(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 June 2013 (27.06.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/095136 Al

(51) International Patent Classification:
F03D 1/00 (2006.01) *B63B 35/00* (2006.01)

(21) International Application Number:
PCT/NL20 12/050909

(22) International Filing Date:
2 1 December 2012 (21 .12.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2008018 22 December 201 1 (22. 12.201 1) NL

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available):* ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

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(54) Title: METHOD FOR INSTALLING AN OFFSHORE WIND TURBINE, INSTALLATION BARGE FOR INSTALLING AN OFFSHORE WIND TURBINE

(57) Abstract: Method for installing a wind turbine at an offshore location by using an installation barge, comprising the steps of providing an assembly structure arranged on a deck of the installation barge; mounting at least a hub on the assembly structure; fitting at least one blade to the hub while the hub is mounted to the assembly structure, wherein during fitting of the blade to the hub the blade is under an angle with the deck; lifting the completed hub-rotor assembly and mounting the hub-rotor assembly onto a pre-installed wind turbine tower section.

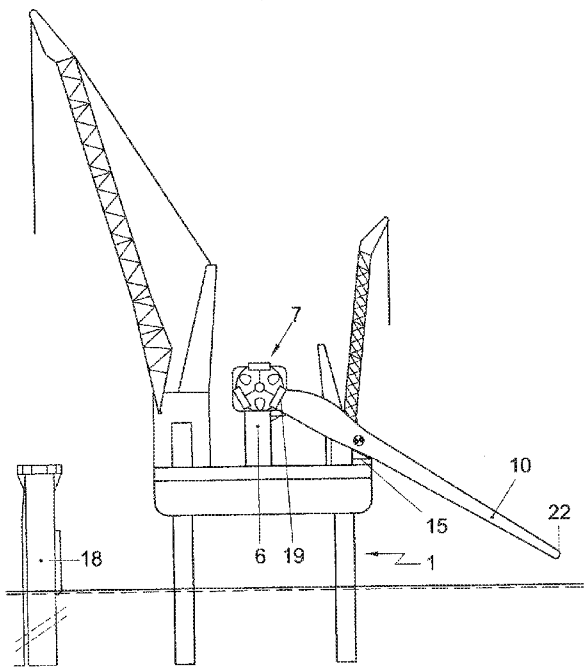

Fig. 1f

WO 2013/095136 A1

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Title: Method for installing an offshore wind turbine, Installation barge for installing an offshore wind turbine.

The invention relates to a method for installing a wind turbine at an offshore location by using an installation barge.

In recent years, more and more wind turbines are installed at an offshore location. The wind turbines can have fixed foundation or a floating foundation. The wind turbines are usually mounted on a pre-installed foundation structure. The foundation structure is usually installed by a dedicated foundation installation vessel. Once the foundation is installed, an installation barge can install the wind turbine. The wind turbine usually comprises a number of tower sections, a nacelle, a hub and blades fitted to the hub. The nacelle usually comprises a generator and a gear box, the hub is usually connected to the shaft of the generator or gear box. Typically an offshore wind turbine has two or three blades.

For installing the wind turbine at an offshore location an installation barge can be used. The installation barge can be a generally equipped barge or can be a barge dedicated equipped for the installation of wind turbines. The installation barge can be a jack-up barge and/or a jack-up vessel or a floating barge and/or a floating vessel. The installation barge can be self-propelled or can be towed or pushed. Also, the installation barge may comprise means to keep approximately its position during installation such as legs, or anchor mooring, or a dynamic positioning system, etc.

Typically jack-up barges or jack-up vessels are used. A jack-up barge or jack-up vessel is provided with legs, typically three or four legs, and a platform comprising a deck. The legs are adjustable between a transport position in which the legs substantially extend above a deck of the barge and the barge is floating, and an installation position in which the legs extend substantially below the deck of the barge and the legs are supported on the seabed. With the legs in the installation position lowered to the seabed, the platform can be jacked up to a height above the water level.

A floating vessel or a floating barge can also be used, in particular when relatively deep water is involved at the offshore location. The floating vessel preferably has a dynamic positioning system such that it can maintain approximately its position without the need for mooring to the seabed.

Different methods are in use to install a wind turbine at an offshore location.

One method is to assemble the wind turbine offshore by lifting a single part at a time onto the pre-installed foundation. Thus, each wind turbine tower section is lifted individually from the installation barge and is fitted individually onto the previous part. When the tower is erected, the nacelle and the hub, whether in combination or not, are lifted onto the tower. Then the blades are fitted to the hub one by one. All parts can be transported onto the deck of a transporting barge or installation barge to the installation site offshore. Due to the individual parts, the deck layout may be organised relatively efficient. However, the method requires a lot of handling on site and is therefore time consuming and/or weather sensitive. Also, by installing part by part, a lot of crane lifts are required, which is not only time consuming, but in addition makes the installation procedure relatively complex. In particular the blades need to be fitted one by one at relatively large height to the hub on top of the wind turbine tower. Fitting the blades at such a height involves risks both for men and for material. Hazardous situations may occur.

Another method is to erect the tower section wise and then to lift a nacelle-hub assembly fitted with two blades onto the tower. Such a nacelle-hub assembly fitted with two blades directed upwards is also known as a 'bunny ear' configuration. After mounting the bunny ear configuration to the tower, the third blade is fitted onto the hub. The bunny ear configuration is usually assembled onshore and transported to the installation site offshore. The bunny ear configuration requires significant deck space and is relatively difficult to handle, in particular during the lift onto the tower. Further, fitting the third blade to the hub while the hub is on the tower, requires complex handling and installation and may involve risks.

Another method is to install the tower section wise and, once the tower is completed, to fit the nacelle onto the tower. Then a complete rotor-hub assembly is lifted and fitted to the nacelle onto the tower. Such a complete rotor-hub assembly is usually assembled onshore and then transported to the installation site offshore. Due to the relatively large dimensions of the completed rotor-hub assembly, the rotor-hub assembly is usually transported in a lying configuration onto the deck of the transporting barge, which requires a lot of deck space. On site, the lying rotor-hub assembly needs to be hfted and tilted to an upward configuration to position it onto the nacelle. This requires complex handling and manoeuvring of the rotor-hub assembly with a crane holding the assembly.

In another method, the complete wind turbine tower including the hub, nacelle and blades is assembled onshore and then transported to the installation site offshore either in a lying configuration on deck or in a standing configuration on deck. Both configurations imply difficult transporting conditions due to the vast dimensions of the completed wind turbine.

In publication WO 2010/126369 in the name of the applicant, another method is presented to transport the blades in a standing position onto the deck of the installation barge. Each blade is standing in its individual frame having on top of the frame supports, guides and a bumper to temporarily receive a nacelle. On site on the deck of the installation barge, two blades are fitted in a bunny ear configuration to the hub, then the hub-nacelle assembly with the bunny ear configuration is lifted on top of the frame of the third blade to fit the third blade to the hub. In a rather complex operation, the completed hub-nacelle-rotor assembly is hfted upwardly such that the third blade is lifted out of its frame and then the hub-nacelle-rotor assembly is installed on the pre-installed tower.

Wind turbine blades are relatively long, typically 60 meter or more. Mainly due to their length a wind turbine blade is rather vulnerable and requires cautious handling. Furthermore, depending on the design characteristics, a wind turbine blade can have a relatively flexible structure, which also requires cautious handling of the wind turbine blade. In particular in an offshore environment, where there are limitations in terms of e.g. deck space or crane capacity cautious handling of the blades requires attention. In addition, the environmental conditions on an offshore site can be rather harsh which may influence the handling of the blades as well and may create hazardous situations.

Due to the offshore nature of the wind turbine installation, usually a limited weather window is available for installation. Environmental conditions such as tide, wind, current, etc. can influence the availability of e.g. equipment and capacity, but also can influence the installation, in particular the handling of the relatively vulnerable blades. Therefore, a relatively time efficient installation method is advantageous.

Further, deck space on an installation barge is limited and many deck layouts have been developed to transport all components to the installation site. Lying blades or a lying rotor-hub assembly requires a lot of deck space, whereas standing blades or a standing wind turbine has a significant height which complicates the transport.

The known methods for installing a wind turbine at an offshore site involve many drawbacks and show room for improvement in terms of for example efficiency, handling, installation time, safety, etc. Therefore, an object of the invention is to provide an installation method for installing a wind turbine at an offshore location that obviates at least one of the above mentioned drawbacks.

Thereto, the invention provides for a method for installing a wind turbine at an offshore location by using an installation barge, comprising the steps of providing an assembly structure arranged on a deck of the installation barge; mounting at least a hub on the assembly structure; fitting at least one blade to the hub while the hub is mounted to the assembly structure, wherein during fitting of the blade to the hub the blade is under an angle with the deck; lifting the completed hub-rotor assembly and mounting the hub-rotor assembly onto a pre-installed wind turbine tower section.

By providing an assembly structure on deck of the installation barge, to which the hub can be temporarily mounted, the blades can be fitted to the hub. All blades that require offshore installation, and are therefore not pre-assembled to the hub onshore, can thus be fitted to the hub while the hub is on the assembly structure on the deck. The installation can therefore be performed in a more controlled way. Contrary to many prior art methods where e.g. the third blade is installed when the hub is already on the wind turbine tower.

According to the invention, the blades are fitted to the hub when the blade is under an angle with respect to the deck of the installation barge. By fitting the blade under an angle to the hub, the height of the assembly tower can become less than the length of the blade. Also, when for example two blades are already fitted in a bunny ear configuration onshore, the third blade can be fitted to the hub while the hub is on the assembly tower and the third blade under an angle to the deck.

In prior art methods, in particular the third blade, can be assembled in standing position to the hub offshore. This requires lifting of the hub to a relatively large height, higher than the length of the blade to avoid damages on e.g. the blade tip. Working at such a height involves serious risks, not only for the work men involved, but also for the relatively vulnerably blade, since manoeuvring of, typically, a crane on such a height can be rather difficult. By assembling the blades on the assembly tower, which may have a relatively low height, less installation risks may be involved.

In addition, by fitting the blades to the hub on the assembly tower, which is higher than deck level, but usually lower than blade length and/or tower height, the remaining lift of the completed rotor-hub assembly is less than starting from deck level, which may facilitate handling and lifting and may limit hazardous situations.

By assembling all blades on the installation barge offshore a balance is sought between efficient deck layout for transport and efficient installation handlings offshore. When a more efficient deck layout becomes possible, the installation barge may transport more parts per trip and therefore can remain a longer time on site for installation. Thus, fewer trips to the shore may be needed to collect the parts and to bring them to the offshore site. This may increase efficiency and may lead to a significant gaining of time.

When all blades are fitted to the hub offshore, the individual components can be relatively efficiently configured onto the deck space. Also, when already one or two blades are installed onshore they can be transported in a single-blade-up configuration or in the bunny ear configuration, while the remaining components can be configured on the deck for transport. Also, when all blades are fitted to the hub offshore with the hub on the assembly tower, the installation of the blades can become more time efficient since no repositioning of the hub is needed between the installation of two subsequent blades, such as in some prior art methods when the hub requires to be lifted for the installation of e.g. the third blade.

After fitting the blades to the hub, the hub-rotor assembly is lifted onto the pre-installed wind turbine tower section. The assembly structure itself may be a wind turbine tower section that, with the nacelle-hub-rotor assembly mounted on it, is connected to the already installed wind turbine tower section or sections. Alternatively, the wind turbine tower may be pre-installed with the nacelle mounted to it. The hub-rotor assembly is then lifted from the assembly structure to connect it to the nacelle on the wind turbine tower. Alternatively, the nacelle-hub-rotor assembly may be lifted from the assembly tower and may be connected to the pre-installed wind turbine tower.

According to the invention, the hub may be rotated between the fitting of subsequent blades while the hub is mounted to the assembly structure. Since the blades are fitted to the hub with the blades under an angle to the deck, it is advantageous to rotate the hub when more than one blade needs to be assembled between the fitting of subsequent blades. By rotating the hub between the fitting of subsequent blades, the subsequent blade can be fitted to the hub having approximately the same angle to the deck. The hub can be rotated for example by supplying power to either an external motor or to the motor placed in the nacelle. When the hub is mounted to the assembly tower, the hub can be coupled to an external motor which can rotate the hub. When a hub-nacelle assembly is mounted on the assembly tower, power can be supplied to the motor placed in the nacelle to rotate the hub, thereby obviating the need of a separate power pack and/or external motor for rotating the hub.

By mounting a hub-nacelle assembly onto the assembly tower, the installation may become more time efficient, since the step of separately manoeuvring and lifting the nacelle onto the tower can be obviated. A hub-nacelle assembly can be assembled onshore and transport as an assembled component on the installation barge, thus the deck layout of the installation barge may become more efficient allowing the installation barge to transport more parts per trip to the offshore site. Alternatively, the hub and nacelle are transported individually on the installation barge and, once at the offshore location, are assembled to be mounted on the assembly tower.

Preferably, the angle of the blade with respect to the deck is between approximately 10° and approximately 80°, more preferably between approximately 20° and approximately 60°, more preferably between approximately 25° and approximately 45°, and more preferably around approximately 30°. An angle of approximately 30° may be relatively optimal for for example a jack-up vessel or jack-up barge. Depending on whether a floating installation barge or a jack-up installation barge is used the angle of the blade with respect to the deck can be smaller or larger to avoid the blade tip from dipping in the water. It is to be expected that, when using a floating installation barge, the angle of the blade with respect to the deck may become smaller.

According to an aspect of the invention, the blade is positioned in a blade support structure before fitting the blade in the hub. The support structure can provide additional support during fitting of the blade to the hub. Before fitting the blade to the hub, the blade will be hfted by a blade handling tool connected to a crane from its transport position on the deck of the installation barge towards its installation position near the hub. The blade handling tool can tilt the blade until the desired angle is reached. The blade support structure can be of assistance in obtaining the desired angle and/or in positioning the blade adequately near the hub. By positioning the blade onto the support structure, the blade can approximately maintain its angle with respect to the deck when manoeuvring the blade towards the hub to fit the blade to the hub.

The blade support structure can be a passive structure, i.e. it is a structure that only provides support to the blade, or the blade support structure can be an active structure. An active blade support structure is actively driven to assist manipulation of the blade towards the hub. The active blade support structure therefore can be provided with drive means such as hydraulic cylinders to assist manipulation of the blade in one or more degrees of freedom.

Advantageously, the blade support structure is arranged for supporting the blade around its center of gravity. By providing support of the blade around its center of gravity a relatively stable supporting may be provided, while in addition, manipulation and/or manoeuvring of the blade can be more effective.

The blade support structure may be provided with a supporting area that is complementary to the blade external dimensions in the area where the blade is to be supported. To provide the blade supporting area in fact as a counter form of the blade external dimensions, an effective support can be provided. Also, it can be of assistance to manoeuvre the blade to the desired position.

In an advantageous embodiment, the assembly structure is a fixed structure onto the deck of the installation barge. The assembly structure can also be itself an upper section of the wind turbine tower, but typically, such a section is not rigidly connected to the deck since it has to be lifted, once fitted with a hub, nacelle and blades, onto a pre-installed wind tower section on the foundation. By providing a rigidly connected assembly structure, an area on the deck can be dedicated to the fitting of the blades to the hub. This may leave room to dedicate another area on the deck for the installation of the tower sections onto the foundation. In this way, parallel processing of the tower installation and the blade assembly can be done, such that, when the tower is installed the hub-nacelle-blades assembly can be hfted onto the tower. This parallel processing may significantly reduce installation time.

Further, by providing a fixed assembly structure and dedicating a deck area to the blade installation, efficient fitting of the blades may be obtained. This may result in installation time reduction.

Advantageously, the assembly structure is provided with a connection for connecting at least the hub. By providing on the assembly structure the same or similar connection as provided on the wind turbine tower, the hub and/or nacelle can be relatively easy temporarily connected to the assembly structure. The connection on the assembly tower is preferably complementary to the connection of the hub and/or nacelle. When the hub is to be connected to the assembly structure, the assembly structure preferably is provided with a hub flange connection. When the nacelle-hub assembly is connected to the assembly structure, the assembly structure is preferably provided with a nacelle flange connection. Providing the flange connection allows relatively easy fastening and loosening of the hub and/or nacelle to the assembly structure for temporarily mounting the hub and/or nacelle for fitting the blades to the hub.

According to an aspect of the invention, the assembly structure is provided with a safe working deck at an upper end of the assembly structure. Such a safe working deck near an upper side of the assembly structure may provide a relatively safe working space for the workmen involved in fitting the blade to hub and/or in manipulating and/or in manoeuvring the blade. This may be a significant improvement in safety with respect to prior art methods wherein the work men are working from a crane or hanging in a harness from a crane to fit the blade and/or to manipulate the blade.

The invention further relates to an assembly structure. The invention also relates to an installation barge comprising such an assembly structure.

Further advantageous embodiments are represented in the subclaims.

The invention will further be elucidated on the basis of exemplary embodiments which are represented in the drawings. The exemplary embodiments are given by way of non-limitative illustration of the invention.

In the drawings:

Figs. 1a - 1i show schematic views of a first embodiment of an installation method according to the invention;

Fig. 2 shows a schematic view of an embodiment of a deck layout of an installation barge according to the invention;

Figs. 3a - 3c show schematic views of a side view and cross-sectional views of a first embodiment of a blade support structure according to the invention;

Figs. 4a - 4c show schematic views of a side view and cross-sectional views of a second embodiment of a blade support structure according to the invention;

Fig. 5a - 5b show schematic views of a second embodiment of an installation method according to the invention;

Figs. 6a - 6b show schematic views of a third embodiment of an installation method according to the invention;

Fig. 7 shows a schematic view of a fourth embodiment of an installation method according to the invention.

It is noted that the figures are only schematic representations of embodiments of the invention that are given by way of non-limited example. In the figures, the same or corresponding parts are designated with the same reference numerals.

Fig. 1a shows a schematic view of an installation barge 1 according to the invention. In this embodiment the installation barge 1 is a jack-up vessel 1 having four legs 2 and a platform 3. The legs 2 are adjustable between a transport position in which they substantially extend above a deck 4 of the platform 3 and an installation position in which they extend substantially below the deck 4 of the platform 3. With the legs 2 in the transport position, the platform 3 is floating and the jack-up vessel can be transported, either by towing, pushing or self-propelled from one location to another. In Fig. 1a the legs 2 of the jack-up vessel 1 are in the installation position on the seabed. The platform 3 is jacked up along the legs 2 and is positioned above the water level 5 such that the platform is approximately free from normal wave activity.

The installation barge 1 is provided with an assembly structure 6 on the deck 4. The assembly structure 6 is arranged to receive, in this embodiment, a hub-nacelle assembly 7. The hub-nacelle assembly comprises a hub 8 and a nacelle 9 which are connected to each other, either onshore or offshore.

Further, the installation barge 1 is loaded with wind turbine blades 10 which need to be installed offshore to the hub-nacelle assembly 7. An example of a deck layout is given in Fig. 2. Fig. 2 shows that the installation barge 1 is loaded with hub-nacelle assemblies 7, blades 10 and wind turbine tower sections 11. The assembly structure 6 is positioned on the deck 4, and in this particular example, at the stern of the jack-up vessel 1. Further, a secondary crane 12 and a main crane 13 are provided on the deck 4. The secondary crane 12 and the main crane 13 typically have a different lift capacity. Of course, the assembly structure 6 can be placed at any other position on the deck 4, depending on the chosen deck layout.

The assembly structure 6 can be of a column-type structure and/or of a truss type structure. Means allowing work men to mount the assembly structure 6, such as ladders and/or stairs can be provided inside and/or outside the assembly structure 6.

The sequences of the embodiment of the installation method shown in Figs 1a - 1i are as follows.

Once the jack-up vessel 1 has arrived at the installation site offshore and is in the installation position with the legs 2 on the seabed and the platform 3 above the water level 5, the installation of the wind turbine may commence.

The main crane 13 lifts the hub-nacelle assembly 7 from its position on the deck 4 onto the assembly structure 6, shown in Fig. 1a. Then the secondary crane 12 lifts the blade 10 by using a blade handhng tool 14. Such a blade handling tool, or yoke, is known and is commonly used to lift the relatively vulnerable wind turbine blades 10. The yoke may clamp itself over the blade 10 to grab the blade 10, shown in Fig. 1b.

Fig. 1c shows the manoeuvring of the blade 10 towards a blade support structure 15. Embodiments of the blade support structure 15 are shown in Figs 3 and Figs. 4. The blade support structure 15 is arranged to support the blade 10 under an angle a with respect to the deck 4. The blade support structure 15 may also be omitted, then the blade 10 is maintained under angle a by the secondary crane 12 and the blade handling tool 14 only. In Fig. Id the blade 10 rests on the blade support structure 15.

With the blade 10 resting on the blade support structure 15, the blade 10 can be manipulated towards the hub-nacelle assembly 7 to connect the blade 10 to the hub 8. The blade 10 is connected to the hub 8 by means of a flange connection 19 which needs to be closed and/or secured for example by relatively large bolts. The blade 10 and the hub 8 are provided with complementary flanges.

Manipulation of the blade 10 can be done manually and/or by the crane 12 and the blade handling tool 14. To manually assist the connection of the blade 10 to the hub 8, the assembly structure 6 is provided with a safe working deck 16. Manipulation of the blade 10 can also at least partly be done by an active blade support structure 15, as will be explained in relation to Figs. 4.

On the safe working deck 16, work men can stand to assist the manipulation and/or the connection of the blade root 17 to the hub 8. The safe working deck 16 can be equipped with a relatively simple crane for that purpose, e.g. a Davit crane. Providing a safe working deck 16 is a significant improvement in safety with respect to prior art methods where a work man is positioned in the nacelle and/or is hanging in a harness from a crane.

Fig. If shows schematically that the blade 10 is connected to the hub 8. Once the blade 10 is connected to the hub 8, the blade handling tool 14 can be removed from the blade 10. In Fig. If is also shown the pre-installed foundation 18 for the wind turbine tower. Since in this embodiment, the assembly structure is located near the stern of the jack-up vessel 1, at the other side of the jack-up 1, the bow side, there is space for the installation of the tower sections 11. By choosing such a layout, parallel installation of the tower sections 11 and the blades 10 can be possible, which may result in significant reduction of the installation time.

Fig. 1g shows the installation of a first tower section 11 by using the main crane 13 to lift the tower section 11 onto the pre-installed foundation 18. In addition, Fig. 1g shows that between the installation of subsequent blades 10, the hub 8 is rotated such that the subsequent free flange is in position to receive the second blade 10. In this embodiment, three blades 10 need to be fitted to the hub 8 such that advantageously, the hub 8 is rotated over an angle β which is here approximately 120°. A hub to which two blades will be connected will be rotated over approximately 180°.

The second blade 10 is lifted, manoeuvred and connected in the same way as shown in Figs. 1a - 1f.

In Fig. 1h the parallel installation of a second wind tower section 11 and of a third blade 10 are shown. Once the hub-nacelle-rotor assembly 20 is complete, the hub-nacelle-rotor assembly 20 can be lifted by crane 14 onto the completed wind turbine tower 12.

According to the method of the invention, the installation of the blades 10 and/or of the nacelle-hub-rotor assembly 20 can be done in a more controlled way, thereby decreasing risks, weather sensitivity and/or minimizing possible hazardous situations, while in the same time increasing efficiency.

According to the invention, all blades 10 that are to be installed offshore, are fitted to the hub 8 while the hub 8 is mounted to the assembly structure 6. So, contrary to prior art methods, there is no intermediate manoeuvring of the hub 8 from one position to another position between the installation of subsequent blades. Between the installation of subsequent blades 10, the hub 8 remains mounted on the assembly structure 6.

A state of the art wind turbine blade 10 is approximately 60 m long. Typically, the jack-up vessel 1 has in installation position a free height A of approximately 12 m with respect to the water level 5. Advantageously, the angle α is approximately 30° such that the blade tip 22 has sufficiently free height with respect to the water level 5. For example, the free height B of the blade tip 22 is approximately 5 m. The height H of the assembly structure 6 is in this example approximately 11 m. These dimensions are given as a mere indication. It is evident that depending on the installation barge, wind turbine blades, weather conditions, etc. the dimensions will vary. For example, the angle a may be between approximately 10° and approximately 80° depending on the free height of the jack-up or on the height of the deck of a floating installation barge. It is to be expected that when a floating installation barge is used, the angle a may become smaller, for example between approximately 10° and approximately 45°, depending on the height of the blade root above the water level 5 to avoid the blade tip 22 from dipping into the water.

Figs. 3 and Figs. 4 show a schematic arrangement of a blade support structure 15. The blade support structure 15 is arranged to support the blade 10 under the angle a with respect to the deck 4. To that end, the blade support structure 15 is provided with a relatively soft support cushion 23 as can be seen in Fig. 3b, Fig. 3c and Fig. 4b, Fig. 4c. The support cushion 23 preferably is of a material that is softer than the material of the blade 10 to minimize damages on the blade 10. Typically, the blade support cushion 23 can be of Teflon® or similar materials, e.g. rubber. The blade support cushion 23 is housed in a frame 24 as shown in Fig. 3b, Fig. 3c and Fig. 4b, Fig. 4c. The frame 24 is usually a steel frame.

To provide optimal support to the blade 10 the surface 25 of the blade support cushion 23 is formed complementary to the blade external shapes as a counter form, as can be seen in Fig. 3b, Fig. 3c and Fig. 4b, Fig. 4c. By providing such a complementary support surface 25, not only the blade 10 can be supported more optimally but also the blade 10 can be guided towards the region to be supported. Due to the three dimensional shape of the wind turbine blade 10, there will be a predetermined region of the blade 10 that corresponds to the blade support surface 25. Preferably, the blade 10 is supported around the center of gravity G. Typically, the blade 10 is supported over a length L of approximately 4 m, but this can be longer, e.g. for larger blades, or shorter when there may be e.g. deck space limitations.

Figs. 4a - 4c show an actively driven blade support structure 15 provided with drive means 26, here shown as hydraulic cylinders. The drive means 26 can however be any suitable drive component, e.g. a compressed air cylinder or means comprising bellows or rubber, etc. Depending on the number of drive means provided, the support structure 15 can be actuated in one, two, three or four degrees of freedom. An active blade support structure 15 can be of assistance in manipulating the blade 10 towards the hub 8 which may reduce handling complexity and/or handling time and may decrease safety risks. In the embodiment of Figs. 4, sufficient drive means 26 are provided to allow driving the support structure 15 in rotational dimensions Dl and D2 and in two translational dimensions resulting in translation in direction D3 along a longitudinal axis of the blade 10.

In the embodiment shown in Figs. l a - li, it is shown to mount all blades 10, here three, to the hub 8 offshore. It is however also possible, to pre-fit one or two blades 10 to the hub 8 onshore and to fit the remaining two or one blades respectively to the hub 8 offshore. This is shown in Figs. 5 and Figs. 6 respectively.

Fig. 5a shows a configuration in which a single blade 10 is pre-mounted to the hub-nacelle assembly 7 onshore. This configuration can be transported on the deck 4 of the barge 1 as a 'single blade up' configuration. Once arrived at the offshore location, the remaining two blades 10 can be fitted to the hub 8 by the method shown in Figs. l a - If. As shown in Fig. 5b, advantageously, the two blades 10 can be installed simultaneously resulting in more reduction of the installation time.

In another alternative, two blades 10 can be already pre-fitted to the hub 8 or to the hub-nacelle assembly 7 onshore. Such a pre-fitted configuration can be transported in a so-called 'bunny ear' configuration on the deck 4 of the installation barge 1. Once on site at the offshore location, the third blade 10 can be fitted to the hub 8 with the method shown in Figs. 1a - 1f.

In another embodiment, a tower section 11 is used as the assembly structure 6 to mount the hub-nacelle configuration for fitting the blades 10 to the hub 8. Once all blades 10 are fitted to the hub 8, the hub-rotor-nacelle assembly with the tower section 11 can be lifted onto a previously installed tower section. In this variant, no deck space is taken up by a fixed assembly structure. If desired, a blade support structure 15 can be provided.

Many variants will be apparent to the skilled person in the art. The invention is not limited to the above shown examples. In particular, dimensions and angles are given by way of an example and may vary depending on the dimensions of the parts and/or installation barge used. All variants are understood to be comprised within the scope of the invention defined in the following claims.

Claims

1. Method for installing a wind turbine at an offshore location by using an installation barge, comprising the steps of
- providing an assembly structure arranged on a deck of the installation barge;
- mounting at least a hub on the assembly structure;
- fitting at least one blade to the hub while the hub is mounted to the assembly structure, wherein during fitting of the blade to the hub the blade is under an angle with the deck;
- lifting the completed hub-rotor assembly and mounting the hub-rotor assembly onto a pre-installed wind turbine tower section.

2. Method according to claim 1, comprising rotating the hub between the fitting of subsequent blades while the hub is mounted to the assembly structure.

3. Method according to claim 1 or 2, wherein the angle of the blade with respect to the deck is between approximately 10° and approximately 80°, more preferably between approximately 20° and approximately 60° .

4. Method according to claim 3, wherein the angle of the blade with the deck is approximately 30°.

5. Method according to any one of the preceding claims, comprising positioning the blade in a support structure before fitting the blade to the hub.

6. Method according to any one of the preceding claims, comprising mounting a hub-nacelle assembly on the assembly structure.

7. Installation barge for the offshore installation of a wind turbine comprising an assembly structure arranged on a deck for mounting at least a hub to allow fitting of at least one blade to the hub, with the blade having an angle with respect to the deck, while the hub is mounted to the assembly structure.

8. Installation barge according to claim 7, wherein the assembly structure is a fixed structure on the deck of the installation barge.

9. Installation barge according to claim 7 or 8, further comprising a support structure to support the blade under an angle to the deck when the blade is fitted to the hub.

10. Installation barge according to claim 9, wherein the support structure is arranged to support the blade under an angle between approximately 10° and approximately 60°.

11. Installation barge according to claim 10, wherein the support structure is arranged to support the blade under an angle of approximately 30°.

12. Installation barge according to any one of the claims 9 - 11, wherein the blade support structure is actively driven to assist manipulation of the blade towards the hub.

13. Installation barge according to any one of the claims 9 - 12, wherein the support structure is arranged for supporting the blade around the center of gravity of the blade.

14. Installation barge according to any one of the claims 9 - 13, wherein the support structure is provided with a supporting area complementary to the blade external dimensions.

15. Installation barge according to any of the claims 7 - 14, wherein the assembly structure is provided with a connection for connecting at least the hub.

16. Installation barge according to any of the claims 7 - 15, wherein the assembly structure is provided with a safe working deck near an upper side of the assembly structure.

17. Assembly structure arranged for mounting of at least a hub at an upper side of the assembly structure, wherein the assembly structure is arranged for mounting on a deck of an installation barge according to any one of the claims 7 - 16 for installation of a wind turbine at an offshore location.

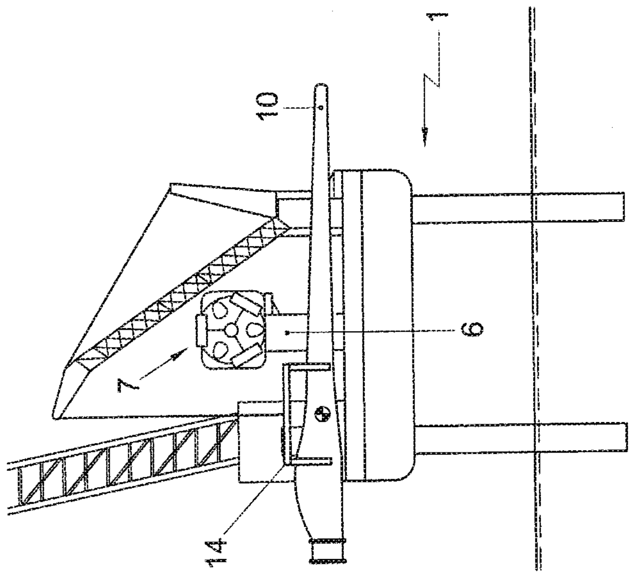

Fig. 1b

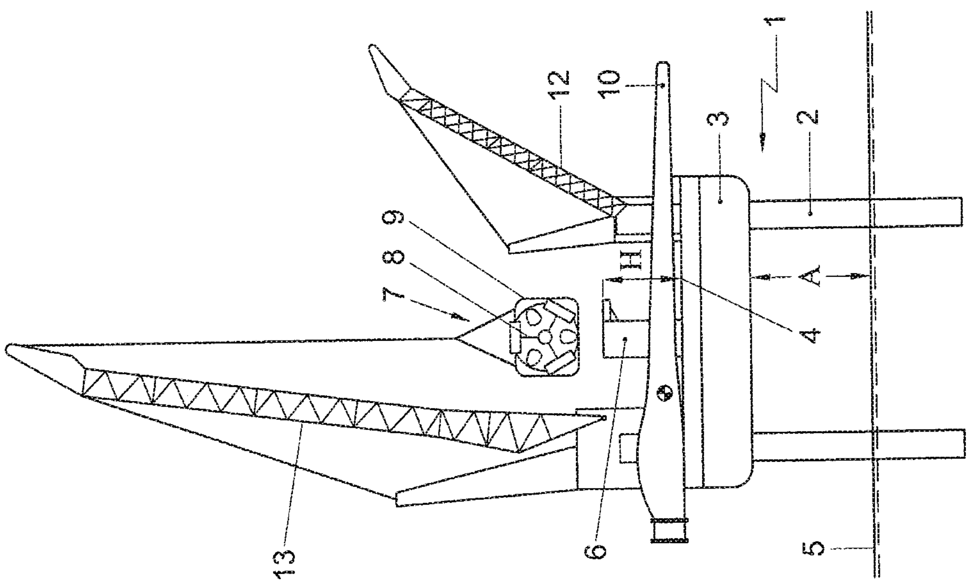

Fig. 1a

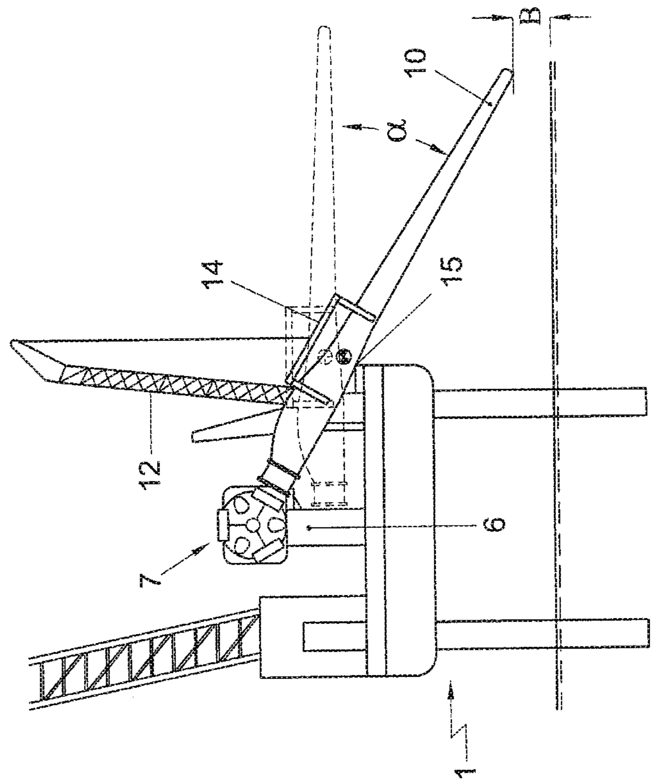

Fig. 1d

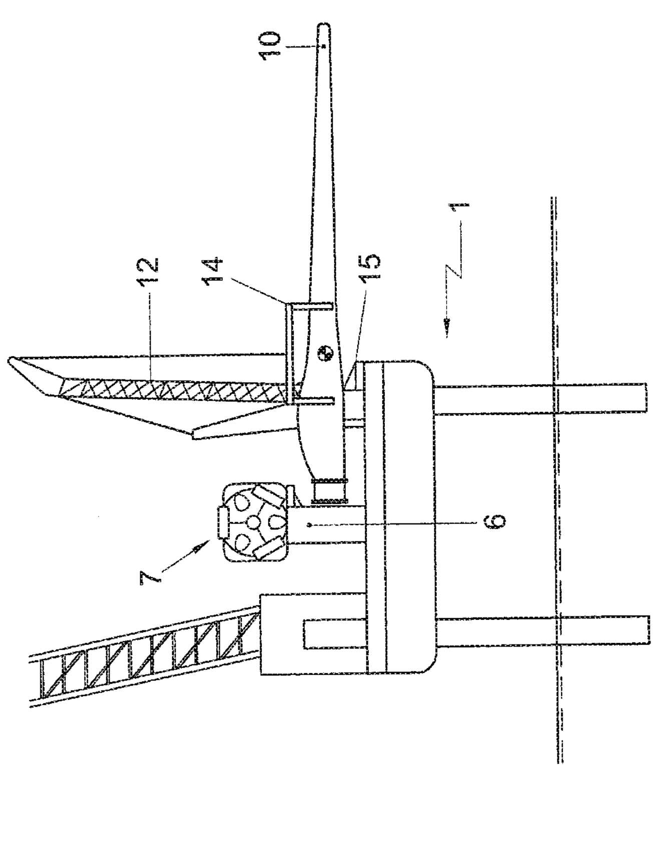

Fig. 1c

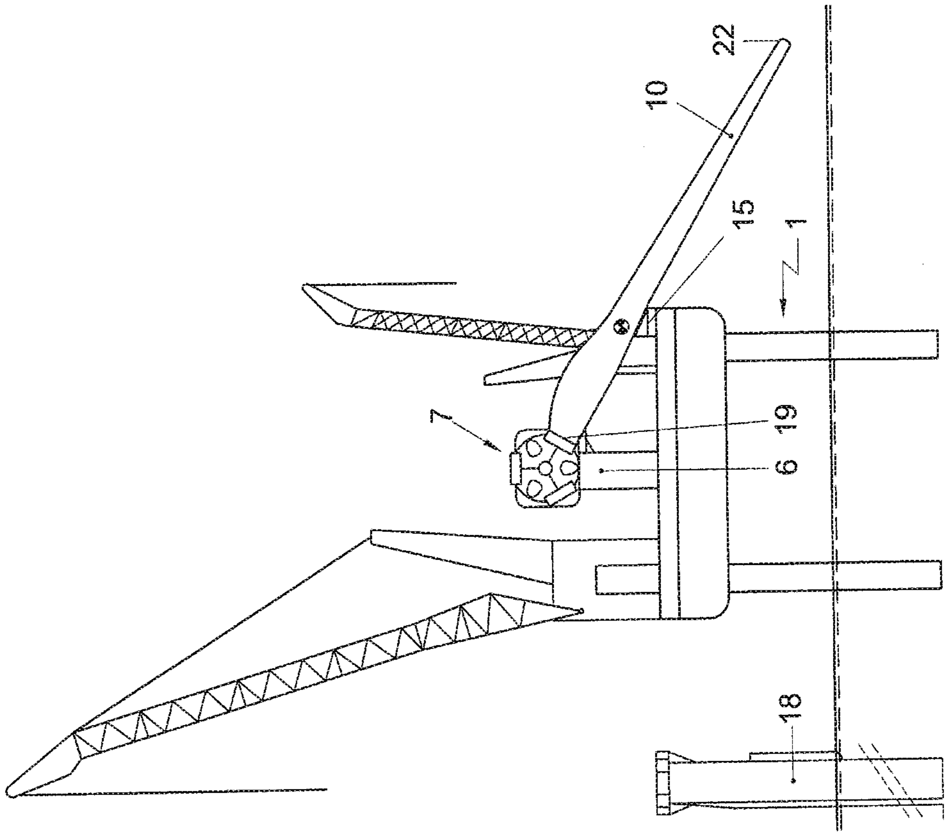

Fig. 1f

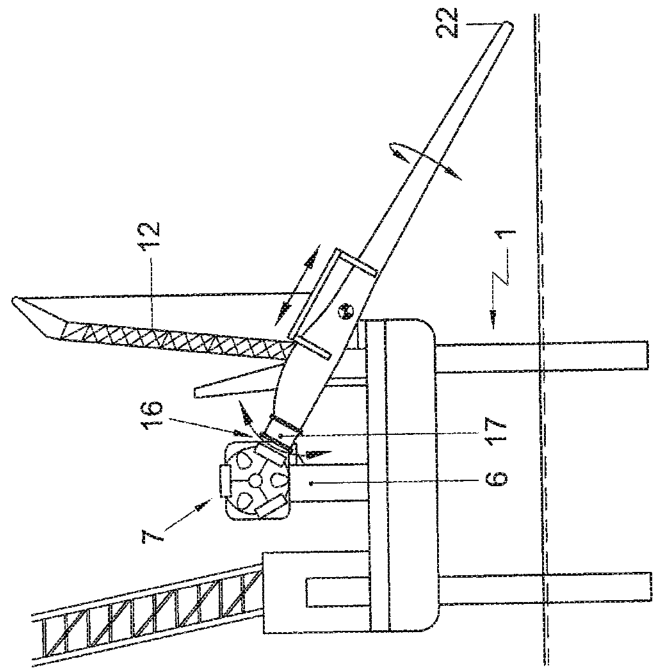

Fig. 1e

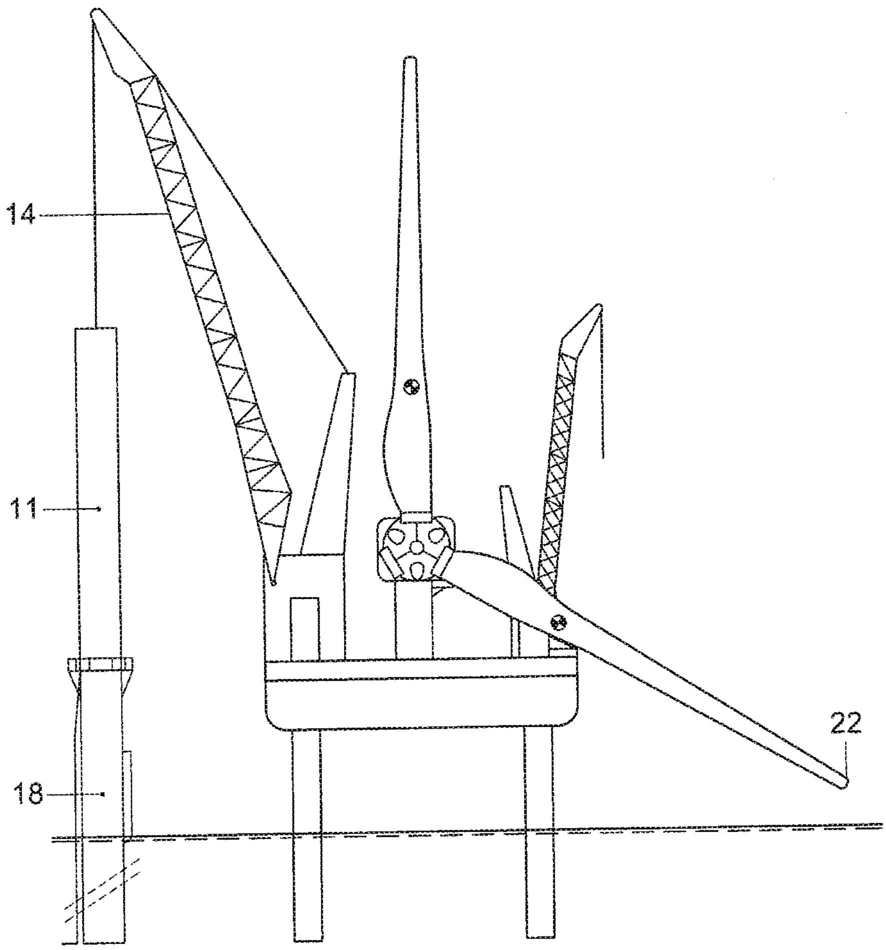

Fig. 1g

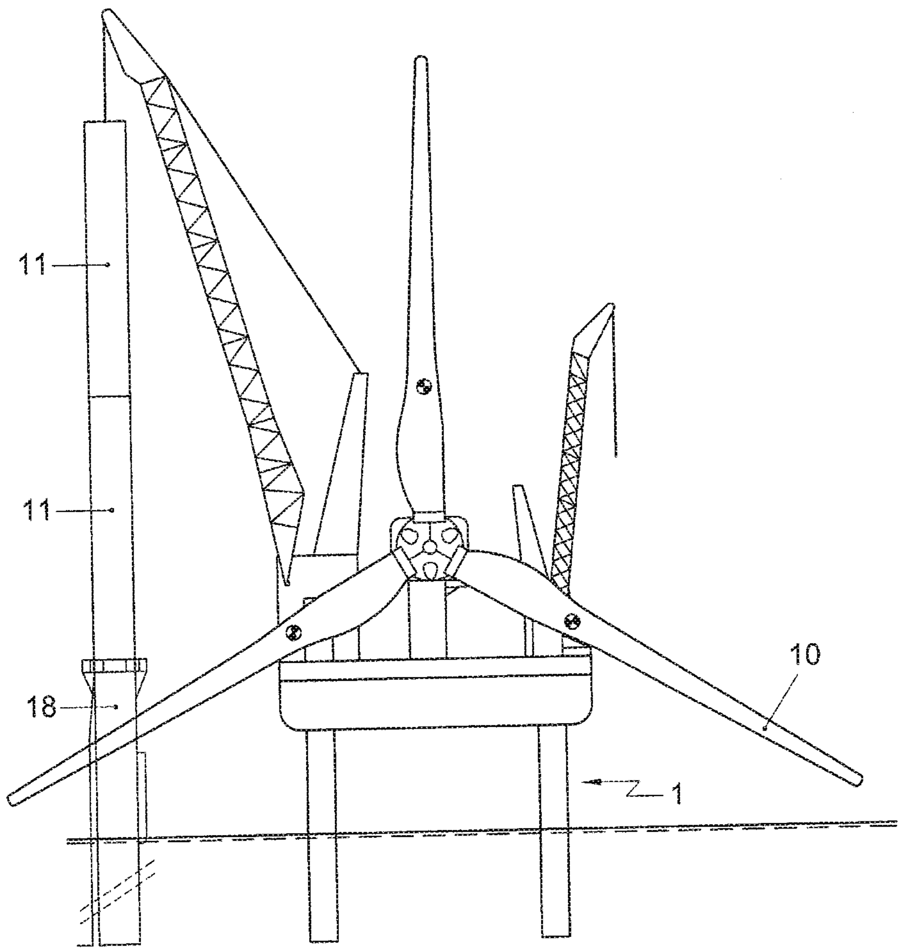

Fig. 1h

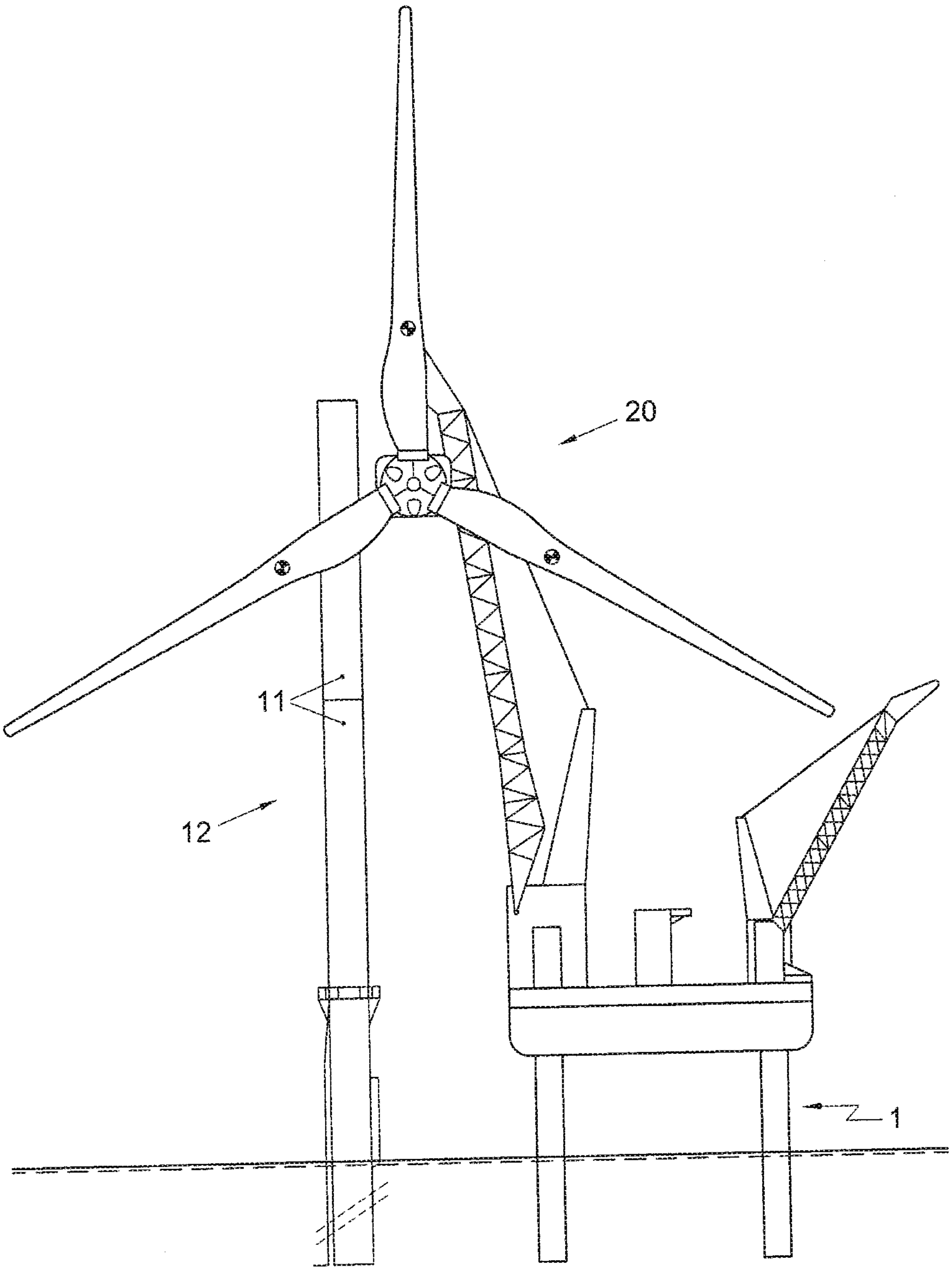

Fig. 1i

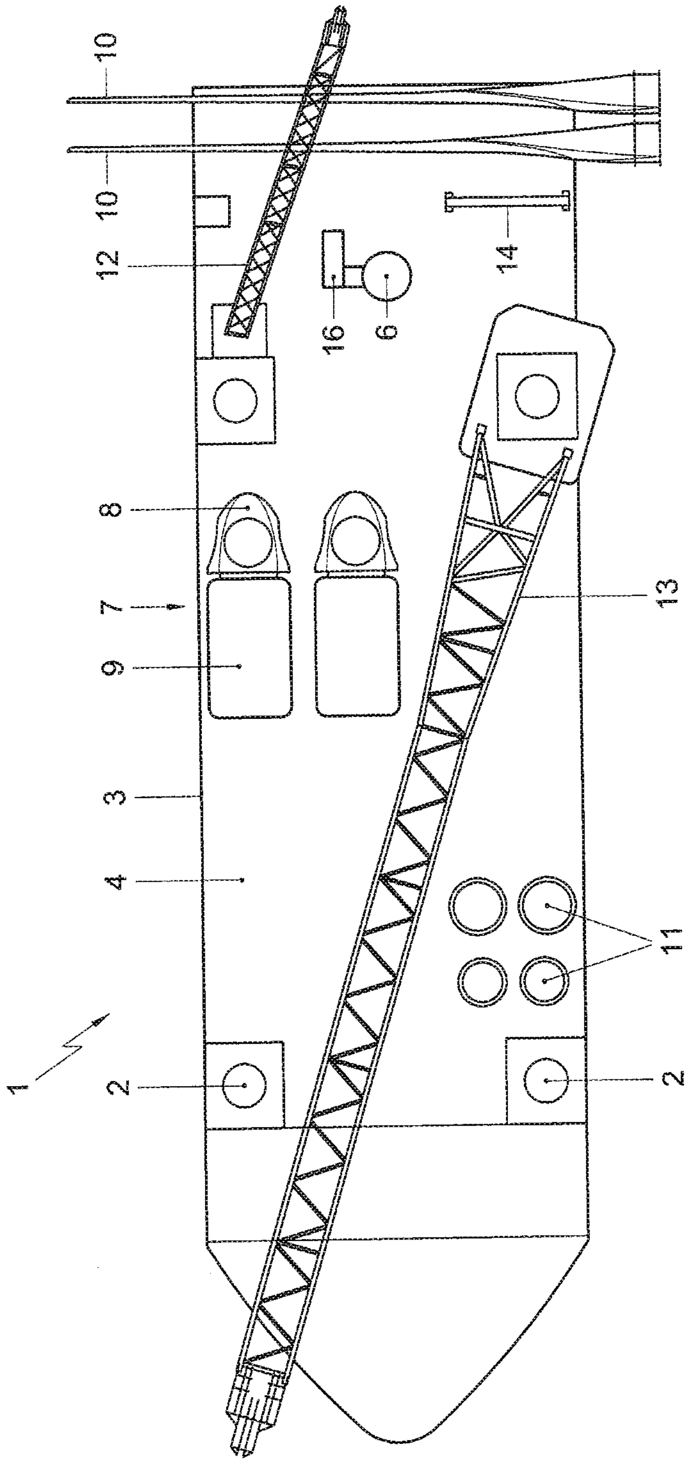

Fig. 2

8/12

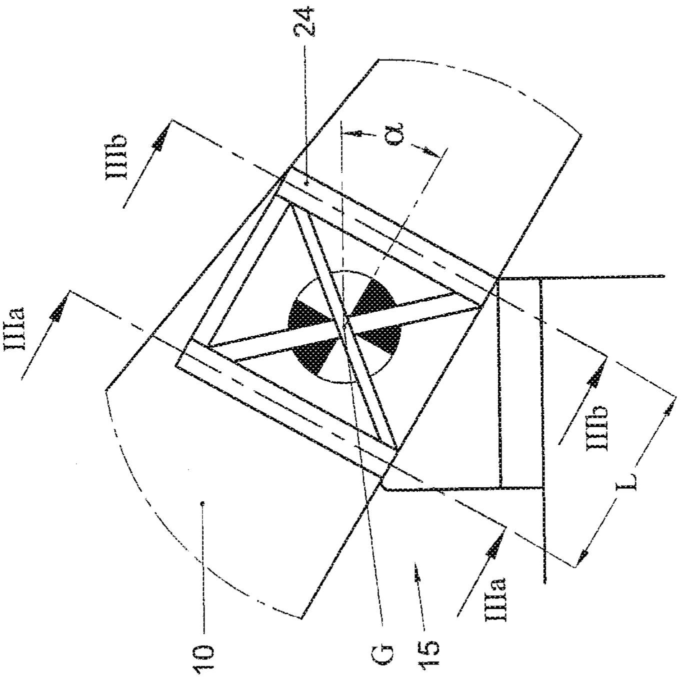

Fig. 3a

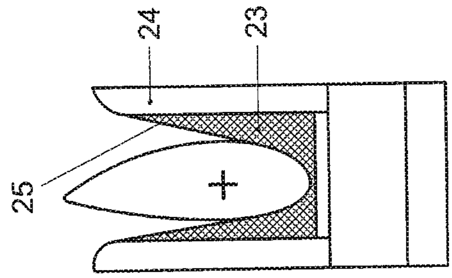

Fig. 3b

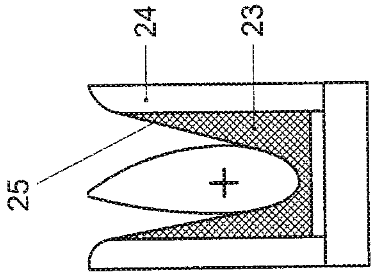

Fig. 3c

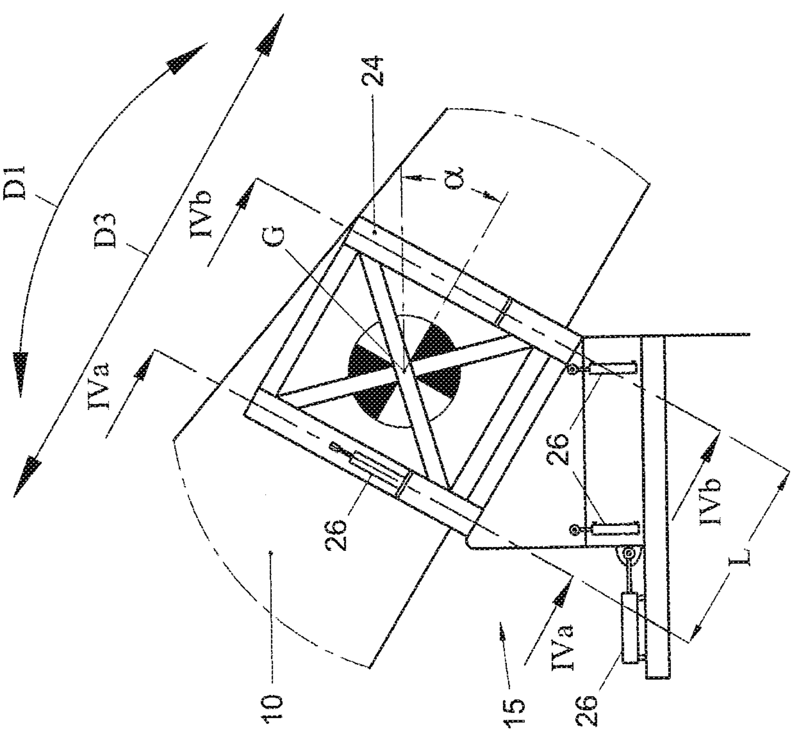

Fig. 4a

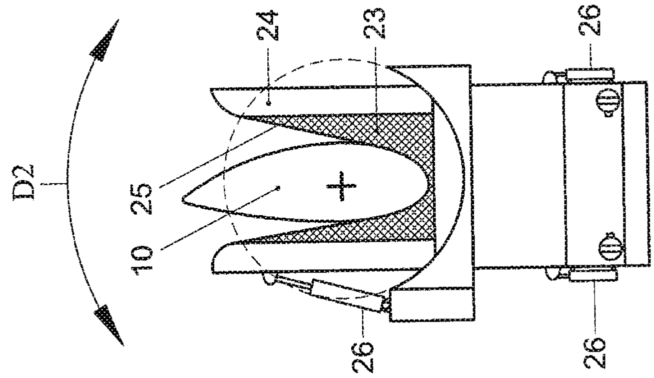

Fig. 4b

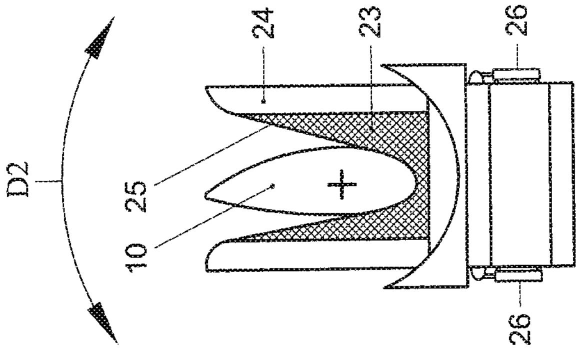

Fig. 4c

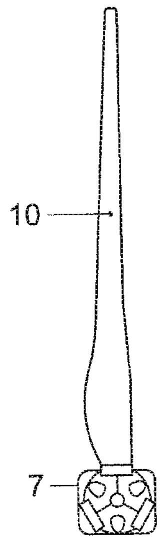

Fig. 5a

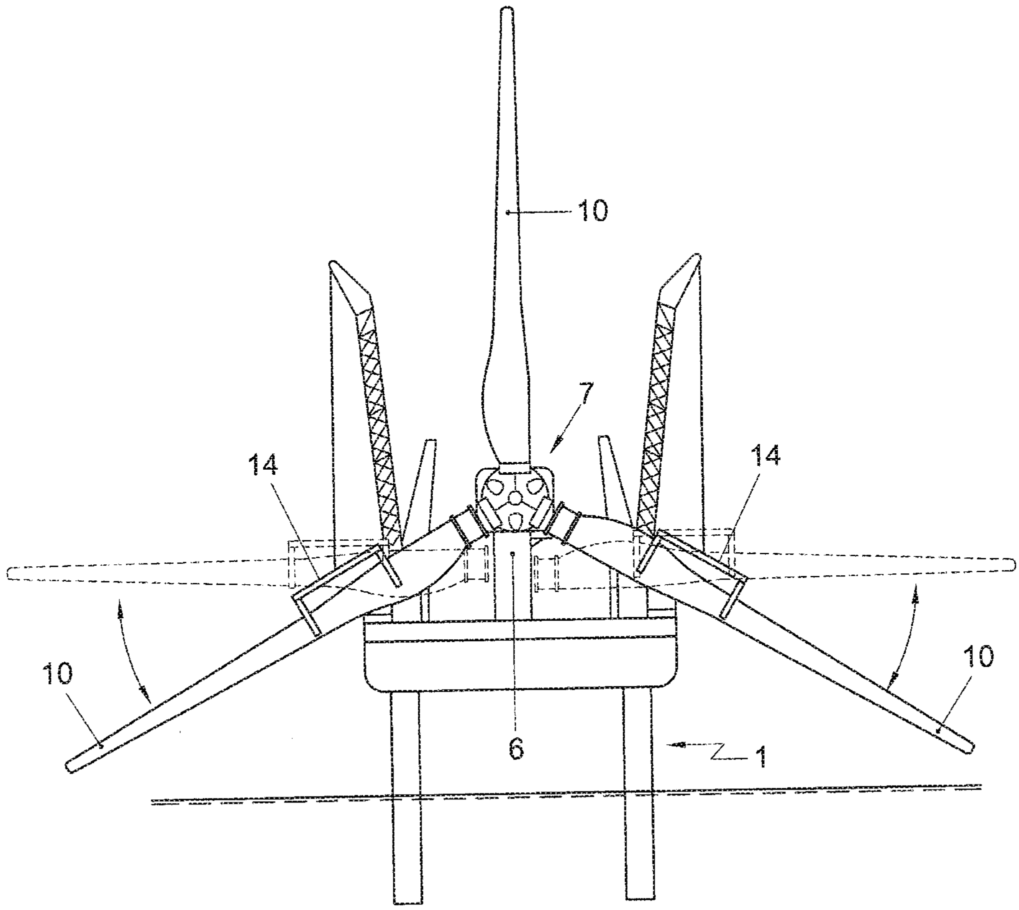

Fig. 5b

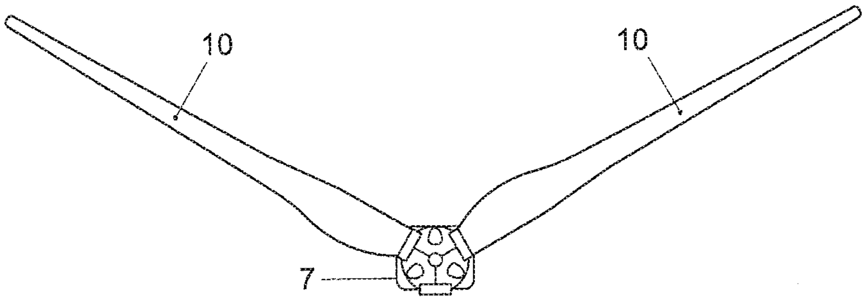

Fig. 6a

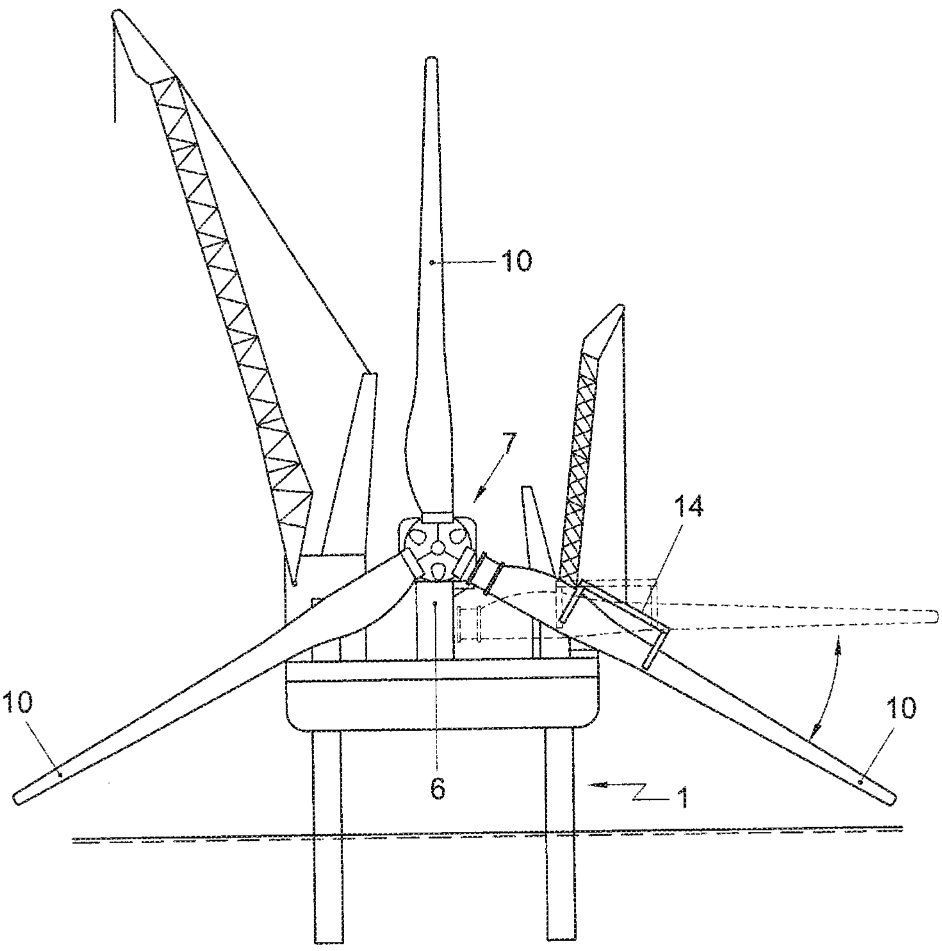

Fig. 6b

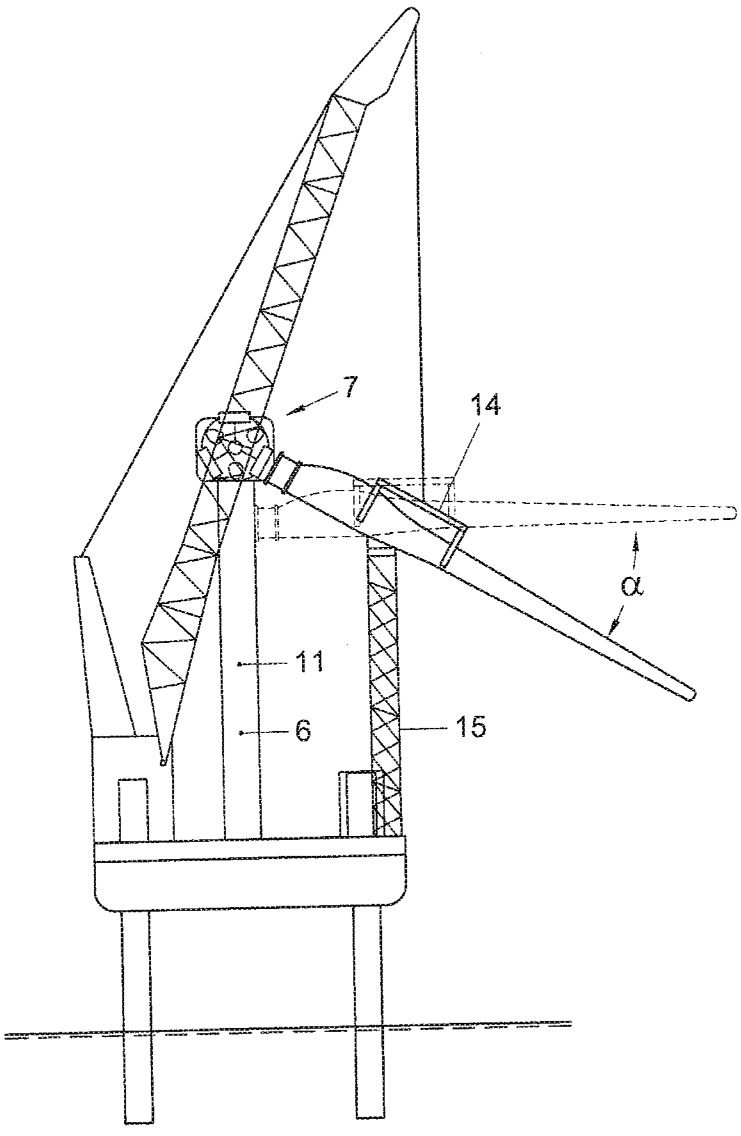

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2012/05Q909

A. CLASSIFICATION OF SUBJECT MATTER
INV. FO3D1/00 B63B35/0O
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03D B63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 354 537 AI (GEOSEA NV [BE]) 10 August 2011 (2011-08-10) abstract paragraph [0023] - paragraph [0037] figures -----	1-17
X	W0 2010/126369 AI (GUSTO B V [NL] ; VAN N00D CORNELLS PIETER AAPJDRIANUS [NL] ; B00NST0PPEL) 4 November 2010 (2010-11-04) cited in the application abstract page 5, line 32 - page 8, line 31 figures -----	1,3-17
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 February 2013	06/03/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kolby, Lars

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2012/05Q909

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	W0 2009/041812 Al (GUSTO B V [NL] ; VAN NOOD NI LS [NL]) 2 Apri l 2009 (2009-04-02) abstract page 7, l i ne 16 - page 8, l ine 31 f i gures -----	1-17
A	EP 2 256 079 Al (GE0SEA NV [BE]) 1 December 2010 (2010-12-01) abstract paragraph [0020] - paragraph [0029] f i gures -----	1-17

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2012/05Q909

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