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US 20120027522 A1

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(54) Title of the Invention: **Underwater turbine installation apparatus and methods**
Abstract Title: **Underwater turbine installation apparatus and method**

(57) The invention relates to an installation apparatus 101 and method for the installation or removal of a tidal turbine nacelle151 on an underwater substructure 153. The apparatus comprises a buoyant platform 101 with may comprise two hull portions 103, 103b with a number of inflatable buoyancy units 107. The apparatus also comprises lifting equipment 109, 113, 123, 124, (125 figure 7) for lowering and/or raising the tidal turbine nacelle, and positioning means for positioning the installation apparatus relative to the underwater substructure. The apparatus enables the installation or removal of a turbine nacelle on a substructure without having to deploy a separate barge or heavy lift vessel. Instead, such an installation apparatus can be towed and positioned by a workboat, multicat or any other suitable marine vessel 161. Positioning can be achieved by a propulsion system comprised in the apparatus itself, or manoeuvred by another vessel.

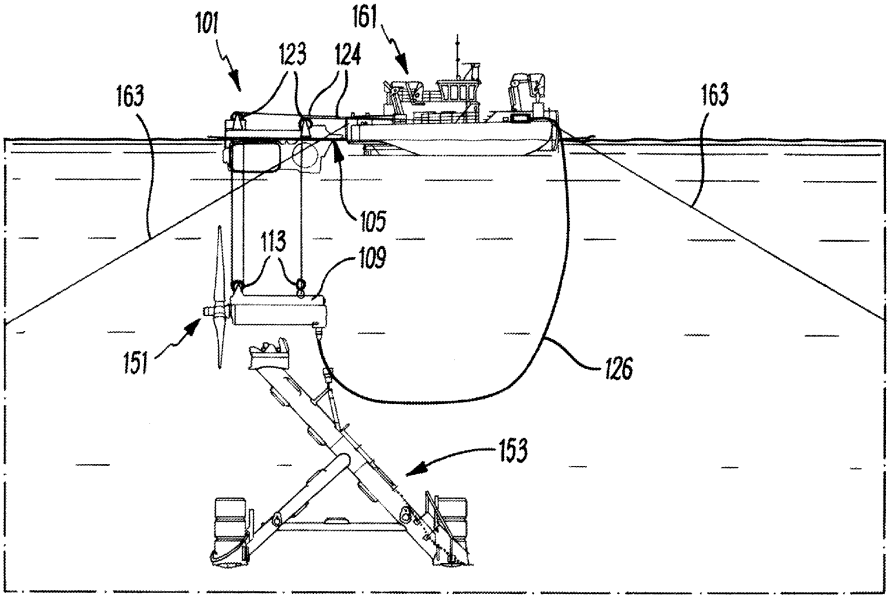

Fig. 10

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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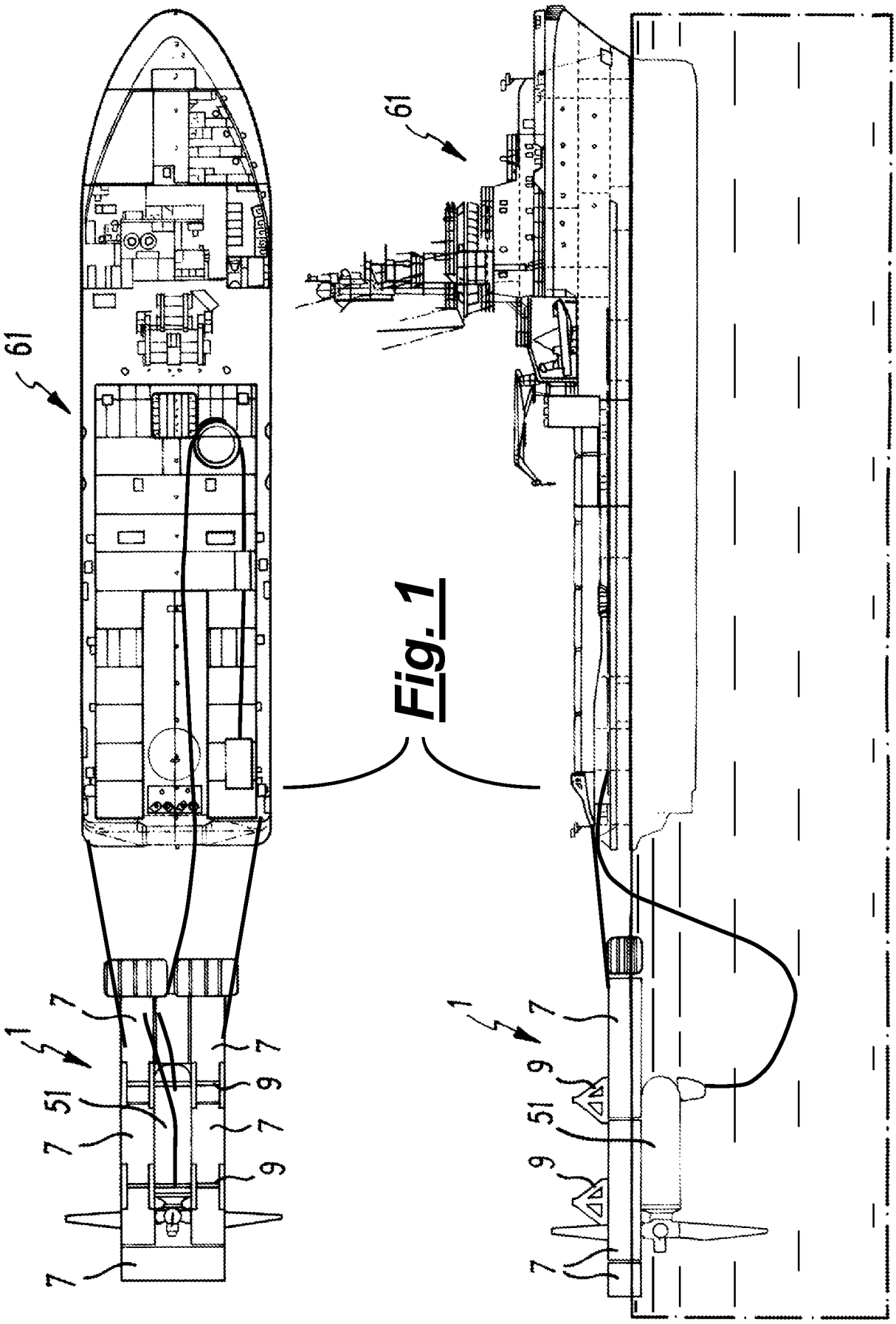

Fig. 1

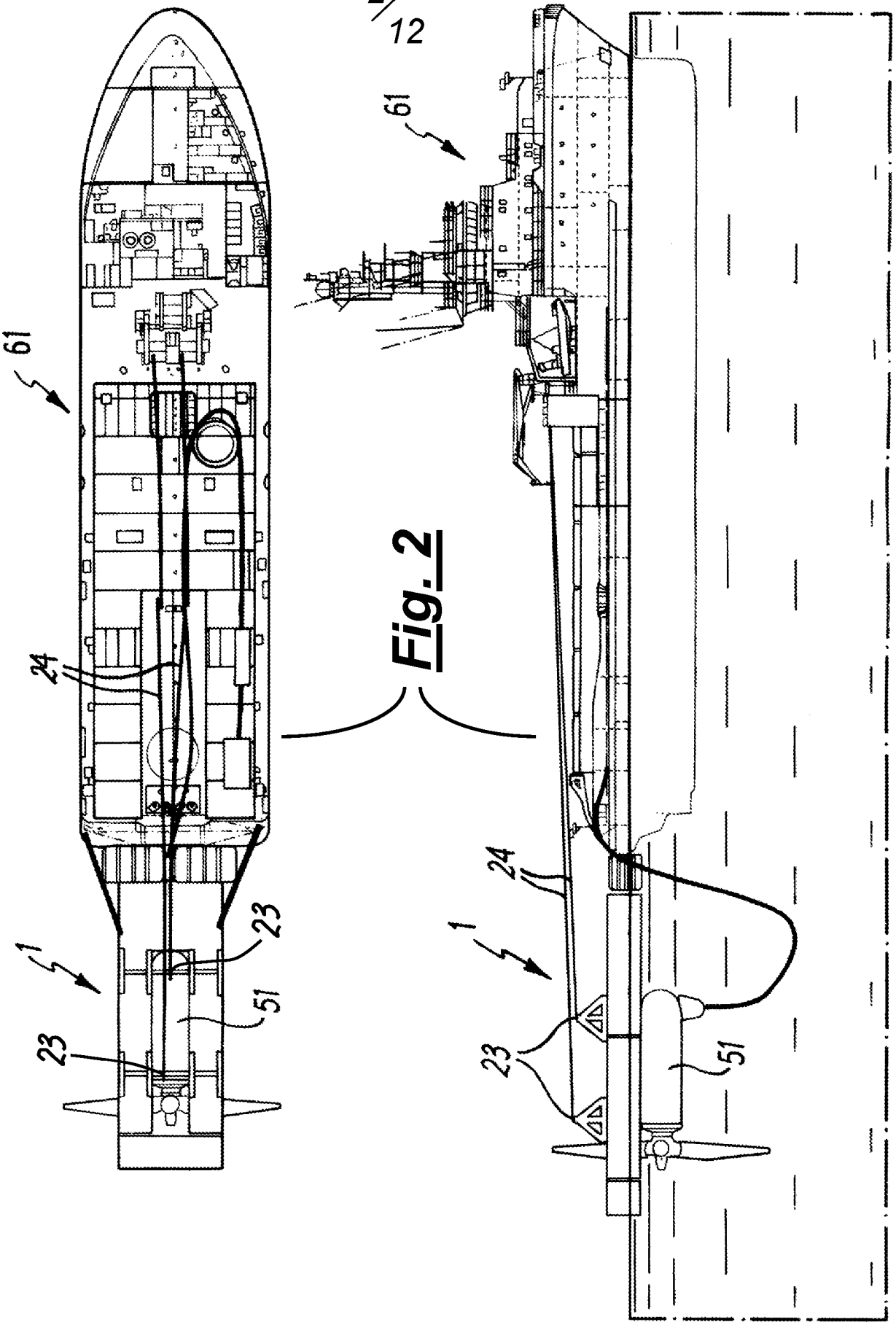

Fig. 2

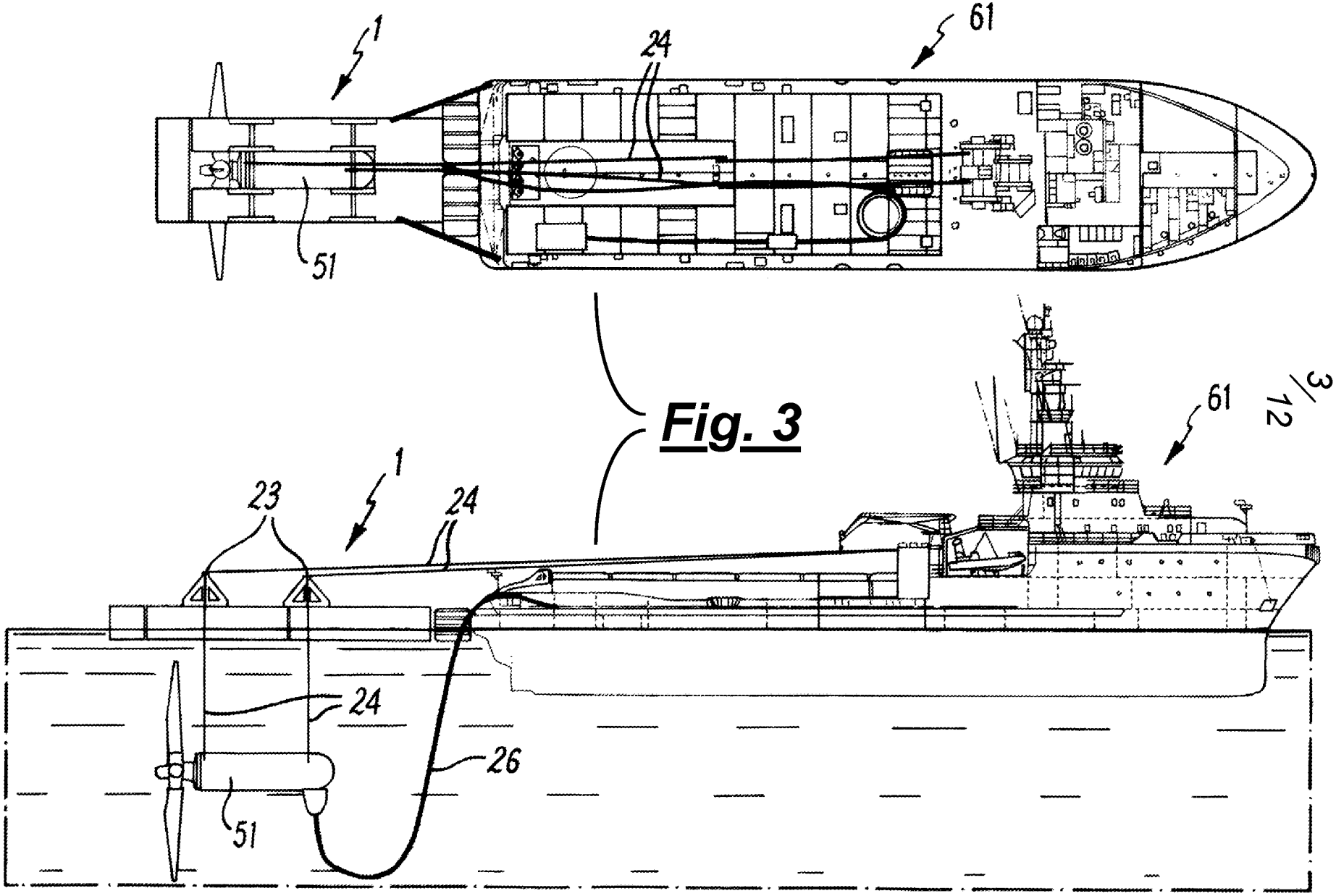

Fig. 3

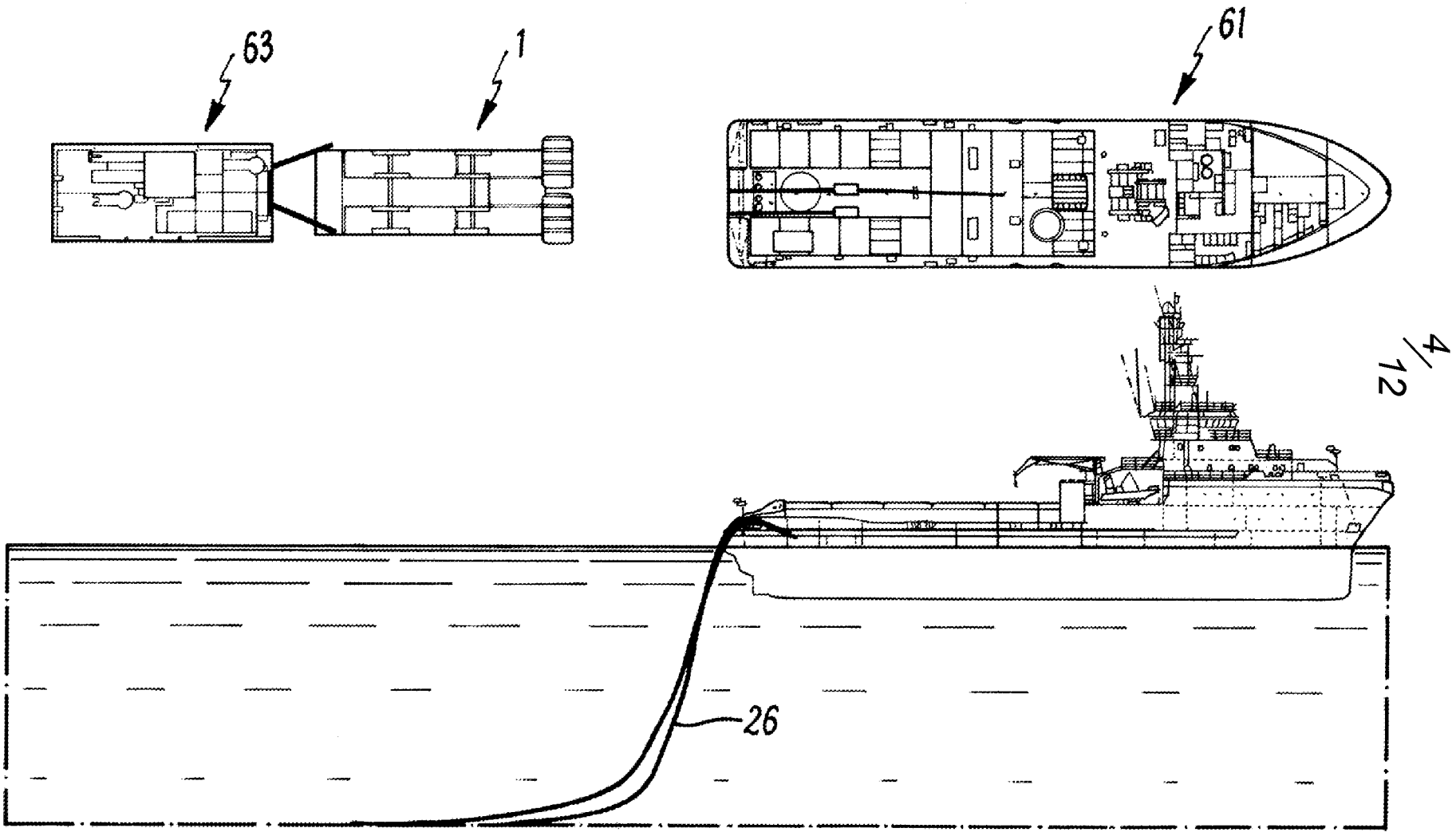

Fig. 4

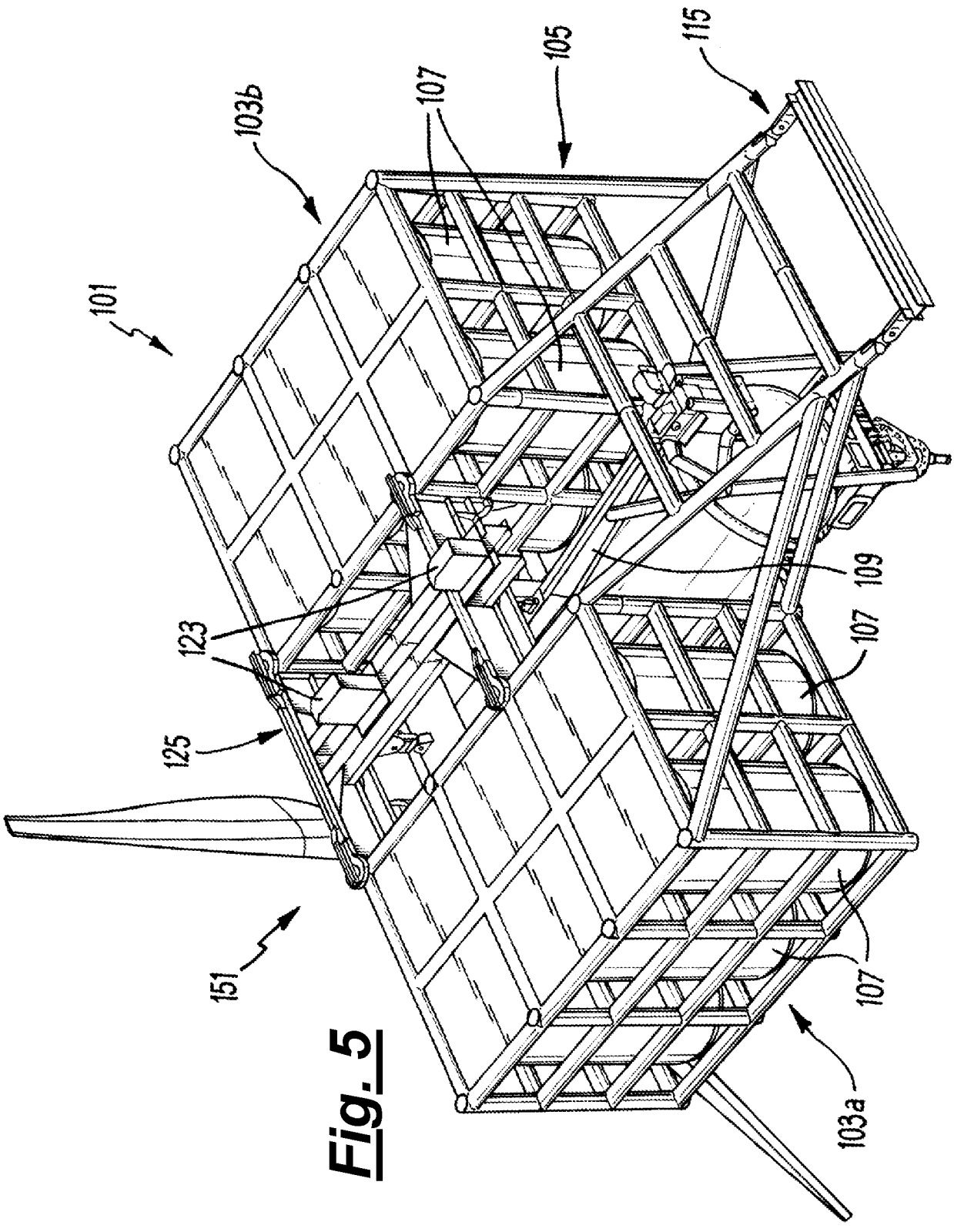

Fig. 5

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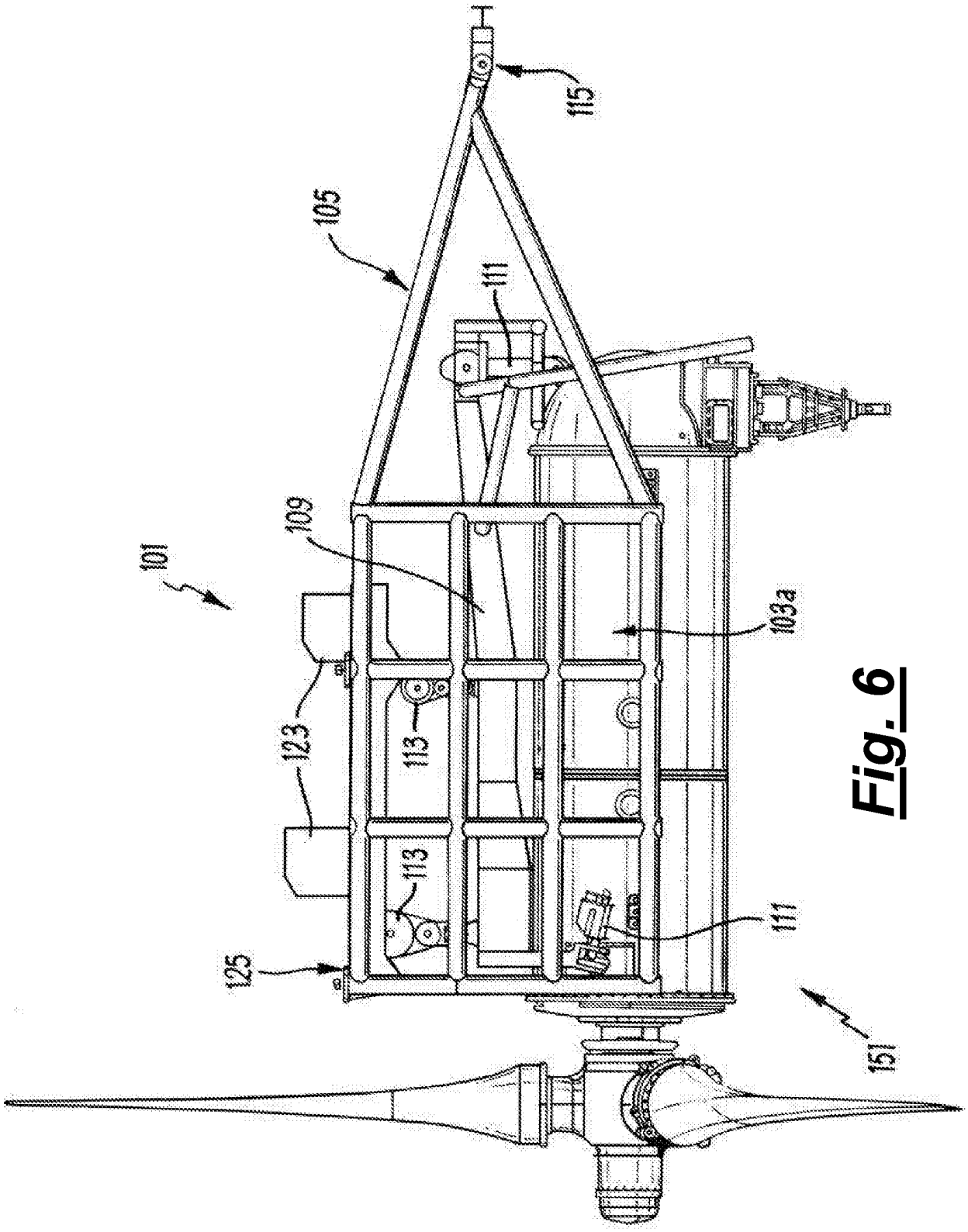

Fig. 6

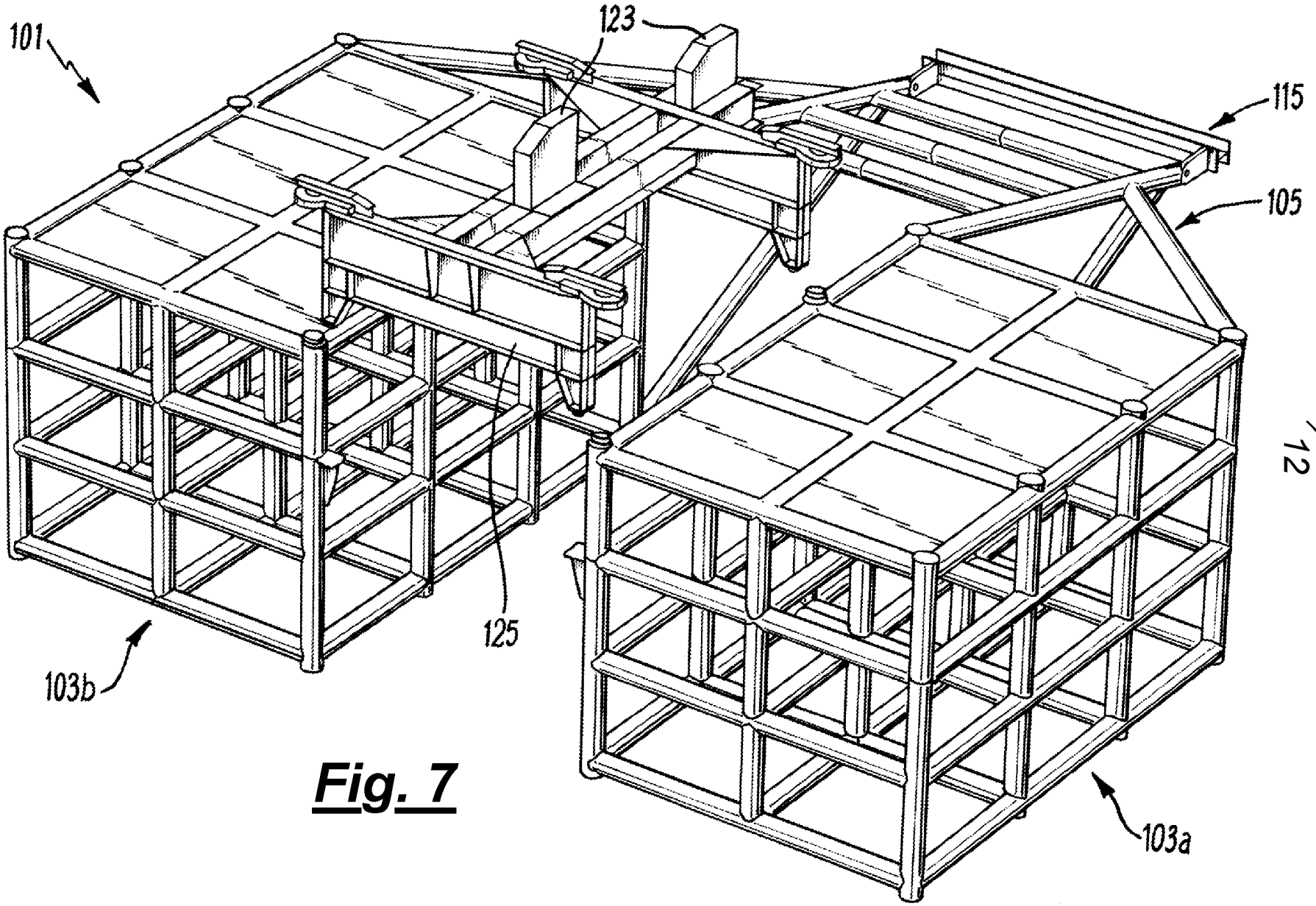

Fig. 7

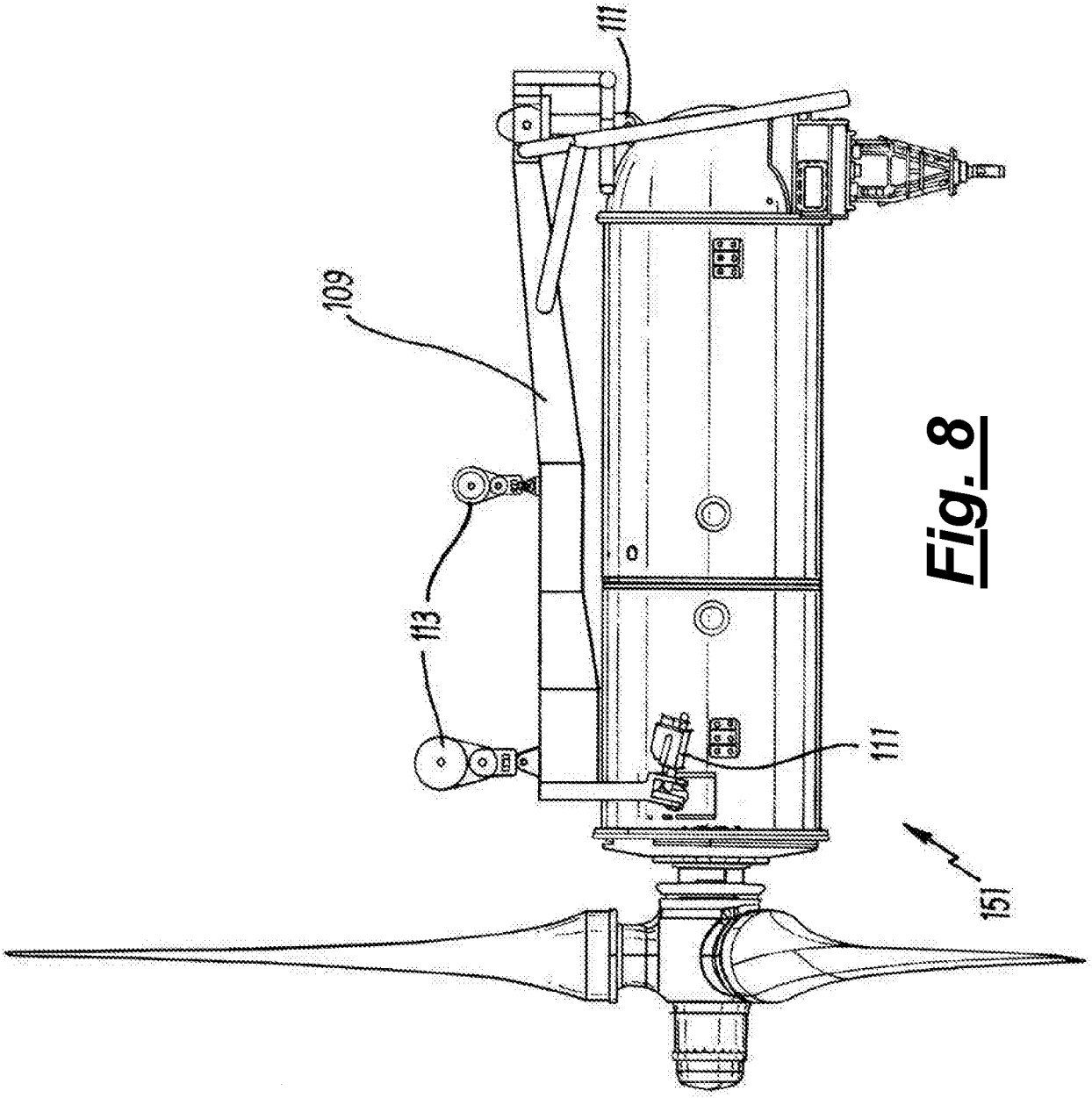

Fig. 8

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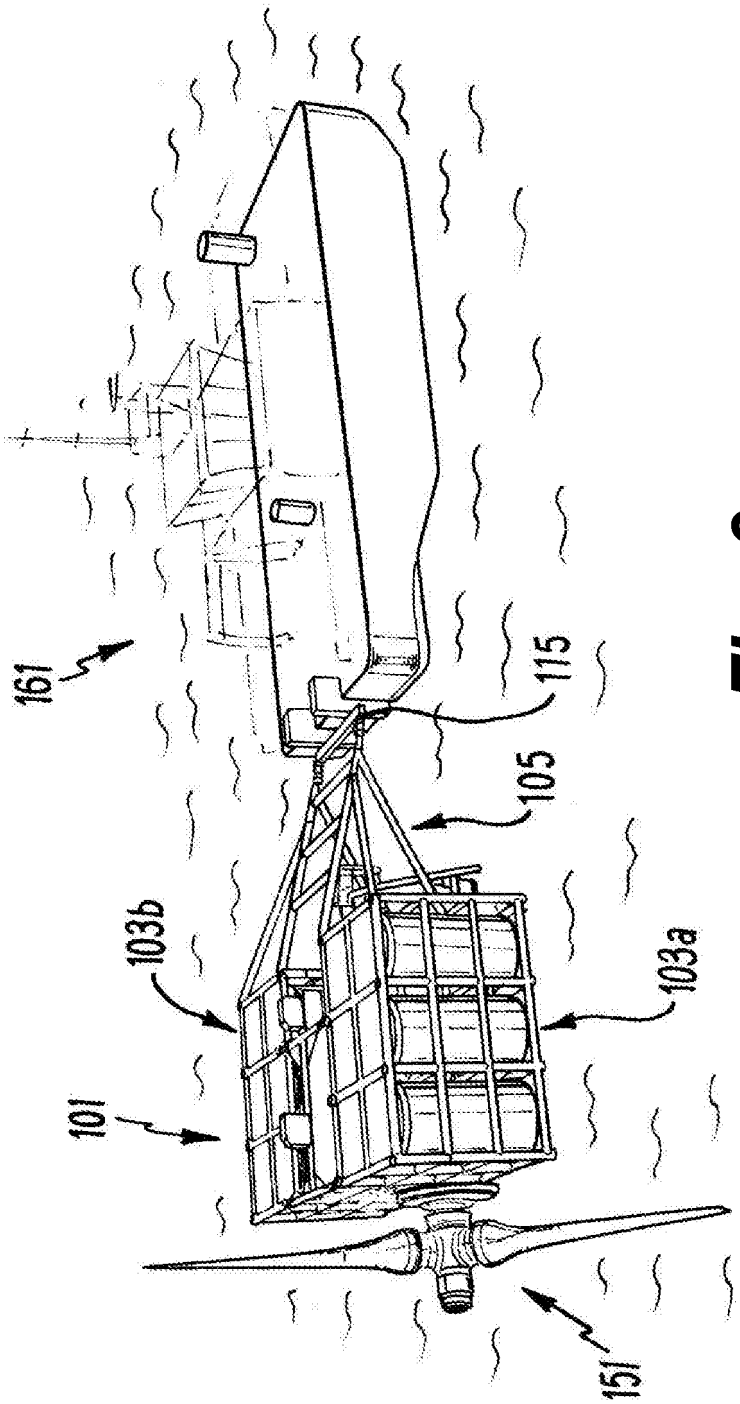

Fig. 9

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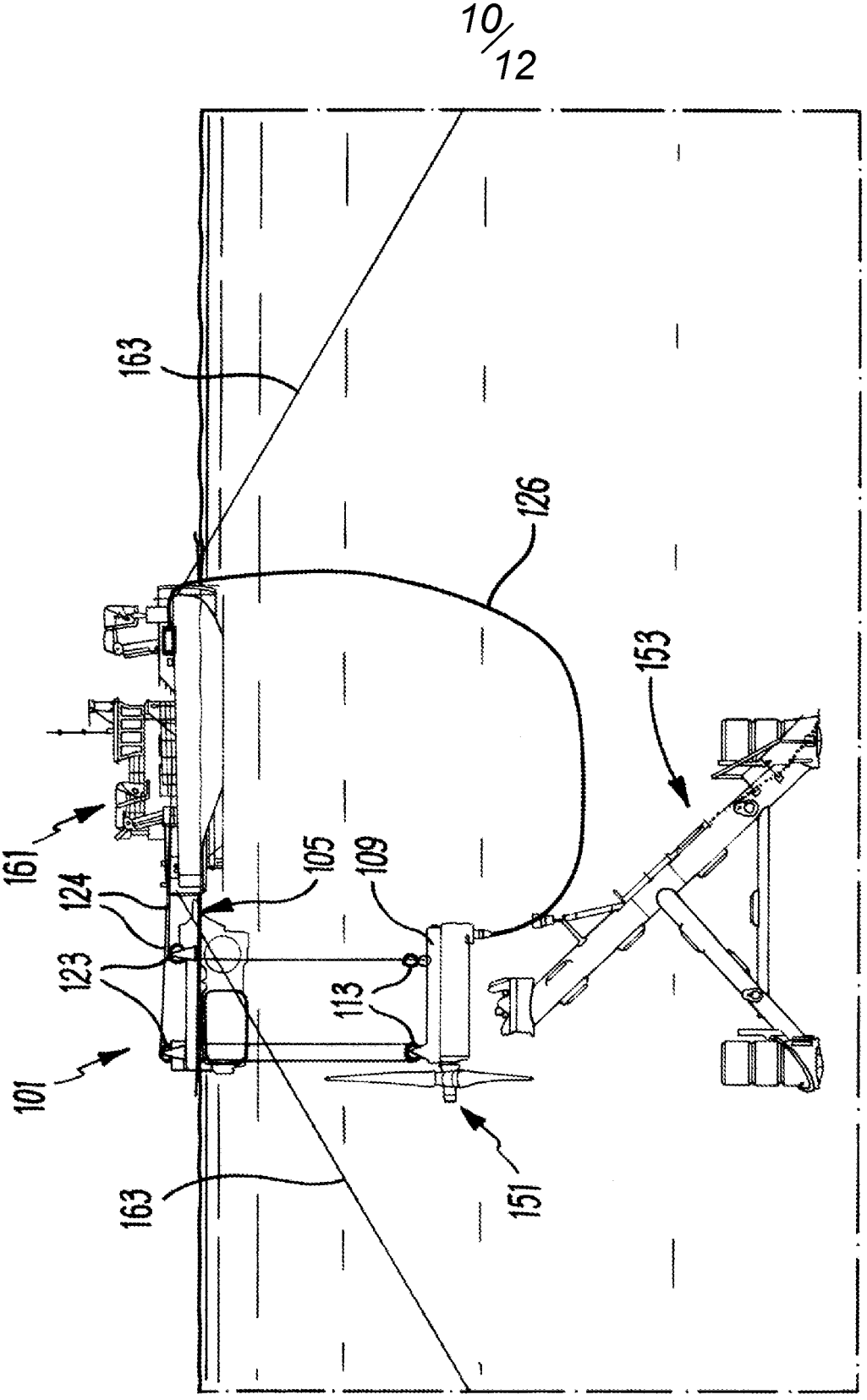

Fig. 10

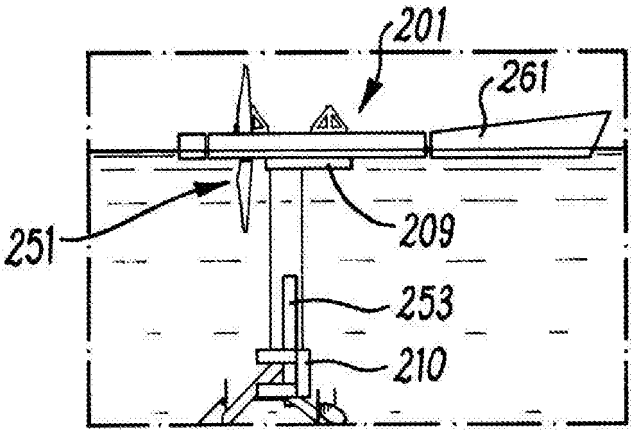

Fig. 11(a)

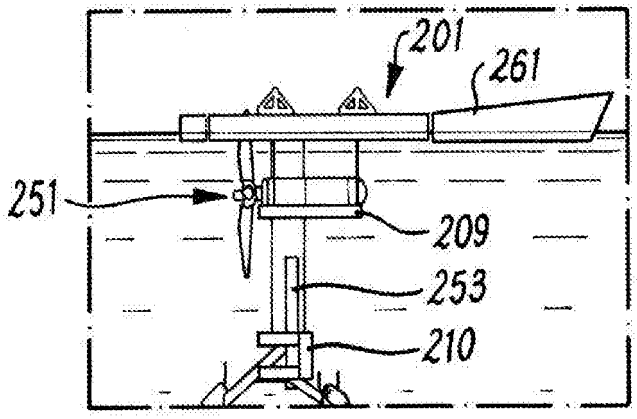

Fig. 11(b)

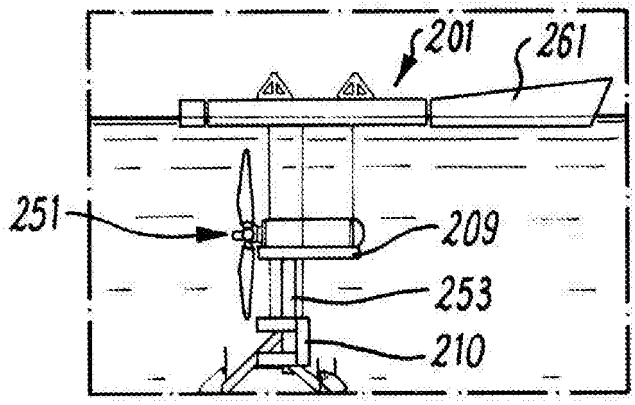

Fig. 11(c)

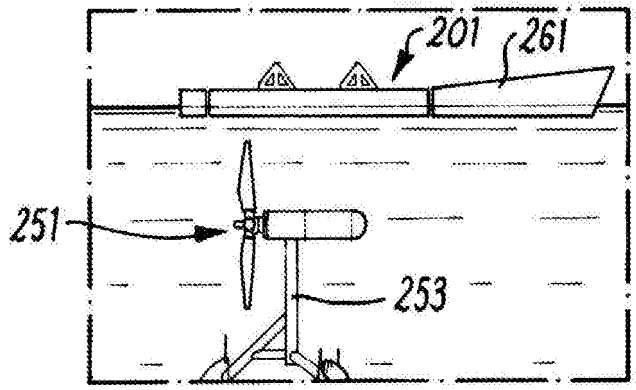

Fig. 11(d)

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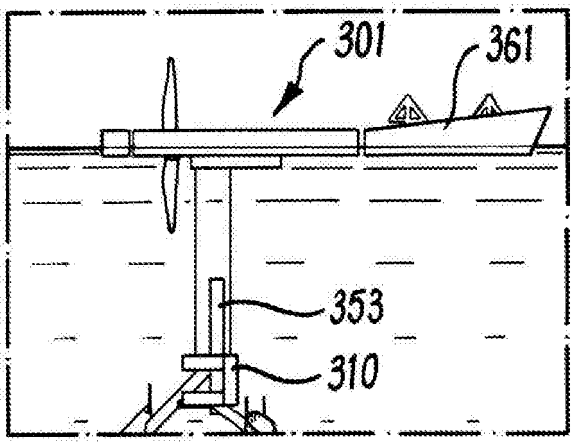

Fig. 12(a)

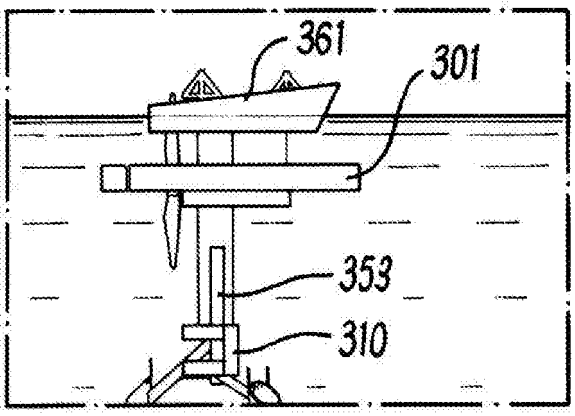

Fig. 12(b)

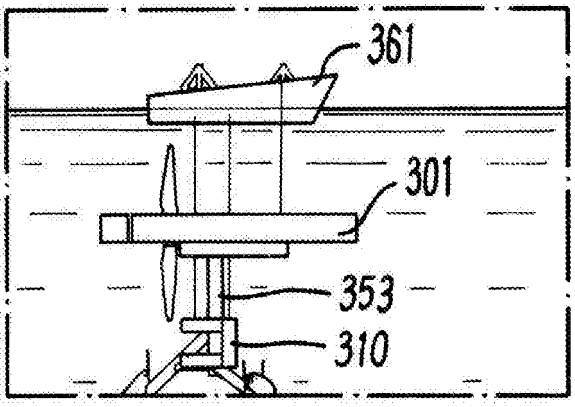

Fig. 12(c)

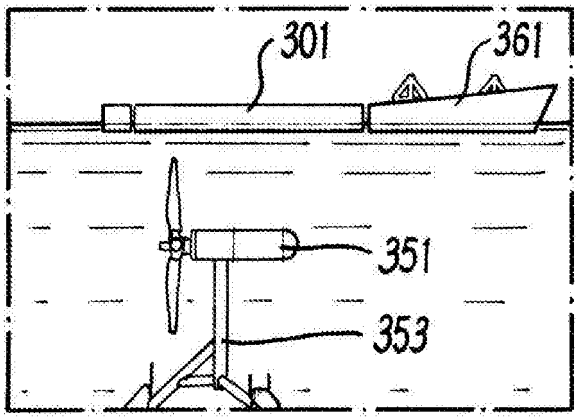

Fig. 12(d)

Underwater Turbine Installation Apparatus and Methods

The present invention relates to the field of underwater turbines such as tidal turbines installed in areas of tidal flow. More specifically, the present invention concerns improvements in the installation, and removal, of underwater turbine nacelles. In a particular embodiment of the invention there is provided an installation apparatus which comprises a buoyant platform and lifting equipment for lowering and/or raising the tidal turbine nacelle relative to the buoyant platform, and in another embodiment of the invention there is provided a method of installing a turbine nacelle on a substructure using such apparatus.

Background to the invention

It is recognised that the long-term financial viability of marine energy conversion devices such as tidal turbines is contingent on reducing the costs of installation and access for

maintenance. Studies have shown that the cost of marine operations accounts for a significant percentage of the lifecycle costs when standard installation and retrieval processes are used. A key consideration in making these devices commercially viable is therefore to minimise or at least reduce costs.

Presently, the installation of tidal turbines is realised using vessels such as dynamic positioning (DP) vessels or moored barges which are provided with large cranes to lower the turbine and/or substructure onto the seabed. The cost of operating such vessels is significant. Furthermore, access to such vessels may be limited due to demands in the hydrocarbon exploration and production industry which also makes use of such vessels.

It has been proposed that the production of a bespoke DP barge for dedicated installation and maintenance would meet requirements, but the cost is likely to be prohibitive.

Adopting a similar but more cost-effective approach, OpenHydro's "OpenHydro Installer" is a heavy lift barge which has been custom built to enable full scale tidal turbine deployment. However, the "OpenHydro Installer" is still a barge which requires other vessels to manoeuvre and position it, and the structure of the barge is particularly geared towards the enclosed blade type turbine preferred by OpenHydro.

WO 2009/127415 (in the name OpenHydro Group Limited), discloses a method of installing a hydroelectric turbine onto the seabed by lowering it from such a barge using a number of cables or support lines attached to the turbine base. However, it can be difficult to ensure that the turbine is aligned with the base as it is lowered into position. In any case, the barge was built at significant cost which in turn increases the effective energy cost. Furthermore this barge requires its own winches which if on long term charter is expensive and on short term is time consuming and also expensive to mobilise and commission.

Accordingly, the applicant recognises that there is an outstanding requirement for a solution that permits cost effective and efficient tidal turbine installation.

Accordingly, it is an object of at least one aspect of the present invention to provide an apparatus for the installation of a tidal turbine that is simpler to produce and/or easier to operate than current or proposed solutions.

Further aims and objects of the invention will become apparent from reading the following description.

Summary of the invention

According to a first aspect of the invention, there is provided an installation apparatus for the installation or removal of a tidal turbine nacelle on an underwater substructure, the apparatus comprising a buoyant platform, lifting equipment for lowering and/or raising the tidal turbine nacelle, and positioning means for positioning the installation apparatus relative to the underwater substructure.

The apparatus is therefore a tool that can enable the installation or removal of a turbine nacelle on a substructure without having to deploy a separate barge or heavy lift vessel with lifting capability such as a DP barge. A tool according to the first aspect can itself be packaged and shipped to a location where it is required, and (for example) when towed by and positioned by a workboat, multicat or any other suitable marine vessel can serve the same purpose and hence replace a larger and more expensive to operate heavy lift vessel. This positioning could be either achieved via moorings or via a DP system on the towing vessel. The installation apparatus may also be self-propelled and therefore independently positionable.

Preferably, the lifting equipment lowers and/or raises the tidal turbine nacelle relative to the buoyant platform.

The positioning means may comprise attachment means for attaching the buoyant platform to a marine vessel such as a work boat or multicat which can subsequently position the installation apparatus. Alternatively, the positioning means may comprise a propulsion system. Further alternatively, or additionally, the positioning means may comprise mooring apparatus to moor the installation apparatus to, or relative to, the underwater substructure.

Optionally, the positioning means is configured, or further configured, to control the position of the turbine nacelle and/or a frame associated with the turbine nacelle during installation or retrieval of the turbine nacelle. This may be achieved by propulsion means, steering aids and/or fins comprised in the installation apparatus. Alternatively, this may be achieved by controlling the position of a vessel to which the installation apparatus is attached or tethered, or which can otherwise manoeuvre the installation apparatus (for example by pushing). The installation apparatus could be moored, for example to the

substructure. Further alternatively, or additionally, a frame which supports or is suspended from the turbine nacelle during lowering or retrieval may comprise the positioning means – that is, the lifting/lowering/guide frame itself may be provided with propulsion means, steering aids and/or fins.

In a particular embodiment of the invention, the buoyant platform comprises one or more hollow steel tanks. The buoyancy of the tanks can be controlled by flooding with seawater as required.

Optionally, the buoyant platform comprises at least two hull portions disposed on either side of a void which accommodates the turbine nacelle when in a raised position. Preferably, each hull portion is provided with one or more buoyancy devices. Optionally, the buoyancy devices are inflatable. Alternatively, the buoyancy devices are solid. Alternatively, the buoyant platform comprises a single hull portion.

Optionally, the apparatus comprises a support configured to support the weight of the nacelle during installation or removal, the lifting equipment attachable to the nacelle by the support. Preferably, the support comprises a lifting frame. The support may comprise one or more A-frames.

Alternatively, the lifting equipment is attachable directly to the nacelle.

Preferably, the lifting equipment comprises at least one sheave block configured to receive at least one corresponding wire from a winch on board the marine vessel to which the apparatus is attached. Alternatively, the winch on board the marine vessel may be directly attached to the nacelle or a corresponding support.

Alternatively, the lifting equipment comprises one or more winches.

Preferably, the apparatus comprises a winch frame which comprises the lifting equipment and is removeably attachable to the buoyant platform. Optionally, the winch frame is configured to span a void between two hull portions.

Optionally, the apparatus comprises a guide configured to align the turbine nacelle with the substructure as it is progressed towards the substructure. Preferably, the guide is

disposed towards the lower end of a support which supports the weight of the turbine nacelle; the support may be a lifting frame.

Alternatively, the guide is configured to be suspended beneath the turbine nacelle.

In an embodiment of the invention, the guide is disposed on a frame for the installation or removal of an underwater turbine nacelle on a substructure. The frame comprises a support which is configured to support the weight of the nacelle during installation or removal, and further comprises the guide is arranged to align the frame with the substructure as the frame is moved towards the substructure. Alternatively, the nacelle can be suspended from or otherwise attached to, for example by hanging off hooks, the frame without the provision of a weight-bearing support. In any case, the frame particularly aids in installation by guiding the turbine nacelle onto the substructure in a predetermined manner, and aids in removal as the guide allows the frame to be guided onto the turbine nacelle prior to lifting away from the substructure. The support or the guide may be omitted in particular embodiments so as to benefit from each feature separately; in a particular embodiment this allows the guide to be mounted (or formed) on the substructure, and in another particular embodiment the frame can be suspended from the turbine nacelle.

Alternatively, or additionally, the guide comprises one or more wires or cables for connection to the substructure, the apparatus configured to lower the turbine nacelle onto the substructure along said one or more wires or cables.

Alternatively, the guide comprises one or more wires or cables for connection to the substructure, the apparatus configured to pull at least part of the buoyant platform and the turbine nacelle along the one or more wires or cables down onto the substructure.

Optionally, the positioning means comprises a connection frame connected to the buoyant platform at one end and comprising a connector to attach the connection frame to the marine vessel.

Optionally, the connector is articulated to allow relative movement between the apparatus and the work vessel. The connector may comprise a hinge. Alternatively, the connector may comprise one or more chains.

Optionally, the buoyant platform comprises an arrangement of tubular members. Optionally, the connection frame also comprises an arrangement of tubular members.

Optionally, the apparatus further comprises one or more imaging devices configured, arranged or adapted to observe the turbine nacelle and/or components of the apparatus. These may be disposed on a frame or directly on the turbine nacelle for example.

According to a second aspect of the invention there is provided a method of installing a tidal turbine nacelle on an underwater substructure, the method comprising transporting the turbine nacelle to the substructure in or on an installation apparatus according to the first aspect, and lowering the turbine nacelle to the substructure using the lifting equipment.

Optionally, the method further comprises connecting a winch cable from a winch on board the marine vessel to the nacelle via the lifting equipment of the apparatus.

Optionally, the method comprises connecting one or more wires or cables to the substructure and lowering the turbine nacelle onto the substructure along said one or more wires or cables.

Alternatively, the method comprises connecting one or more wires or cables to the substructure and pull at least a part of the buoyant platform and the turbine nacelle along the one or more wires or cables down onto the substructure.

Embodiments of the second aspect of the invention may comprise features corresponding to the preferred or optional features of the first aspect of the invention or vice versa.

According to a third aspect of the invention there is provided a method of removing an underwater turbine nacelle from a substructure, the method comprising transporting an apparatus according to the first aspect to the substructure, and raising the turbine nacelle from the substructure to the apparatus using the lifting equipment..

Embodiments of the third aspect of the invention may comprise features corresponding to the preferred or optional features of the first or second aspects of the invention or vice versa.

According to a fourth aspect of the invention there is provided a method of installing an array of tidal turbines comprising installing at least one turbine nacelle on at least one substructure of the array in accordance with the method of the second aspect.

Preferably, the method of the second aspect is repeated for each of the turbines of the array.

Embodiments of the fourth aspect of the invention may comprise features corresponding to the preferred or optional features of the first to third aspects of the invention or vice versa.

According to a fifth aspect of the invention, there is provided a marine vessel and an installation apparatus according to the first aspect positioned behind or attached to the marine vessel.

Optionally, the marine vessel is a work boat. Alternatively, the marine vessel is a multicat. Alternatively the marine vessel is a tug or a anchor handling vessel.

Embodiments of the fifth aspect of the invention may comprise features corresponding to the preferred or optional features of the first to fourth aspects of the invention or vice versa.

According to a sixth aspect of the invention, there is provided a tidal turbine comprising a turbine nacelle and an underwater substructure, the turbine nacelle having been installed on the substructure using one or more of: a frame according to the first aspect; a method according to the second or fourth aspect, or a marine vessel according to the fifth aspect.

Embodiments of the sixth aspect of the invention may comprise features corresponding to the preferred or optional features of the first to fifth aspects of the invention or vice versa.

According to a yet further aspect of the invention, there is provided an installation apparatus, a method of installing a turbine nacelle or removing a turbine nacelle from a

substructure, a method of installing a turbine array, or a marine vessel incorporating an installation apparatus or having an installation apparatus attached thereto, substantially as herein described with reference to the appended drawings.

Brief description of the drawings

Aspects and advantages of the present invention will become apparent upon reading the following detailed description and upon reference to the following drawings (like reference numerals referring to like features) in which:

Figure 1 is a schematic representation of an installation apparatus according to at least one aspect of the invention, a corresponding turbine nacelle suspended from the installation apparatus, and an anchor handling tug supply vessel towing the installation apparatus;

Figures 2 to 4 are further schematic representations of the installation apparatus shown in Figure 1, and in conjunction with Figure 1 illustrating the subsea deployment of the turbine nacelle;

Figure 5 is a schematic representation of an alternative installation apparatus according to at least one aspect of the invention and a corresponding turbine nacelle;

Figures 6 to 8 are further schematic representations of the installation apparatus shown in Figure 5, in various views and with some features omitted;

Figure 9 is a schematic representation of the installation apparatus shown in Figures 5 to 8 attached to a work vessel;

Figure 10 is a schematic representation of the installation apparatus being used to install a turbine nacelle on a substructure in accordance with at least one aspect of the invention; and

Figure 11 is a schematic representation of a number of stages in the installation of a turbine nacelle on a substructure in accordance with at least one aspect of the invention.

Detailed description of preferred embodiments

As discussed in the background to the invention above, known installation vessels are expensive to operate in practice and the lack of accessible and cost effective alternatives is currently preventing large scale device deployment. As such, an alternative installation methodology is desired.

An installation apparatus 1 according to an embodiment of the present invention is illustrated in Figure 1 and overcomes a number of problems with the prior art. To demonstrate the features of the invention, Figures 1 to 4 illustrate the subsea deployment of turbine nacelle 51. The installation apparatus 1 comprises a number of buoyancy units 7 which surround and define a void through which lifting equipment 9 is connected to the turbine nacelle 51. The buoyancy units 7 in this embodiment comprise a number of steel tanks or drums.

The installation apparatus 1 is tethered to a vessel 61, which in this embodiment is an anchor handling tug supply (AHTS) vessel, which tows the installation apparatus 1 and turbine nacelle 51 (which is suspended from the installation apparatus 1) to an installation site. Once at site, or when approaching site, the installation apparatus 1 is pulled towards the stern of the AHTS vessel 61 at which point any seafastenings rigidly connecting the turbine nacelle 51 to the installation apparatus 1 are removed so that it can be raised and lowered. Winches on board the AHTS vessel 61 are then operatively connected to the turbine nacelle 51 via sheave blocks 23 mounted on the installation apparatus by winch lines 24.

The winch lines 24 can connect directly to the turbine nacelle as in the current embodiment, but it is also foreseen that the winch lines 24 could connect to a lifting frame attached to, supporting or suspending, the turbine nacelle 51 (as in the later described embodiment). Furthermore, the winch lines could be connected to winch lead lines already so connected.

As shown in Figure 3, the turbine nacelle 51 is then lowered from the installation apparatus 1, via sheave blocks 23, by winch lines 24 connected to winches on board the AHTS vessel 61. A pigtail cable 26, connected to the turbine nacelle 51 and hanging in a lazy loop over a stern roller (not shown) on the AHTS vessel 61, is paid out by a tugger winch

mounted on the deck of the AHTS vessel 61. As noted below, the turbine nacelle 51 can be guided onto a substructure by using cameras mounted on the turbine nacelle 51 (or an associated lifting frame) and subsequently disconnected or disengaged from the winch lines 24 (or lifting frame) using hydraulics.

The winch lines 24 are then retracted and, as shown in Figure 4, another vessel (in this example a multicat 63) brought in to tow the installation apparatus 1 away from the AHTS 61 – from which the installation apparatus 1 is now detached. The AHTS 61 can then be used to pay out cable 26 to the seabed.

In this embodiment, the installation apparatus 1 is independently stable and the connection to the AHTS vessel 61 can be a flexible attachment such as may be provided by chains. A bumper disposed between the installation apparatus 1 and the AHTS vessel 61 (on the installation apparatus 1 as illustrated and/or the AHTS vessel 61). A more rigid connection between a vessel and the installation apparatus may also be provided, such as the hinged connection described in the alternative embodiment below.

Notwithstanding the nature of the connection, the apparatus enables the installation or removal of a turbine nacelle on a substructure without having to deploy a separate barge or heavy lift vessel. Such an installation apparatus can be easily packaged and/or shipped to a location where it is required, and when attached (flexibly, rigidly or otherwise) to a suitable marine vessel, the resulting assembly provides a direct replacement for a larger, slower and more expensive to operate heavy lift vessel which may also need to be modified for the specific purpose of lowering and raising a turbine nacelle – the present invention is specifically made for this purpose. Of course, the installation apparatus could be self-propelled and itself serve as a direct replacement for such vessels.

An alternative installation apparatus 101 according to an embodiment of the present invention is illustrated in Figure 5 and overcomes a number of problems with the prior art. To demonstrate the features of the invention, Figures 6 to 8 show alternative views of the installation apparatus 101 with some features omitted to allow a clearer view of some of the otherwise obscured features. Figure 9 shows the installation apparatus 101 attached to a work vessel 161 and en route to an installation site carrying a turbine nacelle 151, and Figure 10 shows the installation apparatus at the installation site and the turbine nacelle 151 being lowered towards an underwater substructure 153.

The installation apparatus 101 comprises two hull portions 103a,103b held in a spaced apart arrangement by a connection frame 105. The spaced apart arrangement accommodates the turbine nacelle 151 between the hull portions 103a,103b when it is in a raised or retracted position. The connection frame 105 provides for attachment of the installation apparatus 101 to the work vessel 161 via a hinged connector 115, as shown in Figure 9. The hinged connector 115 permits relative movement or rotation between the apparatus 101 and the work vessel 161.

Each hull portion 103a,103b is provided with a number of buoyancy units 107 which lend buoyancy to the apparatus 101 and thus provide a buoyant platform from (and/or to) which the nacelle can be lowered (and/or raised). In this embodiment, the buoyancy units 107 are inflatable.

The turbine nacelle 151 is held in a lifting frame 109 which is attached to the nacelle 151 at the front and back ends. The attachment is via a number of hydraulic connectors 111 which can be remotely actuated. The lifting frame 109 also comprises two sheave block connectors 113 which cooperate with sheave blocks 123 to receive winch cables from the work vessel to which the apparatus 101 is attached. It will be understood that many work vessels do not have winches of sufficient capacity to handle the raising and lowering of a turbine nacelle otherwise; the sheave block arrangement provides mechanical advantage to allow smaller vessels to deploy relatively large turbine nacelles.

As shown in Figure 10, the lifting frame 109 is lowered (and/or raised) by winches on board the work vessel 161 by cables 124 connected via sheave blocks 123 on the apparatus 101 and sheave block connectors 113 on the lifting frame 109.

In this embodiment, the sheave blocks 123 themselves are located on a winch frame 125 which spans the space between the hull portions 103a,103b. In Figure 5, the winch frame 125 is connected to the hull portions 103a,103b as would be the case during transport to an installation site and during lowering (or raising) of the turbine nacelle 151. Figure 7 shows the installation apparatus 101 with the turbine nacelle and lifting frame omitted, and the winch frame 125 raised up from the hull portions 103a,103b.

This permits the winch frame 125 to be attached to the turbine nacelle 151 or lifting frame 109 by one or more hydraulic connectors, while on a quayside for example, and the turbine nacelle 151 then lowered onto the apparatus 101 (into the space between the hull portions 103a,103b) using cranes or similar until the winch frame 125 engages with the hull portions 103a,103b. The winch frame 125 can then be fixed to the hull portions 103a,103b and thus the turbine nacelle 151 is held with the apparatus 101 from above.

Note that in an alternative embodiment, not illustrated here, the winch frame is integral with the apparatus and the apparatus is instead floated over the turbine nacelle and the turbine nacelle or lifting frame subsequently attached to the winch frame or apparatus by a suitable fastener. In a further alternative embodiment, the nacelle can be trailered onto the buoyant body into an A-frame structure which lowers the nacelle between the hull portions.

Once the turbine nacelle 151 is located within the apparatus 101, the work vessel 161 tows the apparatus 101 (and attached nacelle 151) to the deployment site. It is then moored to two or more pre-installed moorings by mooring lines 163.

In an alternative embodiment, to avoid the need for mooring the work vessel a work vessel such as a multicat, tug or anchor handler with dynamic positioning could be employed.

Once in place over the substructure 153, the connection between the turbine nacelle 151 or lift frame 109 and the winch frame 125 is released and the nacelle 151 lowered using the winches onboard the work vessel 161 via the sheave blocks 123 as described above and as shown in Figure 10. Once the turbine nacelle 151 is in place, the connectors attaching it to the lift frame 109 can be released and the lift frame 109 recovered to the surface.

In a removal or servicing operation, the apparatus 101 can be towed out to the turbine site, positioned over the substructure and nacelle, and the lift frame lowered until it can be connected to the nacelle. Once connected, the nacelle can be lifted away from the substructure and up towards the apparatus. Once retrieved, the work vessel can tow the apparatus plus nacelle to a quayside or to another servicing location or vessel.

Figure 11 illustrates an alternative embodiment of the apparatus 201 in various stages during deployment of a turbine nacelle 251 on a substructure 253 in accordance with

another embodiment of the invention. In Figure 11(a) the apparatus 201 has been towed to the installation location and positioned above the substructure 253, although as will become apparent the apparatus 201 does not need to be directly above or aligned with the substructure 253. Guide wires extend from the apparatus 201 to the substructure 253, where they are connected to a guide frame 210 which is clamped onto the substructure.

The guide frame 210 may be lowered from the apparatus 201 with the guide wires already attached and the guide frame 210 subsequently attached to the substructure, or the guide frame 210 may be attached to the substructure 253 and the guide wires subsequently attached to the guide frame 210. In an alternative embodiment the guide wires may be connected directly to the substructure. In a further alternative embodiment the guide frame is not connected to the substructure but has sufficient mass to adequately tension the guide wires.

The turbine nacelle 251 is cradled by a lifting frame 209 which is lowered, as shown in Figure 11(b), along the guide wires to guide the turbine nacelle 251 into place on the substructure 253, as shown in Figure 11(c). The lifting frame 209 is then disengaged from the nacelle 251 and the guide frame 210 disengaged from the substructure, leaving the turbine nacelle 251 mounted on the substructure 253. The apparatus can then be towed away, although it is envisaged that the apparatus in this embodiment could instead be self-propelled.

Note that it is foreseen that instead of using a lowering frame to lower the turbine nacelle onto the substructure, the guide wires may be used instead as winch cables, and winches on the apparatus (or the guide frame or even the substructure) used to pull the apparatus and the turbine nacelle down onto the substructure. Once attached to the substructure the apparatus can release the turbine nacelle and the winch cables paid out to return the apparatus to the surface.

The positive buoyancy provided by the apparatus makes the descent of the turbine nacelle onto the substructure easier to control, and in the event of damage to the guide wires or winch cables the turbine nacelle will be returned to surface rather than sinking to the seabed and risking damage to the turbine nacelle and/or the substructure.

Alternatively, as shown in Figure 12, the buoyancy tanks of the apparatus 301 are flooded with water to reduce the total buoyancy of the apparatus 301 plus turbine nacelle 351. When negative buoyancy is achieved, the apparatus 301 and turbine nacelle 351 begin to sink towards the seabed, and the vessel 361 is then manoeuvred over the apparatus 301 as shown in Figure 12(b) where on-board winches are then used to control the descent of the apparatus 301 and nacelle 351, and the positioning of the nacelle 351 relative to the substructure 353. Similarly to Figure 11, guide wires can extend between the vessel 361 and a guide frame 310 which guide the turbine nacelle 351 onto the substructure 353 as it is lowered as shown in Figure 12(c). This may assist or be an alternative to positioning using the vessel 361.

Once in place on the substructure 353, the apparatus 301 can be retrieved and towed away by the vessel 361 as shown in Figure 12(d). Prior to detaching the apparatus 301 from the turbine nacelle 351 it may be preferable to further flood the buoyancy tanks to compensate for the change in buoyancy resulting from the nacelle 351 being removed from the assembly, and pull the apparatus 301 to the surface against negative buoyancy. Otherwise, the apparatus 301 might be allowed to float to the surface.

It is envisaged that the attachment of the lift frame to the nacelle, or indeed the attachment of the nacelle to the substructure in an installation operation, can be assisted by the use of ROVs. It is also envisaged that the use of subsea cameras mounted on the lift frame, nacelle, substructure and/or any other part of the apparatus can be used to aid docking of the nacelle on the substructure as well as monitoring the behaviour of attached cables and any dry-mate or wet-mate connections.

The apparatus described in at least one embodiment above comprises an arrangement of steel tubulars which effectively form two cages which receive and support the buoyancy units. However, it is ancitipated that the hull portions could comprise solid or sheet steel hulls. Furthermore, the buoyancy units can be solid instead of inflatable. For example, the apparatus described with reference to Figures 1 to 4 comprises large steel tanks which provide buoyancy.

In an alternative embodiment of the invention, the lifting frame can cradle or otherwise extend below the nacelle, and comprise a guide disposed towards a lower end of the frame to guide the frame with respect to the substructure as it is lowered into place. The

frame can be moved towards the substructure by appropriate thrusting or other position control of the work vessel to which the apparatus is attached. It will be understood that alignment of the frame with the substructure during installation serves to align the nacelle with the substructure, and during removal serves to align the frame with the nacelle.

In a further alternative embodiment of the invention the frame does not support the weight of the turbine nacelle but is instead suspended from the turbine nacelle and the winch cables connected directly to the turbine nacelle. However, the frame is provided with a corresponding guide or functionally equivalent arrangement to allow the alignment function provided by the embodiment described immediately above.

The invention provides an installation apparatus and corresponding methods for the installation or removal of a tidal turbine nacelle on an underwater substructure. A buoyant platform, lifting equipment for lowering and/or raising the tidal turbine nacelle, and positioning means for positioning the installation apparatus relative to the underwater substructure, enables the installation or removal of a turbine nacelle on a substructure without having to deploy a separate barge or heavy lift vessel. Instead, such an installation apparatus can be towed by and positioned by a workboat, multicat or any other suitable marine vessel and hence serve the same purpose. Positioning can be achieved by a propulsion system comprised in the apparatus itself, or manoeuvring by another vessel.

Throughout the specification, unless the context demands otherwise, the terms 'comprise' or 'include', or variations such as 'comprises' or 'comprising', 'includes' or 'including' will be understood to imply the inclusion of a stated integer or group of integers, but not the exclusion of any other integer or group of integers.

The foregoing description of the invention has been presented for the purposes of illustration and description and is not intended to be exhaustive or to limit the invention to the precise form disclosed. The described embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilise the invention in various embodiments and with various modifications as are suited to the particular use contemplated. Therefore, further modifications or improvements may be incorporated without departing from the scope of the invention as defined by the appended claims. In particular, it will be

appreciated that features of the embodiments described herein may be interchanged with or added to one another in alternative embodiments of the invention, and that combinations of features other than those expressly claimed are within the scope of the invention.

Claims

1. An installation apparatus for the installation or removal of a tidal turbine nacelle on an underwater substructure, the apparatus comprising a buoyant platform, lifting equipment for lowering and/or raising the tidal turbine nacelle relative to the buoyant platform, and positioning means for positioning the installation apparatus relative to the underwater substructure.

2. The installation apparatus according to claim 1, wherein the positioning means comprises attachment means for attaching the buoyant platform to a marine vessel such as a work boat or multicat which can subsequently position the installation apparatus.

3. The installation apparatus according to claim 1, wherein the positioning means comprises a propulsion system.

4. The installation apparatus according to any preceding claim, wherein the positioning means may comprise mooring apparatus to moor the installation apparatus to, or relative to, the underwater substructure.

5. The installation apparatus according to any preceding claim, wherein the positioning means is configured, or further configured, to control the position of the turbine nacelle and/or a frame associated with the turbine nacelle during installation or retrieval of the turbine nacelle.

6. The installation apparatus according to claim 5, further comprising propulsion means, steering aids and/or fins configured to control the position of the turbine nacelle and/or frame.

7. The installation apparatus according to any preceding claim, comprising a frame which supports or is suspended from the turbine nacelle during lowering or retrieval and comprises the positioning means.

8. The installation apparatus according to any preceding claim, wherein the buoyant platform comprises at least two hull portions disposed on either side of a void which accommodates the turbine nacelle when in a raised position.

9. The installation apparatus according to claim 8, wherein each hull portion is provided with one or more buoyancy devices.

10. The installation apparatus according to claim 9, wherein the buoyancy devices are inflatable.

11. The installation apparatus according to claim 9, wherein the buoyancy devices are solid.

12. The installation apparatus according to any of claims 1 to 7, wherein the buoyant platform comprises a single hull portion.

13. The installation apparatus according to any preceding claim, wherein the apparatus comprises a support configured to support the weight of the nacelle during installation or removal, the lifting equipment attachable to the nacelle by the support.

14. The installation apparatus according to claim 13, wherein the support comprises a lifting frame.

15. The installation apparatus according to claim 13, wherein the support comprises an A-frame.

16. The installation apparatus according to any of claims 1 to 12, wherein the lifting equipment is attachable directly to the nacelle.

17. The installation apparatus according to any preceding claim, wherein the lifting equipment comprises at least one sheave block configured to receive at least one corresponding wire from a winch on board the marine vessel to which the apparatus is attached.

18. The installation apparatus according to claim 17, wherein the winch on board the marine vessel is directly attached to the nacelle or a corresponding support.

19. The installation apparatus according to any preceding claim, wherein the lifting equipment comprises one or more winches.

20. The installation apparatus according to any preceding claim, wherein the apparatus comprises a winch frame which comprises the lifting equipment and is removeably attachable to the buoyant platform.

21. The installation apparatus according to claim 20, wherein the winch frame is configured to span a void between two hull portions.

22. The installation apparatus according to any preceding claim, wherein the apparatus comprises a guide configured to align the turbine nacelle with the substructure as it is progressed towards the substructure.

23. The installation apparatus according to claim 22, wherein the guide is disposed towards the lower end of a support which supports the weight of the turbine nacelle.

24. The installation apparatus according to claim 22, wherein the guide is configured to be suspended beneath the turbine nacelle.

25. The installation apparatus according to claim 22, wherein, the guide is disposed on a frame comprising a support which is configured to support the weight of the nacelle during installation or removal, and the guide arranged to align the frame with the substructure as the frame is moved towards the substructure.

26. The installation apparatus according to any of claims 22 to 25, wherein the guide comprises one or more wires or cables for connection to the substructure, the apparatus configured to lower the turbine nacelle onto the substructure along said one or more wires or cables.

27. The installation apparatus according to any of claims 22 to 25, wherein the guide comprises one or more wires or cables for connection to the substructure, the apparatus configured to pull at least part of the buoyant platform and the turbine nacelle along the one or more wires or cables down onto the substructure.

28. The installation apparatus according to any preceding claim, wherein the positioning means comprises a connection frame connected to the buoyant platform at one end and comprising a connector to attach the connection frame to a marine vessel.

29. The installation apparatus according to claim 28, wherein the connector is articulated to allow relative movement between the apparatus and the vessel.

30. The installation apparatus according to claim 28 or claim 29, wherein the connector comprises a hinge.

31. The installation apparatus according to claim 28 or claim 29, wherein the connector comprises one or more chains.

32. The installation apparatus according to any preceding claim, wherein the buoyant platform comprises an arrangement of tubular members.

33. The installation apparatus according to any preceding claim, wherein the connection frame also comprises an arrangement of tubular members.

34. The installation apparatus according to any preceding claim, wherein the apparatus further comprises one or more imaging devices configured, arranged or adapted to observe the turbine nacelle and/or components of the apparatus.

35. A method of installing a tidal turbine nacelle on an underwater substructure, the method comprising transporting the turbine nacelle to the substructure in or on an installation apparatus according to any of claims 1 to 34, and lowering the turbine nacelle from the apparatus to the substructure using the lifting equipment.

36. The method according to claim 35, further comprising connecting a winch cable from a winch on board the marine vessel to the nacelle via the lifting equipment of the apparatus.

37. The method according to claim 35 or claim 36, further comprising connecting one or more wires or cables to the substructure and lowering the turbine nacelle onto the substructure along said one or more wires or cables.

38. The method according to claim 35, further comprising connecting one or more wires or cables to the substructure and pulling at least a part of the buoyant platform and the turbine nacelle along the one or more wires or cables down onto the substructure.

39. A method of removing an underwater turbine nacelle from a substructure, the method comprising transporting an apparatus according to any of claims 1 to 34 to the substructure, and raising the turbine nacelle from the substructure to the apparatus using the lifting equipment.

40. A method of installing an array of tidal turbines comprising installing at least one turbine nacelle on at least one substructure of the array in accordance with the method of the second aspect.

41. The method according to claim 40, wherein the method of the second aspect is repeated for each of the turbines of the array.

42. A marine vessel and an installation apparatus according to the first aspect positioned behind or attached to the marine vessel.

43. A tidal turbine comprising a turbine nacelle and an underwater substructure, the turbine nacelle having been installed on the substructure using one or more of an apparatus according to any of claims 1 to 34; a method according to any of claims 35 to 38 or 40 to 41; or a marine vessel and installation apparatus according to the claim 42.

44. An installation apparatus, a method of installing a turbine nacelle or removing a turbine nacelle from a substructure, a method of installing a turbine array, or a marine vessel incorporating an installation apparatus or having an installation apparatus attached thereto, substantially as herein described with reference to the appended drawings.

Claims

1. An installation apparatus for the installation or removal of a tidal turbine nacelle on an underwater substructure, the apparatus comprising a buoyant platform, lifting equipment for lowering and/or raising the tidal turbine nacelle relative to the buoyant platform, and positioning means for positioning the installation apparatus relative to the underwater substructure wherein the positioning means comprises attachment means to directly attach the buoyant platform to a marine vessel such as a work boat or multicat which can subsequently position the installation apparatus.

2. The installation apparatus according to claim 1, wherein the attachment means comprises a connection frame connected to the buoyant platform at one end and comprising a connector to attach the connection frame to a marine vessel.

3. The installation apparatus according to claim 2, wherein the connector is articulated to allow relative movement between the apparatus and the vessel.

4. The installation apparatus according to claim 2 or claim 3, wherein the connector comprises a hinge.

5. The installation apparatus according to any preceding claim, wherein the lifting equipment comprises at least one sheave block configured to receive at least one corresponding wire from a winch on board a marine vessel to which the apparatus is attached.

6. The installation apparatus according to claim 5, wherein the winch on board the marine vessel is directly attached to the nacelle or a corresponding support.

7. The installation apparatus according to any preceding claim, wherein the positioning means further comprises mooring apparatus to moor the installation apparatus to, or relative to, the underwater substructure.

8. The installation apparatus according to any preceding claim, wherein the positioning means is further configured to control the position of the turbine nacelle and/or a frame associated with the turbine nacelle during installation or retrieval of the turbine nacelle.

9. The installation apparatus according to claim 8, further comprising propulsion means, steering aids and/or fins configured to control the position of the turbine nacelle and/or frame during installation or retrieval of the turbine nacelle.

10. The installation apparatus according to claim 9, comprising a frame which supports the turbine nacelle or is suspended from the turbine nacelle during lowering or retrieval and comprises the propulsion means, steering aids and/or fins.

11. The installation apparatus according to any preceding claim, wherein the buoyant platform comprises one or more hollow steel tanks.

12. The installation apparatus according to claim 11, wherein the buoyancy of the one or more hollow steel tanks can be controlled by flooding with seawater.

13. The installation apparatus according to any of claims 1 to 10, wherein the buoyant platform comprises at least two hull portions disposed on either side of a void which accommodates the turbine nacelle when in a raised position.

14. The installation apparatus according to claim 13, wherein each hull portion is provided with one or more buoyancy devices.

15. The installation apparatus according to claim 14, wherein the buoyancy devices are inflatable.

16. The installation apparatus according to claim 14, wherein the buoyancy devices are solid.

17. The installation apparatus according to any of claims 1 to 12, wherein the buoyant platform comprises a single hull portion.

18. The installation apparatus according to any preceding claim, wherein the apparatus comprises a support configured to support the weight of the nacelle during installation or removal, the lifting equipment attachable to the nacelle by the support.

19. The installation apparatus according to claim 18, wherein the support comprises a lifting frame.

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20. The installation apparatus according to claim 18, wherein the support comprises an A-frame.

21. The installation apparatus according to any of claims 1 to 17, wherein the lifting equipment is attachable directly to the nacelle.

22. The installation apparatus according to any preceding claim, wherein the lifting equipment comprises one or more winches.

23. The installation apparatus according to any preceding claim, wherein the apparatus comprises a winch frame which comprises the lifting equipment and is removeably attachable to the buoyant platform.

24. The installation apparatus according to claim 23, wherein the winch frame is configured to span a void between two hull portions.

25. The installation apparatus according to any preceding claim, wherein the apparatus comprises a guide configured to align the turbine nacelle with the substructure as it is progressed towards the substructure.

26. The installation apparatus according to claim 25, wherein the guide is disposed towards the lower end of a support which supports the weight of the turbine nacelle.

27. The installation apparatus according to claim 25, wherein the guide is configured to be suspended beneath the turbine nacelle.

28. The installation apparatus according to claim 25, wherein, the guide is disposed on a frame comprising a support which is configured to support the weight of the nacelle during installation or removal, and the guide arranged to align the frame with the substructure as the frame is moved towards the substructure.

29. The installation apparatus according to any of claims 25 to 28, wherein the guide comprises one or more wires or cables for connection to the substructure, the apparatus configured to lower the turbine nacelle onto the substructure along said one or more wires or cables.

30. The installation apparatus according to any of claims 25 to 28, wherein the guide comprises one or more wires or cables for connection to the substructure, the apparatus configured to pull at least part of the buoyant platform and the turbine nacelle along the one or more wires or cables down onto the substructure.

31. The installation apparatus according to any preceding claim, wherein the buoyant platform comprises an arrangement of tubular members.

32. The installation apparatus according to any preceding claim, wherein the connection frame also comprises an arrangement of tubular members.

33. The installation apparatus according to any preceding claim, wherein the apparatus further comprises one or more imaging devices configured, arranged or adapted to observe the turbine nacelle and/or components of the apparatus.

34. A method of installing a tidal turbine nacelle on an underwater substructure, the method comprising transporting the turbine nacelle to the substructure in or on an installation apparatus according to any of claims 1 to 33, and lowering the turbine nacelle from the apparatus to the substructure using the lifting equipment.

35. The method according to claim 34, further comprising connecting a winch cable from a winch on board the marine vessel to the nacelle via the lifting equipment of the apparatus.

36. The method according to claim 34 or claim 35, further comprising connecting one or more wires or cables to the substructure and lowering the turbine nacelle onto the substructure along said one or more wires or cables.

37. The method according to claim 34, further comprising connecting one or more wires or cables to the substructure and pulling at least a part of the buoyant platform and the turbine nacelle along the one or more wires or cables down onto the substructure.

38. A method of removing an underwater turbine nacelle from a substructure, the method comprising transporting an apparatus according to any of claims 1 to 33 to

the substructure, and raising the turbine nacelle from the substructure to the apparatus using the lifting equipment.

39. A method of installing an array of tidal turbines comprising installing at least one turbine nacelle on at least one substructure of the array in accordance with the method of any of claims 34 to 37.

40. The method according to claim 39, wherein the method of any of claims 34 to 37 is repeated for each of the turbines of the array.

41. A marine vessel and an installation apparatus according to any of claims 1 to 33 attached directly to the marine vessel.

42. A tidal turbine comprising a turbine nacelle and an underwater substructure, the turbine nacelle having been installed on the substructure using one or more of an apparatus according to any of claims 1 to 33; a method according to any of claims 34 to 37 or 39 to 40; or a marine vessel and installation apparatus according to claim 41.

43. An installation apparatus, a method of installing a turbine nacelle or removing a turbine nacelle from a substructure, a method of installing a turbine array, or a marine vessel incorporating an installation apparatus or having an installation apparatus attached thereto, substantially as herein described with reference to Figures 5 to 12d.

Application No: GB1309851.2 **Examiner:** Mr Haydn Gupwell

Claims searched: 1-43 **Date of search:** 21 October 2013

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-7, 10-16, 19-27, 32, 35, 37-39-43	WO2009/127415 A1 (OPENHYDRO GROUP LTD) see whole document especially the figures noting nacelle 10 on an underwater structure 22, buoyant platform 12 and positioning means 14.
X	1-11, 13, 15, 16, 19-27, 32, 34, 35, 37, 39-43	EP1980746 A1 (OPENHYDRO GROUP LTD) see whole document especially the figures noting nacelle 10, structure 12, buoyant platform 14 and positioning means T.
X	1-11, 13-16, 19, 20-27, 32, 34, 35, 37-43	US2012/027522 A1 (IVES JAMES et al) see whole document especially figures 3 & 4.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[X] :

Worldwide search of patent documents classified in the following areas of the IPC

E02B; F03B; H02G

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI.

International Classification:

Subclass	Subgroup	Valid From
E02B	0009/08	01/01/2006