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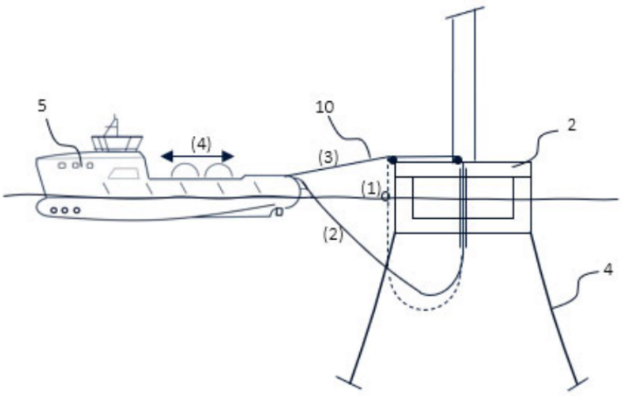
(54) Title PULL-IN OF DYNAMIC CABLES FOR FLOATING WIND TURBINES

(57) Abstract

System for remote cable pull-in of a dynamic cable (3) to a floating wind turbine (2) from a vessel (5), the system comprising: - a floating wind turbine (2) comprising: - a pull-in wire (10) attachable to a dynamic cable (3) to be connected to the floating wind turbine (2); - a vessel (5) for performing a dynamic cable pull-in operation for connecting the dynamic cable (3) to the floating wind turbine (2), wherein the pull-in wire is attachable to the dynamic cable (3), the vessel (5) is adapted for pulling the pull-in wire and the attached dynamic cable (3) to the floating wind turbine, and - wherein the system is adapted for compensating a relative movement between the vessel (5) and the floating wind turbine (2) during the pull-in operation.



PULL-IN OF DYNAMIC CABLES FOR FLOATING WIND TURBINES

INTRODUCTION

The present invention concerns a system for remote cable pull-in of a dynamic cable to a floating wind turbine (FWT) from a vessel, a floating wind turbine (FWT), and a vessel for performing a pull-in operation of a dynamic cable on a FWT, as well as a method for pull-in of dynamic cables on floating wind turbines (FWTs).

BACKGROUND

FWTs organized in floating wind turbine parks as illustrated in Figure 1, or as individual FWTs, are typically connected to a subsea power cable for transporting the electrical energy harvested by the wind turbines to its destination which may e.g. be onshore, offshore or for export. The subsea export cable may be connected to an offshore converter or substation (OSS) and further connected to the electric grid. The wind turbines in the floating wind turbine park may be connected together by inter-array power cables. For export of the harvested electrical energy, the inter-array cables may be connected in strings to an offshore converter station or an offshore substation. The offshore substation typically serves to step up the voltage from the site distribution voltage to a higher voltage. For projects located far from the grid connection point, the electrical energy may be converted from AC to DC.

The capacity in inter-array power cables are typically 36kV or 66kV. High capacity cables or export cables may have up to 220kV. The inter-array dynamic power cable of the wind turbine is typically connected to the subsea power cable in a transition joint. For a larger wind turbine park, the turbines may be connected to several “strings” towards the converter/ sub-station before the power continues in the export cable. An inter-array cable may include a specific cross-section in the dynamical part of the cable with a transition joint against a reduced cross-section in the static part of the cable. The static part may be pre-installed and connected to the dynamic part in connection with the dynamic cable installation. Alternatively, it is possible to only have one dynamically dimensioned cross-section in the entire inter-array cable length between turbine a and turbine b, but this is a cost issue with respect to fabrication and installation.

The FWT require dynamic, high-capacity submarine cable systems to collect and export the power generated. FWT motions and excursions in addition to waves and currents subject the inter-array dynamic power cables to significant dynamic stresses. Therefore, these inter-array dynamic cables must accommodate all movements and loading from the ocean in relation to the floating wind turbine and in addition the weight of the dynamic cable itself. The inter-array dynamic cables are sensitive to voltage and bending and the potential for damage is high during installation of the inter-array dynamic cable on the floating wind turbine (FWT). The operation to install and connect an inter-array dynamic cable to a floating wind turbine can be complex and time consuming. Today’s solutions for dynamic cable installation require personnel onboard the cable installation vessel and also access by the personnel onboard the floating wind turbine for winch control. For installation of an inter-array dynamic cable to a floating wind turbine, a pull-in winch for pulling in the inter-array dynamic cable may be pre-installed on the floating wind turbine (FWT) together with other necessary infrastructure and instrumentation. The pull-in winch may be either a permanent system left on the floating wind turbine or a temporary system demobilized after use. A support vessel with motion compensated gangway may be used for providing access to the FWT for the pull-in crew. A vessel with a 3D crane may be used to lift on/off the pull-in winch system if temporary installed on the FWTs. The motion compensated gangway and the 3D crane may allow for operation in a higher weather criterion (higher waves, more wind etc) and also provide a safer installation of the inter-array dynamic cable to the floating wind turbine.

For floating wind turbines going from demonstration and pilot projects to large-scale developments there is an industry need to develop new and improved methods to install and connect the inter-array dynamic cables to the floating wind turbines.

SUMMARY OF THE INVENTION

The invention provides a system for remote cable pull-in of a dynamic cable to a floating wind turbine from a vessel. The system comprising:

- a floating wind turbine comprising:

- a pull-in wire attachable to a dynamic cable to be connected to the floating wind turbine;
- a vessel for performing a dynamic cable pull-in operation for connecting the dynamic cable to the floating wind turbine, wherein the pull-in wire is attachable to the dynamic cable, the vessel is adapted for pulling the pull-in wire and the attached dynamic cable to the floating wind turbine, and
- wherein the system is adapted for compensating a relative movement between the vessel and the floating wind turbine during the pull-in operation.

The system may be adapted to compensate for axial movement of the pull-in wire relative to the floating wind turbine (2) as may result from a variable distance between the vessel (5) and floating wind turbine (2) caused by vertical and/or lateral motions of either the vessel (5) and/or the floating wind turbine (2). The system may further comprise a first sensor being a distance sensor for measuring the distance between the floating wind turbine and the vessel, preferably an optical sensor. A relative movement between the vessel (5) and the floating wind turbine (2) may be estimated indirectly by using data from at least two absolute position sensors, where at least one first absolute position sensor is arranged on the vessel (5) and the at least one second absolute position sensor is arranged on the floating wind platform (2).
The vessel (5) may be provided with a dynamic positioning system (51) adapted for controlling the vessel (5) based on at least one first input parameter. A winch control (61) system may be adapted for controlling a winch (6) on the vessel based on at least one second input parameter.
The at least one first input parameter may comprise at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;

- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the winch control system.

The at least one second input parameter may comprise at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the DP system.

The system may further comprise at least one inertial navigation system (INS) (13). The system may further comprise at least one of a satellite navigation system or an inertial measurement unit. The inertial measurement unit may be at least one of a motion reference unit (MRU) and a motion gyro compass (MGC).
At least one second sensor for monitoring a hang-off area on the floating wind turbine for the dynamic cable (3) may be provided. The second sensor may preferably be an optical sensor. The system may further include a first communication system (15) adapted for communicating at least one sensor signal from the floating wind platform to the vessel (5); and a second communication system (18) on the vessel for receiving the at least one sensor signal. The first communication system and the second communication system may be a marine broad band radio (MBR) (15).

The invention provides a floating wind turbine (2) comprising: a pull-in wire (10) attachable to a dynamic cable (3) to be connected to the floating wind turbine (2); and, - wherein the pull-in wire is attachable to a vessel (5) for performing a pull-in operation of the dynamic cable (3) to the floating wind turbine and wherein the vessel (5) is adapted for compensating a relative movement between the floating wind turbine (2) and the vessel (5) during the pull-in operation. The cable may be compensated to allow a relative movement between the vessel and the floating wind turbine.

The vessel (5) may be adapted to compensate for axial movement of the pull-in wire relative to the floating wind turbine (2) as may result from a variable distance between the vessel (5) and floating wind turbine (2) caused by vertical and/or lateral motions of either the vessel (5) and/or the floating wind turbine (2).

The floating wind turbine (2) may further be provided with a distance sensor for measuring the distance between the floating wind turbine and the vessel. The floating wind turbine (2) may further comprise at least one inertial navigation system (INS) (13).

The floating wind turbine (2) may further comprise at least one of a satellite navigation system and an inertial measurement unit (13), preferably being a motion reference unit (MRU) or a motion gyro compass (MGC). The floating wind turbine (2) may further be provided with at least one sensor for monitoring a hang-off area for the dynamic cable (3). This sensor may be an optical sensor. The at least one sensor may be adapted to provide a signal when the dynamic cable is in a final hang-off position. The floating wind turbine (2) may further comprise a hang-off clamp arrangement adapted for automatic hang-off of the dynamic cable (3) to be pulled-in and connected to the floating wind turbine. The floating wind turbine (2) may further include a communication system (15), preferably a marine broad band radio (MBR) 15, adapted for communicating at least one signal from the floating wind turbine to the vessel (5).

The invention provides a vessel for performing a dynamic cable pull-in operation for connecting a dynamic cable to a floating wind turbine provided with a pull-in wire, wherein the pull-in wire is attachable to the dynamic cable, the vessel comprising a winch adapted for pulling the pull-in wire for pulling in the dynamic cable to the floating wind turbine, wherein the vessel is adapted for compensating a relative movement between the floating wind turbine and the vessel during the pull-in operation. The cable may be compensated to allow a relative movement between the vessel and the floating wind turbine.

The vessel may be adapted to compensate for axial movement of the pull-in wire relative to the floating wind turbine (2) as may result from a variable distance between the vessel (5) and floating wind turbine (2) caused by vertical and/or lateral motions of either the vessel (5) and/or the floating wind turbine (2). The vessel may further include a distance sensor for measuring the distance between the floating wind turbine and the vessel.

The vessel (5) may further be provided with a dynamic positioning system (51) adapted for controlling the vessel (5) based on at least one first input parameter. A winch control (61) system may be adapted for controlling the winch based on at least one second input parameter. The at least one first input parameter further comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the winch control system.

The at least one second input parameter may further comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;

- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the DP system.

The vessel (5) may be provided with a communication system (15), preferably a marine broadband radio (MBR) (15), for receiving at least one sensor signal from the floating wind turbine (2).

The invention also provides a method for performing a cable pull-in of a dynamic cable to a floating wind turbine according to the system above. The method comprising: attaching the dynamic cable to a pull-in wire on the floating wind turbine, pulling the pull-in wire by the vessel until the dynamic cable is positioned in a hang-off arrangement on the floating wind turbine, and compensating a relative movement between the floating wind turbine and the vessel during the pull-in operation. The cable may be compensated to allow a relative movement between the vessel and the floating wind turbine. The pulling by the vessel may be performed by a winch on the vessel.
The system may be adapted to compensate for axial movement of the pull-in wire relative to the floating wind turbine (2) as may result from a variable distance between the vessel (5) and floating wind turbine (2) caused by vertical and/or lateral motions of either the vessel (5) and/or the floating wind turbine (2).
The method may further comprise measuring a distance between the floating wind turbine and the vessel. The distance may be measured between an exit for the pull-in wire on the floating wind turbine and an entry for the pull-in wire on the vessel.

The method may further comprise controlling the vessel by a dynamic positioning system based on at least one first input parameter. The method may further comprise controlling the winch by a winch control system based on at least one second input parameter. The at least one first input parameter comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;

- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the winch control system.

The at least one second input parameter comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the DP system.

The idea with this concept is to make a dynamic cable pull-in system that can be installed and operated from the vessel installing or performing pull-in of the inter-array dynamic cables. A vessel in the context of the present invention is floating and is substantially kept stationary by dynamic positioning. The vessel may also perform the pull-in operation without a DP system. Eliminating the need for a pull-in winch installed on each of the FWTs and reducing the need for personnel and equipment transfer to and from the FWTs during the construction phase, addresses an industry challenge. For a scale wind park, in particular a large scale wind park, the invented system with its outlined methodology will:

1. Significantly reduce the overall inter-array dynamic cable installation cost.

2. Avoid personnel and heavy equipment transfers to and from the FWTs during cable pull-in and hang-offs.
3. Increase flexibility in the marine schedule by reducing the need for support vessel, and personnel coordination.
4. With easy retrofit on FWT and vessel reduce the mobilization time to perform a future disconnection/ hook-up of cables.

The remote dynamic cable pull-in system according to the invention addresses industry challenges for dynamic cable installation and connection operations. The new solution provides a more standardized operation that is faster to install compared to today's solutions, reduces the need for equipment and personnel on the floater and reduces the need for ROVs in the operation.

The benefits with the new remote Dynamic Cable Pull-in solution include:

- The dynamic cable pull-in and hang off operations can be performed faster and in higher sea states compared to known solutions, without compromising on safety.
- The pre-mobilized equipment needed on the FWT is significantly reduced, and there is no need for a pull-in winch on the FWT.
- The need for a secondary vessel to support the operation is significantly reduced, since the dynamic cable pull-in and temporary hang-off of the dynamic cable can be performed remotely from the cable installation/ pull-in vessel without personnel on the FWT.
- With a pre-installed messenger wire that can be picked up at the surface, the need for ROV is reduced.

Preliminary benchmark studies show significant cost reductions implementing the DP remote dynamic cable pull-in solution of the present invention.

- Increased operability and productivity without compromising on operational safety.
- Integrated DP and winch control for automated consistent vessel and winch operation with reduced human interaction.

- DP integrated mission/park activity specific operation guidelines with nowcast and forecast for optimized dynamic vessel position/heading and winch control to increase safe operational envelope.

BRIEF DESCRIPTION OF DRAWINGS

Example embodiments will now be described with reference to the following drawings, where:

Figure 1 illustrates three floating wind turbines 2 in an offshore wind turbine park, where the floating wind turbines are interconnected with inter-array power cables 3. The floating wind turbines are moored to the seabed by mooring lines and anchors 4.

Figure 2 illustrates an example of a DP remote dynamic cable pull-in concept for installation of inter-array dynamic power cables on a floating wind turbine;

Figure 3 illustrates example equipment on the floating wind turbine to enable installation of the inter-array dynamic cable to the floating wind turbine using the DP remote dynamic cable pull-in concept.

Figure 4 illustrates an example of a pull-in winch system on the installation vessel;

Figure 5 illustrates an example with enhanced functionality of the DP control system of the installation vessel including a dynamic working area for safe operation.

Figure 6 illustrates a combined DP and winch control system which may also be operated manually by personnel onboard the installation vessel.

Figure 7 illustrates an exemplary remote hang-off connection for the dynamic cable to be installed on the floating wind turbine.

Figure 8 illustrates a concept integration between instrumentation on the floating wind turbine, the pull-in winch and the dynamic positioning system on the installation vessel.

Figure 9 illustrates steps (1)-(4) in a “direct cross-haul” of the first inter array dynamic cable end at the first floating wind turbine.

Figure 10 illustrates steps (5)-(7) in a “direct cross-haul” of the first inter array dynamic cable end at the first floating wind turbine.

Figure 11 illustrates steps (8)-(10) in a “direct cross-haul” of the first inter array dynamic cable end at the first floating wind turbine.

Figure 12 illustrates an example of the inter array dynamic cable installation between a first and a second floating wind turbine.

Figure 13 illustrates an example of a vessel approach for inter-array dynamic cable pull-in and hang-off at the second floating wind turbine.

Figure 14 illustrates an example of steps for a cross-haul operation of the inter-array dynamic cable at the second floating wind turbine, where the installation vessel is initially positioned close to the second floating wind turbine to perform inter-array cable cross-haul with pre-installed messenger wire connected to the floating wind turbine.

Figure 15 illustrates an example of steps for a pull-in and hang-off operation of the second inter-array dynamic cable end at the second floating wind turbine, where the inter-array dynamic cable is pulled in through a guide tube on the floating wind turbine and the cable hang-off on the floating wind turbine.

Figure 16 illustrates an example of the last step of a pull-in and hang-off operation of the second inter-array dynamic cable end at the second floating wind turbine where the messenger wire is disconnected from the pull-in system and is free from the installation vessel.

Figure 17 illustrates an example of steps for a recovery and pull-in operation where the inter-array dynamic cable is recovered from a wet store at the seabed.

DETAILED DESCRIPTION

Example embodiments are described with reference to the drawings. The examples are not to be considered as limiting for the invention. The same reference numerals are used for the same or similar features in all the drawings and throughout the description.

Figure 1 illustrates three floating wind turbines 2 in an offshore wind turbine park. The floating wind turbines are interconnected with inter-array power cables 3. The floating wind turbines are moored to the seabed by mooring lines and anchors 4.

Figure 2 illustrates an example of a DP remote dynamic cable pull-in concept for installation of inter-array dynamic power cables on a floating wind turbine. Figure 2 illustrates a system for remote cable pull-in of a dynamic cable 3 to a floating wind turbine (FWT) 2 from a vessel 5. The floating wind turbine 2 may be provided with a pull-in wire 10 attachable to a dynamic cable 3 to be connected to the floating wind turbine 2. The FWT may also be provided with a hang-off arrangement for the dynamic cable 3 attachable to the floating wind turbine 2. The hang-off arrangement will be described in detail later. The system may also include a vessel 5 for performing a dynamic cable pull-in operation for connecting the dynamic cable 3 to the floating wind turbine 2, wherein the pull-in wire is attachable to the dynamic cable 3. The vessel 5 may be provided with a winch 6 adapted for pulling the pull-in wire and the attached dynamic cable 3 to the floating wind turbine. The system may be adapted for compensating a relative movement between the vessel 5 and the floating wind turbine 2 during the pull-in operation. Relative movement may e.g. be wave or current induced and/or caused as the vessel decides to move.

The system may be adapted to compensate for movement on the pull-in wire by the relative distance between the FWT 2 and the vessel 5, and the vertical and/or sideways motions of FWT 2 and the vessel 5. This enables to synchronize a movement of the pull-in wire with a movement of the floating wind turbine 2.

A first sensor in the form of a distance sensor for measuring the distance between the floating wind turbine and the vessel may be provided on the FWT and/ or the vessel. The distance sensor may be an optical sensor. The optical sensor may be a laser or IR sensor. Other distance sensors like radar or ultrasound may also be used depending on the system and system requirements.

A relative movement between the vessel 5 and the floating wind turbine 2 may alternatively be estimated indirectly by using data from at least two absolute position sensors, where at least one first absolute position sensor is arranged on the vessel 5 and the at least one second absolute position sensor is arranged on the floating wind platform 2.

The vessel 5 may be provided with a dynamic positioning system 51. Dynamic positioning (DP) involves automatic or semi-automatic control of a vessel’s position and heading by using its own propellers and thrusters with respect to one or more position references. The dynamic positioning (DP) system may keep the position of the vessel fixed within given parameters or manoeuvre the vessel in a way that it could not do without the dynamic positioning system. A dynamic positioning (DP) system may manoeuvre a vessel based on a number of input parameters. These input parameters may e.g. come from:

- sensors for location, heading, speed;
- sensors for external factors such as wind, waves, current; and
- input from a user to execute a mission such as maintain position or move in a particular pattern.

Control algorithms of the dynamic positioning (DP) system takes in the sensor and user input parameters and executes manoeuvre of the vessel by controlling the on-board propellers and thrusters even with changes in external forces.

The DP system may adapted for controlling the vessel 5 based on at least one first input parameter, which may comprise at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the winch control system.

In the described examples the vessel is provided with a DP system. However, a vessel 5 without a DP system may also be used.

A winch control 61 system is adapted for controlling the winch 6 on the vessel based on at least one second input parameter, which may comprise at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the DP system.

The system may be provided with at least one inertial navigation system (INS) 13, which may be a satellite navigation system or an inertial measurement unit. The inertial measurement unit may be at least one of a motion reference unit (MRU) and a motion gyro compass (MGC).

As explained above, Figure 2 illustrates an example DP remote dynamic cable pull in concept 1 for a floating wind turbine (FWT) 2. The cable to be pulled in is an inter-array dynamic cable 3 to be connected to the floating wind turbine 2. The floating wind turbine may be part of an offshore wind turbine plant. As earlier explained, inter-array dynamic cables are sensitive to voltage and bending, and the potential for damage is high during installation. The floating wind turbine 2 is in the example in Figure 2 provided with a guide tube 20 for the inter array dynamic cable 3. Floater instrumentation kit 7 as described in detail below is provided for monitoring the messenger wire 10. An installation vessel 5 is provided with a dynamic positioning system (DP) and a pull-in winch 6. The winch 6 is provided with a winch control system. The winch control system is connected to the DP control system for providing winch parameters to the DP control system and for control of the winch 6 by the DP control system. The pull-in winch 6 pulls in the messenger wire/pull-in wire 10 connected to the inter array dynamic cable 3 through the guide tube 20. The messenger wire/pull-in wire 10 passes over rollers or sheaves on the floating wind turbine deck that support and guide the messenger wire/pull-in wire 10. Rollers and sheaves may also be provided on the installation vessel 6 to support and guide the messenger/pull-in wire 10 when it comes onboard and further on the vessel deck before reaching the pull-in winch 6. The installation vessel 5 and the floating wind turbine 2 are provided with wireless communication for communicating signals from the instrumentation on the floating wind turbine 2 to the installation vessel 5.

An example of equipment typically provided on the floating wind turbine 2 is illustrated in Figure 3. A first sheave/guide 11 is arranged to centralize the messenger/ pull-in wire 10 in the guide tube 20 on the floating wind turbine. The sheave/guide 11 is arranged above the guide tube hang-off 16. A second sheave/ guide 12 is arranged to support and deflect the messenger wire from the floating wind turbine 1 before the messenger wire 10 exits the floating wind platform and passes on to the installation vessel 5. A topside guide tube hang-off arrangement 16 for remote cable hang-off is provided on the top of the guide tube 20. This is where the messenger wire and the inter array dynamic cable 3 exits the guide tube 20. One or more sensors may be provided for monitoring a hang-off area for the dynamic cable 3. The sensor may be a distance sensor e.g. in the form of a laser or IR sensor or radar. The sensor may an optical sensor, e.g. a camera or video camera. A first camera 14 may be arranged to monitor the dynamic cable hang-off area. A second camera 17 may be arranged to monitor the messenger wire 10 in the further sheave/guide 12. The second camera 17 may also monitor the exit of the messenger wire from the further sheave/guide 12. The first and second camera may e.g. be a video camera. The FWT may be provided with at least one sensor adapted to provide a signal when the dynamic cable is in a final hang-off position.

The floating wind turbine may be provided with an Inertial Navigation System (INS) 13. The Inertial Navigation System 13 may include at least one of a satellite navigation system (e.g. Global Navigation Satellite System (GNSS) or GPS) and an Inertial Measurement Unit (MRU or MGC) to measure position and movements of the floating wind turbine 2. The satellite navigation system may e.g. be GNSS, GPS, GLOANASS, BeiDou, Galileo, QZSS, IRNASS or NavIC. The Inertial Navigation System (INS) may be attached near the second sheave/guide 12 where the messenger wire exits the floating wind turbine. This enables monitoring of the floating wind turbine’s movements; i.e. heave, sway, surge, roll, pitch and yaw. The floating wind turbine 2 may further be provided with a communication system (transceiver) 15 for communication of the signals from the floating instrumentation, e.g. signals from the Inertial Navigation System (INS), sensors and cameras, onboard the floating wind turbine to the installation vessel. The communication system may e.g. be a Marine Broadband Radio (MBR), but other wireless communication systems may also be used. The instrumentation on the floater may be pre-installed. The installation on the floater may be removable. Also, the messenger wire/pull-in wire 10 may be pre-installed on the floating wind turbine 2. The floating wind turbine may be provided with a distance sensor for measuring a relative distance between the floating wind turbine 2 and the vessel 5. The distance sensor may e.g. be a laser, IR sensor, ultrasound sensor or radar.

The pull-in winch system on the installation vessel 5 may be fitted at different positions and with various sheave arrangements to route and support the pull-in wire (e.g. see Figure 4). This allows for the concept to be implemented into different vessel lay spreads; e.g. Horizontal Lay Spread (HLS) with dynamic cable installed over the stern or over the side, Vertical Lay Spread (VLS) with dynamic cable installed though moonpool or over side.

The messenger wire on the floating wind turbine may be pre-installed in different arrangements for release and connection to the dynamic cable and pull-in winch. A hang-off arrangement may also be incorporated in the messenger wire arrangement to be able to temporary hang-off the dynamic cable and release the pull-in winch wire in case of an abandonment.

The remote cable hang-off onboard the floating wind turbine 2 may be a mechanism incorporated in the hang-off clamp design, a mechanism incorporated in the hang-off flange, or a combined clamp and hang-off flange mechanism. The combined hang-off flange mechanism may be a remote operated connector design similar to a diverless bend stiffener connector.

The pull-in winch 6 on the installation vessel 5 is illustrated in more detail in Figure 4. The pull-in winch is provided with a control system (PIW) 61. The control system

61 may also have a back-up in the form of human personnel 62 (PIW local HMI) onboard the installation vessel 5 that may manually control the pull-in winch. The control system is connected to a communication system 18 for communicating with transceiver 15 on the floating wind turbine. The communication system may be a Marin Broadband Radio (MBR). The equipment on the installation vessel may also include a sheave/ guide arrangement 63 to support and deflect the messenger/pull-in wire 10. The sheave/ guide arrangement may allow the vessel to optimize position and heading. The dynamic positioning system (DP) 51 (Figure 6) on the installation vessel 5 may also be provided with a special enhanced mission equipment functionality to control the installation vessel 5 during the dynamic cable pull-in operation also based on input from the sensor systems on the floating wind turbine 2. The dynamic positioning system 51 on the installation vessel 5 may have a communication module to enable communication with the pull-in winch control system 61 and for controlling the pull-in winch control system 61. As a security system in case of system failure, the DP system and the pull-in winch control system may be provided with manual controls 52, 64 for control by human personnel onboard the installation vessel 5.

Figure 5 is an example of how the DP control system on the installation vessel 5 may include a working area definition where it is safe to position the installation vessel in the current operation step. When the installation vessel is connected directly to the dynamic cable, the working area is defined by limits that avoids damaging the dynamic cable by for instance bending or dragging. After the dynamic cable is connected to the messenger/pull-in wire, the position and heading limits of the installation vessel are defined by the operation angles and length of the pull-in winch. The defined limits can be used by the DP control system to prevent the operator from moving the installation vessel or heading outside the safe operation area. Alarms and warnings may also be issued to the operator if the installation vessel approaches these limits.

The floating wind turbine 2 (FWT) instrumentation, the vessel pull-in winch (PIW) system 6 and the dynamic positioning (DP) system 51 of the installation vessel 5 work together to accomplish the mission of the pull-in operation procedure of the inter-array dynamic cable onboard the floating wind turbine 2. Figure 8 illustrates this concept of integration between the instrumentation kit 7 of the floating wind turbine 2, the pull-in winch 6 and the dynamic positioning system 51. The floating wind turbine 2 instrumentation measure the floating wind turbine’s 2 position and movements (heave, sway, surge, roll, pitch, yaw). These position and movement parameters are transmitted to the installation vessel 5. The pull-in winch 6 control system 61 and the dynamic positioning system 51 receive the position and movement parameters from the instrumentation 7 on the floating wind turbine. The dynamic positioning system 51 controls the installation vessel 5 based on a number of parameters including the position of the installation vessel and the position and movement parameters from the instrumentation 7 on the floating wind turbine and compensates the relative movements between the floating wind turbine 2 and the installation vessel to enable a controlled cable pull-in and hang-off operation. The dynamic positioning system 51 also provides input parameters to the winch control system 61 controlling the pull-in winch 6 as illustrated in Figure 8.

The integration of the winch control system 61 with the vessel DP system 51 enables to perform coordinated vessel positioning and winch pay-out/pay-in operation, and also to increase the overall safety in case of a vessel DP incident or winch failure. To perform a dynamic cable pull-in operation with no personnel onboard, the floating wind turbine 2 has in addition a pre-installed messenger wire 10 routed through the guide tube 20 and sheave arrangements 11, 12 as described above. To perform a dynamic cable hang-off operation with no personnel onboard the floating wind turbine 2 is provided with an automatic hang-off clamp arrangement 31. The automatic hang-off clamp arrangement may be placed on the floater topside, and may typically be placed on the topside of the guide tube 16 end of which an example is shown in Figure 7.

Figure 7 illustrates an example of an automatic hang-off arrangement on the FWT. The guide tube 20 is provided with a topside hang-off flange arrangement/ interface 16 for remote cable hang-off. The inter array dynamic cable 3 may be provided with a hang-off clamp with a spring-loaded latch arrangement 31. When the inter array dynamic cable 3 is pulled up through the guide tube 20 and exits the topside of the guide tube 16, the spring-loaded latch arrangement 31 expands and secures the inter array dynamic cable 3 in position on top of hang-off plate and prevent the inter array dynamic cable from slipping back down into the guide tube 20. Further functions of the guide tube when guiding the cable in a pull-in operation will be described.

Figure 8 illustrates a concept integration between the instrumentation kit 7 on the floating wind turbine 2, the pull-in winch 6 and the dynamic positioning (DP) system 51 on the installation vessel. The instrumentation on the floating wind turbines share information about the floating wind turbine position and floating wind turbine motions to the control system 61 of the winch and to the dynamic positioning system. The pull-in winch may send information about the messenger wire/pull-in wire length and messenger wire/pull-in wire tension to the DP system 51. The pull-in winch control system 61 may receive messenger wire/pull-in wire length setpoints from the dynamic positioning (DP) system 51.

A method for performing a cable pull-in of a dynamic cable to a floating wind turbine for the system described above is disclosed. The dynamic cable is attached to a pull-in wire on the floating wind turbine. Pulling the pull-in wire by the vessel is performed until the dynamic cable is positioned in a hang-off arrangement on the floating wind turbine. The pulling of the pull-in wire may be performed by moving the vessel by towing and/or by hauling in the pull-in wire. The hauling in may be performed by use of a winch or by use of sheaves (e.g. as in a heave compensation system). The sheaves perform dynamic compensation. The winch may be controlled dynamically. A relative movement between the floating wind turbine and the vessel is compensated during the pull-in operation.

The system is adapted to compensate for movement on the pull-in wire by a relative distance between the floating wind turbine 2 and the vessel 5 and the vertical motions of the floating wind turbine 2 and the vessel 5. To control the pull-in operation a distance may be measured between the floating wind turbine and the vessel. The distance may be measured between an exit for the pull-in wire on the floating wind turbine and an entry for the pull-in wire on the vessel. The exit/entry points may be departing point/entry points or vice versa depending upon the circumstances. The vessel may be controlled by a dynamic positioning system based on at least one first input parameter. The winch may be controlled by a winch control system based on at least one second input parameter. The at least one first input parameter comprises at least one of, position of the floating wind turbine, position of the vessel; motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw; position of the pull-in wire and the dynamic cable; and tension in the dynamic cable; tension in pull-in wire; position of the pull-in wire relative to the FWT; movement of the pull-in wire relative to the FWT; position of the dynamic cable relative to the FWT; movement of the dynamic cable relative to the FWT; output from the winch control system. The at least one second input parameter comprises at least one of: position of the floating wind turbine; position of the vessel; motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw; position of the pull-in wire and the dynamic cable; and tension in the dynamic cable; tension in pull-in wire; position of the pull-in wire relative to the FWT; movement of the pull-in wire relative to the FWT; position of the dynamic cable relative to the FWT; movement of the dynamic cable relative to the FWT; output from the DP system.

Cable pull-in operation

As mentioned above, the cables are sensitive to voltage and bending and the pull-in procedure must be performed with care. A cable pull-in performed onboard the floating wind turbine limits tension monitoring to heave / excursions on the floating wind turbine. Pull-in from a vessel is known from bottom fixed turbines, where tension monitoring are limited to the vessel's heave / excursions (if operated on DP). Pull-in to a floating wind turbine from a DP vessel may involve monitoring and compensation for relative distance / movements of both the vessel and the floating wind turbine. The described pull-in solution includes automated systems for coordinating floater movements, pull-in winch and DP set points during normal operation and during contingency scenarios.

<u>Direct cross-haul of the first inter array dynamic cable end at the first floating wind turbine</u>

Figure 9 illustrates the different steps (1)-(4) shown in brackets in Figure 9 preparing for performing a direct cross-haul of a first inter array dynamic cable end at the first floating wind turbine 2 by the installation vessel 5. The floating wind turbine has mooring lines 4 for attachment to the seabed.

At the start of the operation, the installation vessel may be positioned close to the floating wind turbine. Operation tasks in step (1) - step (4) in Figure 9:

1. The installation vessel 5 may pick up the pre-installed messenger wire 10 on the floating wind turbine on the sea surface or the messenger wire 10 may be picked up below the sea surface by an ROV.
2. The messenger wire end routed subsea is picked up by the installation vessel or ROV and connected onboard the installation vessel to the topside of the inter array dynamic cable 3 onboard the installation vessel 5.
3. The messenger wire end routed topside on the floating wind turbine is connected to vessel pull-in winch 6.
4. The vessel position and heading are optimized within procedure limits for cross-hauling the inter array dynamic cable 3 to the floating wind turbine 2.

The installation vessel is now ready to perform the cross-haul of the first inter array dynamic cable to the first floating wind platform.
Operation steps (5)-(7) in Figure 10:

5. The first end of the inter array dynamic cable is deployed from installation vessel to cross haul depth. The cable is sensitive to bending and a cross haul depth is determined that provides an acceptable bending of the cable without damaging the cable.
6. Continue pay out on cable from installation vessel 5 and start to pull-in first end of cable with pull-in winch 6. The mission may have a lay table for each dynamic cable. The lay table is a detailed description of the positions and movements of the installation vessel, the dynamic cable pay-in/pay-in, the winch pay-out/pay-in based on analysis of the mission. The lay table is followed by the operator of the installation vessel and/or may be programmed into the dynamic positioning system. The subsea operation is typically monitored by an ROV.
7. Continue to pull-in cable by the pull-in winch and monitor topside end by camera 14 when the cable enters the bottom of the guide tube 20. The

installation vessel position is adjusted and pay out of cable performed to ensure correct entering of the cable into the guide tube 20.

Pull-in and hang-off of the inter array dynamic cable on the floating wind turbine can now be performed.

Figure 11a illustrates the different steps (8) – (10) shown in brackets for a pull-in and hang-off of a first inter array dynamic cable end at the first floating wind turbine 2 by the installation vessel 5. Figure 11b also shows the cable 3 with hang-off clamp when entering the guide tube 20 attached to the pull-in wire 10 in step (8) and after hang-off clamp 31 has been pulled through and above the guide tube resting on the topside hang-off flange/ interface 16 (step (9) – (10)).

Operation steps (8) – (10):

8. The installation vessel continues to pull-in the cable topside end into the guide tube, monitoring cable carefully when entering the bottom guide tube. The bottom of the guide tube may be provided with a bellmouth or alternative bend stiffener connector (not shown). For dynamic cables one bed stiffener arrangement may be appropriate for FWTs.
9. Continue to pull-in cable until hang-off clamp is pulled through the guide tube and above the topside hang-off flange/ interface, monitored by topside camera – followed by stop of pull-in.
10. Lower hang-off clamp with extracted latches down on the hang-off flange/ interface.

After the first inter array dynamic cable pull-in and hang-off are completed, the installation vessel disconnects the pull-in winch wire at the first floating wind turbine and continues installing the inter array cable towards the second FWT as illustrated in Figure 12.

Until the hang-off clamp is pulled past the guide tube hang-off flange/interface, the pull-in operation can be reversed. After this point the installation vessel will continue to install the inter array cable.

The approach for inter-array dynamic cable pull-in and hang-off at the second floating wind turbine are illustrated in Figure 13.

The installation vessel 5 is positioned close to the floating wind turbine 2 to perform inter-array dynamic cable pull-in and hang-off at the second floating wind turbine. Approaching the second floating wind turbine 2, the installation vessel 5 rotates ending up with the bow of the installation vessel pointing away from the floating wind turbine and with the stern towards the floating wind turbine. The installation vessel then backs towards the floating wind turbine with the stern first. The method in Figure 13 is illustrated for a horizontal lay system with a chute over the stern of the vessel. This implies that the vessel must rotate and back towards the floater stern first as described above. The illustrated method in Figure 13 is an alternative and other methods may be possible depending on the floating installation and the vessel.

Figure 14 illustrates a cross-haul of the inter array dynamic cable 3 end at the second floating wind turbine 2.
In Figure 14, the installation vessel is positioned close to the floating wind turbine to perform inter-array dynamic cable cross-haul operation tasks.
The installation vessel has deployed the inter-array cable 3 from the 1st floating wind turbine towards the second floating wind turbine. The subsea routed end and the topside routed end of the pre-installed messenger wire is picked up and connected similar to the steps in Figure 9 at the first floating wind turbine 2.

1. The installation vessel 5 lowers the dynamic cable on its «A&R wire» to (Abandonment and Recovery wire) transfer depth. At transfer depth the pull-in winch is tensioned to take out slack in the messenger wire.
2. The installation vessel 5 continues to pay out on the A&R (Abandonment and Recovery) wire and starts to pull-in the second end of the inter-array dynamic cable 3 with pull-in winch 6 following the lay table for the operation. The subsea operation is typically monitored by an ROV.
3. When the catenary load of the inter-array dynamic cable is transferred to the pull-in winch 6 the A&R (Abandonment and Recovery) wire is ready to be disconnected.
4. The installation vessel continue cable pull-in after A&R (Abandonment and Recovery) wire is disconnected. An ROV is typically used to disconnect the A&R wire.

Figure 15 illustrates a pull-in and hang-off of the inter array dynamic cable 3 end at the second floating wind turbine 2. In step 1, the inter-array dynamic cable is pulled-in through a guide tube 20 on the floating wind turbine 2. In step 2 the inter-array dynamic cable is hung-off on the floating wind turbine.

In Figure 16, the messenger wire/pull-in wire is disconnected from the installation vessel 5. On the floating wind turbine, the second inter-array dynamic cable end pull-in and hang-off operation are similar to the first inter-array dynamic cable end pull-in and hang-off operation. Until the hang-off clamp is pulled past the guide tube hang-off flange/ interface the operation can be reversed.

Recovery and Pull-in from Wet store

Figure 17 A-C illustrates recovery and pull-in of an inter array dynamic cable from a wet store. The wet store is at the seabed.

Stage 1:

1. Position installation vessel 5 above topside end of the wet stored inter-array dynamic cable.
2. Deploy and connect recovery wire to the inter-array dynamic cable.

Stage 2:

3. Start to recover inter-array dynamic cable, monitor configuration and touch down point (TDP) of the inter-array dynamic cable by typically an ROV.
4. Move installation vessel in position for the pull-in operation close to the floating wind turbine.

Stage 3:

5. Pick up the pre-installed messenger wire on the floating wind turbine.
6. Connect messenger wire end routed subsea to the inter-array dynamic cable.
7. Connect messenger wire end routed topside to pull-in winch.

Continue cross-haul, pull-in and hang-off in the same way as described for the second inter-array dynamic cable end cross-haul, in a pull-in and hang-off operation as described above.

The steps illustrated in Figures 9-17 are examples only and the DP remote pull-in concept may also be performed in other steps following the lay plan of the dynamic cable installation. Alternative methods may be envisaged depending upon the vessel and the lay spread, the configuration of the dynamic cable and the interface on the floating installation. The remote pull-in concept may be adapted to different variants and scenarios.

The examples are illustrated and described for a floating wind turbine, but the dynamic cable pull-in concept may also be used for other floating installations to be provided with a dynamic cable and the examples and the invention is not limited to a floating wind turbine. The concept may be used on other floating installations where it is possible to pre-install and integrate equipment and instrumentation as described above for the FWT on the floating installation.

In the examples an inter array dynamic cable is connected between the floating wind turbines, but this is only an example and dynamic cables in general may be installed by use of the DP remote pull-in concept described above. The DP remote pull-in winch concept may also be used for installation of dynamic cables to and/or between floating installations, in particular where there are many floating installations that are to be connected together by a dynamic cable. The pull-in winch concept for performing a pull-in operation may also be used on floating installations where it is difficult or dangerous to get personnel and equipment onboard/offboard the floating installation. In some floating installations the space for larger necessary equipment, e.g. a winch performing a pull-in operation, is limited or not available. The space on the floating installation may also be limited or too small for personnel needed during the pull-in operation.

The process of cable installation may be carried out by the described method above by controlling the relative position of the FWT and the vessel through dynamic positioning on the vessel combined with winch control and position signal from the FWT. Thus, the cable installation may be controlled by monitoring the distance between the vessel and the FWT. The movement of the pull-in wire and cable may alternatively be monitored versus a reference point on the FWT and compensated by the pull-in system.

Having described preferred embodiments of the invention it will be apparent to those skilled in the art that other embodiments incorporating the concepts may be used. These and other examples of the invention illustrated above are intended by way of example only and the actual scope of the invention is to be determined from the following claims.

CLAIMS

1. System for remote cable pull-in of a dynamic cable (3) to a floating wind turbine (2) from a vessel (5), the system comprising:

- a floating wind turbine (2) comprising:
    - a pull-in wire (10) attachable to a dynamic cable (3) to be connected to the floating wind turbine (2);
- a vessel (5) for performing a dynamic cable pull-in operation for connecting the dynamic cable (3) to the floating wind turbine (2), wherein the pull-in wire is attachable to the dynamic cable (3), the vessel (5) is adapted for pulling the pull-in wire and the attached dynamic cable (3) to the floating wind turbine, and
- wherein the system is adapted for compensating a relative movement between the vessel (5) and the floating wind turbine (2) during the pull-in operation.

2. System according to claim 1, wherein the system is adapted to compensate for axial movement of the pull-in wire relative to the floating wind turbine (2) as may result from a variable distance between the vessel (5) and floating wind turbine (2) caused by vertical and/or lateral motions of either the vessel (5) and/or the floating wind turbine (2).

3. System according to claim 1 or claim 2, further comprising a first sensor being a distance sensor for measuring the distance between the floating wind turbine and the vessel, preferably an optical sensor.

4. System according to claim 1, wherein a relative movement between the vessel (5) and the floating wind turbine (2) is estimated indirectly by using data from at least two position sensors, where at least one first position sensor is arranged on the vessel (5) and the at least one second absolute position sensor is arranged on the floating wind platform (2).

5. System according to one of claims 1-4, wherein the vessel (5) is provided with a dynamic positioning system (51) adapted for controlling the vessel (5) based on at least one first input parameter.

6. System according to one of claims 1-5, wherein a winch control (61) system is adapted for controlling a winch (6) on the vessel based on at least one second input parameter.

7. System according to claim 5 or claim 6, wherein the at least one first input parameter comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the winch control system.

8. System according to one of claims 5 to 7, wherein the at least one second input parameter comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the DP system.

9. System according to one of claims 1-8, further comprising at least one inertial navigation system (INS) (13).

10. System according to one of claims 1-9, wherein the system further comprising at least one of a satellite navigation system or an inertial measurement unit.

11. System according to claim 10, wherein the inertial measurement unit is at least one of a motion reference unit (MRU) and a motion gyro compass (MGC).

12. System according to one of claims 1-11, further comprising at least one second sensor for monitoring a hang-off area on the floating wind turbine for the dynamic cable (3), preferably an optical sensor.

13. System according to one of claims 1-12, further comprising:
- a first communication system (15) adapted for communicating at least one sensor signal from the floating wind platform to the vessel (5); and
- a second communication system (18) on the vessel for receiving the at least one sensor signal,

14. System according to claim 13, wherein the first communication system and the second communication system are preferably a marine broad band radio (MBR) (15).

15. Floating wind turbine (2) comprising:
- a pull-in wire (10) attachable to a dynamic cable (3) to be connected to the floating wind turbine (2); and
- wherein the pull-in wire is attachable to a vessel (5) for performing a pull-in operation of the dynamic cable (3) to the floating wind turbine and wherein the vessel (5) is adapted for compensating a relative movement between the floating wind turbine (2) and the vessel (5) during the pull-in operation.

16. Floating wind turbine (2) according to claim 15, wherein the vessel (5) is adapted to compensate for axial movement of the pull-in wire relative to the

floating wind turbine (2) as may result from a variable distance between the vessel (5) and floating wind turbine (2) caused by vertical and/or lateral motions of either the vessel (5) and/or the floating wind turbine (2).

17. Floating wind turbine (2) according to claim 15 or claim 16, further comprising a distance sensor for measuring the distance between the floating wind turbine and the vessel.

18. Floating wind turbine (2) according to one of claims 15-17, further comprising at least one inertial navigation system (INS) (13).

19. Floating wind turbine (2) according to one of claims 15-18, further comprising at least one of a satellite navigation system and an inertial measurement unit (13), preferably being a motion reference unit (MRU) or a motion gyro compass (MGC).

20. Floating wind turbine (2) according to one of claims 15-19, further comprising at least one sensor for monitoring a hang-off area for the dynamic cable (3), preferably being an optical sensor.

21. Floating wind turbine (2) according to claim 20, wherein the at least one sensor is adapted to provide a signal when the dynamic cable is in a final hang-off position.

22. Floating wind turbine (2) according to one of claims 15-21, further comprising a hang-off clamp arrangement adapted for automatic hang-off of the dynamic cable (3) to be pulled-in and connected to the floating wind turbine.

23. Floating wind turbine (2) according to one of claims 15-22, further comprising a communication system (15), preferably a marine broad band radio (MBR) 15, adapted for communicating at least one signal from the floating wind turbine to the vessel (5).

24. Vessel (5) for performing a dynamic cable pull-in operation for connecting a dynamic cable (3) to a floating wind turbine (2) provided with a pull-in wire, wherein the pull-in wire is attachable to the dynamic cable (3), the vessel (5) comprising a winch (6) adapted for pulling the pull-in wire for pulling in the dynamic cable (3) to the floating wind turbine, wherein the vessel is adapted for compensating a relative movement between the floating wind turbine (2) and the vessel (5) during the pull-in operation.

25. Vessel (5) according to claim 24, wherein the vessel is is adapted to compensate for axial movement of the pull-in wire relative to the floating wind turbine (2) as may result from a variable distance between the vessel (5) and floating wind turbine (2) caused by vertical and/or lateral motions of either the vessel (5) and/or the floating wind turbine (2).

26. Vessel (5) according to claim 24 or 25, further comprising a distance sensor for measuring the distance between the floating wind turbine and the vessel.

27. Vessel (5) according to one of claims 24-26, further comprising a dynamic positioning system (51) adapted for controlling the vessel (5) based on at least one first input parameter.

28. Vessel (5) according to one of claims 24-27, wherein a winch control (61) system is adapted for controlling the winch based on at least one second input parameter.

29. Vessel according to claim 27 or 28, wherein the at least one first input parameter further comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;

- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the winch control system.

30. Vessel according to one of claims 27-29, wherein the at least one second input parameter further comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the DP system.

31. Vessel (5) according to one of claims 24-30, further comprising a communication system (15), preferably a marine broadband radio (MBR) (15), for receiving at least one sensor signal from the floating wind turbine (2).

32. Method for performing a cable pull-in of a dynamic cable to a floating wind turbine according to the system of claim 1, the method comprising:
- attaching the dynamic cable to a pull-in wire on the floating wind turbine,
- pulling the pull-in wire by the vessel until the dynamic cable is positioned in a hang-off arrangement on the floating wind turbine, and
- compensating a relative movement between the floating wind turbine and the vessel during the pull-in operation.

33. Method according to claim 32, wherein the system is adapted to compensate for axial movement of the pull-in wire relative to the floating wind turbine (2) as may result from a variable distance between the vessel (5) and floating wind turbine (2) caused by vertical and/or lateral motions of either the vessel (5) and/or the floating wind turbine (2).

34. Method according to claim 32 or claim 33, further comprising measuring a distance between the floating wind turbine and the vessel.

35. Method according to one of claims 32-34, further comprising measuring a distance between an exit for the pull-in wire on the floating wind turbine and an entry for the pull-in wire on the vessel.

36. Method according to one of claims 32-35, further comprising controlling the vessel by a dynamic positioning system based on at least one first input parameter.

37. Method according to one of claims 32-35, further comprising controlling the winch by a winch control system based on at least one second input parameter.

38. Method according to claim 36 or claim 37, wherein the at least one first input parameter comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the winch control system.

39. Method according to one of claims 36 to 38, wherein the at least one second input parameter comprises at least one of:

- position of the floating wind turbine;
- position of the vessel;
- motions of the floating wind turbine including at least one of heave, sway, surge, roll, pitch and yaw;
- position of the pull-in wire and the dynamic cable; and
- tension in the dynamic cable;
- tension in pull-in wire;
- position of the pull-in wire relative to the FWT;
- movement of the pull-in wire relative to the FWT;
- position of the dynamic cable relative to the FWT;
- movement of the dynamic cable relative to the FWT;
- output from the DP system.

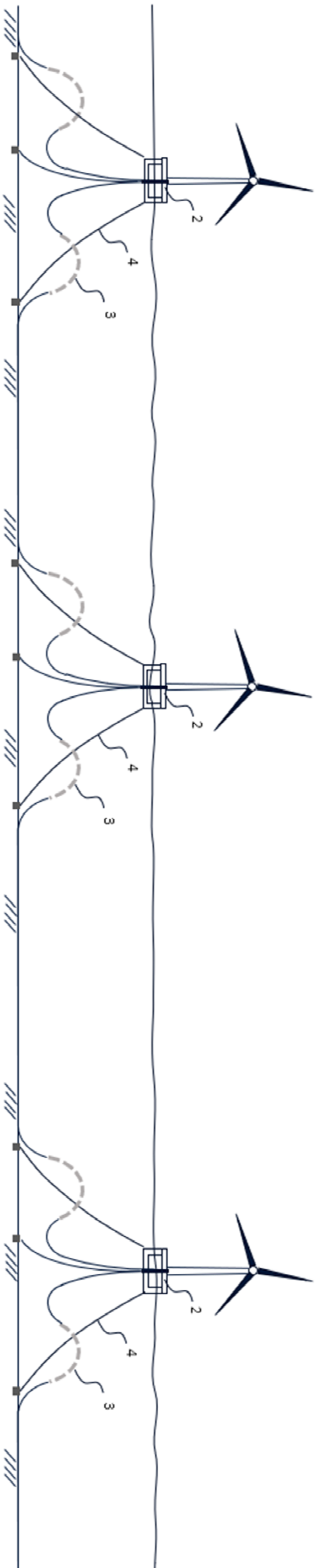


Figure 1:

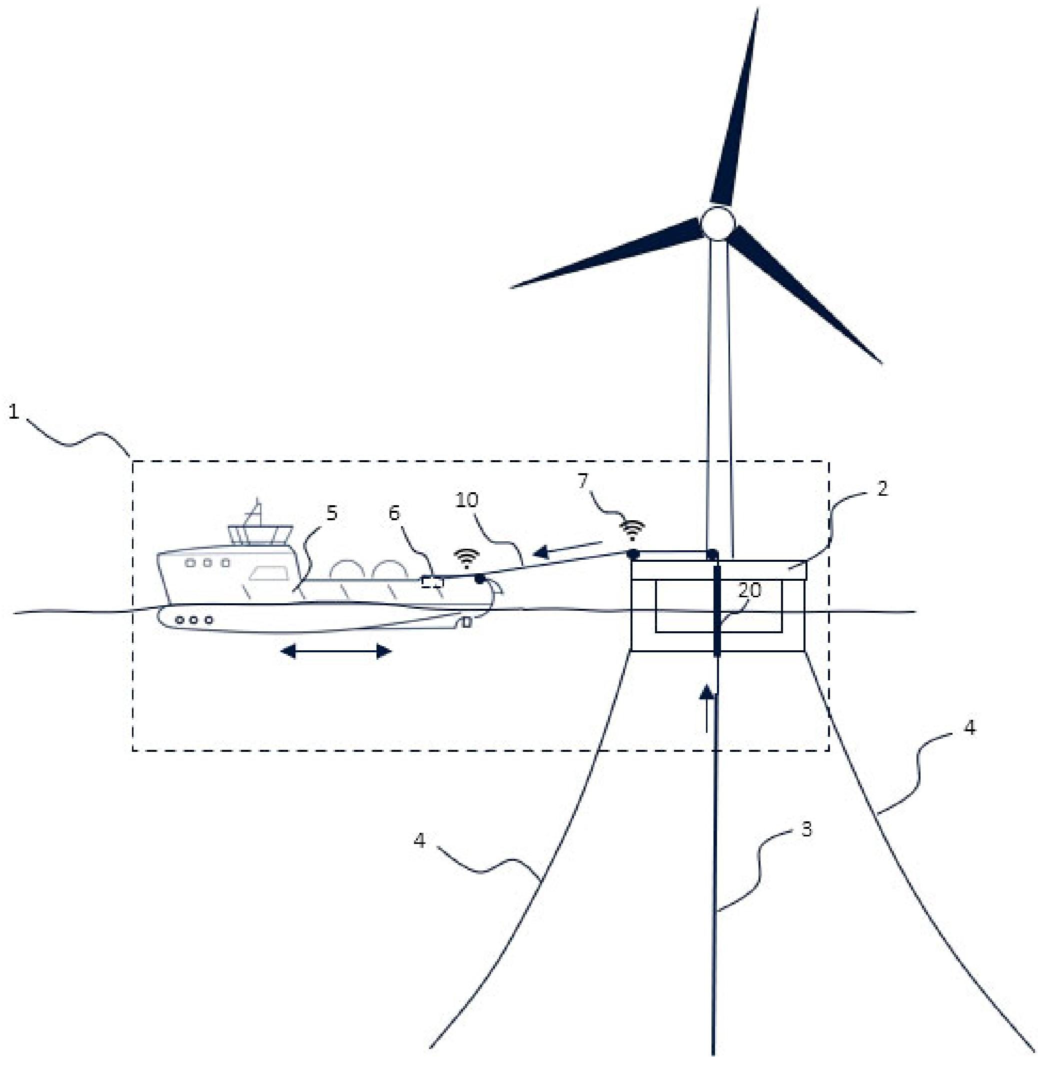
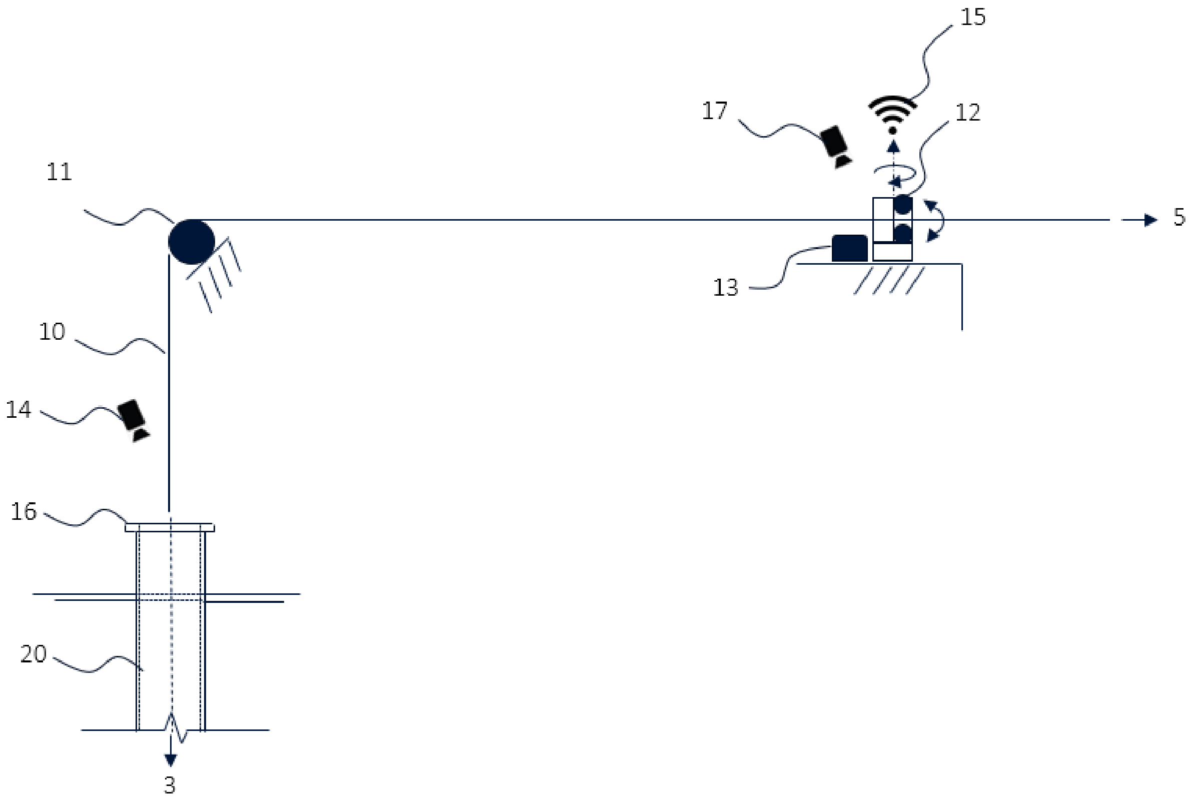


Figure 2:



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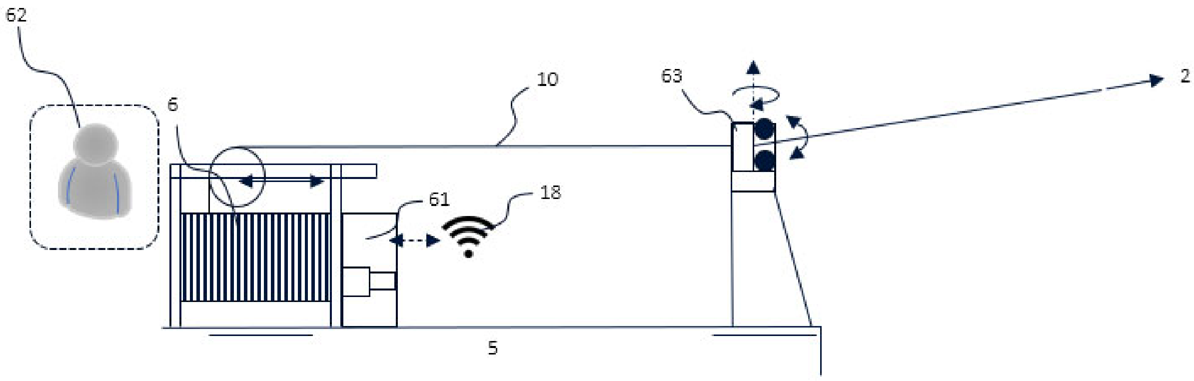


Figure 4:

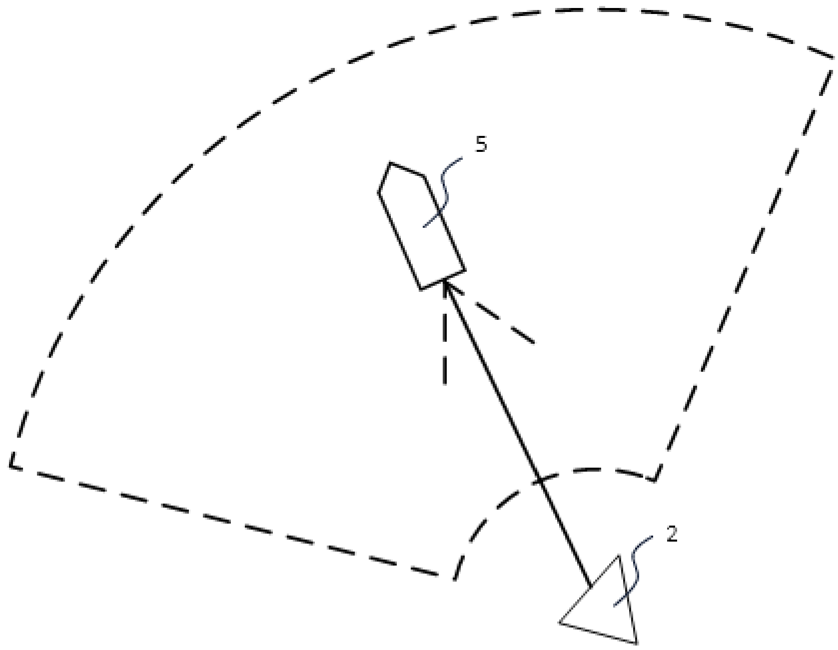


Figure 5:

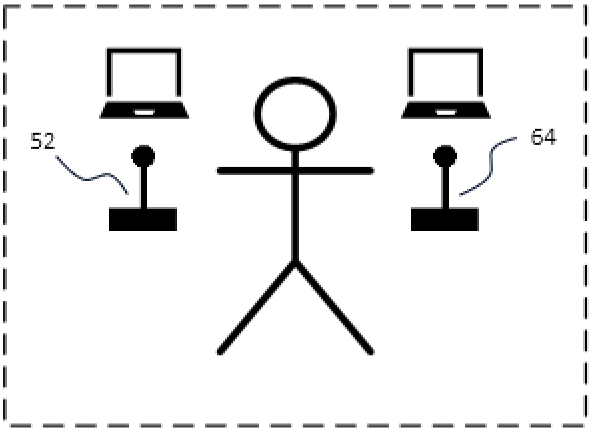
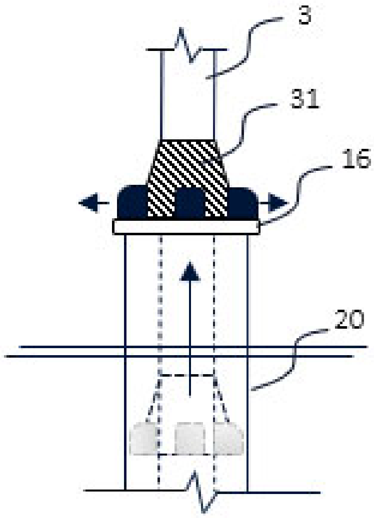


Figure 6:



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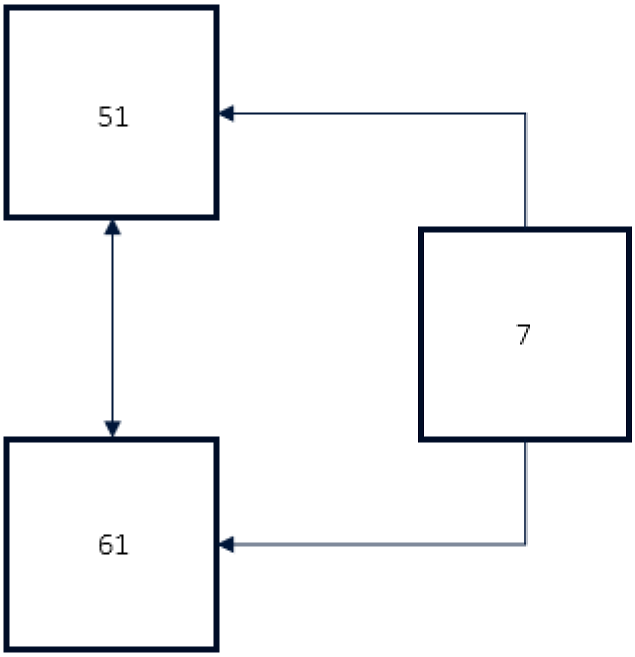

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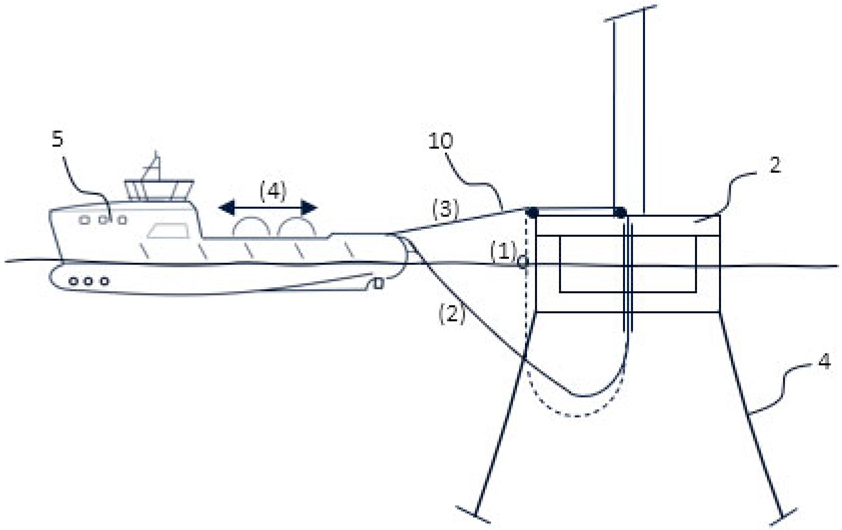


Figure 9: Step 1 to step 4

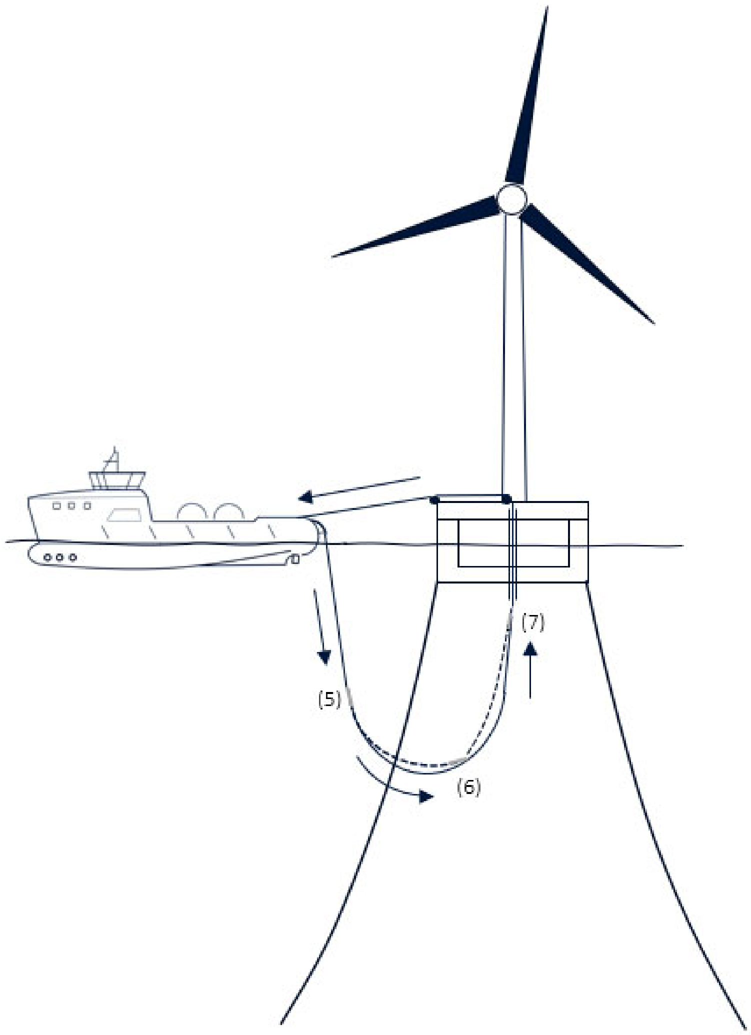


Figure 10: Step 5 to step 7

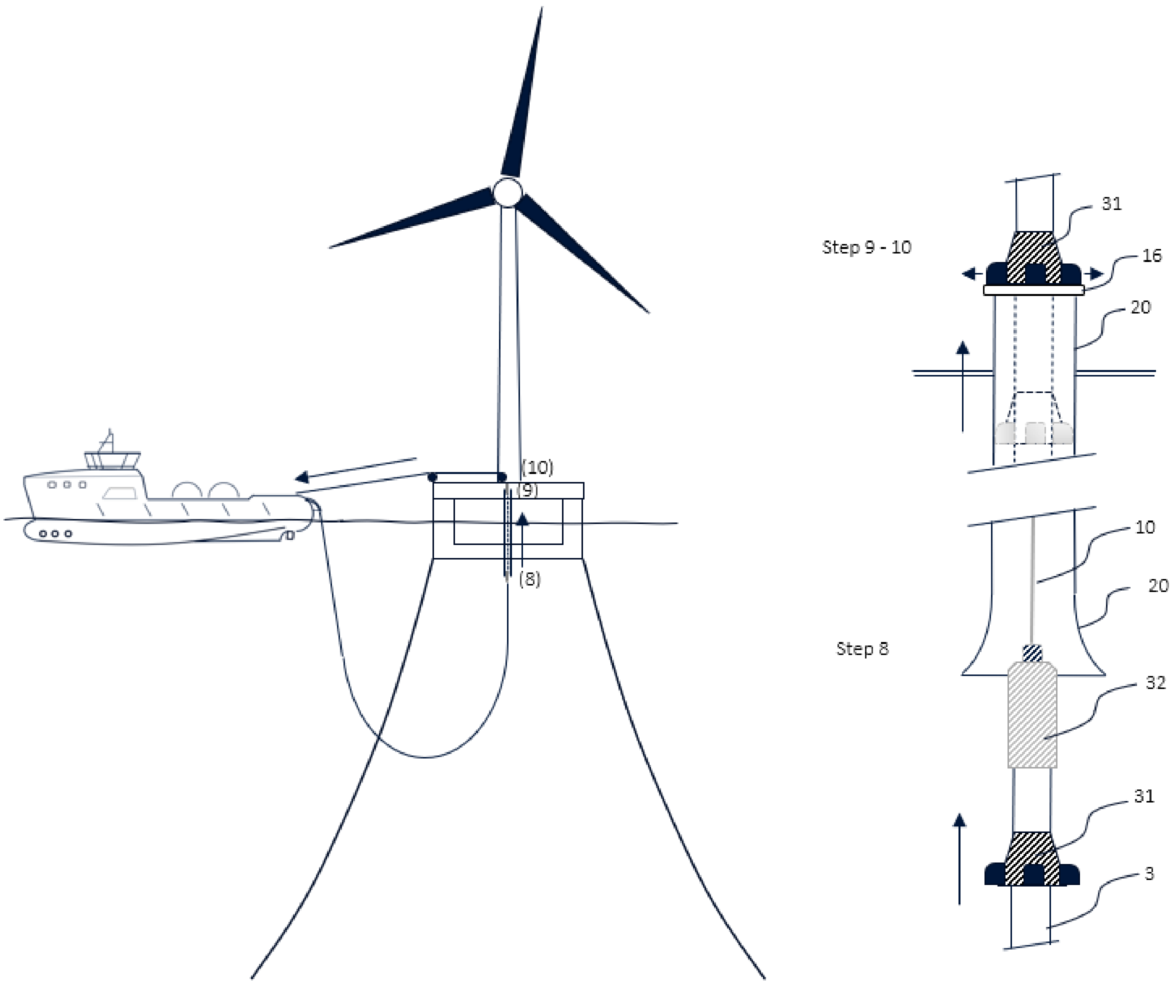


Figure 11: Step 8 to step10

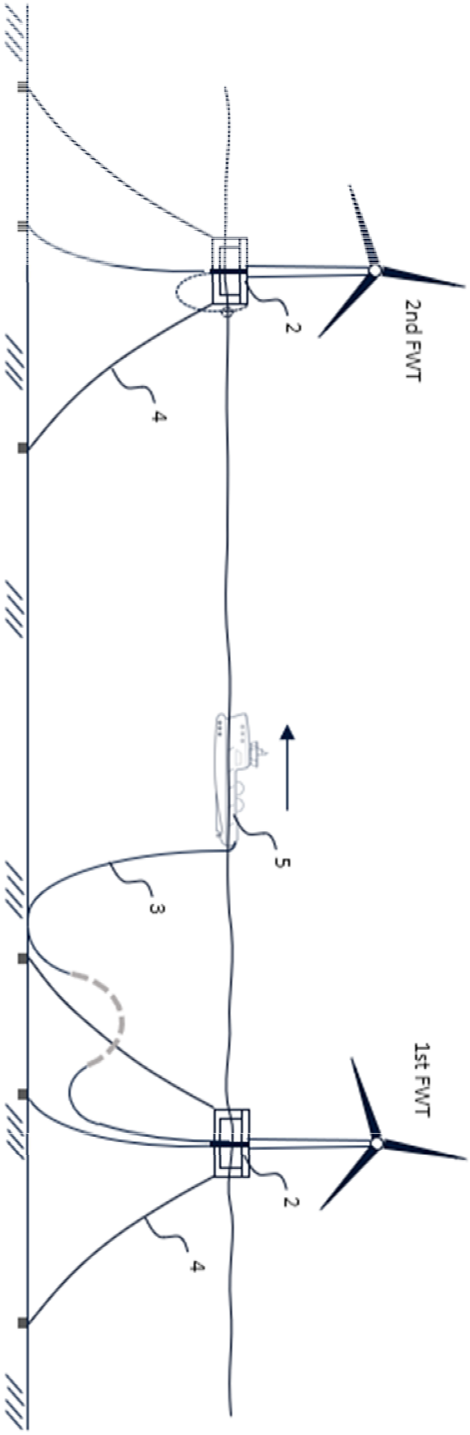


Figure 12:

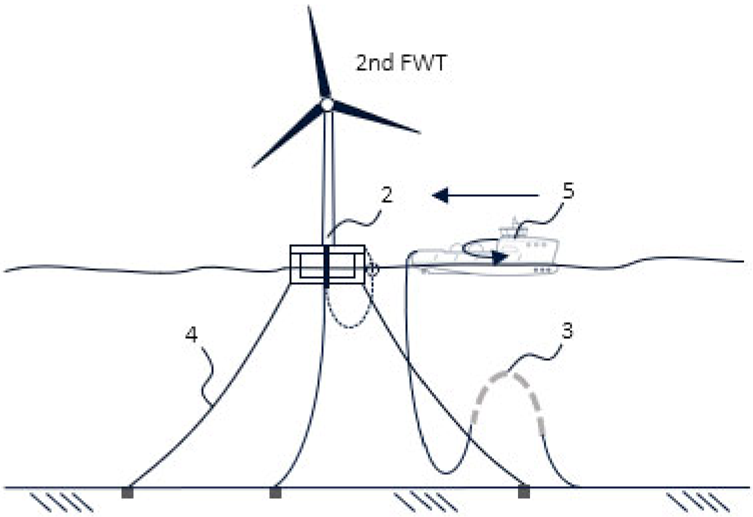
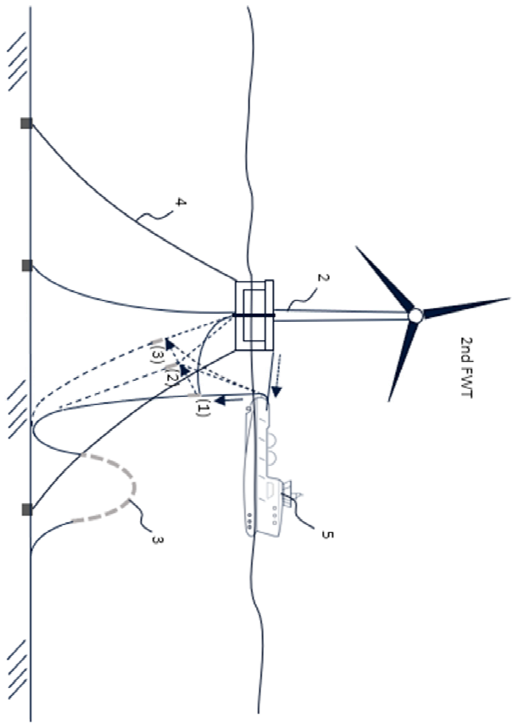
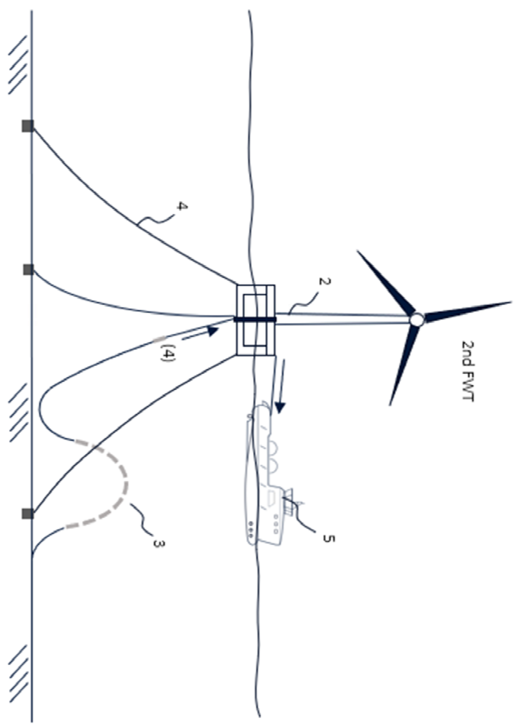


Figure 13:





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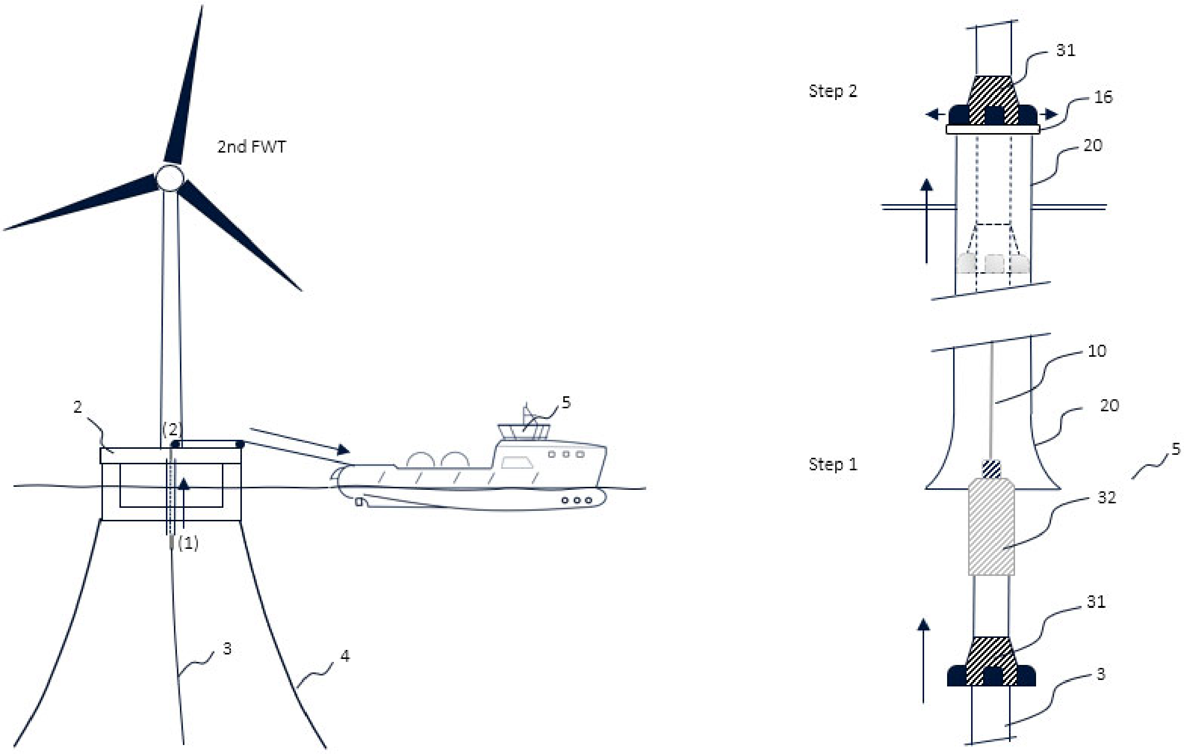

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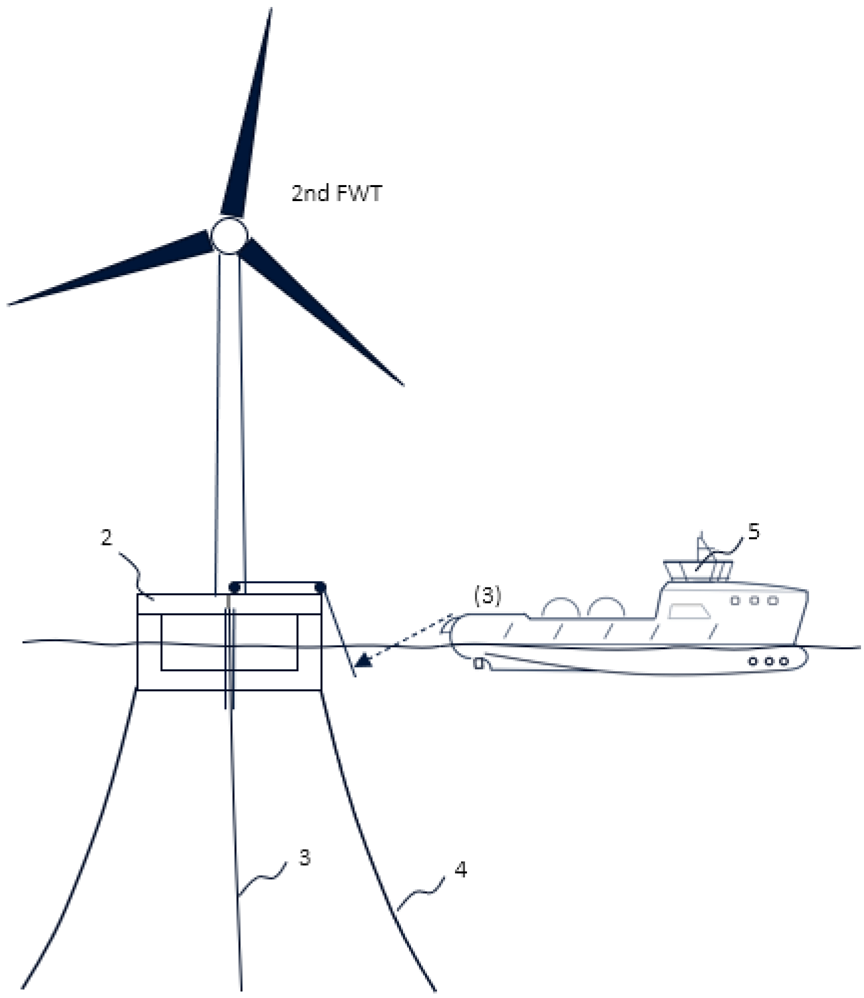

Figure 16:

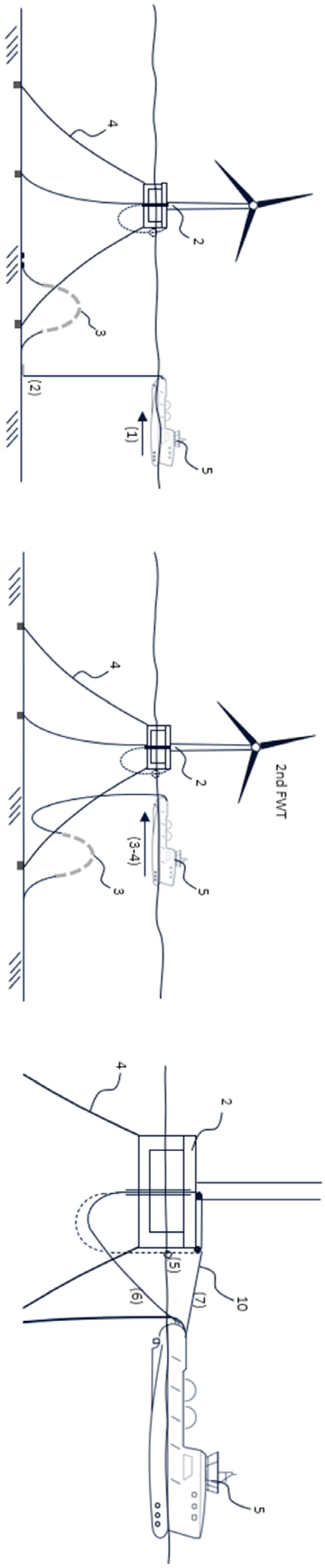

Figure 17: