangsmåden omfatter trinnene:

- at forbinde den første del (22a) af den flydbare vindenergienhed (1) til forskydningselementet (50),
- at forskyde forskydningselementet (50) med den første del (22a) af den flydbare vindenergienhed (1) fra den første position, placeret ved eller i nærhed af overfladen af vandet, til den anden position, placeret ved eller i nærhed af bundsedimentet, ved at reducere opdriften af den første del (22a) af den flydbare vindenergienhed (1), mens den anden del (22b) af den flydbare vindenergienhed (1) fastholdes flydende.

15. Anvendelse af en forankringsanordning (40) ifølge et hvilket som helst af kravene 1-13 til at forankre en flydbar vindenergienhed (1) i vand.

DRAWINGS

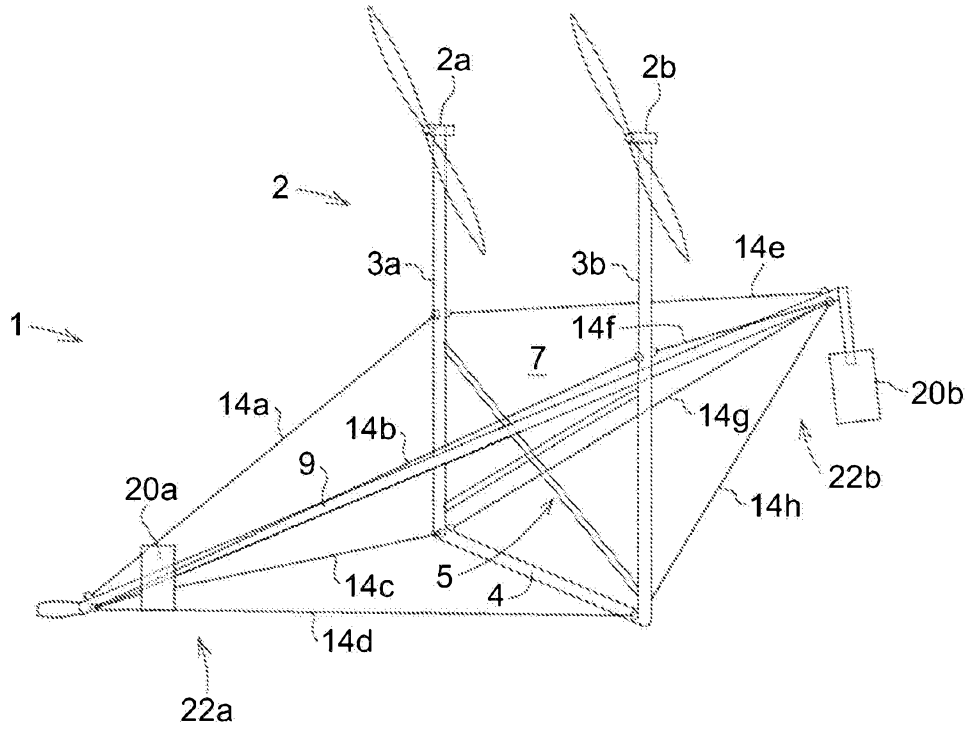

Fig. 1

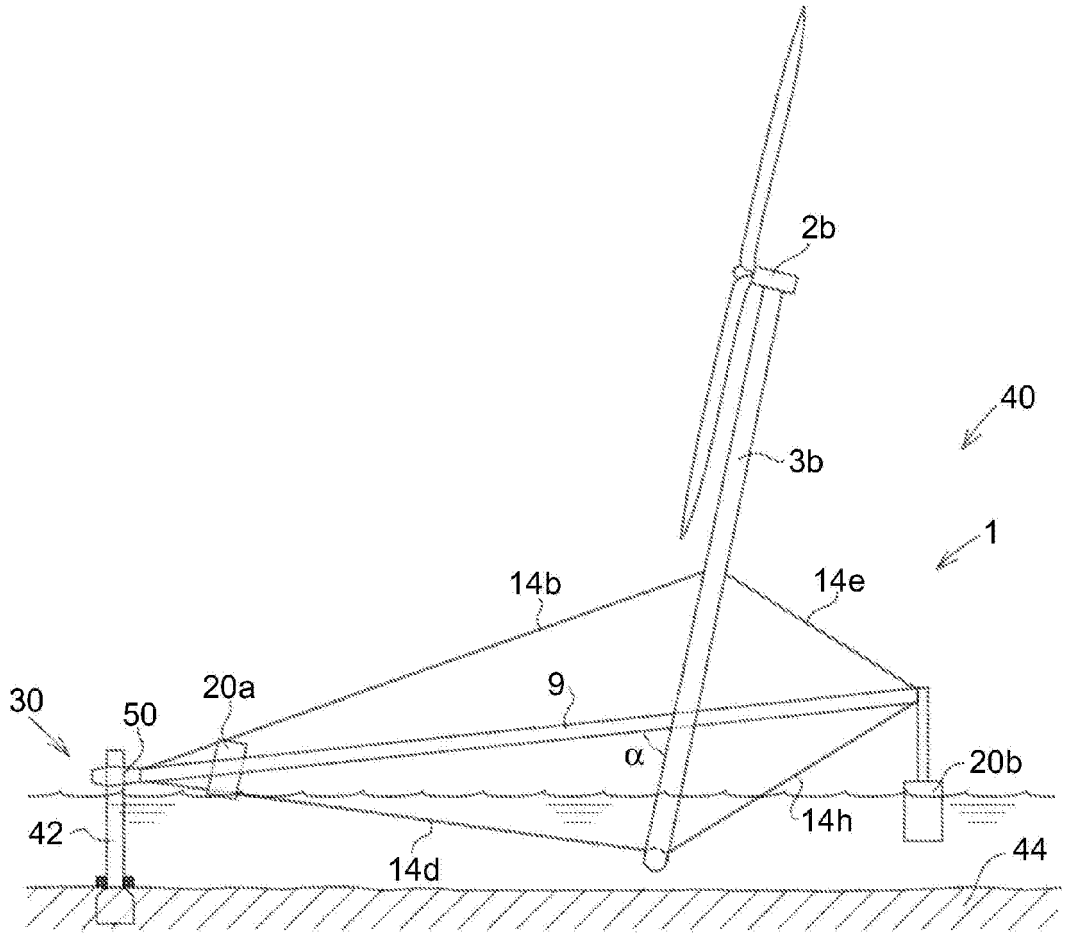

Fig. 2

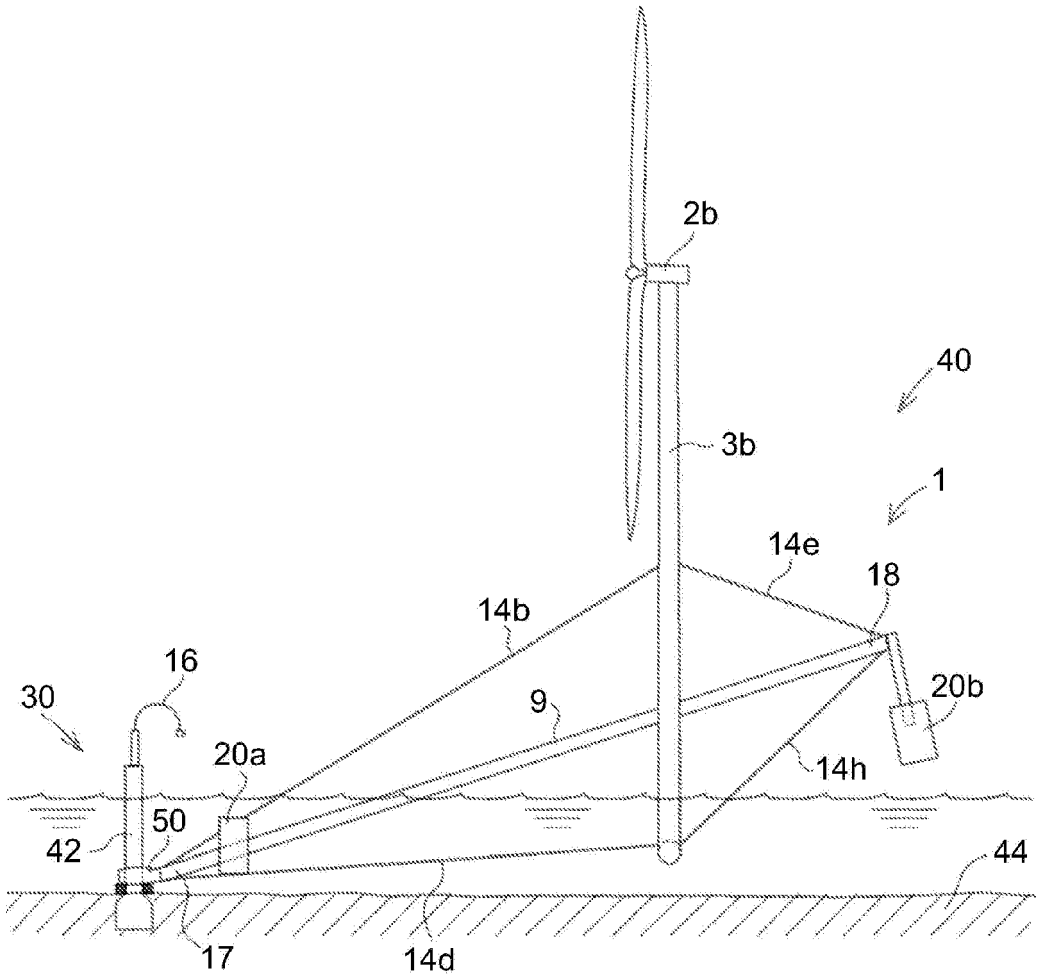

Fig. 3

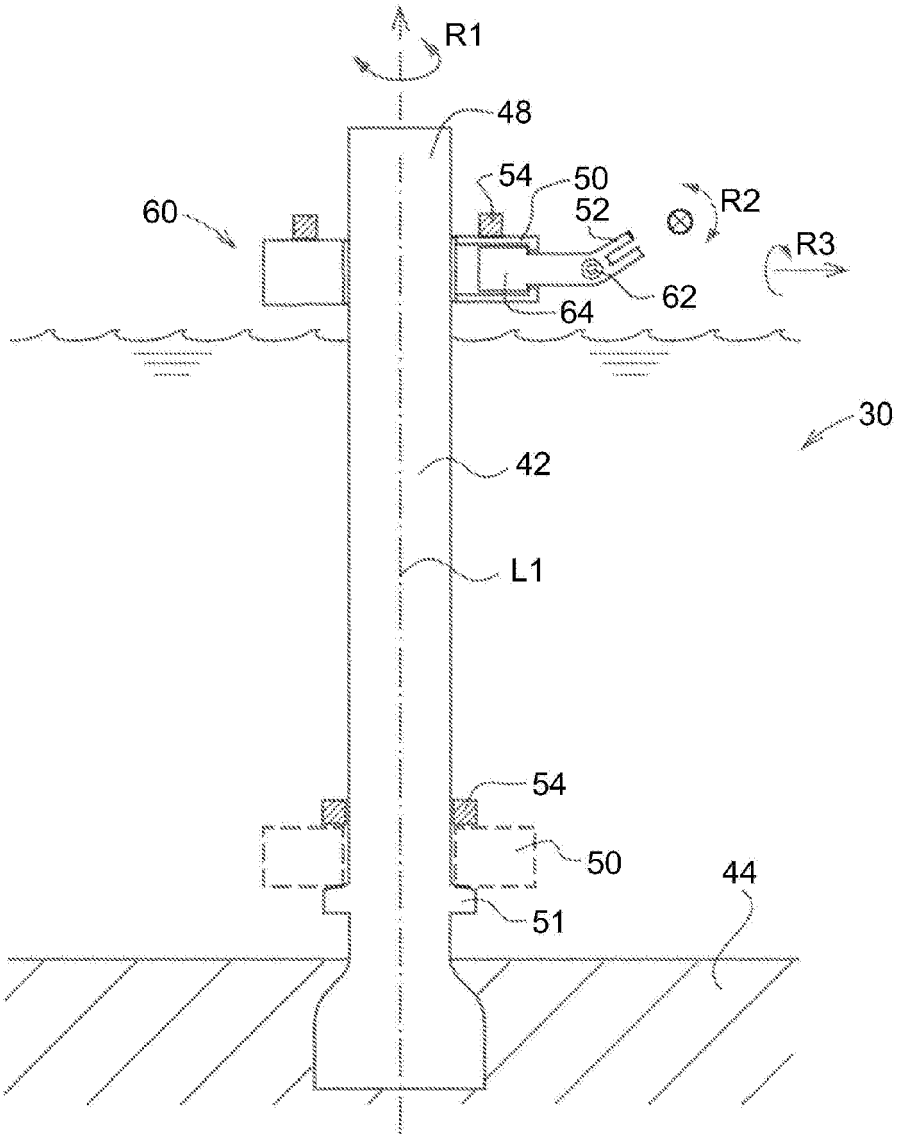

Fig. 4

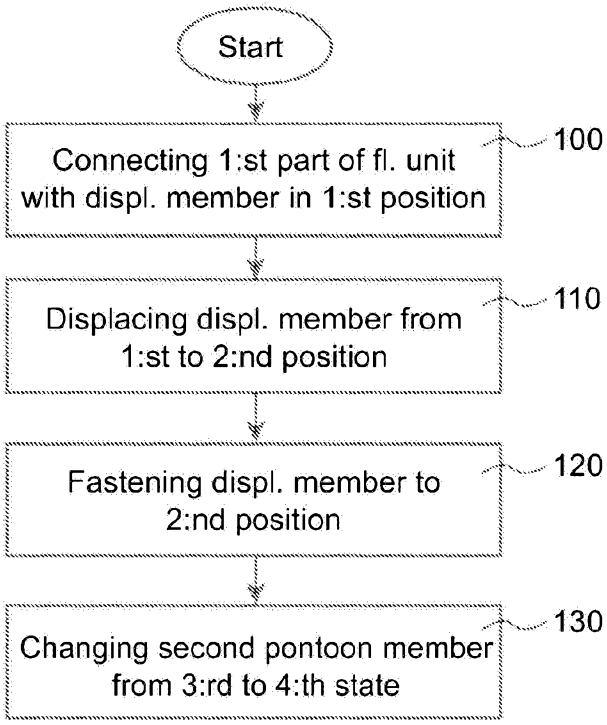
Start
Connecting 1:st part of fl. unit with displ. member in 1:st position
100
Displacing displ. member from 1:st to 2:nd position
110
Fastening displ. member to 2:nd position
120
Changing second pontoon member from 3:rd to 4:th state
130

Fig. 5a

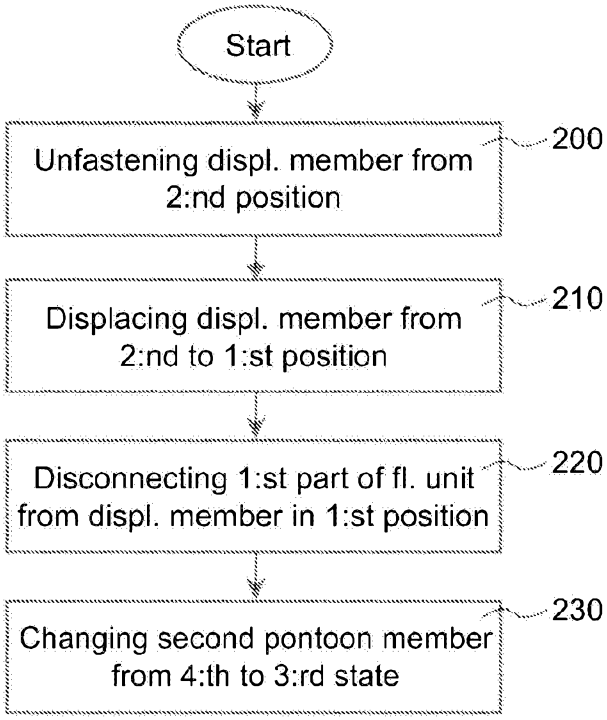
Start
Unfastening displ. member from 2:nd position
200
Displacing displ. member from 2:nd to 1:st position
210
Disconnecting 1:st part of fl. unit from displ. member in 1:st position
220
Changing second pontoon member from 4:th to 3:rd state
230

Fig. 5b