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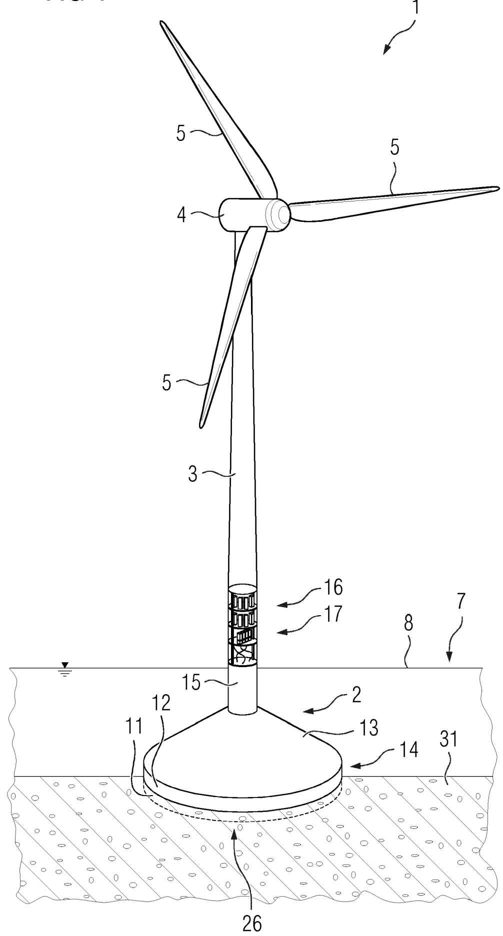
(54) **METHOD FOR ASSEMBLING AN OFFSHORE WIND TURBINE, TOWER FOUNDATION FOR AN OFFSHORE WIND TURBINE AND OFFSHORE WIND TURBINE**

(57) Method for assembling an offshore wind turbine (1), wherein the wind turbine (1) comprises a tower foundation (2) with at least one hollow ballast chamber (24, 25), wherein the method comprises the following steps:
- assembling the tower foundation (2) on a dry dock-like construction site (6), wherein the construction site (6) is located below the sea level (8) and separated from the sea (7) by a barrier (9),
- launching the tower foundation (2) to the sea (7) by, at least partially, removing or opening the barrier (9) and/or filling water into the construction site (6) leading to a flooding of the construction site (6),
- towing the swimming tower foundation (2) to a target position (26) on the sea (7) by a vessel (27),
- loading the at least one ballast chamber (24, 25) of the tower foundation (2) with ballast material (24, 25) causing the tower foundation (2) to sink down until it permanently rests on the sea ground (31), and
- installing a tower (3) of the wind turbine (1) on the tower foundation (2).

FIG 1



EP 3 767 035 A1

Description

[0001] The present invention relates to a method for assembling an offshore wind turbine, to a tower foundation for an offshore wind turbine and to an offshore wind turbine.

[0002] Typically, the upper parts of an offshore wind turbine like a tower, a nacelle, several blades etc. are supported or held by a tower foundation of the wind turbine. The tower foundation typically is typically situated at the ground of the sea and stands out above the sea level. So far, several tower foundation concepts have been developed. Which tower foundation concept is the best for a certain offshore wind turbine typically depends on the size and the weight of the wind turbine and on specific conditions of the location where the wind turbine will be installed, like the water depth and the state of the sea ground.

[0003] One of these concepts is the monopile foundation concept, wherein one central pile extends into the sea ground and supports the remaining parts of the wind turbine. This concept is typically used at locations with a medium water depth, a sand-clay seabed and for medium size wind turbines.

[0004] Another concept is the jacket structure concept, wherein several smaller piles extend into the ground of the sea and a jacket structure which holds the tower is attached to and held by the piles. Compared to the monopile foundation concept, the jacket structure concept is typically used for deep water depth up to several tenth of meters and larger wind turbines. It is suitable for different seabed conditions.

[0005] Another concept is the gravity base structure concept, wherein a heavy tower foot consisting of steel reinforced concrete rests on the seabed and is held in position mainly by its own gravitational force. This concept is suitable for all water depths which are typical for offshore wind turbines, and also for larger wind turbines. The gravity base structure is typically capable to absorb relatively high load bearings.

[0006] It is an object of the present invention to provide an enhanced and simplified concept for offshore wind turbines, in particular with respect to the assembling process.

[0007] To solve this problem, a method for assembling an offshore wind turbine is provided, wherein the wind turbine comprises a tower foundation with at least one hollow ballast chamber, wherein the method comprises the following steps:

- assembling the tower foundation in a dry dock-like construction site, wherein the construction site is located below the sea level and separated from the sea by a barrier,
- launching the tower foundation to the sea by, at least partially, removing or opening the barrier and/or filling water into the construction site leading to a flooding of the construction site,
- towing the swimming tower foundation to a target position on the sea by a vessel,
- loading the at least one ballast chamber of the tower foundation with ballast material causing the tower foundation to sink down until it permanently rests on the sea ground, and
- installing a tower of the wind turbine on the tower foundation while the tower foundation is located in the dry dock-like construction site or at the target position.

[0008] The ballast chamber is an empty section or room of the tower foundation adapted to be filled with ballast material. The ballast material increases the total mass of the tower foundation without changing the total volume of the tower foundation. If the tower foundation is arranged in water, this causes a change in the buoyancy or lifting force of the tower foundation.

[0009] The target position is the location on the sea or ocean where the offshore wind turbine is supposed to be installed or built. In particular, the target position or location can be in an area of an offshore wind park. The construction site is preferably located at the coast close to the target position. Hence, fabricating the tower foundation can be done locally and such that no long transportation routes are required.

[0010] The barrier prevents water from flooding or streaming into the construction site during the fabrication process of the tower foundation. After the tower foundation has been fabricated, the barrier is opened or removed allowing water, in particular from the sea, to stream into the dry dock-like construction site. Since the at least one ballast chamber is in the unloaded state, the buoyancy of the tower foundation is large enough leading the tower foundation to swim or float on the surface of the sea water or, in other words, sea level. The buoyancy of the tower foundation can either be large enough such that it floats on its own or with the additional help of buoyancy means like pontoons. The buoyancy means increase the total buoyancy of the tower foundation which is the sum of the buoyancy of the tower foundation itself and the additional buoyancy provided by the buoyancy means.

[0011] Next, the floating tower foundation is towed or dragged to the target position. For this purpose, the sea can preferably be accessed directly from the flooded construction site. The tower foundation can be connected with the vessel or tug boat or other suitable water vehicle, e.g. by ropes, right at the place where the tower foundation has been fabricated. Hence, the tower foundation can be transported from its fabrication location to the target position exclusively on a seaway. Countryside transportation means are not necessary at all.

[0012] Once the tower foundation has reached the target position, the total buoyancy of the tower foundation is decreased by loading or filling the at least one ballast chamber with ballast material. Additionally, if provided, the buoyancy means are disconnected from the tower foundation. Once the force of gravity of the tower foundation exceeds the buoyancy force of the tower foundation, the tower foundation will start sinking down to the sea ground. After finishing the loading process of the ballast chamber, there is enough ballast material within the ballast chamber of the tower foundation so that the gravitational force of the tower foundation is large enough, such that it permanently or safely rests on the sea ground. Especially the expected sea current, in particular caused by tidal movements or storms, is not strong enough to remove the tower foundation from the target position or to overthrow the tower foundation or wind turbine, respectively.

[0013] Preferably, as will be described later in more detail, a section of the tower foundation is located above the sea level if the tower foundation rests on the sea ground, wherein the tower or a tower section of the wind turbine with other components like a nacelle and several blades can be attached to the section of the tower foundation which is located above the sea level. Alternatively, installing the tower or tower section can already be performed while the tower foundation is still located at the dry dock-like construction site, preferably before the dry dock-like construction site is flooded. Then, the tower foundation stabilizes the wind turbine when being transported or towed to the target position.

[0014] The present invention allows an offshore wind turbine, in particular the tower foundation, to be installed with comparably low effort and costs. In contrast to already known tower foundation concepts there is no need for expensive equipment like big cranes on vessels or the like. The tower foundation has only to be towed to the target position and the ballast chamber has to be filled with ballast material. Hence, a standard tug boat or vessel can be used for installing the tower foundation.

[0015] In addition, the hollow structure of the tower foundation allows the tower foundation to be designed without strict limitations. In other words, the dimensions of the tower foundation can be selected from a wide range without making the tower foundation, since it swims or floats on the sea level, too heavy to be towed to the target position. E.g., the area of the tower foundation, which is supposed to get in contact with the sea ground, can be enlarged, allowing to install the respective tower foundation at target positions with non-optimal seabed conditions. For example, if the sea ground comprises a flexible and soft structure, the dimensions of the tower foundation can be chosen large enough such that the tower foundation safely rests on the sea ground. Due to this wide range of possible sizes and geometries of the tower foundation, the tower foundation according to the present concept can even be installed on target positions with large water depths, i.e. up to 40 meters and more.

[0016] The assembling of the tower foundation can comprise the following steps:

- assembling a base section of the tower foundation, and
- assembling a support section of the tower foundation on top of the base section,

wherein, if the tower foundation has been towed to the target position and the ballast chamber is loaded, the base section is adapted to rest on the sea ground and the support section is adapted to be located on top of the base section and to be connected to the tower of the wind turbine.

[0017] In this embodiment the tower foundation consists of at least two parts. One of these two parts, namely the base section, preferably comprises the larger part of the mass of the tower foundation. Since the base section is in contact with the seabed, the centre of mass of the tower foundation is located in the lower part of the tower foundation causing it to safely rest on the sea ground. The other part of the tower foundation, namely the support section, acts as a transition piece between the base section and the tower of the wind turbine. In a preferred embodiment, the support section partially extends above the sea level. In this embodiment, the tower can be attached to the support section without being in direct contact with or submerged into the seawater. The assembling of the base section and/or the assembling of the support section may comprise the casting of, preferably steel reinforced, concrete components.

[0018] The tower foundation can be provided as a modular system consisting of base sections with different and support section with equal dimensions. The base sections can comprise equally dimensioned attaching sections for being attached with the support section. Hence the base section can be adapted to the present conditions on the target position like water depth or sea ground conditions, wherein the transition piece provides a uniform interface between the base section and the tower.

[0019] The assembling of the base section may comprise the following steps:

- casting a tower skirt,
- casting a foot part on top of the tower skirt, and
- casting a pedestal on top of the foot part adapted to stabilize the support section on top of the base section.

[0020] The tower skirt is preferably a ring-like structure, whose outer circumference equals the outer circumference of the foot part of a base section. The tower skirt is constructed to be pressed into the sea ground or sea bed, in particular by the gravitational force of the wind turbine. Thus, the tower skirt causes the tower foundation and, hence, the wind turbine to safely stand on the sea ground.

[0021] The foot part preferably comprises a cylindrical and disc-like shape, but can be also conic or cubic or prismatic or the like. The foot part preferably comprises at least one of the at least one ballast chambers.

[0022] The pedestal preferably comprises a conic and hollow structure. The pedestal may comprise a circular hole or opening at its uppermost position. In other words, the geometrical shape of the pedestal can be a truncated and hollow cone. The support section is preferably also a conical or cylindrical body. The lower end of the support section can be received by the hole of the pedestal and preferably stands on the foot part. In a preferred embodiment, the remaining empty or hollow space within the pedestal forms at least one of the at least one ballast chambers of the tower foundation.

[0023] In a preferred embodiment, the assembling of the support section comprises inserting components, in particular electrical and/or mechanical components, preferably a transformer and/or a converter and/or a cable and/or a control devices and/or a switch gear, of the wind turbine into the support section. In the scope of known concepts, the equipment is typically positioned in the tower or in a separate transition piece between the tower foundation and the tower. Having these components inside the tower foundation reduces the complexity of the tower and provides a simplified way to protect these components from the environment, in particular during the transportation of the respective components to the target position. In particular, the whole electrical equipment of the wind turbine that was installed in the tower previously may in this manner be pre-installed into the support section. The components of the wind turbine can be installed in the support section before towing the tower foundation to the target position. This furthermore simplifies the installing process of the wind turbine. As will be described later in more detail, the tower foundation can comprise at least one waterproof storage chamber to house the components of the wind turbine. Since, in this embodiment, the tower foundation comprises a hollow space acting as the ballast chamber and another hollow space to house the components of the wind turbine, the tower foundation can also be called "hybrid tower foundation" or "hybrid gravity foundation".

[0024] Regarding the construction site, an embankment-like structure, in particular a dam, or a floodgate can be used as the barrier. If the embankment-like structure is provided, the construction site or dry dock can be excavated before the tower foundation is fabricated there. To flood the construction site, an excavator can be used to at least partially remove the embankment-like structure allowing water to flood the dry dock, thus lifting the tower foundation.

[0025] If a floodgate is provided, the dry dock can be used several times to fabricate a plurality of tower foundations for several wind turbines, in particular for an offshore wind park. To flood the construction site, the floodgate can be opened to allow water to flood the dry dock and to lift the tower foundation. After the tower foundation has been towed away, the floodgate can be closed and the water can be pumped from the construction site back into the sea. After this, another tower foundation can be fabricated at the construction site.

[0026] Regarding again the situation after towing the tower foundation to the target position, in a preferred embodiment of the invention, seabed material is used as the ballast material. According to already known systems, heavy and dense concrete objects or rocks or the like have been used to secure the tower foundation. Alternatively, like in the scope of the gravity base structure concept, a heavy tower foundation has to be transported from the countryside to the target position. These elaborate and costly steps are not necessary in this embodiment of the current invention any more. Instead, seabed material, which is already present at or not far away from the target position can be used as ballast material to stabilize and secure the tower foundation at the target position.

[0027] In this embodiment, the seabed material can be pumped from the sea ground to the vessel and from the vessel to the tower foundation. To achieve this, a pumping apparatus can be provided which comprises a suction unit which can be remotely controlled from the vessel, a pump which is located on the vessel, a first conduit or hose to transfer the seabed material from the sea ground to the vessel, and a second conduit or hose to transfer the seabed material from the vessel to the tower foundation. The second conduit can be connected with the ballast chamber by a loading inlet of the tower foundation. In this embodiment, seabed material from the vicinity of the target position is pumped into the tower foundation.

[0028] In another variant, it is also possible that the seabed material does not or not completely originate from the vicinity of the target position, but can be transported to the tower foundation from a position which is, e.g. between several hundred metres and several kilometres, away from the target position. For this, the seabed material can be pumped from the sea ground to the vessel using further ship. First, the seabed material is transferred from the sea ground to the further ship by the first conduit. Then, the seabed material can be pumped from the further ship to the vessel via a pipeline. Next, the seabed material is transferred from the vessel to the tower foundation via the second conduit. Respective pumps can be located on the further ship and/or on the vessel.

[0029] In an especially preferred embodiment, a seabed material from the target position of an adjacent tower foundation is used. The seabed material can already have been removed from a previously prepared target position of the adjacent tower foundation, which is supposed to be the tower foundation of an adjacent wind turbine. Alternatively, the target position of the adjacent tower foundation is prepared for positioning the adjacent tower foundation by removing the seabed material from this position and creating a pit in the sea ground adapted to receive the adjacent tower foundation. Hence, the process of removing seabed material from the adjacent target position to the tower foundation synergistically provides ballast material for the tower foundation and prepares the target position of the adjacent tower foundation. This further obviates the need to transport seabed material from tower foundation target positions for larger distances.

[0030] Furthermore, the present invention relates to a tower foundation for an offshore wind turbine, wherein the tower foundation comprises at least one ballast chamber adapted to be loaded with ballast material, wherein, if the at least one ballast chamber is unloaded, a buoyancy of the tower foundation caused by the empty, in particular air-filled ballast chamber is large enough to allow the tower foundation to float, wherein, if the at least one ballast chamber is loaded, the buoyancy of the tower foundation is small enough to allow the tower foundation to permanently rest on the sea ground and to be connected to a tower of the wind turbine to support components of the wind turbine located above the sea level. All features of the method according to the present invention and the explained advantages also apply to the tower foundation according to the present invention and vice versa.

[0031] The tower foundation or the ballast chamber, respectively, can be of a closed design, where the hollow ballast chamber is sealed and waterproof to protect water from flooding or entering into the ballast chamber, especially during towing the tower foundation to its target position.

[0032] Alternatively, the tower foundation or ballast chamber, respectively, can comprise a top open design. In this embodiment, the lateral side walls of the ballast chamber are high enough to prevent water from flowing into the tower foundation or ballast chamber, respectively, when the tower foundation is floating or swimming. In this situation, the tower foundation floats like a ship or nutshell on the surface of the sea. Once the loading process of the ballast chamber with ballast material has started, the tower foundation sinks deeper and deeper into the sea until the ballast chamber or further open chambers are flooded with water and the tower foundation sinks down to the sea ground.

[0033] In an embodiment of the invention the interior of the tower foundation, in particular the or a base section and/or the or a support section, comprises at least one storage chamber adapted to house components of the wind turbine. At least one of the at least storage chamber or storage section can be waterproof, hence, independent of whether the tower foundation is floating or resting on the sea ground, no water can enter into the respective storage chamber. Additionally or alternatively, at least one of the at least storage chambers can be located above the sea level when the tower foundation rests on the sea ground.

[0034] The storage chamber can, in particular, house electrical components of the wind turbine, for example transformers, converters, cables and/or control devices. Additionally or alternatively, switch gears and/or cooling components of the wind turbine and/or components of an elevator of the wind turbine can be housed in the storage chamber. Since these components are located in the tower foundation, in particular in the support section, the structure of the tower, which previously housed these components, is simplified. In particular, the tower can be transported to the target position and stored with very limited or even no special requirements with respect to electrical components.

[0035] In the case that the storage chamber is part of the support section, the components of the wind turbine can be placed inside the storage chamber even before the tower foundation has been towed to and installed at the target position. To place the components into the storage chamber, the principles to provide a modulated storing structure as described in WO 2018/133965 and DE 10 2016 219 413 A1 can be applied in this embodiment.

[0036] The tower foundation according to the present invention, in particular the or a base section and/or the or a support section, can comprise several compartments, wherein at least one of the compartments is the at least one ballast chamber and/or at least one of the compartments forms the or a storage chamber. In particular the foot part can comprise several compartments, optionally interconnected with each other allowing the ballast material to flow from one compartment to the other. Alternatively, the foot part can be hollow, i.e. it can comprise only one large ballast chamber being the empty space inside of the hollow foot part.

[0037] Preferably, the tower foundation comprises at least one loading inlet to insert the ballast material into the tower foundation. The loading inlet can be connected to the second conduit. The loading inlet and/or the respective conduit can comprise adapters which are adapted to be connected with each other.

[0038] The at least one loading inlet is connected with the at least one ballast chamber by one or a system of pipes. The pipes guide the ballast material into the at least one ballast chamber. Hence, filling the ballast material into the ballast chamber can be done in the scope of only one work step, i.e. no re-plugging is needed to load several ballast chambers of the tower foundation. The at least one loading inlet is preferably provided on the support section of the tower foundation. In this embodiment, the loading inlet is still located above the sea level even if the tower foundation has already sunk down to the sea ground, and can be unplugged without much effort.

[0039] The tower foundation, especially the or a support section, can comprise an entrance, preferably comprising a door. This reduces the complexity of the design of tower of the wind turbine even more. A service deck around the tower can be provided allowing staff to enter the wind turbine via the entrance. Preferably, the service deck and/or the entrance can be directly accessed by the vessel. For this purpose, the service deck can comprise a boat landing station for the vessel.

[0040] Furthermore the present invention relates to a wind turbine comprising a tower foundation as described above. All features of the tower foundation and the method according to the present invention and the explained advantages also apply to the offshore wind turbine.

[0041] Other objects and features of the present invention will become apparent from the following detailed description of embodiments considered in conjunction with the accompanying drawings. The drawings, however, are only principle sketches designed solely for the purpose of illustration and do not limit the invention. The drawings show:

Fig. 1 a first embodiment of the offshore wind turbine according to the present invention,

Fig. 2 a flow chart of a method according to the present invention relating to the wind turbine of fig. 1,

Fig. 3-15 steps for assembling the offshore wind turbine of fig. 1 according to the method of fig. 2,

Fig. 16 a detailed view of a tower foundation of the wind turbine of fig. 1,

Fig. 17 a sectional view of the tower foundation of fig. 16 along the line XVII-XVII, and

Fig. 18 a tower foundation of a second embodiment of a wind turbine according to the present invention.

[0042] Fig. 1 shows an offshore wind turbine 1 according to the present invention. The offshore wind turbine 1 comprises a tower foundation 2, wherein a tower 3 of the wind turbine 1 is attached to the tower foundation 2. On top of the tower 2 a nacelle 4 with rotor blades 5 is provided.

[0043] Fig. 2 shows a flow chart of the assembling process of the offshore wind turbine 1 according to the method according to the present invention. Figures 3 to 15 show details concerning the assembling process of fig. 2.

[0044] In step S1 (fig. 3), a construction site 6, which is close to the sea 7, is provided to fabricate the tower foundation 2. The construction site 6 is located in a coastal area which is not far away from a target position 26 where the offshore wind turbine 1 is supposed to be installed. The target position 26 can be positioned within the area of an already existing or planned offshore wind park.

[0045] In step S2 (fig. 4), the construction site 6 is excavated leading to a dry dock-like construction site 6, which is located below the sea level 8 and separated from the sea 7 by a barrier 9. The barrier 9 is an embankment-like structure 10, especially a dam. Alternatively, a floodgate can be used as the barrier 9.

[0046] The figures 5 to 9, which correspond to the steps S3 to S7 of the method as displayed in fig. 2, illustrate the fabrication of the tower foundation 2 at the construction site 6. In step S3 (fig. 5), a ring-like tower skirt 11 of the tower foundation 2 is casted. Next, in step S4 (fig. 6), a cylindrical and disk-like foot part 12 of the tower foundation 2 is casted on top of the tower skirt 11. In step S5 (fig. 7), a conic and hollow pedestal 13 is casted on top of the foot part 12. The tower skirt 11, the foot part 12 and the pedestal 13 form a base section 14 of the tower foundation 2. The base section 14, in particular its components 11, 12, 13, consists of steel reinforced concrete.

[0047] The tower foundation 2 furthermore comprises a cylindrical support section 15. In step S6 (fig. 8), the support section 15 is assembled and stands on top of the base section 14. For this, the pedestal 13 comprises a circular opening at its uppermost end, where the lower part of the support section 15 is arranged. The support section 15 consists of casted and steel reinforced concrete.

[0048] Next, in step S7 (fig. 9), components 16 of the wind turbine 1 are inserted into the support section 15. Details regarding the components 16 are displayed in fig. 16, where the tower foundation 2 is displayed together with an enlarged view of the components 16. A cross section along the line XVII-XVII through the tower foundation 2 of fig. 16 is shown in fig. 17. The cylindrical support section 15 is hollow and comprises a storage chamber 17 to house the components 16. The components 16 are stored in the storage chamber 17 on several platforms 18. The components 16 are components 19 of an elevator of the wind turbine 1, control devices 20 of the wind turbine 1, switchgear components 21 of the wind turbine 1 and cables 22. According to known concepts for wind turbines, the components 16 are typically housed within the tower 3, which makes it complicated to transport and to install the tower 3 on the tower foundation 2. Already inserting the components 16 into the tower foundation 2 on the construction site 6 simplifies the design of the tower 3 and the installation process of the wind turbine 1.

[0049] Next, in step S8 (fig. 10), the embankment-like structure 10 or barrier 9, respectively, is at least partially removed or opened to allow water 23 from the sea 7 to flood the construction site 6. To open the barrier 9, an excavator or other suitable means can be used. For the case that the construction site 6 is separated from the sea 7 by a floodgate, the construction site 6 can be flooded by opening the floodgate.

[0050] Flooding the construction site 6 with water 23 causes the tower foundation 2 to swim or float on the sea level 8 or surface of the sea 7. The tower foundation 2 comprises ballast chambers 24, 25 which are empty or filled with air, respectively, while the construction site 6 is flooded with water 23. Hence, the buoyancy of the tower foundation 2 caused by the empty ballast chambers 24, 25 is large enough that the tower foundation 2 swims or floods on the sea level 8. The ballast chamber 24 is the empty space defined by the inside surface of the pedestal 13 and the outer surface of the lower part of the support section 15. The ballast chamber 25 is the hollow space inside the foot part 12 of the base section 14. Since the ballast chambers 24, 25 are waterproof, no water can enter the ballast chambers 24, 25 during step S8. This ensures that the tower foundation 2 is floating on the sea 7 instead if sinking down.

[0051] Next, in step S9 (fig. 11), the floating tower foundation 2 is towed to the target position 26 on the sea 7 by a vessel 27. The tower foundation 2 can be attached with the vessel 27 by a rope 28 or another suitable towing means.

[0052] Next, in step S10, the ballast chambers 24, 25 of the tower foundation 2 are loaded or filled with ballast material 29. In the figures, the ballast material 29 in the ballast chambers 24, 25 is indicated by a shaded area. Fig. 12 and 13 show alternative ways to load the ballast chambers 24, 25 with the ballast material 29. In both cases, the ballast material 29 is seabed material 30 originating from the sea ground 31. The seabed material 30, which consists typically of sand, gravel, mud or the like, is pumped into the ballast chambers 24, 25 by a pumping apparatus 32. The pumping apparatus 32 consists of a suction unit 33 located on the sea ground 31 to collect the seabed material 30 at the sea ground 31. The pumping apparatus 32 furthermore consists of a pump 34 which is located on the vessel 27. To transport the seabed material 30 from the suction unit 33 by the pump 34 into the ballast chambers 24, 25, a first conduit 35 between the suction unit 33 and the pump 34 and a second conduit 36 between the pump 34 and the tower foundation 2 are provided.

[0053] In the embodiment as shown in fig. 12, seabed material 30 from the vicinity of the target position 26 can be used. However, in some cases it can be useful to use seabed material 30 originating from another location of the sea ground 31. For example, if a plurality of wind turbines are to be in-tailed, e.g. in ranges between 50 meters to 10 kilometers from each other, seabed material 30 from a target position 42 of an adjacent tower foundation of an adjacent wind turbine can be used as ballast material 29 for the tower foundation 2. A pumping apparatus 37 as shown in fig. 13 allows to transport seabed material 30 to the target position 26 of the tower foundation 2, even over a distance of several kilometres. Like the pumping apparatus 32 shown in fig. 12, the pumping apparatus 37 in fig. 13 comprises a suction unit 33 on the sea ground 31 to collect seabed material 30 from the sea ground 31. The seabed material is transferred to a further ship 38 via a first conduit 35. The further ship 38 is, like the target position 42 of the adjacent tower foundation where the seabed material 30 is collected, at a distance to the target position 26 of, for example, 50 metres to 10 kilometres. The seabed material 30 is sucked in by the suction unit 33 via a first pump 39 located on the further ship 38. A second pump 41 of the pumping apparatus 37 is provided on the vessel 27 to transport the seabed material 30 from the further ship 38 to the vessel 27 via a pipeline 40. Next, the seabed material 30 is transferred from the vessel 27 to the tower foundation 2 by the second pump 41 via a second conduit 36.

[0054] By using the pumping apparatus 37 as shown in fig. 13, two purposes are fulfilled simultaneously. First, the seabed material 30, which is collected at the target position 42 of the adjacent tower foundation, is used as the ballast material 29 leading the tower foundation 2 to sink down, as will be described later on in more detail. Second, the removal of the seabed material 30 from the target position 42 of the adjacent tower foundation prepares this target position 42 for the process of installing the adjacent tower foundation.

[0055] The tower foundation 2 comprises a loading inlet 43 to load the ballast material 29 into the ballast chambers 24, 25. The loading inlet 43 is a connector, socket or adapter adapted to be connected with the second conduit 36. An end section of the second conduit 36 and the loading inlet 43 can be attached to each other by clamping or screwing or the like.

[0056] As can be seen from fig. 17, the ballast material 29 is transferred from the loading inlet 43 to the ballast chambers 24, 25 via a system 44 of pipes 45. Hence, although there are two ballast chambers 24, 25, these ballast chambers 24, 25 can be loaded with ballast material only by connecting the second conduit 36 with the loading inlet 43 and pumping the seabed material 30 into the system 44 of pipes 45. No re-plugging or the like is necessary for this working step.

[0057] One of the fundamental ideas of the present invention is illustrated in fig. 14 which corresponds to the step S11. By loading the ballast chambers 24, 25 with ballast material 29, the buoyancy of the tower foundation 2 is reduced causing the tower foundation 2 to finally sink down into the sea 7 until it permanently rests on the sea ground 31 at its target position 26. Before loading the ballast chambers 24, 25 with ballast material 29, these ballast chambers 24, 25 are mainly empty or filled only with air. Hence, if the ballast chambers 24, 25 are unloaded, the buoyancy of the tower foundation 2 is large enough leading the tower foundation 2 to float on the sea level 8 or the surface of the sea 7. Buoyancy means like pontoons or the like also be used to support the floating of the tower foundation 2. During the loading process of the ballast chambers 24, 25, the volume of the tower foundation 2 is not changed, however, the total weight of the tower foundation 2 is increased by the ballast material 29. Once the gravitational force of the tower foundation 2 exceeds the buoyancy force, the tower foundation 2 will start sinking until it rests on the sea ground 31 on the target position 26. Finally, a sufficient amount of ballast material 29 is pumped into the ballast chambers 24, 25 leading the tower foundation 2 to permanently rest on the sea ground 31. In particular, expected tidal forces or sea current are not able to relocate or overthrow the tower foundation 2 or wind turbine 1.

[0058] Although the seabed material 30 may have a lower density compared to rocks or the like, which in previous systems have been used stabilize tower foundations, the ballast chambers 24, 25 can be dimensioned large enough such that the additional gravitational force of the ballast material 29 is sufficiently strong to ensure a permanent resting of the tower foundation 2 in the target position 26. In contrast to traditional systems, for the present invention ballast material like rocks or the like do not have to be transported from the shore to the offshore wind turbine 1. For this purpose, advantageously already present seabed material 30 is used.

[0059] The tower foundation 2 is further stabilized at its target position 26 by the geometrical shape of the tower foundation. Because of the conical base section 14, the centre of mass of the tower foundation 2 is located at a low position. In addition, the tower skirt 11 is pressed into the sea ground 31 by the gravitational force of the tower foundation 2. The tower foundation 2 is further stabilized by the fact that the area of the base section 14 which is in contact with the sea ground 31 can be dimensioned large enough that, even in the case that the composition and structure of the sea ground 31 is not stable, the tower foundation 2 safely stands at its target position 26.

[0060] Finally, in step S12 (fig. 15), the tower 3 of the wind turbine 1 is installed on the tower foundation 2 or the support section 15, respectively, and the wind turbine 1 is finished by mounting the remaining components like the nacelle 4 and the blades 5 etc. Alternatively, installing the remaining parts of the wind turbine 1 on the tower foundation 2 can be performed even before the tower foundation is towed to the target position 26 and still located at the construction site 6. Especially this step can be performed before step 9 or, preferably, before step 8. The tower foundation 2 stabilizes the wind turbine 1 when being transported or towed to the target position 26.

[0061] As shown in figures 14 and 15, the tower foundation 2, namely the upper part of the support section 15, where the components 16 are located, is positioned above the sea level.

[0062] The support section 15 of the tower foundation 2 comprises an entrance 46 with a door 47 allowing staff to access the wind turbine 1 at the level of the components 16. In traditional systems, entrances are typically provided at the towers of wind turbines, which typically consist of steel or the like. Providing the entrance on the casted concrete tower foundation 2 leads to a reduction of the complexity of the tower 3.

[0063] Although it is not shown in the present figures, there is a service deck around the tower at the height of the entrance 46 which allows staff to simply enter into the wind turbine 1. A boat landing can also be provided at the service deck of the wind turbine 1.

[0064] Fig. 18 shows a tower foundation 2 of a second embodiment of a wind turbine 1. Like in the first embodiment, the tower foundation 2 also comprises a base section 14 and a support section 15, however, the tower foundation 2, namely the support section 15, comprises several compartments 48, wherein the compartments 48 are open at the top. This causes the tower foundation 2 to float on the sea level 8 like a boat or nutshell, wherein, when the compartments 48, which act as the ballast chambers 24, 25, are filled with ballast material 29, the tower foundation 2 will sink down into the sea 7 causing the compartments 48 to be flooded with water 23.

[0065] Alternatively, the compartments 48 can also be waterproof or, in other words, closed at the top, wherein some of the compartments 48 can be used as ballast chambers 24, 25 and other compartments 48 can be used as storage chambers 17.

[0066] Although the present invention has been described in detail with reference to the preferred embodiment, the present invention is not limited by the disclosed examples from which the skilled person is able to derive other variations without departing from the scope of the invention.

Claims

1. Method for assembling an offshore wind turbine (1), wherein the wind turbine (1) comprises a tower foundation (2) with at least one hollow ballast chamber (24, 25), wherein the method comprises the following steps:

- assembling the tower foundation (2) on a dry dock-like construction site (6), wherein the construction site (6) is located below the sea level (8) and separated from the sea (7) by a barrier (9),
- launching the tower foundation (2) to the sea (7) by, at least partially, removing or opening the barrier (9) and/or filling water into the construction site (6) leading to a flooding of the construction site (6),
- towing the swimming tower foundation (2) to a target position (26) on the sea (7) by a vessel (27),
- loading the at least one ballast chamber (24, 25) of the tower foundation (2) with ballast material (24, 25) causing the tower foundation (2) to sink down until it permanently rests on the sea ground (31), and
- installing a tower (3) of the wind turbine (1) on the tower foundation (2) while the tower foundation is located in the dry dock-like construction site (6) or at the target position (26).

2. Method according to claim 1, **characterized in that** assembling the tower foundation (2) comprises the following steps:

- assembling a base section (14) of the tower foundation (2), and
- assembling a support section (15) of the tower foundation (2) on top of the base section (14),

wherein, if the tower foundation (2) has been towed to the target position (26) and the ballast chamber (24, 25) is loaded, the base section (2) is adapted to rest on the sea ground (31) and the support section (15) is adapted to be located on top of the base section (14) and to be connected to the tower (3) of the wind turbine (1).

3. Method according to claim 2, **characterized in that** assembling the base section (14) comprises the following steps:

- casting a tower skirt (11),
- casting a foot part (12) on top of the tower skirt (11), and
- casting a pedestal (13) on top of the foot part (12) adapted to stabilize the support section (15) on top of the base section (14).

4. Method according to claim 2 or 3, **characterized in that** assembling the support section (15) comprises the inserting of components (16) of the wind turbine (1), in particular electrical and/or mechanical components, preferably a transformer and/or a converter and/or a cable and/or a control devices and/or a switch gear, into the support section (15).

5. Method according to one of the preceding claims, **characterized in that** an embankment-like structure (10), especially a dam, or a floodgate is used as the barrier (9).

6. Method according to one of the preceding claims, **characterized in that** seabed material (30) is used as the ballast material (29).

7. Method according to claim 6, **characterized in that** the seabed material (30) is pumped from the sea ground (31) to the vessel (27) and from the vessel (27) to the tower foundation (2).

8. Method according to claim 7, **characterized in that** the seabed material (30) is pumped from the sea ground (31) to the vessel (27) via a further ship (38).

9. Method according to one of the claims 6 to 8, **characterized in that** a seabed material (30) from the target position (42) of an adjacent tower foundation is used.

10. Tower foundation for an offshore wind turbine (1), **characterized in that** the tower foundation (2) comprises at least one ballast chamber (24, 25) adapted to be loaded with ballast material (29), wherein, if the at least one ballast chamber (24, 25) is unloaded, a buoyancy of the tower foundation (2) caused by the empty ballast chamber (24, 25) it large enough to allow the tower foundation (2) to swim, wherein, if the at least one ballast chamber (24, 25) is loaded, the buoyancy of the tower foundation (2) is small enough to allow the tower foundation (2) to permanently rest on the sea ground (31) and to be connected with a tower (3) of the wind turbine (1) to support components of the wind turbine located above the sea level.

11. Tower foundation according to claim 10, **characterized in that** the interior of the tower foundation (2), in particular the or a base section (14) and/or the or a support section (15), comprises at least one storage chamber (17) adapted to house components (16) of the wind turbine (1).

12. Tower foundation according to one of the claims 10 or 11, **characterized in that** the tower foundation (2), in particular the or a base section (14) and/or the or a support section (15), comprises several compartments (48), wherein at least one of the compartments (48) is the at least one ballast chamber and/or at least one of the compartments (48) forms the or a storage chamber.

13. Tower foundation according to one of the claims 10 to 12, **characterized in that** the tower foundation (2) comprises at least one loading inlet (43) to load the ballast material (29) into the at least one ballast chamber (24, 25).

14. Tower foundation according to claim 13, **characterized in that** the at least one loading inlet (43) is connected with the at least one ballast chamber (24, 25) by one or a system (44) of pipes (45).

15. Offshore wind turbine, comprising a tower foundation according to one of the claims 10 to 14.

FIG 1

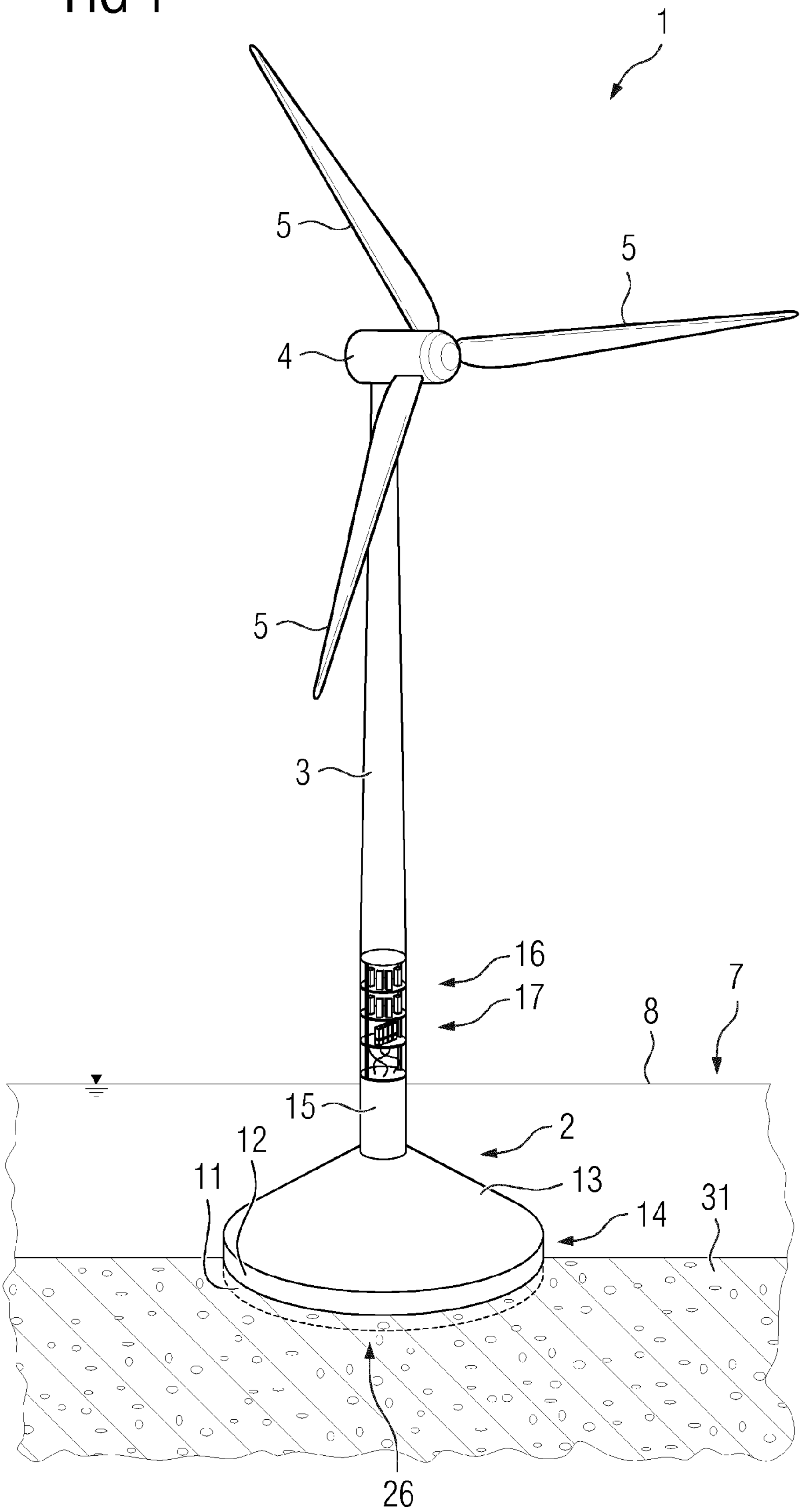
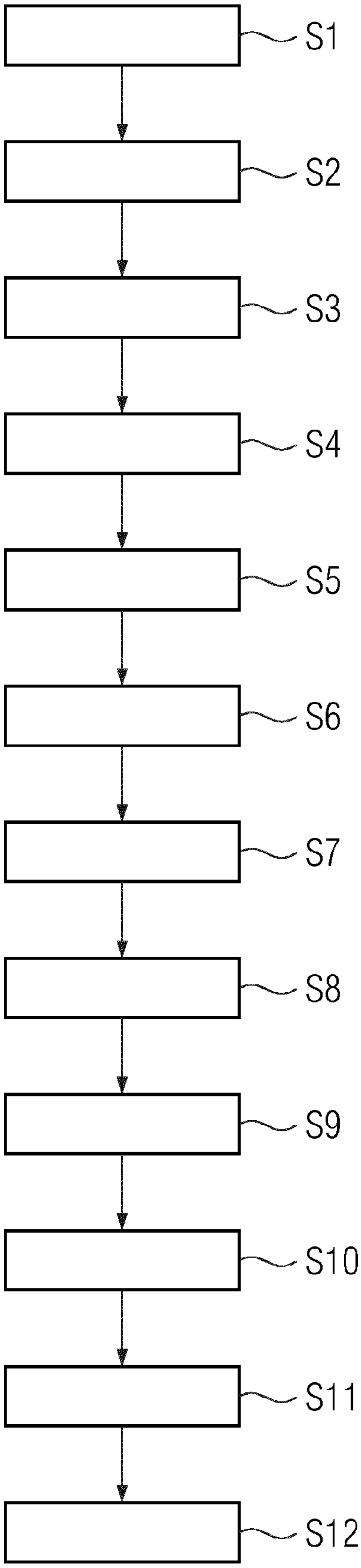


FIG 2



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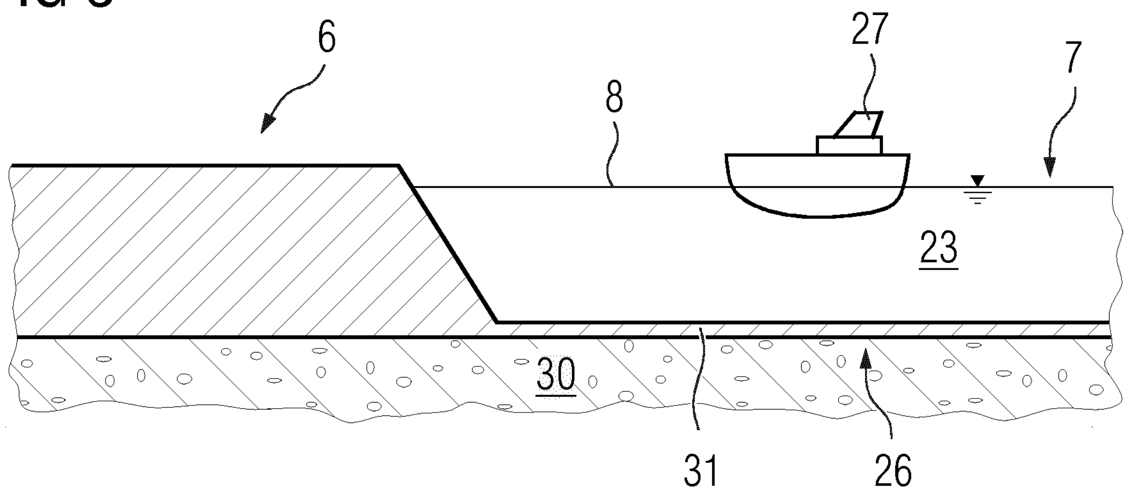


FIG 4

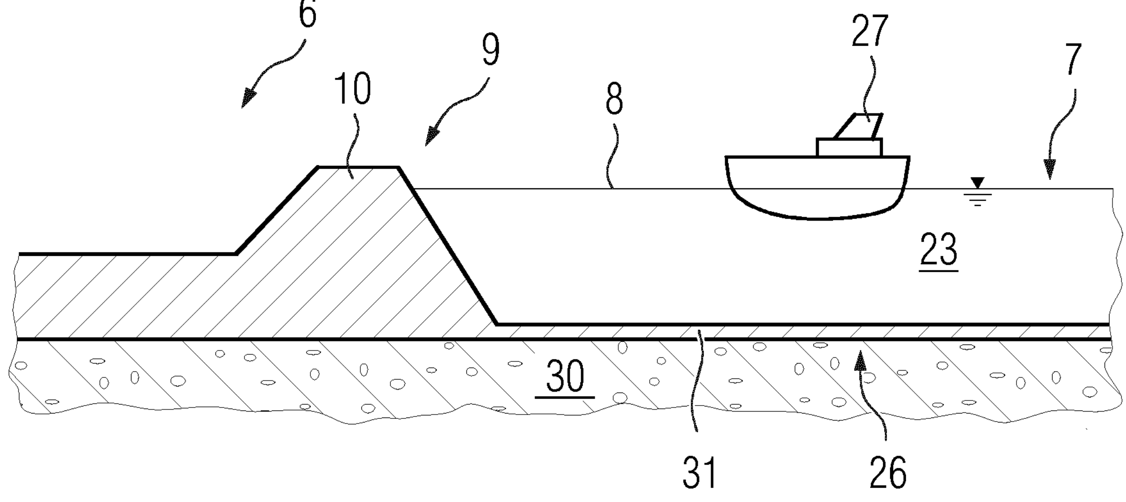
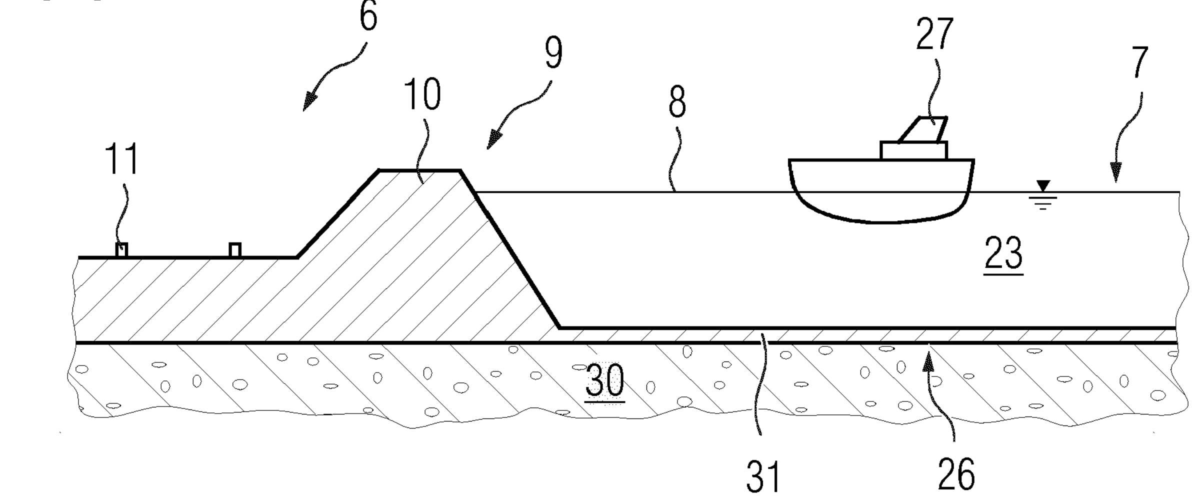


FIG 5



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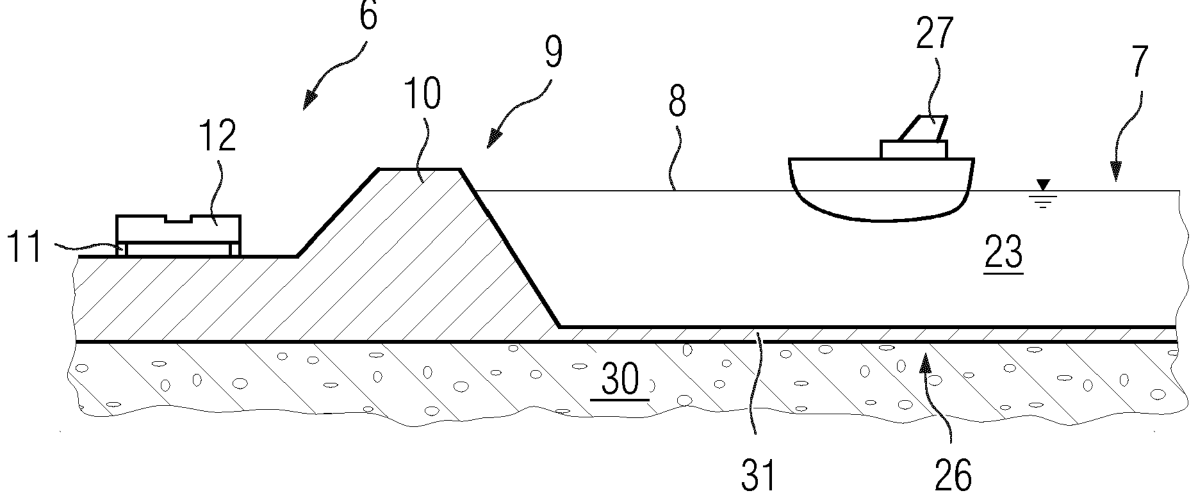

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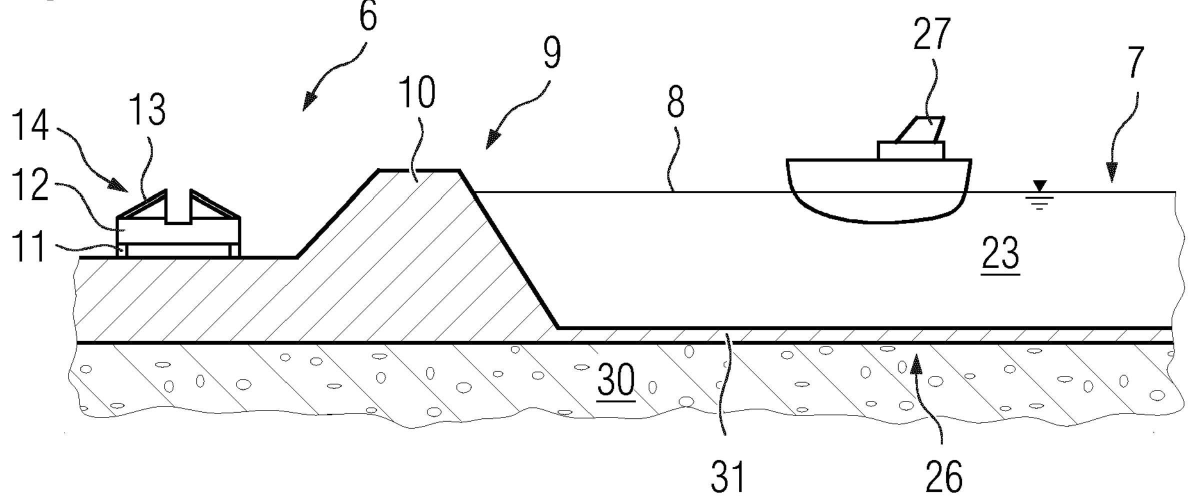
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FIG 8

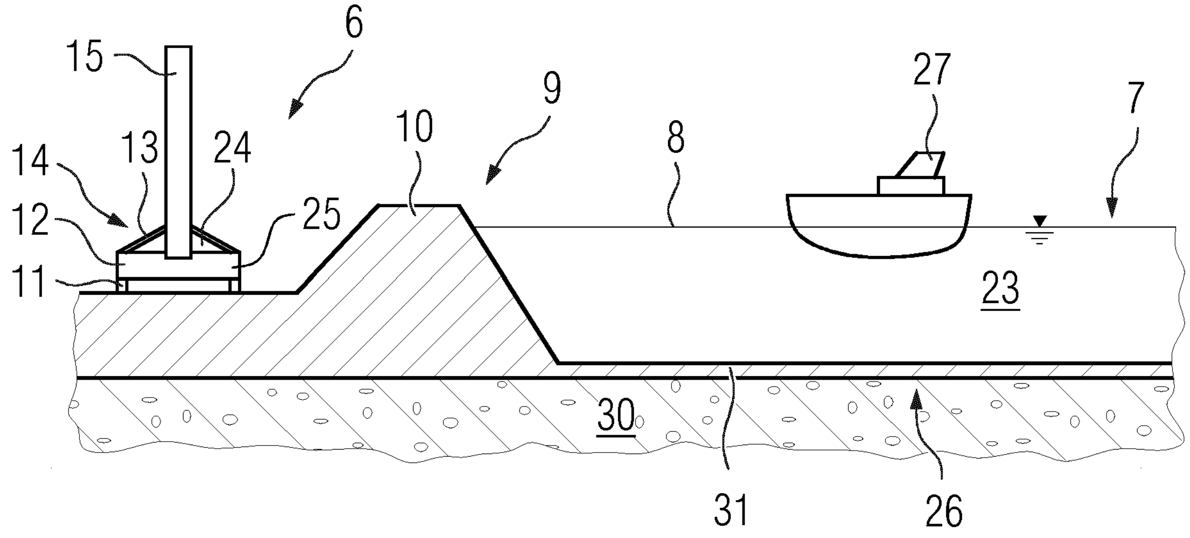
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FIG 9

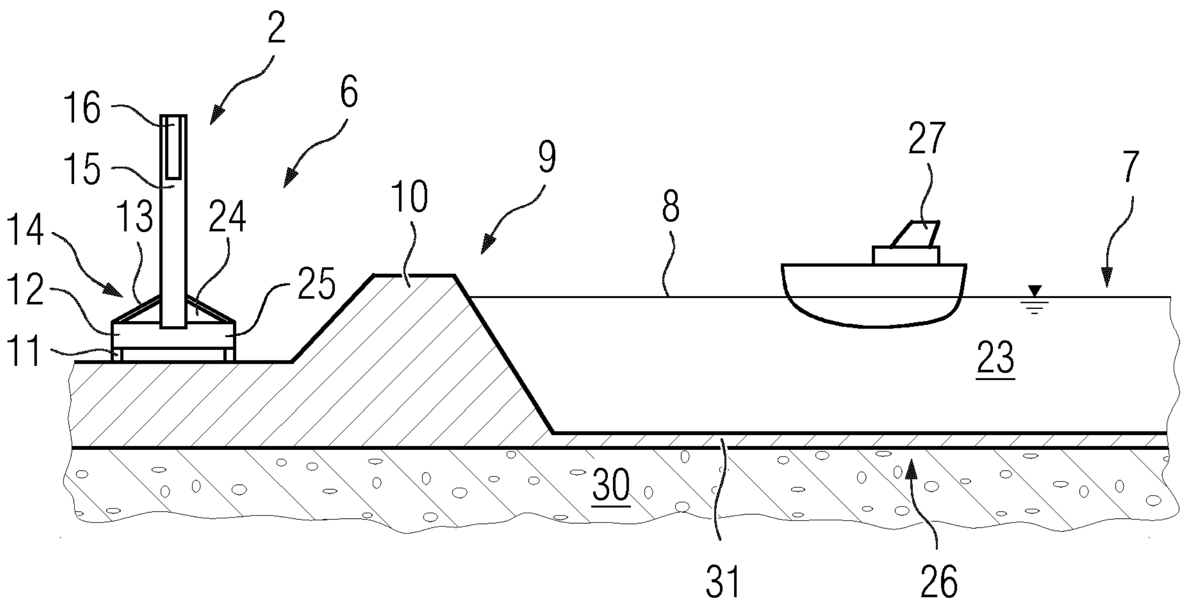
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FIG 10

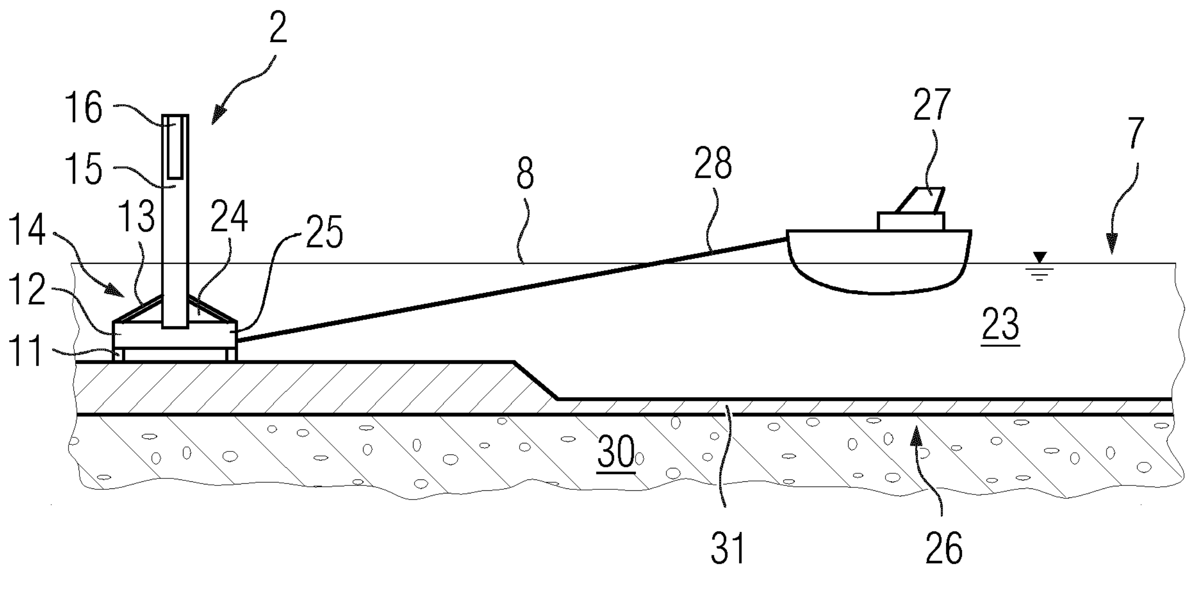
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FIG 11

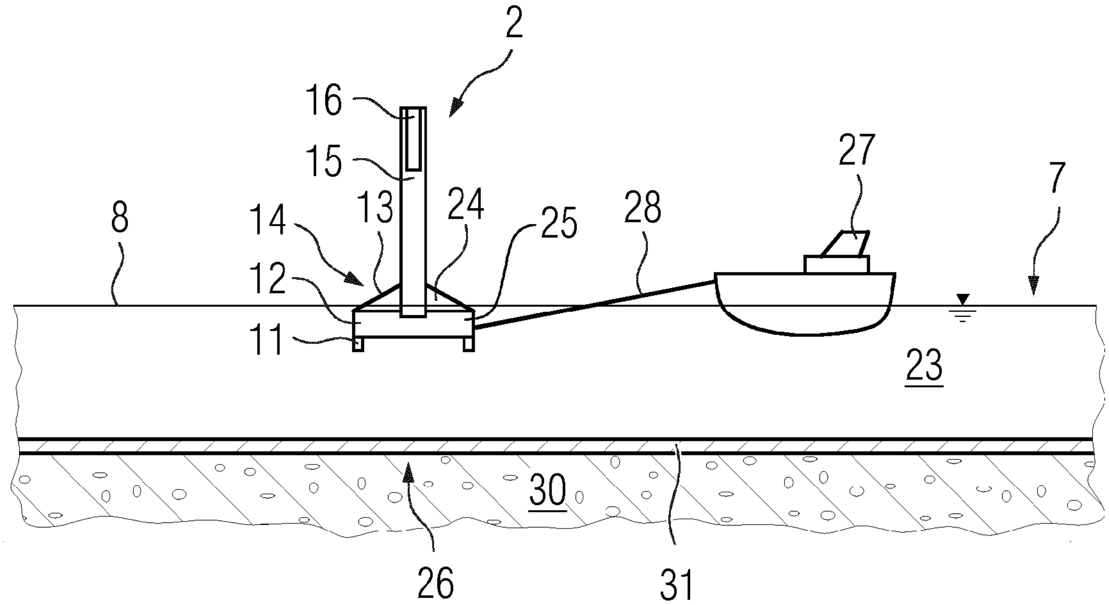
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FIG 12

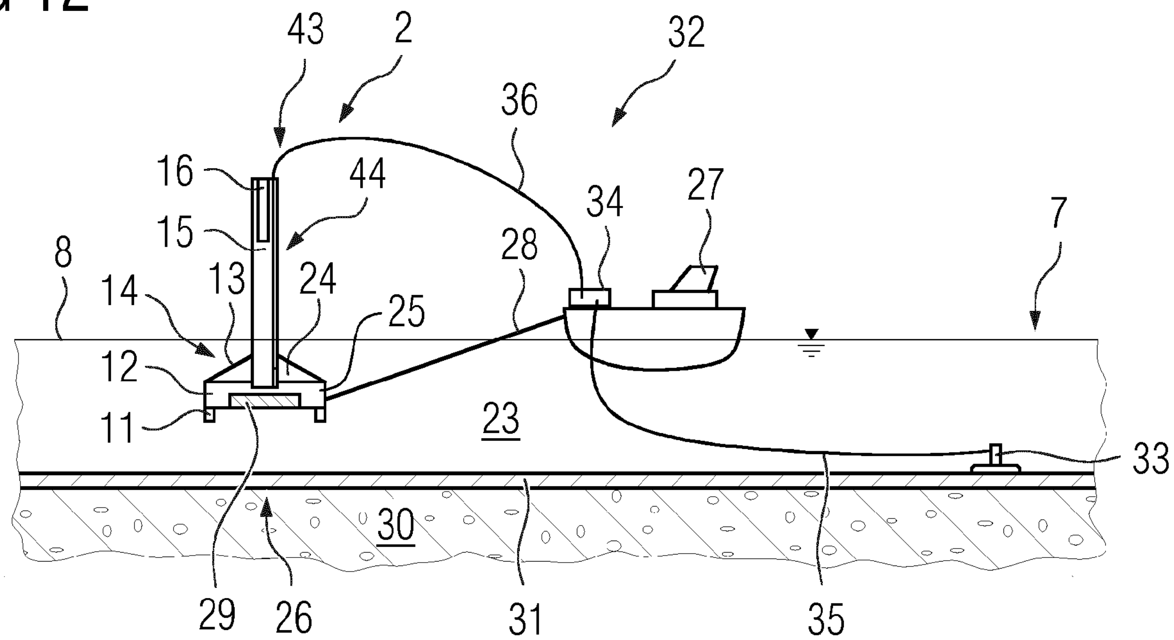
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FIG 13

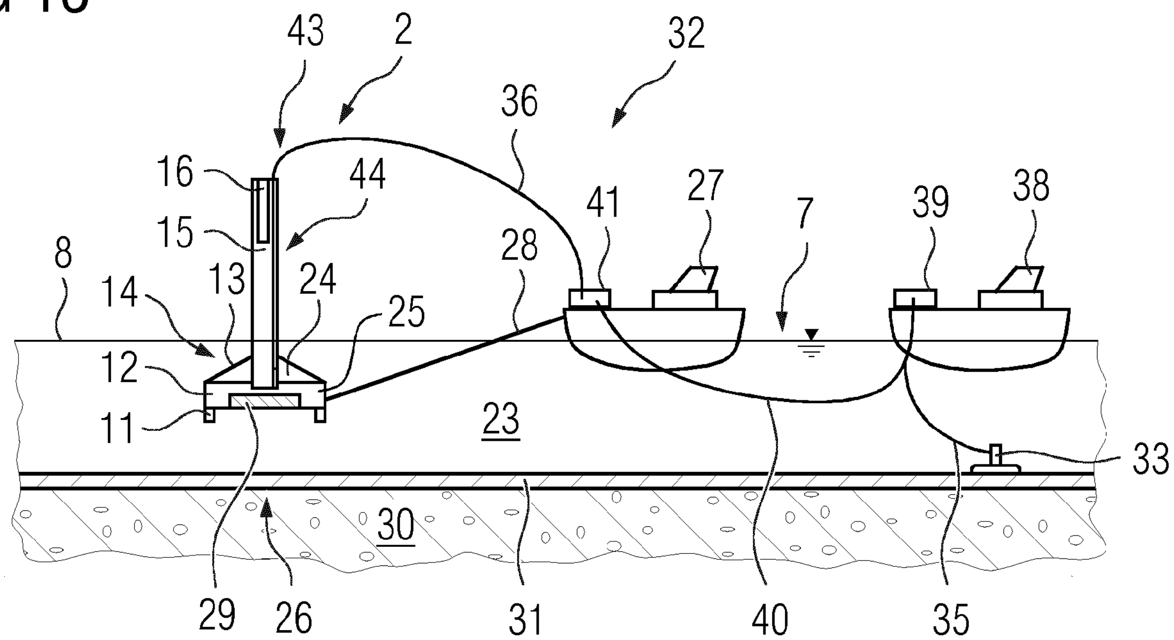
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FIG 14

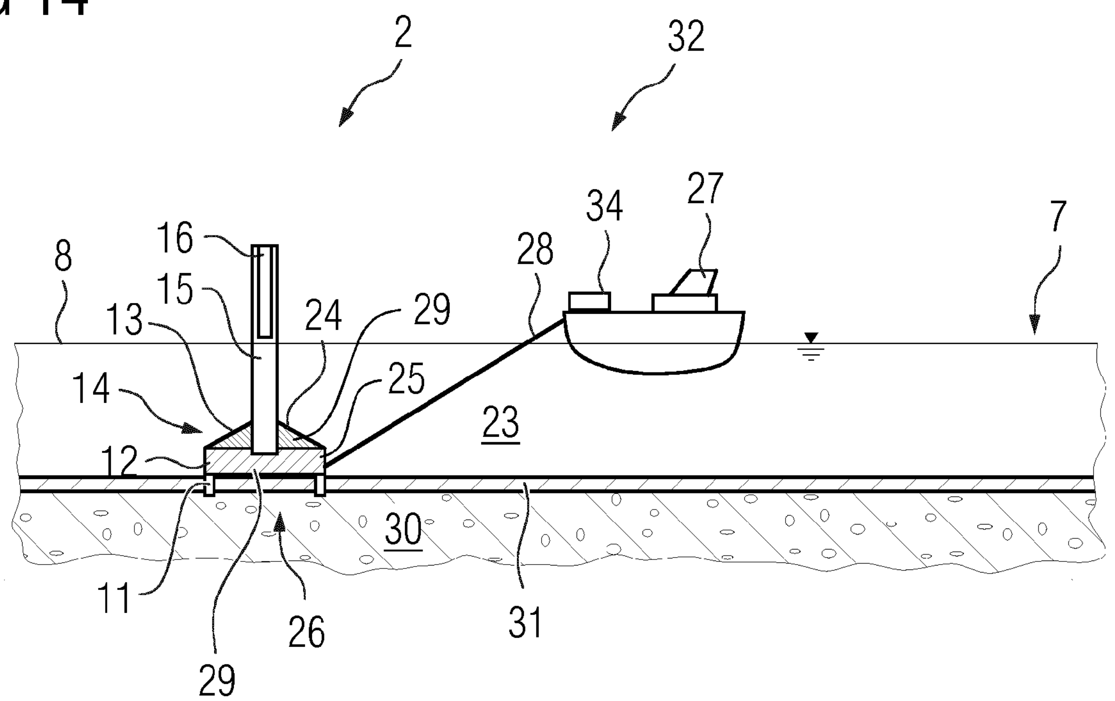
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FIG 15

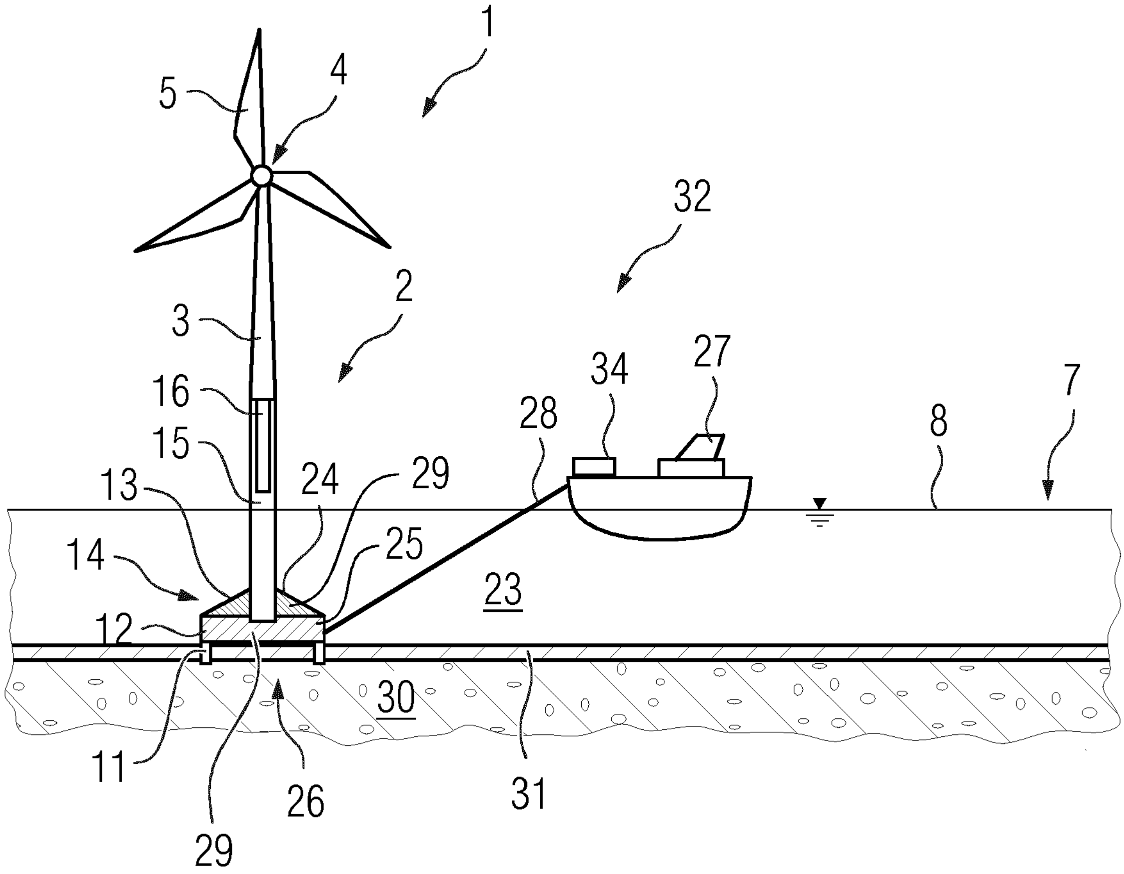


FIG 16

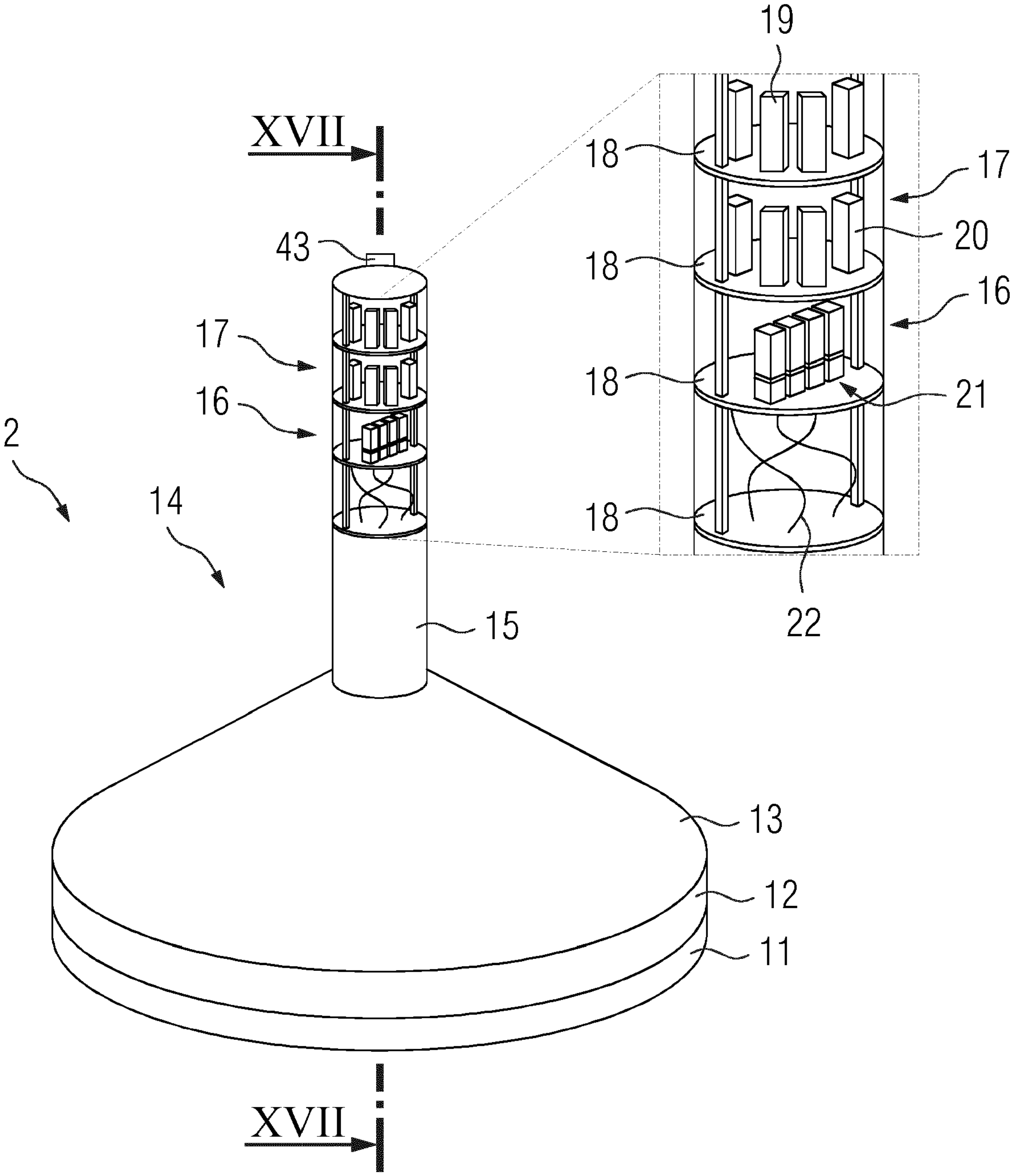


FIG 17

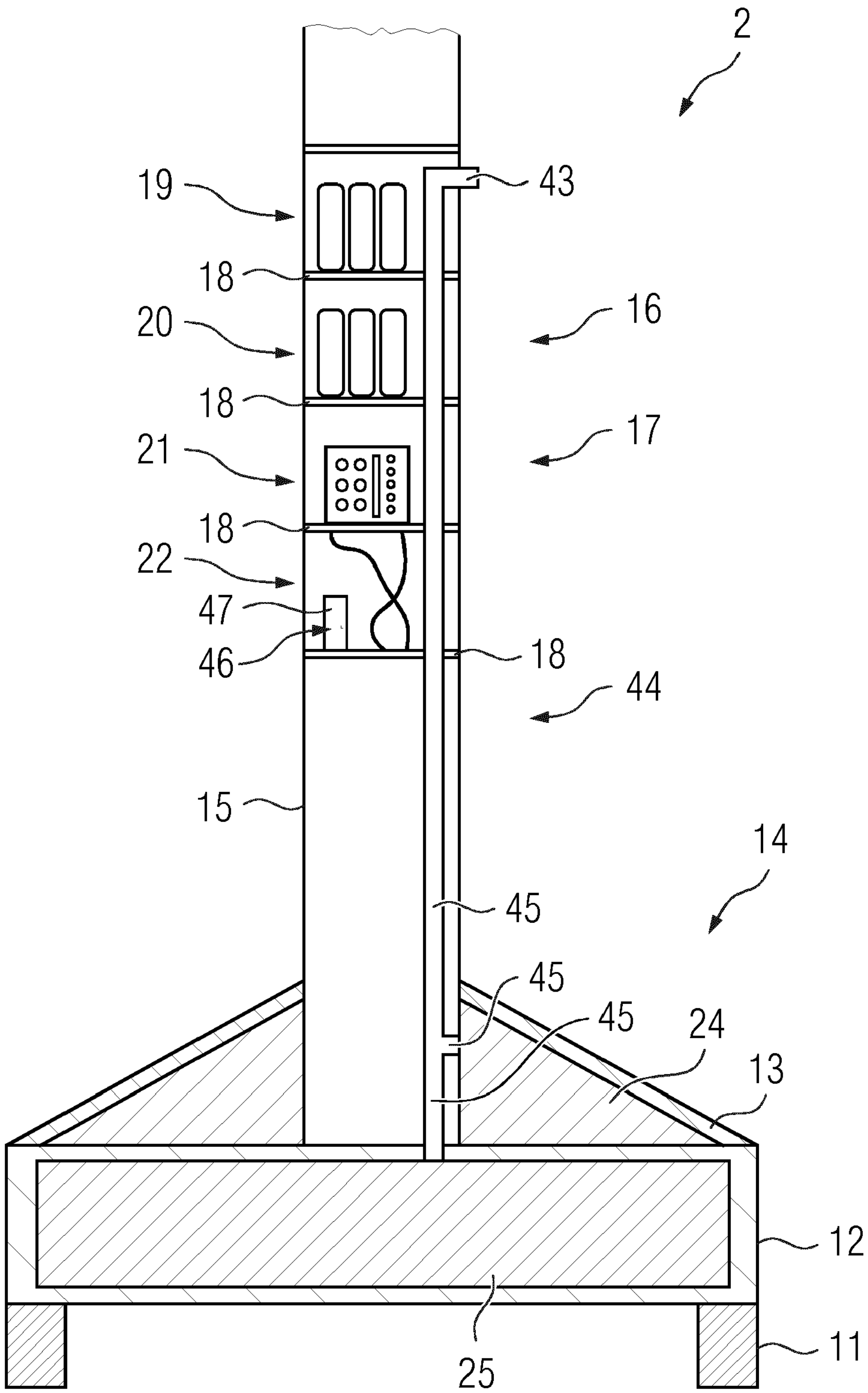
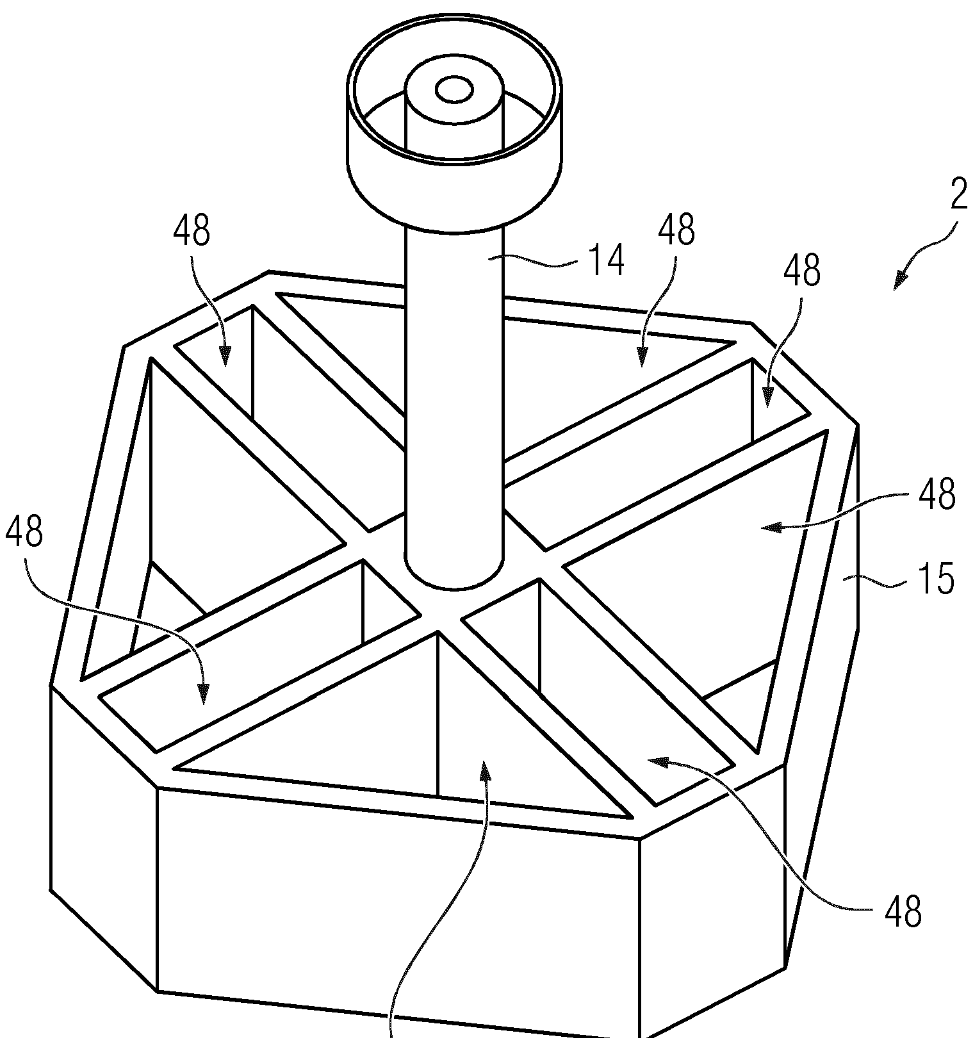


FIG 18



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EUROPEAN SEARCH REPORT

Application Number
EP 19 18 7004

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X Y	WO 2010/019050 A1 (OLAV OLSEN AS DR TECHN [NO]; MELING JOHN [NO] ET AL.) 18 February 2010 (2010-02-18) * page 2, paragraph 4 - page 3, paragraph 1 * * page 5, line 3; figures 1-3 *	1-5, 10-15 6-9	
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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	10 December 2019	Geiger, Harald

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