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- (73) Patenthaver: **Freia Offshore AB, Östgötagatan 100, 116 64 Stockholm, Sverige**
- (72) Opfinder: **HUMMEL, Niklas, Älgövägen 343, 133 37 Saltsjöbaden, Sverige**
RAHM, Magnus, Lönnviksvägen 7, 756 51 Uppsala, Sverige
DYACHYK, Eduard, Dalgränd 12, 121 30 Enskededalen, Sverige
- (74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**
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DESCRIPTION

Technical field

[0001] The present invention relates generally to floating wind power platform.

Background art

[0002] It is known to use a catenary mooring system as anchoring system for floating wind power platforms for offshore power production. A catenary mooring system comprises a plurality of mooring points in the sea bed via catenaries. In order to increase stability of such floating wind power platforms in the horizontal plane, essentially to keep the platform upright in windy conditions and to prevent them from falling over, size, shape as well as weight distribution are critical parameters that need to be well balanced. For instance, larger platforms comprising a plurality of towers and turbines may often be adapted for weather vaning, and need to have a sufficient distance from the rotation point to the towers, but may also require a sufficient weight at the point of rotation to be sufficiently stable. Achieving stability for larger weather vaning systems are thus critical. Mooring in the above mentioned prior art provides and has the sole purpose of station keeping of the platform, but has no impact on the stability and the platforms are constructed to have similar movement patterns in the sea regardless if they are anchored to the sea bed via the anchoring system or not. The inherited characteristic of the catenary mooring systems is further that a significant weight in mooring lines are necessary to create sufficient tension in mooring line holding force and system stiffness at the seabed. Thus, the catenary mooring systems further require a significant use of the seabed space as well as material. Prior art document D1, US2012/043763 A1, relates to a wind farm comprising at least one buoyant structure having two corners provided with a wind turbine and a third corner comprising a mooring section, e.g., with a disconnectable mooring turret. Prior art document D2, US2011/311360 A1, relates to an offshore wind turbine which includes at least one floating body supporting a wind turbine tower with belonging rotor and machinery house containing components necessary for production of energy based on wind. The at least one floating body consists of a buoyancy body, spacer and ballast structure, the floating body being connected to a steering arm which is further connected to a connecting structure having a turntable which is connected to anchor lines tied to seabed anchors. Prior art document D3, WO2011/137903 A2, relates to a semi-submerged multiple windturbine system for use in offshore wind power production implying that it is a floating system with means to maintain a permanent position at sea. The invention allegedly increases the technical and economical feasibility of multiple windturbine systems most significantly by the reduction and/or control of the loads or forces on to and within the system with derived advantages on structural induced loadings and cost as a consequence. Prior art document D4, US2016/177927 A1 relates to a wind power generation system comprising: a wind power generation equipment having a rotor which is operative to convert energy of received wind to rotational energy, a nacelle which

supports the rotor rotatably, a tower which supports the nacelle rotatably, a floating body which supports the tower and at least a part of itself is positioned above the surface of the sea, a fixing member which is installed or fixed on the sea bed, a mooring member which couples the floating body and the fixing member, wherein the mooring member is coupled to the floating body at place upward of the center of gravity of the floating body and the wind power generation equipment, and the floating body is practically supported by one fixing member. Prior art document D5, US2013/272846 A1 relates to a floating offshore wind turbine including a rotor which is rotated by wind, a nacelle in which a rotation shaft of the rotor is accommodated, and a tower including a turning seated bearing which supports the nacelle such that the nacelle can turn with respect to a sea surface to exert a weathercock effect. Prior art document D6, US2015/354532 A1 relates to a motion controller for a floating wind turbine with a plurality of rotor blades, is arranged to control a motion of the floating wind turbine in a yaw direction. The controller adjusts the blade pitch of each rotor blade so as to create a net force to control the motions. The controller includes a control action which is proportional to a yaw offset angle and/or a control action which is proportional to an integral of the yaw offset angle. Non patent prior art document D8, Mayorga Pedro: "EERA DeepWind 2016 CoAuthors: Paper presented at EERA", discloses validation tests performed on a model of W2Power Platform in scale 1:40 and a catenary mooring type configuration.

[0003] A drawback with known solutions is that the floating units are material- as well as space consuming, whereby both manufacturing and transport is expensive. As a result, the manufacturing cost further increases.

Summary of invention

[0004] An object of the present invention is to alleviate some of the disadvantages of the prior art and to provide a floating wind power platform with weather vaning capabilities which requires less material during manufacturing, is cheaper to manufacture and is less space consuming and more compact yet provide sufficient stability. A further object of the present invention is to provide a floating wind power platform with an increased efficiency.

[0005] According to one embodiment, a floating wind power platform for offshore power production is provided, comprising: a floating unit, wherein the floating unit comprises a first, a second and a third interconnected semisubmersible column each being arranged in a respective corner of the floating unit,

wherein a tension leg device is arranged to the third semisubmersible column, wherein the tension leg device is adapted to be anchored to the seabed by an anchoring device, and wherein the third semisubmersible column provides a buoyancy force adapted to create a tension force in the tension leg device, wherein the floating wind power platform is further adapted to weather vane in relation to the wind direction.

[0006] According to one embodiment, the third semisubmersible column provides an excess buoyancy force adapted to create a tension force in the tension leg device.

[0007] According to the invention, a tension leg device is arranged solely to the third semisubmersible column.

[0008] According to one embodiment, the tension leg device is arranged to the base end portion of the third semisubmersible column, wherein a diameter D_{3c} of the third semisubmersible column 3c is in the interval of $0,1 \cdot D_{30c} \leq D_{3c} \leq 0,3 \cdot D_{30c}$ in relation to a diameter D_{30c} of the base end portion of the semisubmersible column.

[0009] According to one embodiment, a diameter D_{3c} of the third semisubmersible column 3c is in the interval of $0,2 \cdot D_{3a/3b} \leq D_{3c} \leq 0,6 \cdot D_{3a/3b}$ in relation to the diameter $D_{3a/3b}$ of the first and second semisubmersible columns, respectively.

[0010] According to one embodiment, the base end portion of the third semisubmersible column is adapted to be entirely submersed in the water.

[0011] According to one embodiment, the tension leg device comprises at least one tension leg device member.

[0012] According to one embodiment, the tension leg device comprises a plurality of tension leg device members.

[0013] According to one embodiment, the tension leg device is adapted to be arranged essentially vertically between the sea bed and the third semisubmersible column.

[0014] According to one embodiment, the tension leg device is adapted to be arranged radially outwards with an angle β with respect to a reference direction z between the sea bed and the third semisubmersible column.

[0015] According to one embodiment, the angle β is in the interval of $0^\circ \leq \beta \leq 45^\circ$.

[0016] According to one embodiment, the at least one tension leg device member comprises any one of tension mooring lines, cables, chains, ropes, wires or tubular steel members.

[0017] According to one embodiment, the tension leg device is adapted to be anchored to the seabed, by an anchoring device.

[0018] According to the invention, a turret is arranged to the third semisubmersible column.

[0019] According to one embodiment, the floating unit is shaped as a triangle wherein the corners of the triangle form the corners of the floating unit.

[0020] According to one embodiment, the height h of the triangle is in the range of

30m≤h≤70m, more preferably 40m≤h≤60m, most preferably 45m≤h≤55m.

[0021] According to the invention, the floating wind power platform further comprises a first and second wind turbine, arranged to the first and second semisubmersible columns, respectively, via a first and second tower respectively.

[0022] According to one embodiment, the reference direction z is a vertical direction z.

[0023] According to one embodiment, the interconnected semisubmersible column each having a longitudinal column central axis, wherein the first and second towers have a first and second longitudinal tower central axis, respectively, wherein the first and second semisubmersible columns are arranged in the floating unit with a first and second angle α_1 , α_2 respectively, with respect to a reference direction z, and directed away from each other, wherein the first and second longitudinal tower central axes are parallel to the first and second longitudinal column central axes, respectively.

[0024] According to one embodiment, the first and second angles α_1 , α_2 are the same.

[0025] According to one embodiment, the first and second angles are in the interval of $5^\circ \leq \alpha_1$, $\alpha_2 \leq 25^\circ$, more preferably $10^\circ \leq \alpha_1$, $\alpha_2 \leq 20^\circ$, most preferably $12^\circ \leq \alpha_1$, $\alpha_2 \leq 17^\circ$.

[0026] According to one embodiment, the first and second angles α_1 , α_2 are 15° .

[0027] According to one embodiment, the floating unit comprises a truss structure.

[0028] According to one embodiment, the semisubmersible columns are interconnected to each other via upper connection members and parallelly arranged corresponding lower connection members, wherein the lower connection members are shorter than the upper connection members.

[0029] According to one embodiment, the first and second towers are interconnected to the first and second semisubmersible column, respectively.

[0030] According to one embodiment, abutment surfaces, forming interfaces between the first and second towers and the first and second semisubmersible columns, respectively, have a normal direction parallel to the first and second longitudinal tower central axes and the first and second longitudinal column central axes, respectively.

[0031] According to one embodiment, the first and second towers are integral with and forms the first and second semisubmersible columns.

[0032] According to one embodiment, the diameter and cross-sectional area of the first and second towers and the first and second semisubmersible columns, respectively, are similar.

[0033] According to one embodiment, the first and second semisubmersible columns span a plane, wherein the plane has a normal direction in a horizontal direction.

[0034] According to one embodiment, the first and second longitudinal tower central axes are aligned with the first and second longitudinal column central axes, respectively.

[0035] According to one embodiment, first and second supporting members are arranged to interconnect the first and second towers with the floating unit respectively.

[0036] According to one embodiment, the anchoring device 60 comprises a weight adapted to be arranged on the sea bed 8 by gravity.

[0037] According to one embodiment, the anchoring device comprises at least one anchoring device member adapted to be anchored to the sea bed.

[0038] According to one embodiment, the anchoring device comprises a plurality of anchoring device members adapted to be anchored to the sea bed.

[0039] According to one embodiment, the at least one anchoring device member is a suction pile anchor.

[0040] According to one embodiment of the invention, a floating wind power platform for offshore power production is provided, comprising,

a floating unit, wherein the floating unit comprises a first, a second and a third interconnected semisubmersible column each having a longitudinal column central axis and each being arranged in a respective corner of the floating unit,

a first and second wind turbine, arranged to the first and second semisubmersible columns, respectively, via a first and second tower respectively, wherein the first and second towers have a first and second longitudinal tower central axis, respectively, wherein the first and second semisubmersible columns are arranged in the floating unit with a first and second angle (α_1 , α_2) respectively, with respect to a reference direction (z), and directed away from each other, wherein the first and second longitudinal tower central axes are parallel to the first and second longitudinal column central axes, respectively.

[0041] According to one embodiment, the first and second angles (α_1 , α_2) are the same.

[0042] According to one embodiment, the first and second angles are in the interval of $5^\circ \leq (\alpha_1, \alpha_2) \leq 25^\circ$, more preferably $10^\circ \leq (\alpha_1, \alpha_2) \leq 20^\circ$, most preferably $12^\circ \leq (\alpha_1, \alpha_2) \leq 17^\circ$.

[0043] According to one embodiment, the first and second angles (α_1 , α_2) are 15° .

[0044] According to one embodiment, the floating unit is shaped as a triangle wherein the corners of the triangle form the corners of the floating unit.

[0045] According to one embodiment, the floating unit comprises a truss structure.

[0046] According to one embodiment, the semisubmersible columns are interconnected to each other via upper connection members and parallelly arranged corresponding lower connection members, wherein the lower connection members are shorter than the upper connection members.

[0047] According to one embodiment, the first and second towers are interconnected to the first and second semisubmersible column, respectively.

[0048] According to one embodiment, abutment surfaces, forming interfaces between the first and second towers and the first and second semisubmersible columns, respectively, have a normal direction parallel to the first and second longitudinal tower central axes and the first and second longitudinal column central axes, respectively.

[0049] According to one embodiment, the first and second towers are integral with and forms the first and second semisubmersible columns.

[0050] According to one embodiment, the diameter and cross-sectional area of the first and second towers and the first and second semisubmersible columns, respectively, are similar.

[0051] According to one embodiment, the first and second semisubmersible columns span a plane, wherein the plane has a normal direction in a horizontal direction.

[0052] According to one embodiment, the first and second longitudinal tower central axes are aligned with the first and second longitudinal column central axes, respectively.

[0053] According to one embodiment, first and second supporting members are arranged to interconnect the first and second towers with the floating unit respectively.

[0054] According to one embodiment, the floating wind power platform is further adapted to weather vane in relation to the wind direction.

[0055] According to one embodiment, the reference direction (z) is a vertical direction (z).

Brief description of drawings

[0056] The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows a perspective view of a floating wind power platform for offshore power production.

Fig. 2 shows a side view of the floating wind power platform according to Fig. 1.

Fig. 3 shows a side view of the floating wind power platform according to Figs. 1-2.

Fig. 4 shows a side view of the floating wind power platform according to Figs. 1-3.

Fig. 5 shows a side view of the floating wind power platform according to Figs. 1-4.

Description of embodiments

[0057] In the following, a detailed description of the invention will be given. In the drawing figures, like reference numerals designate identical or corresponding elements throughout the several figures. It will be appreciated that these figures are for illustration only and are not in any way restricting the scope of the invention.

[0058] Fig. 1 shows a perspective view of a floating wind power platform 1 for offshore power production comprising a floating unit 2. According to one embodiment, the floating unit 2 comprises three interconnected semisubmersible columns 3a, 3b, 3c, i.e. a first, a second, and a third semisubmersible column 3a, 3b, 3c, each having a longitudinal column central axis 3a', 3b', 3c' as can be further seen in Fig. 2. According to one embodiment, the floating unit 2 comprises a plurality of semisubmersible columns. According to one embodiment, the floating unit 2 comprises more than three semisubmersible columns. According to one embodiment, the floating unit 2 comprises at least three semisubmersible columns 3a, 3b, 3c. According to one embodiment, the semisubmersible columns are interconnected to each other via at least three connection members 10a, 10b, 10c, 20a, 20b, 20c. In the case of a floating unit 2 comprising more than three semisubmersible columns, the first, second and third semisubmersible columns may be indirectly interconnected to each other. According to one embodiment, the semisubmersible columns are interconnected to each other via upper connection members 10a, 10b, 10c and parallelly arranged corresponding lower connection members 20a, 20b, 20c. According to one embodiment, the lower connection members 20a, 20b, 20c are shorter than the upper connection members 10a, 10b, 10c. As a result, the total use of material in the floating unit 2 may be reduced as compared to a floating unit 2 of upper and lower connection members of similar length. According to one embodiment, the normal water level or water line 7 during use of the floating wind power platform 1 is half the distance between the upper connection members 10a, 10b, 10c, and the lower connection members 20a, 20b, 20c, respectively. According to one embodiment, the semisubmersible columns are each being arranged in a respective corner of the floating unit 2. According to one embodiment, the semisubmersible columns are buoyant structures. According to one embodiment, the semisubmersible columns extend to and has an upper end at least above the

upper connection members 10a, 10b, 10c. According to one embodiment, the semisubmersible columns 3a, 3b, 3c have a respective base end portion 30a, 30b, 30c of increased diameter which increases the buoyancy and the displacement of the semisubmersible columns 3a, 3b, 3c as well as their respective areas and thus resistance to move in the water. According to one embodiment, the base end portions 30a, 30b, 30c are cylinder shaped comprising a central axis 30a', 30b', 30c' respectively (not shown), wherein each central axis 30a', 30b', 30c' is parallel to a reference direction z. According to one embodiment, the distance between the central axis 30a' and central axis 30b' is approximately 100 m, also referred to as the length of the platform. According to one embodiment, the distance between the central axis 30c' and either of central axis 30a' or 30b' is approximately 70 m. According to one embodiment, the reference direction z is essentially parallel to or parallel to a normal direction of a plane spanned by the end points of the of the longitudinal column central axes 3a', 3b', 3c' on the respective semisubmersible columns 3a, 3b, 3c. According to one embodiment, the reference direction z is essentially parallel to or parallel to a normal direction of a plane spanned by the upper connection members 10a, 10b, 10c, or alternatively, the lower connection members 20a, 20b, 20c, or both. According to one embodiment the reference direction z is essentially parallel to or parallel to a vertical line or a plumb line during normal use of the wind power platform 1. According to one embodiment the reference direction z is a vertical direction z. According to one embodiment, the floating unit 2 is shaped as a triangle wherein the corners of the triangle form the corners of the floating unit 2. According to one embodiment the triangle is an isosceles triangle. According to one embodiment, the connection members 10a, 10c, and/or 20a, 20c have different lengths, respectively thus forming a non-isosceles or non-uniform, i.e. and oblique triangle. According to one embodiment, the floating unit is shaped as a polygon with semisubmersible columns in each corner. According to one embodiment, semisubmersible columns may be arranged centrally in the floating unit 2. According to one embodiment, the floating unit 2 comprises a truss structure. According to one embodiment, the floating unit 2 comprises a framework structure. According to one embodiment, a plurality of connection members are arranged to interconnected upper and lower connection members.

[0059] According to one embodiment, a tension leg device 6 is arranged to the third semisubmersible column 3c, wherein the tension leg device 6 is adapted to be anchored to the seabed 8. According to one embodiment, the tension leg device 6 is arranged to the base end portion 30c of the third semisubmersible column 3c. According to one embodiment, the base end portion 30c of the third semisubmersible column 3c has a significantly increased diameter compared to the third semisubmersible column 3c. According to one embodiment, as can be further seen in Fig. 2, diameter D_{3c} of the third semisubmersible column 3c is in the interval of $0,1 \cdot D_{30c} \leq D_{3c} \leq 0,3 \cdot D_{30c}$ in relation to the diameter D_{30c} of the base end portion 30c of the semisubmersible column 3c. According to one embodiment, diameter D_{3c} of the third semisubmersible column 3c is in the interval of $0,2 \cdot D_{3a/3b} \leq D_{3c} \leq 0,6 \cdot D_{3a/3b}$ in relation to the diameter $D_{3a/3b}$ of the first and second semisubmersible columns 3a, 3b, respectively. According to one embodiment, the diameter $D_{3a/3b}$ of the first and second semisubmersible columns 3a, 3b is measured at the water line 7 during use. According to one embodiment, the

diameter D_{3c} of the third semisubmersible columns 3c is measured at the water line 7 during use. According to one embodiment, the third semisubmersible column 3c has a diameter which is significantly smaller than the diameter of the first and second semisubmersible columns 3a, 3b. According to one embodiment, the diameter of the semisubmersible columns 3a, 3b are in the interval of $5\text{m} \leq D_{3a/3b} \leq 10\text{m}$. According to one embodiment, the diameter of the semisubmersible columns 3a, 3b are in the interval of $6\text{m} \leq D_{3a/3b} \leq 8\text{m}$. According to one embodiment, reducing the diameter D_{3c} in relation to D_{30c} provides a reduced water line area of the third semisubmersible column 3c which reduces the exposure to waves and thus risk of resulting unwanted movements of the floating wind power platform 1. According to one embodiment, the third semisubmersible column 3c provides a buoyancy force adapted to create a tension force in the tension leg device 6. According to one embodiment, the third semisubmersible column 3c provides an excess buoyancy force adapted to create a tension force in the tension leg device 6. According to one embodiment, excess buoyancy is defined as a buoyancy occurring when weight of the displaced water is higher than the weight of the platform 1. According to one embodiment, the upward directed force is held by the tension leg device 6 preventing the rising of the platform 1. According to one embodiment, during excess buoyancy, the buoyancy of the platform 1 exceeds its weight creating a rising or upward directed force on the platform 1 in a z direction. According to one embodiment, stability of the floating wind power platform 1 is provided by excess buoyancy and the resulting tension force in the tension leg device 6. According to one embodiment, stability of the floating wind power platform is provided partially by the platform buoyancy and partially from the tension leg device mooring system with weather vaning capability. According to one embodiment, the base end portion 30c of the third semisubmersible column 3c is adapted to be entirely submersed in the water. According to one embodiment, the base end portion 30c of the third semisubmersible column 3c is adapted to be entirely submersed below the water line 7, or mean sea level 7, as seen in Fig. 2. According to the invention, the tension leg device 6 is arranged solely to the third semisubmersible column, i.e. the first and second semisubmersible columns 3a, 3b are not provided with respective tension leg devices 6. According to one embodiment, the tension leg device 6 comprises at least one tension leg device member 6a, 6b, 6c, 6d, 6e, 6f. According to one embodiment, the tension leg device 6 comprises a plurality of tension leg device members 6a, 6b, 6c, 6d, 6e, 6f. According to one embodiment, the tension leg device 6 comprises at least six tension leg device members 6a, 6b, 6c, 6d, 6e, 6f. According to one embodiment, the tension leg device 6 comprises at least six tension leg device members 6a, 6b, 6c, 6d, 6e, 6f but may require any suitable number of tension leg device members 6a, 6b, 6c, 6d, 6e, 6f based on the application or environmental conditions. According to one embodiment, the tension leg device 6 is adapted to be arranged essentially vertically between the sea bed 8 and the first semisubmersible column 3c. According to one embodiment, the tension leg device 6 is adapted to be arranged vertically between the sea bed 8 and the first semisubmersible column 3c. According to one embodiment, the tension leg device members 6a, 6b, 6c, 6d, 6e, 6f are adapted to be arranged with an angle β with respect to the reference direction z between the sea bed 8 and the third semisubmersible column 3c. According to one embodiment, at least one of the tension leg device members 6a, 6b, 6c, 6d, 6e, 6f are adapted to be arranged with an angle β with respect to the reference direction z between the sea bed 8

and the third semisubmersible column 3c. According to one embodiment, the tension leg device members 6a, 6b, 6c, 6d, 6e, 6f are adapted to be arranged radially outwards with an angle β with respect to the reference direction z which is in the interval of $0^\circ \leq \beta \leq 45^\circ$. According to one embodiment, the at least one tension leg device member 6a, 6b, 6c, 6d, 6e, 6f comprises tension mooring lines or cables or chains or ropes or wires. According to one embodiment, the at least one tension leg device member 6a, 6b, 6c, 6d, 6e, 6f comprises tubular steel members sometimes referred to as tendons. According to one embodiment, the tension leg device 6 is adapted to be anchored to the sea bed 8 by an anchoring device 60. According to one embodiment, the anchoring device 60 comprises a weight adapted to be arranged on the sea bed 8 by gravity. According to one embodiment, the anchoring device 60 comprises at least one anchoring device member 60a, 60b, 60c, 60d, 60e, 60f adapted to be anchored to the sea bed 8. According to one embodiment, the anchoring device 60 comprises a plurality of anchoring device members 60a, 60b, 60c, 60d, 60e, 60f adapted to be anchored to the sea bed 8. According to one embodiment, each tension leg device member 6a, 6b, 6c, 6d, 6e, 6f is provided with an anchoring device member 60a, 60b, 60c, 60d, 60e, 60f respectively. According to one embodiment, the anchoring devices members 60a, 60b, 60c, 60d, 60e, 60f are suction pile anchors.

[0060] According to the invention, the floating wind power platform 1 is adapted to weather vane in relation to the wind direction. According to one embodiment, weather vaning is provided by a turret 9 arranged to the floating unit 2. According to the invention, the turret 9 is arranged to the third semisubmersible column 3c. According to one embodiment, the turret 9 is arranged to the base end portion 30c of the third semisubmersible column 3c. According to one embodiment, the turret 9 is interconnected to a mooring system. According to one embodiment, the turret 9 is interconnected to the tension leg device 6. According to one embodiment the turret 9 is interconnected to the tension leg device 6 via the third semisubmersible column 3c.

[0061] According to one embodiment, as can be further seen in Fig. 2, the weight distribution, or center of gravity may be changed in the platform 1 by a ballast system 12. The platform 1 comprises the ballast system 12, wherein the ballast system 12 comprises ballast tanks 12a, 12b provided in at least the first and second semisubmersible columns 3a, 3b, respectively. According to one embodiment, the ballast system 12 comprises ballast tanks 12a, 12b, 12c provided in at least the first, second and third semisubmersible columns 3a, 3b, 3c, respectively. A control system 11 adapted to control the amount of water in the ballast tanks is further provided. According to one embodiment, the ballast system 12 enables leveling of the platform 1 e.g. during changes of water level between ebb and flow. According to one embodiment, controlling the amount of water in the ballast tank 12c in the third semisubmersible column 3c enables controlling the draught and buoyancy of the semisubmersible column 3c whereby the tension force in the tension leg device 6 may further be controlled. According to one embodiment, provisional or temporary stability during transportation and installation of the platform 1 may be achieved by using a reduced amount of ballast water in the ballast tanks 12a, 12b, 12c which provide a reduced draught of the platform 1 causing the base end portion 30c of the third semisubmersible column 3c to be at the water

line 7 increasing the water line area and the stability during transportation and installation. According to one embodiment, provisional or temporary stability during transportation and installation of the platform 1 may be achieved by arranging a provisional or temporary volume on the third semisubmersible column 3c providing additional buoyancy, whereby the water line area is increased and consequently the stability of the platform 1 during transportation and installation of the same. According to one embodiment the volume is bolted or welded onto the third semisubmersible column 3c. As a step of the installation, the volume is removed from the third semisubmersible column 3c whereby the tension leg device 6 is arranged to the third semisubmersible column 3c.

[0062] In prior art solutions in general, weather vaning platforms or structures get all their stability from buoyancy forces. Mooring in such prior art provides and has the sole purpose of station keeping. Weather vaning platforms or structures needs extra stability as they rotate around one point at which they are connected to the sea bed and otherwise float freely based on the buoyancy of the structure. Such structures are usually large as weather vaning enables using a plurality of towers on the same platform in an efficient manner. The larger size reflects both the required displacement as well as structure size. Sufficient distance from the towers to the rotation point in a y-direction is required, as is a sufficient weight and buoyancy and thus material at the rotation point to provide a stable platform. The platform or structure with weather vaning capabilities of the prior art are consequently constructed to be inherently stable and would not fall over even if they would be disconnected from the sea bed. At the same time, the larger size of weather vaning platforms to achieve sufficient stability may have negative implications on their ability to rotate during weather vaning, as the larger displacement also in relation to tower size results in a slowness to move in the water and thus adapt to changes in the weather conditions such as e.g wind direction. Further, a larger displacement would make the platform more inclined to adapt to changes in water current direction than wind direction which have negative implications on the resulting equilibrium state of the platform 1 from current and wind. Overall, this causes a drawback of reduced efficiency of such platforms.

[0063] According to one embodiment, the triangle forming the floating unit 2 has a height, i.e. a distance from the upper connection member 10b to the third semisubmersible column 3c in the y-direction which can be significantly reduced compared to floating units of wind power platforms which do not rely on constant tension force in the tension leg device 6 according to the embodiment of the invention. The height is also referred to as the platform beam or platform width. According to one embodiment, the platform height or beam may be reduced by between 40-60% compared to such wind power platforms of the prior art. According to one embodiment, the platform beam is approximately 50 meters wherein the platform length, as described in [0031], is approximately 100 meters. According to one embodiment, the height h of the triangle is in the range of $30\text{m} \leq h \leq 70\text{m}$, more preferably $40\text{m} \leq h \leq 60\text{m}$, most preferably $45\text{m} \leq h \leq 55\text{m}$. According to one embodiment, the ratio r_{b-hh} of the beam of the platform 1 and the hub-height, i.e. distance from the water line 7 during use, to the rotational axis 4a', 4b' of the turbine rotors at its intersection of the first and second longitudinal tower central axis 5a', 5b' respectively, is in the interval of $0,3 \leq r_{b-hh} \leq 0,70$, more preferably $0,4 \leq r_{b-hh} \leq 0,60$, most preferably $0,5 \leq r_{b-hh} \leq 0,6$. According to one embodiment, the ratio r_{b-rd} of the beam of the

platform 1 and the rotor diameter is in the interval of $0,25 \leq r_{b-rd} \leq 0,60$, more preferably $0,3 \leq r_{b-rd} \leq 0,55$, most preferably $0,35 \leq r_{b-rd} \leq 0,50$. As previously discussed herein, the invention enables lower ratios above than in prior art solutions, which reduces cost and increases efficiency of the platform 1.

[0064] According to the invention, the floating wind power platform comprises a first and second wind turbine 4a, 4b, arranged to a first and second semisubmersible column 3a, 3b, respectively, via a first and second tower 5a, 5b, respectively. According to one embodiment, if the floating unit 2 comprises more than three semisubmersible columns, further wind turbines may be arranged in the floating unit 2, e.g. on semisubmersible columns. According to one embodiment, if further wind turbines are arranged in the floating unit 2, they may be arranged in a row. According to the invention, a turret is attached to a third semisubmersible column 3c. According to one embodiment, the first and second tower 5a, 5b has a first and second longitudinal tower central axis 5a', 5b', respectively as can be further seen in Fig. 2. According to one embodiment, the first and second towers 5a, 5b are interconnected to the first and second semisubmersible column 3a, 3b, respectively. According to one embodiment, if three semisubmersible columns are arranged in a row, the middle semisubmersible column and wind tower may have a longitudinal column central axis and longitudinal tower central axis that are parallel to the reference direction z. According to one embodiment, the diameter and cross-sectional area of the first and second towers 5a, 5b and the first and second semisubmersible columns 3a, 3b respectively, are similar. According to one embodiment, abutment surfaces 3a'', 5a'' and 3b'', 5b'' forming interfaces between the first and second towers 5a, 5b and the first and second semisubmersible columns 3a, 3b, respectively, have a normal direction parallel to the first and second longitudinal tower central axes 5a', 5b' and first and second longitudinal column central axes 3a', 3b', respectively. According to one embodiment, the abutment surfaces 3a'', 5a'' and 3b'', 5b'' have a circular ring shape. According to one embodiment, the abutment surfaces 3a'', 5a'' and 3b'', 5b'' have a circular area shape. Thus, the selection of such normal direction of the abutment surfaces enables the use of circular, circular ring or circular areas as opposed to elliptically shaped abutment surfaces resulting from abutment surfaces of the towers and/or columns having a normal direction being non-parallel to the longitudinal tower central axis and/or longitudinal column central axis. The shaping of elliptical abutment surfaces is difficult to achieve with a sufficient accuracy to enable the necessary fit between two elliptical abutment surfaces required during attachment between the tower 5a, 5b and the semisubmersible column 3a, 3b. This is particularly so since the abutment surfaces are commonly shaped as bolt flanges comprising holes for bolts or bolted connections which need to match during attachment procedure. As a result, standard wind towers 5a, 5b may be used for the floating wind power platform 1 according to the invention and no specially made or designed wind towers have be used which would increase the cost of manufacture. Further, if both tower 5a'', 5b'' and column abutment surfaces 3b'', 5b'' have a normal direction parallel to the respective longitudinal tower central axis 5a', 5b' and longitudinal column central axis 3a', 3b', the difficulty of trying to combine and attach a circular, circular ring, or circular area shape to an elliptical, elliptical ring, elliptical area shape respectively is avoided. According to one embodiment, the first and second towers 5a, 5b are integral with and forms the first and second semisubmersible columns 3a, 3b.

[0065] Fig. 2 shows a side view of the floating wind power platform 1 for offshore power production as seen essentially in a direction parallel to a rotational axis 4a', 4b' of the turbine rotors. According to one embodiment, the first and second semisubmersible columns 3a, 3b are arranged in the floating unit 2 with a first and second angle α_1, α_2 respectively, with respect to a reference direction z, and directed away from each other. According to one embodiment, being directed away from each other also means that the wind turbines are farther away from each other than other portions of their respective semisubmersible columns 3a, 3b, or at least the lowermost base end portion of the semisubmersible columns 3a, 3b. According to one embodiment, the first and second semisubmersible columns 3a, 3b are directed away from each other with a total angle corresponding to $\alpha_1 + \alpha_2$ seen in a plane spanned by the first and second semisubmersible columns 3a, 3b. According to one embodiment, the first and second longitudinal tower central axes 5a', 5b' are parallel to the first and second longitudinal column central axes 3a', 3b', respectively. According to one embodiment the first and second longitudinal tower central axis 5a', 5b' is aligned with the first and second longitudinal column central axis 3a', 3b', respectively. According to one embodiment the inclination of the first and second semisubmersible columns 3a, 3b and first and second towers 5a, 5b enables a more compact floating unit 2, while at the same time the distance between the wind turbines 4a, 4b can be kept at a sufficient or similar distance as without the inclination, thereby also enabling the use of sufficiently large or similarly sized turbine rotor blades for the energy production, as without the inclination. In this sense, the floating unit 2 aims to optimize the size/cost vs its ability of energy production. According to one embodiment the first and second angles α_1, α_2 are the same. According to one embodiment, the first and second angles are in the interval of $5^\circ \leq (\alpha_1, \alpha_2) \leq 25^\circ$, more preferably $10^\circ \leq (\alpha_1, \alpha_2) \leq 20^\circ$, most preferably $12^\circ \leq (\alpha_1, \alpha_2) \leq 17^\circ$. According to one embodiment, the first and second angles (α_1, α_2) are 15° . As a further effect of using first and second semisubmersible columns 3a, 3b that are arranged in the floating unit 2 with a first and second angle α_1, α_2 respectively, with respect to a reference direction z, a floating unit 2 with a higher water line area is provided which provides a higher hydrodynamic rigidity, i.e. a higher resistance in the water. The higher resistance in the water provides a resistance against unwanted movements of the floating unit 2 during use. As a result, the displacement of the floating unit 2, e.g. by the semisubmersible columns 3a, 3b, 3c and their respective end portions 30a, 30b, 30c, may be reduced. The reduction of the displacement enables the reduction of material and thus further lowers the cost of manufacturing the floating unit 2 and wind power platform 1. According to one embodiment, the first and second semisubmersible 3a, 3b are arranged in the floating unit 2 wherein the first and second angle α_1, α_2 is zero, i.e. wherein the first and second semisubmersible 3a, 3b are not directed away from each other.

[0066] Fig. 3 shows a side view of the floating wind power platform 1 for offshore power production, as seen perpendicular to the rotational axis 4a', 4b' of the turbine rotors. As can be seen herein, according to one embodiment, the first and second semisubmersible columns 3a, 3b span a plane, wherein the plane has a normal direction in a horizontal direction y. According to one embodiment, the first and second semisubmersible columns 3a, 3b span a plane,

wherein the plane has a normal direction y which is perpendicular to the reference direction z . According to one embodiment, the z and y directions are defined to form or correspond to the axes of a coordinate system as seen in Fig. 2, further comprising a further horizontal direction x . According to one embodiment, the longitudinal central axis $3c'$ of a third semisubmersible column $3c$ is parallel to the reference direction z . According to one embodiment, if the floating unit 2 is shaped as an oblique triangle, the plane spanned by the first and second semisubmersible columns $3a$, $3b$ will not be in a direction parallel to the wind direction during weather vaning, during use when the platform 1 and floating unit 2 has reached a balanced state. Thus, in these cases the plane spanned by the first wind turbine rotor and the second wind turbine rotor will be different planes, and one of the first and second columns $3a$, $3b$ will be an upwind column and the other will be a downwind column.

[0067] Fig. 4 shows a side view of the floating wind power platform 1 for offshore power production seen in a negative z -direction.

[0068] Fig. 5 shows a side view of the floating wind power platform 1 for offshore power production. As seen herein, according to one embodiment, first and second supporting members $40a$, $40b$ are arranged to interconnect the first and second towers $5a$, $5b$ with the floating unit 2 respectively. According to one embodiment, at least one supporting member $40a$, $40b$ may be arranged between and interconnecting the two towers $5a$, $5b$. According to one embodiment, the use of supporting members $40a$, $40b$ reduces the stress at the connection point of the towers $5a$, $5b$ with the columns $3a$, $3b$, respectively, such as e.g. at the bolt connections at the abutment surfaces $3a''$, $5a''$, and $3b''$, $5b''$, due to gravitation. According to one embodiment, the use of supporting members $40a$, $40b$ increases the stability of the wind power platform 1. According to one embodiment, the wind turbines $4a$, $4b$ are configured to be rotatable in relation to the wind towers $5a$, $5b$, respectively wherein the axis of rotation is parallel to the longitudinal tower central axis $5a'$, $5b'$. According to one embodiment, the wind turbines $4a$, $4b$ are configured to be rotatable in relation to the wind towers $5a$, $5b$, respectively, wherein the axis of rotation is parallel to the reference direction z . According to one embodiment, the rotation, i.e. a relative angular displacement of the wind turbines with respect to the wind towers $5a$, $5b$, respectively are limited whereby engagement of the wind turbine rotor blades and the wind towers are avoided e.g. during use. According to one embodiment, the limitation is configured to be set by the mechanical construction, such as e.g. a mechanical stop. According to one embodiment, the limitation is configured to be set by a software. According to one embodiment, the wind power platform 1 is configured for energy production by the rotation of the wind turbine rotor blades, and generated in the wind turbines or nacelles by e.g. a generator. According to one embodiment, the offshore power /energy production may be transferred to or brought onshore via an energy cable configured for transferring energy.

[0069] A preferred embodiment of a floating wind power platform 1 for offshore power production has been described. However, the person skilled in the art realizes that this can be varied within the scope of the appended claims without departing from the inventive idea.

[0070] All the described alternative embodiments above or parts of an embodiment can be freely combined without departing from the inventive idea as long as the combination is not contradictory.

REFERENCES CITED IN THE DESCRIPTION

Cited references

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Patentkrav

- 1.** Flydende vindkraftplatform (1) til offshore-strømproduktion, omfattende:
- en flydende enhed (2), hvor den flydende enhed omfatter en første, en anden og en tredje indbyrdes forbundet halvt nedsænkkelig søjle (3a, 3b, 3c), der hver er anbragt i et respektivt hjørne af den flydende enhed (2), idet den flydende vindkraftplatform (1) yderligere omfatter en første og anden vindmølle (4a, 4b), indrettet til henholdsvis den første og anden halvt nedsænkkelige søjle (3a, 3b), via henholdsvis et første og andet tårn (5a, 5b),
- hvor en spændingsbensindretning (6) er indrettet udelukkende til den tredje halvt nedsænkkelige søjle (3c), hvor spændingsbensindretningen (6) er indrettet til at blive forankret til havbunden (8) ved hjælp af en forankringsindretning (60), og hvor tredje halvt nedsænkkelig søjle (3c) tilvejebringer en opdriftskraft indrettet til at skabe en spændingskraft i spændingsbensindretningen (6),
- hvor den flydende vindkraftplatform (1) er yderligere indrettet til en vindfane i forhold til vindretningen, hvor et tårn (9) er indrettet til den tredje halvt nedsænkkelige søjle (3c).
- 2.** Den flydende vindkraftplatform (1) ifølge krav 1, hvor den tredje halvt nedsænkkelige søjle (3c) tilvejebringer en overskydende opdriftskraft indrettet til at skabe en spændingskraft i spændingsbensindretningen (6).
- 3.** Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor spændingsbensindretningen (6) er anbragt på basisendedelen (30c) af den tredje halvt nedsænkkelige søjle (3c), hvor en diameter D_{3c} af den tredje halvt nedsænkkelige søjle (3c) er i intervallet $0,1 \cdot D_{30c} \leq D_{3c} \leq 0,3 \cdot D_{30c}$ i forhold til en diameter D_{30c} af basisendedelen (30c) af den halvt nedsænkkelige søjle (3c).
- 4.** Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor en diameter D_{3c} af den tredje halvt nedsænkkelige søjle (3c) er i intervallet $0,2 \cdot D_{3a/3b} \leq D_{3c} \leq 0,6 \cdot D_{3a/3b}$ i forhold til diameteren $D_{3a/3b}$ af henholdsvis den første og anden halvt nedsænkkelige søjle (3a, 3b).

5. Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor basisendedelen (30c) af den tredje halvt nedsænkkelige søjle (3c) er indrettet til at være helt nedsænket i vandet.

5 **6.** Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor spændingsbensindretningen (6) omfatter mindst et spændingsbensindretningselement (6a, 6b, 6c, 6d, 6e, 6f).

7. Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående
10 krav, hvor spændingsbensindretningen (6) omfatter en flerhed af spændingsbensindretningselementer (6a, 6b, 6c, 6d, 6e, 6f).

8. Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor spændingsbensindretningen (6) er indrettet til at være anbragt i det
15 væsentlige vertikalt mellem havbunden (8) og den tredje halvt nedsænkkelige søjle (3c).

9. Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav 6-8, hvor det mindst ene spændingsbensindretningselement (6a, 6b, 6c, 6d,
20 6e, 6f) omfatter en hvilken som helst af spændingsfortøjningslinier, kabler, kæder, reb, wirer eller rørformede stålelementer.

10. Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor spændingsbensindretningen (6) er indrettet til at blive
25 forankret til havbunden (8) ved hjælp af en forankringsindretning (60).

11. Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor den flydende enhed (2) er formet som en trekant, hvori trekantens hjørner danner hjørnerne af den flydende enhed (2).

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12. Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor højden af trekanten er i området $30\text{m} \leq h \leq 70\text{m}$, mere fortrinsvis $40\text{m} \leq h \leq 60\text{m}$, mest fortrinsvis $45\text{m} \leq h \leq 55\text{m}$.

13. Den flydende vindkraftplatform (1) ifølge et hvilket som helst af de foregående krav, hvor referenceretningen (z) er en vertikal retning (z).

DRAWINGS

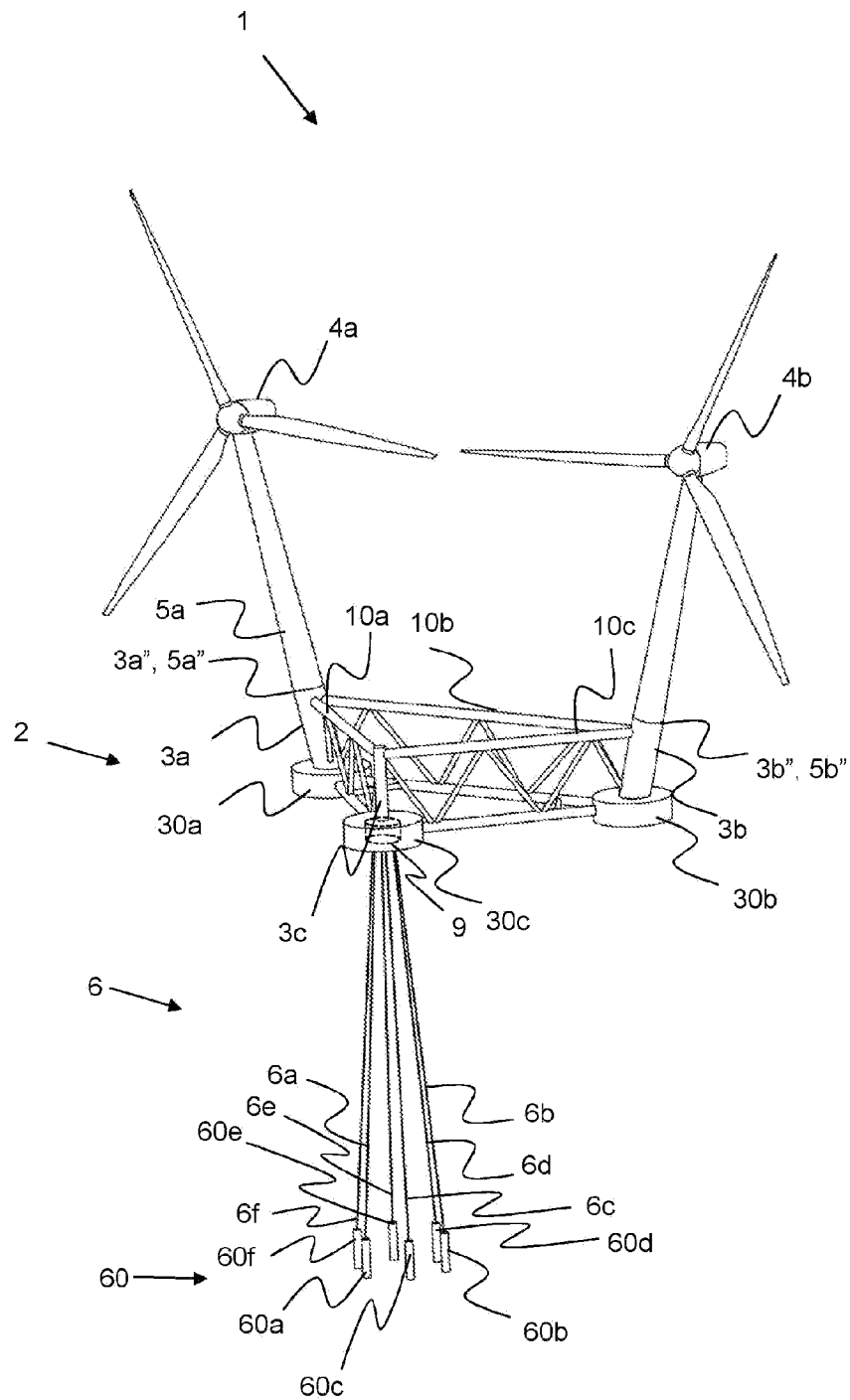


Fig. 1

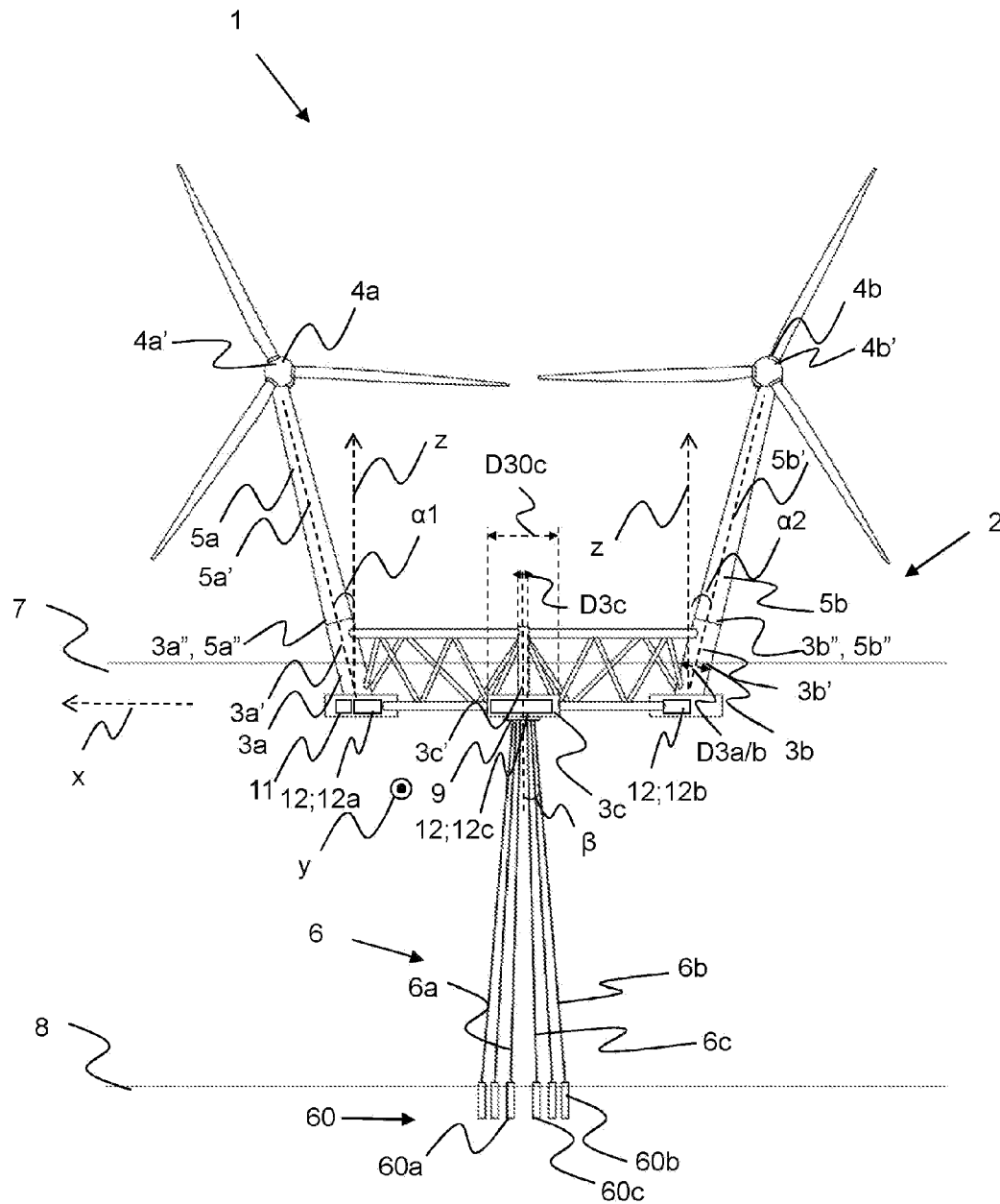


Fig. 2

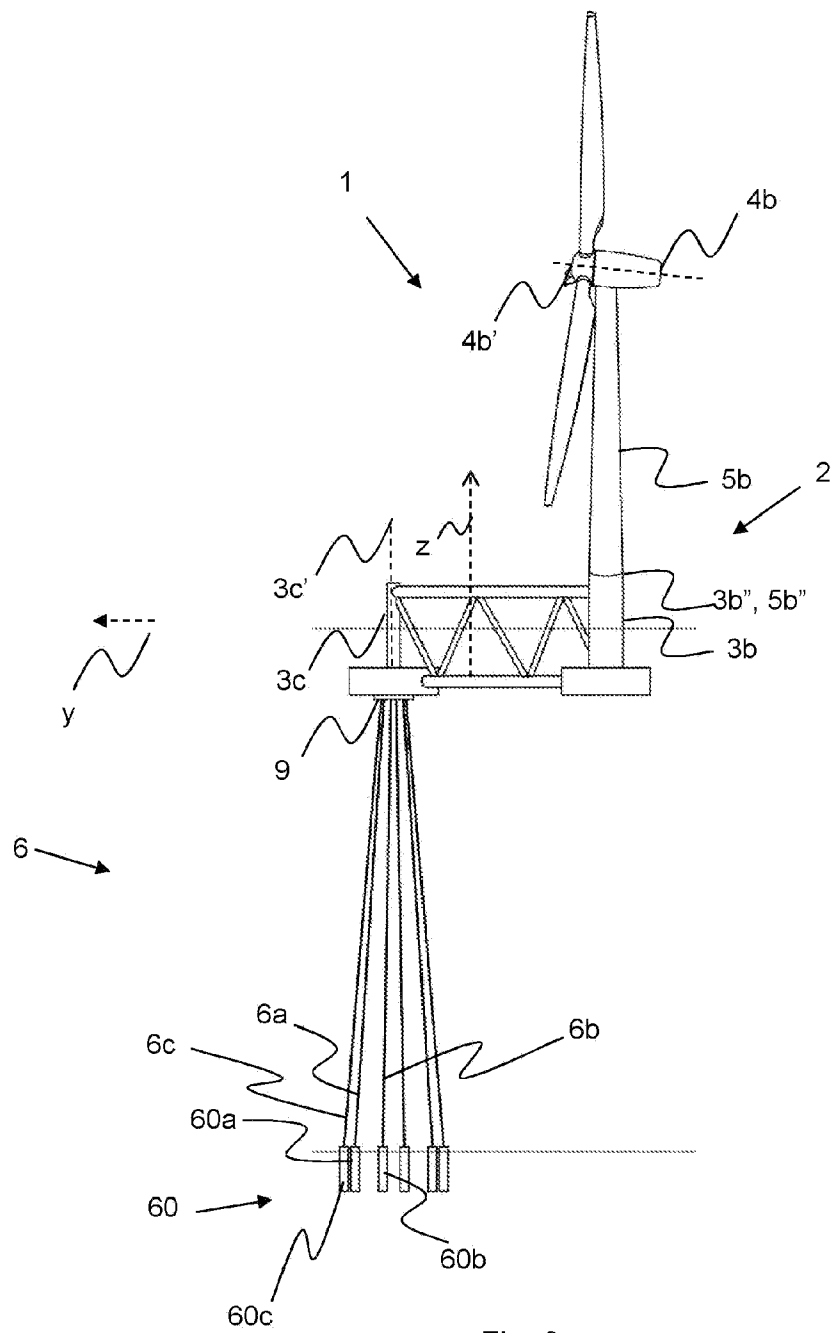


Fig. 3

