Description

Title: Pile installation facility and methods thereof.

FIELD OF THE INVENTION

The present invention relates to an installation facility for installing a pile, in particular a tubular wind turbine pile, on a seabed and methods thereof.

BACKGROUND AND PRIOR ART

Installation of wind turbine monopiles (MP), i.e. substructure of offshore wind turbines, in sea, has been performed for decades. See for example patent publication JP 2001-207948.

As exemplified in patent publication WO 2018/117846 A1, the MPs are normally transported horizontally on a deck of a vessel to their installation site. When the vessel is in place and stabilized, the MP is lifted to a vertical position and then lowered down to the seabed, typically by use of a heavy lift crane and a dedicated up-ending tool. See for example figure 14 in WO 2018/117846 A1. When the MP is positioned in the correct position the MP is typically hammered into the seabed by use of a hammering tool.

In order to achieve sufficient stabilization prior to lifting of the MP a jack-up rig or jack-up vessel is typically employed.

During the installation, it is of utmost important that both the horizontal position and the vertical orientation of the MPs stay within acceptable ranges.

Patent publication EP 3’517’479 A1 describes a device and a method for installing an MP which achieves a high accuracy in horizontal position and vertical orientation by arranging the MP in an upending tool in form of a basket consisting of two enclosing rings for bringing the MP from a horizontal transport position to a vertical orientation. This upending tool works together with a gripping tool in keeping the MP under control and prevent oscillation of the MP during lowering.

One disadvantage with this known solution is its complexity and weight since it requires a high amount of moveable parts. The unit cost will consequently be high.

~~It is therefore an objective~~ Embodiments of the present invention seek to provide an alternative installation facility and methods that may achieve the required horizontal position and vertical orientation with less complexity.

~~Another objective~~Embodiments of the present invention ~~is~~ also seek to provide an installation facility and methods that effectively suppresses dynamic movements of the pile during vertical lowering.

~~Yet another objective~~ Embodiments of the present invention ~~is~~ also seek to provide an installation facility and methods that may increase control and redundancy of positional data of the MP during installation.

~~Yet another objective~~ Embodiments of the invention ~~is~~ also seek to perform a successful pile installation onto the seabed with a minimum amount of human interference.

SUMMARY OF THE INVENTION

The present invention is set forth and characterized in the main claims, while the dependent claims describe other characteristics of the invention.

According to a first aspect of the present invention, there is provided an installation facility for installing a pile in a vertical orientation on a target pile position into a seabed, the vertical orientation being defined relative to global positioning coordinates at the target pile position, the installation facility comprising

- the pile having a longitudinal center axis,
- a vessel comprising a deck for storing a plurality of piles,
- a lifting crane fixed to the vessel, capable of lifting the pile, wherein the lifting crane comprises a crane arm onto which a second end of the crane cable is fixed at a fixation point
- a global positioning system for receiving global positioning coordinates from a navigation system,
- a vessel motion sensor installed on the vessel for measuring the vessel's excursions and rotations during operation at sea, the vessel motion sensor comprising a vessel motion data transmitter allowing transmittal of measurement data and
- an installation tool fixed to an outer boundary of the deck, the installation tool comprising:
    - a suspending structure removably fixed to an upper end of the pile, the suspending structure having means to fix a first end of one or more crane cables,
    - a pile gripper comprising a pile enclosing structure configured to enclose at least a part of an outer circumference of the pile within an enclosing space, the pile enclosing structure comprising at least one receiving arm movable between an open position forming a pile receiving opening into the enclosing space equal or larger than an outer diameter of the pile and a closed position wherein the pile receiving opening is at least partly closed,

- a pile gripper positioning system configured to re-position horizontally the pile during vertical lowering and a control system configured to regulate the pile gripper positioning system based on received measurement data from the vessel motion data transmitter and the pile motion data transmitter to stabilize movements of the pile during a vertical lowering towards the seabed within a predetermined horizontal tolerance range from the target pile position,
- a pile motion sensor installed on at least one of the suspending structure and the pile for measuring at least the position and orientation of the pile relative to the global positioning coordinates at the target pile position, the pile motion sensor comprising a pile motion data transmitter allowing transmittal of measurement data, and

• wherein the lifting crane further comprises a crane motion sensor for measuring at least a horizontal position of the fixation point relative to global positioning coordinates at the target pile position.

~~In a first aspect, the invention concerns~~ There is provided an installation facility suitable for installing an elongated object such as a pile in a vertical orientation on a target pile position into or onto a seabed. The vertical orientation is defined hereinafter relative to global positioning coordinates at the target pile position. The elongated object / pile is preferably a straight tube having an inner diameter *ID* and an outer diameter *OD*.

The installation facility comprising the pile having a longitudinal center axis, preferably in the form a tube being hollow along the entire pile length, a vessel comprising a deck for storing a plurality of piles, a lifting crane fixed to the vessel and capable of lifting the pile from the stored position on the deck, a global positioning system for receiving global positioning coordinates from a navigation system and a vessel motion sensor, preferably a vessel accelerometer, installed on the vessel for measuring the vessel's excursions (typically heave, surge and pitch) and rotations (typically roll, yaw and sway) during operation at sea.

Examples of a navigation system are a global navigation satellite system, a local three-point navigation or a combination thereof.

The vessel motion sensor comprises a vessel motion data transmitter allowing transmittal of measurement data.

The installation facility further comprises an installation tool fixed to an outer boundary of the deck such that the pile is located outside the deck boundaries when oriented vertically relative to the seabed / global coordinates.

The installation tool comprises a suspending structure fixed (preferably removably) to an upper end of the pile, a pile motion sensor suitable for measuring at least the

rotational with a rotational axis parallel to the deck. Further, the pile gripper may be located relative to the rotatable up-ending tool a distance D_{ue} from the end support.

In yet another exemplary configuration of the invention, the pile gripper is rotationally coupled via a fastening structure to the vessel with a rotational axis parallel to the deck and preferably along the vessel's longitudinal direction.

In yet another exemplary configuration of the invention, the lifting crane comprises a crane arm onto which a second end of the crane cable is fixed at a fixation point. The installation facility may further comprise a crane motion sensor suitable for measuring at least a horizontal position of the fixation point relative to global positioning coordinates at the target pile position acquired by the navigation system. As for the vessel and pile motion sensors, the crane motion sensor is preferably an accelerometer allowing measurements of at least velocity vectors and more preferably also accelerator vectors. The horizontal position is thus obtained by single integration (from velocity vector data) or double integration (from acceleration vector data).

In yet another exemplary configuration of the invention, the installation facility further comprises one or more up-ending winches, one or more winch cables, one or more tension sensors (e.g. a load cell) configured to measure a tension in the winch cable(s) and one or more up-ending winch transmitters allowing transmittal of tension data measured by the tension sensor(s). These data may e.g. be transmitted to the control system of the pile gripper and/or a dedicated winch control system for further processing. The wind cable(s) is/are fixed at one end to the suspending structure and fixed at an opposite end to the up-ending winch. The tension sensor(s) may for example be connected between the end of the winch cable and the suspending structure.

~~In a second aspect, the invention concerns~~According to a second aspect of the present invention, there is provided an installation method using an installation facility ~~in accordance with the above description~~ defined in the first aspect.

The method comprises the following steps:

A. moving the at least one receiving arm of the pile enclosing structure into the open position or alternatively controlling that the pile gripper is in the open position before continuing the method,
B. aligning the pile relative to the deck-mounted pile gripper such that the pile's longitudinal center axis intersects an axis going through a center of the pile receiving opening (and thus also the center of the pile enclosing structure / enclosing space),

the pile in order to facilitate connection with external power and/or communication cables forming part of a subsea power distribution network, for example in a wind turbine offshore park.

In yet another exemplary configuration of the second aspect, the lifting crane comprises a crane arm onto which a second end of the crane cable(s) is fixed at a fixation point and the installation facility further comprises a crane motion sensor arranged on the crane arm. For this exemplary configuration step E of the method further comprises

- measuring the horizontal position of the fixation point relative to global positioning coordinates received by the navigation system,
- subtracting the horizontal position of the fixation point with the measured horizontal position of the pile at one or more vertical positions, for example within the pile gripper plane A_{PG} and,
- if the result of the subtraction is outside a predetermined difference tolerance range, transmitting instruction signals to the control system to adjust at least one of the horizontal position of the pile via the pile gripper positioning system and the horizontal position of the fixation point via the lifting crane until the result of the subtraction is within the predetermined difference tolerance range.

In yet another exemplary configuration of the second aspect, the installation tool further comprises a rotatable up-ending tool with a rotational axis parallel to the deck and preferably along the vessel's longitudinal direction (bow-aft).

The up-ending tool comprises an elongated member and an end-support configured to support a lower pile end of the pile. The end-support is fixed (for example rotationally with a rotation axis parallel to the deck) to a lower end of the elongated member. For this exemplary configuration step B of the method may further comprise arranging the pile into the rotatable up-ending tool such that the pile's longitudinal center axis is parallel to the elongated member and the lower pile end is supported into the end-support. Moreover, step C of the method may further comprise tilting the up-ending tool with the pile supported therein.

In yet another exemplary configuration of the second aspect, the predetermined horizontal tolerance range varies depending on the vertical distance between the lower end of the pile and the seabed. For example, the predetermined horizontal tolerance range may be gradually less as said vertical distance is shortened.

~~In a third aspect, the invention concerns a stabilization method enabling stabilization of movements of a pile during vertical lowering of the pile towards a~~

~~seabed by use of an installation facility in accordance with the above description of the first aspect.~~ According to a third aspect of the present invention, there is provided a stabilization method enabling stabilization of movements of a pile during lowering of the pile towards a seabed using an installation facility for installing a pile in a vertical orientation on a target pile position into a seabed, the vertical orientation being defined relative to global positioning coordinates at the target pile position, the installation facility comprising the pile having a longitudinal center axis, a vessel comprising a deck for storing a plurality of piles, a lifting crane fixed to the vessel , capable of lifting the pile, a global positioning system for receiving global positioning coordinates from a navigation system, a vessel motion sensor installed on the vessel for measuring the vessel's excursions and rotations during operation at sea, the vessel motion sensor comprising a vessel motion data transmitter allowing transmittal of measurement data and an installation tool fixed to an outer boundary of the deck, the installation tool comprising a suspending structure removably fixed to an upper end of the pile, the suspending structure having means to fix a first end of one or more crane cables, a pile motion sensor installed on at least one of the suspending structure and the pile for measuring at least the position and orientation of the pile relative to the global positioning coordinates at the target pile position, the pile motion sensor comprising a pile motion data transmitter allowing transmittal of measurement data, a pile gripper comprising a pile enclosing structure configured to enclose at least a part of an outer circumference of the pile within an enclosing space, the pile enclosing structure comprising at least one receiving arm movable between an open position forming a pile receiving opening into the enclosing space equal or larger than an outer diameter of the pile and a closed position wherein the pile receiving opening is at least partly closed, a pile gripper positioning system configured to re-position horizontally the pile during vertical lowering and a control system configured to regulate the pile gripper positioning system based on received measurement data from the vessel motion data transmitter and the pile motion data transmitter to stabilize movements of the pile during a vertical lowering towards the seabed within a predetermined horizontal tolerance range from the target pile position,

wherein the stabilization method comprises the following steps:

- receiving global positioning coordinates from a navigation system,
- setting reference state data based on the global positioning coordinates and vessel positioning coordinates,
- transmitting the reference state data to a dynamic positioning system of the vessel,
- adjusting the vessel positioning coordinates using the dynamic positioning system until vessel state data are achieved within a

predetermined acceptance range relative to the global positioning coordinates,

- setting the vessel state data as input reference data,
- correcting the input reference data with initial pile state data to obtain initial set values,
- transmitting the initial set values to the control system,
- calculating initial instruction data based on the initial set values and a model of the installation facility that forces the movements of the pile to approach, or enter, into the predetermined horizontal tolerance range,
- activating the pile gripper positioning system based on the initial instruction data,
- finding new pile state data relative to the vertical orientation by use of at least
  - the pile motion sensor,
  - measured and/or simulated disturbance data inflicting external force onto the pile and
  - structural pile data,
- correcting the input reference data with the new pile state data to obtain new set values,
- transmitting the new set values to the control system,
- calculating new instruction data based on the new set values and the model of the installation facility and
- activating the pile gripper positioning system based on the calculated new instruction data received from the control system.

The stabilization method comprises the following steps:

- receiving global positioning coordinates from a navigation system, for example a global navigation satellite system or a local three-point navigation system or a combination thereof,
- setting a reference state data based on the global positioning coordinates at the position of the vessel and vessel positioning coordinates,
- transmitting the reference state data to a dynamic positioning system of the vessel,
- adjusting vessel coordinates using the dynamic positioning system until vessel state data are achieved that are within a predetermined acceptance range relative to the global positioning coordinates,
- setting the vessel state data as input reference data,
- correcting the input reference data with initial pile state data to obtain initial set values,
- transmitting the initial set values to the control system,

- calculating initial instruction data (typically force correcting instruction data) based on the initial set values (for example by use of Euler-Lagrange equation) and a model of the installation facility (for example a 2D or a 3D double pendulum model) that forces the movements of the pile to approach, or enter, into the predetermined horizontal tolerance range,
- activating the pile gripper positioning system based on the initial instruction data,
- finding a new pile state data including horizontal position and orientation relative to the vertical orientation by use of measured data from the pile motion sensor, measured and/or simulated disturbance data from external forces such as added mass, waves, current, wind, etc. and structural data of the pile such as length, diameter(s) and mass,
- correcting the input reference data with the new pile state data to obtain new set values,
- transmitting the new set values to the control system,
- calculating new instruction data (typically force correction instruction data values) based on the new set values and the model of the installation facility (e.g. by use of Euler-Lagrange equation and/or by use of double pendulum model) that result in a stabilization of the movements of the pile within the predetermined horizontal tolerance range and
- activating the pile gripper positioning system based on the calculated new instruction data received from the control system.

- measuring the horizontal position of the fixation point,
- subtracting (or in any other way correcting) the horizontal position of the fixation point with a horizontal position of the pile at one or more locations along the pile's longitudinal center axis, for example in a plane set by the pile enclosing structure,
- transmitting the result of the subtraction / correction to the control system of the pile gripper and/or the crane control system,
- calculating the initial instruction data based on the result of the subtraction/correction to the pile gripper positioning system and/or displacement device(s) on the crane arm to minimize the result of the subtraction (or optimizing the result of the correction) and
- activating the pile gripper positioning system and/or the displacement device(s) on the crane arm based on instructions from the control system of the pile gripper and/or the crane control system.

~~In a fourth aspect, the invention concerns~~According to a fourth aspect of the present invention, there is provided a computer-readable medium having stored thereon a computer program comprising instructions to execute the above-mentioned stabilization method of the third aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings depict alternatives of the present invention and are appended to facilitate the understanding of the invention. However, the features disclosed in the drawings are for illustrative purposes only and shall not be interpreted in a limiting sense.

Figure 1 illustrates an installation facility in accordance with the invention and an initial phase of an installation process in accordance with the invention, where fig. 1A shows a vessel transporting a plurality of piles on deck to an installation site and fig. 1B shows an intermediate phase of an upending process from horizontal to vertical orientation.

Figure 2 illustrates an intermediate phase of the installation process in accordance with the invention in which a vertical oriented pile is arranged within a pile gripper of the up-ending tool.

Figure 3 illustrates the pile gripper constituting part of the inventive installation facility into which a vertical oriented pile is arranged, where fig. 3A and fig. 3B show the pile gripper in an open position and in a closed position, respectively.

Figure 4 illustrates another intermediate phase of the installation process in accordance with the invention, in which the vertical oriented pile is arranged within

CLAIMS

1. An installation facility ~~(100)~~ for installing a pile ~~(10)~~ in a vertical orientation on a target pile position ~~(30a)~~ into a seabed ~~(30)~~, the vertical orientation being defined relative to global positioning coordinates at the target pile position ~~(30a)~~, the installation facility ~~(100)~~ comprising
   - the pile ~~(10)~~ having a longitudinal center axis,
   - a vessel ~~(200)~~ comprising a deck ~~(205)~~ for storing a plurality of piles ~~(10)~~,
   - a lifting crane ~~(400)~~ fixed to the vessel ~~(200)~~, capable of lifting the pile ~~(10)~~, wherein the lifting crane ~~(400)~~ comprises a crane arm ~~(404)~~ onto which a second end of the crane cable ~~(403)~~ is fixed at a fixation point ~~(405)~~
   - a global positioning system for receiving global positioning coordinates from a navigation system,
   - a vessel motion sensor ~~(8)~~ installed on the vessel ~~(200)~~ for measuring the vessel's ~~(200)~~ excursions and rotations during operation at sea, the vessel motion sensor ~~(8)~~ comprising a vessel motion data transmitter allowing transmittal of measurement data and
   - an installation tool ~~(1)~~ fixed to an outer boundary of the deck ~~(205)~~, the installation tool ~~(1)~~ comprising:
     - a suspending structure ~~(4)~~ removably fixed to an upper end ~~(10a)~~ of the pile ~~(10)~~, the suspending structure ~~(4)~~ having means to fix a first end of one or more crane cables ~~(403)~~,
     - a pile gripper ~~(2)~~ comprising a pile enclosing structure ~~(2a,b)~~ configured to enclose at least a part of an outer circumference of the pile ~~(10)~~ within an enclosing space, the pile enclosing structure ~~(2a,b)~~ comprising at least one receiving arm ~~(2a)~~ movable between an open position forming a pile receiving opening into the enclosing space equal or larger than an outer diameter of the pile ~~(10)~~ and a closed position wherein the pile receiving opening is at least partly closed,
     - a pile gripper positioning system ~~(2e-i)~~ **~~characterized by~~** ~~being~~ configured to re-position horizontally the pile ~~(10)~~ during vertical lowering and a control system configured to regulate the pile gripper positioning system ~~(2e-i)~~ based on received measurement data from the vessel motion data transmitter and the pile motion data transmitter to stabilize movements of the pile ~~(10)~~ during a

vertical lowering towards the seabed ~~(30)~~ within a predetermined horizontal tolerance range from the target pile position ~~(30a)~~,

- a pile motion sensor ~~(9,9a,9b)~~ installed on at least one of the suspending structure ~~(4)~~ and the pile ~~(10)~~ for measuring at least the position and orientation of the pile ~~(10)~~ relative to the global positioning coordinates at the target pile position ~~(30a)~~, the pile motion sensor ~~(9,9a,9b)~~ comprising a pile motion data transmitter allowing transmittal of measurement data, and

- wherein the lifting crane further comprises a crane motion sensor ~~(406)~~ for measuring at least a horizontal position of the fixation point ~~(405)~~ relative to global positioning coordinates at the target pile position ~~(30a)~~.

2. The installation facility ~~(100)~~ in accordance with claim 1, wherein the pile motion sensor ~~(9,9a,9b)~~ is an accelerometer allowing measurements of magnitude and direction of the pile's ~~(10)~~ acceleration during the vertical lowering towards the seabed ~~(30)~~, wherein the position and orientation of the pile ~~(10)~~ is achieved by double integration of the measured acceleration vector.

3. The installation facility ~~(100)~~ in accordance with claim 1 or 2, wherein at least a part of the pile gripper positioning system ~~(2e-i)~~ are force controlled, and

- wherein the control system comprises a force control system for setting and controlling the force of the force-controlled pile gripper positioning system ~~(2e-i)~~, the force control system being configured

  - to receive at least one of
    - measured velocity vector data and
    - measured acceleration vector data

  from the pile motion sensor ~~(9,9a,9b)~~ and

  - to convert measured data from at least the pile motion sensor ~~(9,9a,9b)~~ into force vectors having a size and a direction allowing the stabilization of the movements of the pile ~~(10)~~.

4. The installation facility ~~(100)~~ in accordance with any one of the preceding claims, wherein the pile enclosing structure ~~(2a,b)~~ comprises two receiving arms ~~(2a)~~ arranged mirror symmetrically relative to each other.

5. The installation facility ~~(100)~~ in accordance with any one of the preceding claims, wherein the pile gripper positioning system ~~(2e-i)~~ comprises

- a first displacement device ~~(2f)~~ configured to displace the pile enclosing structure ~~(2a,b)~~ in direction perpendicular to a hull of the vessel ~~(200)~~ and
- a second displacement device ~~(2g)~~ configured to rotate the pile enclosing structure ~~(2a,b)~~ with a rotational axis perpendicular to the deck ~~(205)~~.

6. The installation facility ~~(100)~~ in accordance with any one of the preceding claims, wherein the pile gripper positioning system ~~(2e-i)~~ comprises
   - two independently displaceable first displacement devices ~~(2f)~~ configured to displace the pile enclosing structure ~~(2a,b)~~ in a direction perpendicular to a hull of the vessel ~~(200)~~, wherein the two first displacement devices ~~(2f)~~ are fixed to opposite sides of the pile enclosing structure ~~(2a,b)~~ extending from the deck ~~(205)~~.

7. The installation facility ~~(100)~~ in accordance with any one of the preceding claims, wherein the pile gripper ~~(2)~~ further comprises
   - a plurality of pile supporting devices ~~(2c,d)~~ arranged within the pile enclosing structure ~~(2a,b)~~ for suppressing movements of the pile ~~(10)~~ within the enclosing space during lowering,

   and wherein the pile gripper positioning system ~~(2e-i)~~ comprises
   - a plurality of displacement devices ~~(2e)~~ coupled between the enclosing structure ~~(2a,b)~~ and the plurality of pile supporting devices ~~(2c,d)~~ to allow displacement of the pile supporting devices ~~(2c,d)~~ between
     - a contact position in which at least a part of each pile supporting device ~~(2c,d)~~ exerts a pressure onto an outer wall of the pile ~~(10)~~ and
     - a retracted position in which each pile supporting device ~~(2c,d)~~ exerts no or insignificant pressure onto the outer wall of the pile ~~(10)~~.

8. The installation facility ~~(100)~~ in accordance with claim 7, wherein each pile supporting device ~~(2c,d)~~ comprises
   - a vertical pile displacement wheel ~~(2e)~~ having a rotational axis parallel to a pile gripper plane ~~(A_{PG})~~ set by the pile enclosing structure ~~(2a,b)~~ and
   - a horizontal pile displacement wheel ~~(2d)~~ having a rotational axis perpendicular to the pile gripper plane ~~(A_{PG})~~,

wherein the plurality of pile supporting devices ~~(2c,d)~~ is further configured to displace the vertical pile displacement wheel ~~(2c)~~ and the horizontal pile displacement wheel ~~(2d)~~ relative to each other such that, when in contact position, either the vertical pile displacement wheel ~~(2c)~~ or the horizontal pile displacement wheel ~~(2d)~~ or both, exert(s) pressure onto the outer wall of the pile ~~(10)~~.

9. An installation method using an installation facility ~~(100)~~ in accordance with any one of the preceding claims,
~~**characterized in that**~~ wherein the method comprises the following steps:
   A. moving the at least one receiving arm ~~(2a)~~ of the pile enclosing structure ~~(2a,b)~~ into the open position,
   B. aligning the pile ~~(10)~~ with the pile gripper ~~(2)~~ such that the pile's longitudinal center axis intersects an axis going through a center of the pile receiving opening,
   C. tilting the pile ~~(10)~~ by use of the lifting crane ~~(400)~~ until the vertical orientation of the pile ~~(10)~~ is achieved, wherein at least the orientation of the pile's longitudinal center axis relative to the vertical orientation is being monitored by measurement data transmitted from the pile motion sensor ~~(9,9a,9b)~~,
   D. moving the at least one receiving arm ~~(2a)~~ of the pile enclosing structure ~~(2a,b)~~ into the closed position,
   E. lowering the pile ~~(10)~~ by use of the lifting crane ~~(400)~~ towards the target pile position ~~(30a)~~ while monitoring the movements of the pile ~~(10)~~ using at least one of the pile motion sensor ~~(9,9a,9b)~~ and the vessel motion sensor ~~(8)~~,
   F. if the movements of the pile ~~(10)~~ within the pile enclosing structure ~~(2a,b)~~ during lowering are measured to be outside the predetermined horizontal tolerance range, transmitting instruction signals to the control system to adjust, via the pile gripper positioning system ~~(2e-i)~~, the pile enclosing structure ~~(2a,b)~~ in order to force the movements of the pile ~~(10)~~ to be within the predetermined horizontal tolerance range.

10. The installation method in accordance with claim 9,
wherein step E of the method further comprises
   - measuring the horizontal position of the fixation point ~~(405)~~ relative to global positioning coordinates,

- subtracting the horizontal position of the fixation point ~~(405)~~ with the measured horizontal position of the pile ~~(10)~~ at one or more vertical positions and,

- if the result of the subtraction is outside a predetermined difference tolerance range, transmitting instruction signals to the control system to adjust, at least one of

the horizontal position of the pile ~~(10)~~ via the pile gripper positioning system ~~(2e-i)~~ and

the horizontal position of the fixation point ~~(405)~~ via lifting crane ~~(400)~~

until the result of the subtraction is within the predetermined difference tolerance range.

11. A stabilization method enabling stabilization of movements of a pile ~~(10)~~ during lowering of the pile ~~(10)~~ towards a seabed ~~(30)~~ using an installation facility ~~(100)~~ for installing a pile ~~(10)~~ in a vertical orientation on a target pile position ~~(30a)~~ into a seabed ~~(30)~~, the vertical orientation being defined relative to global positioning coordinates at the target pile position ~~(30a)~~, the installation facility ~~(100)~~ comprising the pile ~~(10)~~ having a longitudinal center axis, a vessel ~~(200)~~ comprising a deck ~~(205)~~ for storing a plurality of piles ~~(10)~~, a lifting crane ~~(400)~~ fixed to the vessel ~~(200)~~, capable of lifting the pile ~~(10)~~, a global positioning system for receiving global positioning coordinates from a navigation system, a vessel motion sensor ~~(8)~~ installed on the vessel ~~(200)~~ for measuring the vessel's ~~(200)~~ excursions and rotations during operation at sea, the vessel motion sensor ~~(8)~~ comprising a vessel motion data transmitter allowing transmittal of measurement data and an installation tool ~~(1)~~ fixed to an outer boundary of the deck ~~(205)~~, the installation tool ~~(1)~~ comprising a suspending structure ~~(4)~~ removably fixed to an upper end ~~(10a)~~ of the pile ~~(10)~~, the suspending structure ~~(4)~~ having means to fix a first end of one or more crane cables ~~(403)~~, a pile motion sensor ~~(9,9a,9b)~~ installed on at least one of the suspending structure ~~(4)~~ and the pile ~~(10)~~ for measuring at least the position and orientation of the pile ~~(10)~~ relative to the global positioning coordinates at the target pile position ~~(30a)~~, the pile motion sensor ~~(9,9a,9b)~~ comprising a pile motion data transmitter allowing transmittal of measurement data, a pile gripper ~~(2)~~ comprising a pile enclosing structure ~~(2a,b)~~ configured to enclose at least a part of an outer circumference of the pile ~~(10)~~ within an enclosing space, the pile enclosing structure ~~(2a,b)~~ comprising at least one receiving arm ~~(2a)~~ movable between an open position forming a pile receiving opening into the

enclosing space equal or larger than an outer diameter of the pile ~~(10)~~ and a closed position wherein the pile receiving opening is at least partly closed, a pile gripper positioning system ~~(2e i)~~ configured to re-position horizontally the pile ~~(10)~~ during vertical lowering and a control system configured to regulate the pile gripper positioning system ~~(2e i)~~ based on received measurement data from the vessel motion data transmitter and the pile motion data transmitter to stabilize movements of the pile ~~(10)~~ during a vertical lowering towards the seabed ~~(30)~~ within a predetermined horizontal tolerance range from the target pile position ~~(30a)~~,

wherein the stabilization method comprises the following steps:

- ~~(301)~~ receiving global positioning coordinates from a navigation system,
- ~~(302)~~ setting reference state data based on the global positioning coordinates and vessel positioning coordinates,
- ~~(304)~~ transmitting the reference state data to a dynamic positioning system of the vessel ~~(200)~~,
- ~~(303,305,307)~~ adjusting the vessel positioning coordinates using the dynamic positioning system until vessel state data are achieved within a predetermined acceptance range relative to the global positioning coordinates,
- ~~(307,310)~~ **~~characterized by~~** setting the vessel state data as input reference data,
- ~~(307,310-311,314)~~ correcting the input reference data with initial pile state data to obtain initial set values,
- ~~(310-311)~~ transmitting the initial set values to the control system,
- ~~(312)~~ calculating initial instruction data based on the initial set values and a model of the installation facility ~~(100)~~ that forces the movements of the pile ~~(10)~~ to approach, or enter, into the predetermined horizontal tolerance range,
- ~~(313,316-318)~~ activating the pile gripper positioning system ~~(2e i)~~ based on the initial instruction data,
- ~~(314,315,318)~~ finding new pile state data relative to the vertical orientation by use of at least
  - the pile motion sensor ~~(9,9a,9b)~~,
  - measured and/or simulated disturbance data inflicting external force onto the pile ~~(10)~~ and
  - structural pile data,

- ~~(311,312)~~ correcting the input reference data with the new pile state data to obtain new set values,
- ~~(310-311)~~ transmitting the new set values to the control system,
- ~~(316)~~ calculating new instruction data based on the new set values and the model of the installation facility ~~(100)~~ and
- ~~(313,316-318)~~ activating the pile gripper positioning system ~~(2e-i)~~ based on the calculated new instruction data received from the control system.

12. The stabilization method in accordance with claim 11, wherein the method further comprises the following steps:
- ~~(306)~~ transmitting the vessel data or the vessel state data to a crane control system of the lifting crane ~~(400)~~,
- ~~(310)~~ calculating initial input reference data based on crane state data and vector state data,
- ~~(310-311,314)~~ correcting the initial input reference data with the initial pile state data to achieve initial set values and
- ~~(306,307,309,310,312)~~ transmitting the initial set values to the control system.

13. The stabilization method in accordance with claim 11 or 12, wherein the lifting crane ~~(400)~~ comprises a crane arm ~~(404)~~ onto which a second end of the crane cable ~~(403)~~ is fixed in a fixation point ~~(405)~~ and wherein the installation facility ~~(100)~~ further comprises a crane motion sensor ~~(406)~~ arranged on the crane arm ~~(404)~~ for measuring at least a horizontal position of the fixation point ~~(405)~~ relative to the global positioning coordinates, and wherein
the method further comprises the following steps:
- ~~(306)~~ transmitting the vessel coordinates or the vessel state coordinates to a crane control system of the lifting crane ~~(400)~~,
- ~~(309,310)~~ measuring the horizontal position of the fixation point ~~(405)~~,
- ~~(311,314)~~ subtracting the horizontal position of the fixation point ~~(405)~~ with a horizontal position of the pile ~~(10)~~ at one or more locations along the pile's longitudinal center axis,
- ~~(312)~~ transmitting the result of the subtraction to the control system of the pile gripper ~~(2)~~ and/or the crane control system,
- ~~(316)~~ calculating the initial instruction data based on the result of the subtraction to the pile gripper positioning system ~~(2e-i)~~ and

- ~~(313,316-318)~~ activating the pile gripper positioning system ~~(2e-i)~~ and/or moving the crane arm ~~(404)~~ based on instructions from the control system of the pile gripper ~~(2)~~ and/or the crane control system.

14. A computer-readable medium having stored thereon a computer program comprising instructions to execute the method steps of any one of claims 11-13.