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(54) Title: OFFSHORE WIND TURBINE

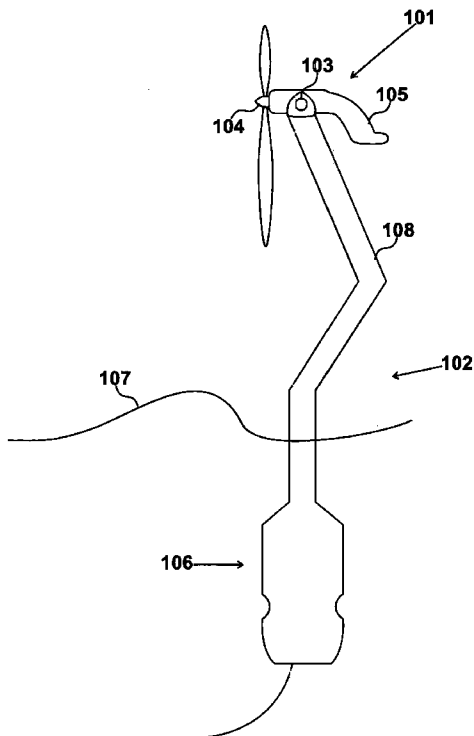


Fig. 1

(57) Abstract: The generation of electricity is described, using an offshore wind turbine. A generating sub-assembly (101) is supported by support mechanism (103) upon a support structure (102). The generating sub-assembly has a wind-responsive turbine and an electrical generator. The support structure includes a buoyancy portion (106) for submersion in water and a mast portion (108) extending from said buoyancy portion to extend the generating sub-assembly above the waterline. The support structure is buoyant and is free to roll when floating in water and the support mechanism is hinged to allow the generating sub-assembly to maintain an operational angle during the rolling of the support structure.

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OFFSHORE WIND TURBINE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority from United Kingdom Patent Application No. 13 23 153.5 filed 31 December 2013, the entire disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus for generating electricity, of the type comprising a generating sub-assembly and a support structure for supporting said generating sub-assembly.

The present invention also relates to a method of generating electricity.

2. Description of the Related Art

It is known to use wind turbines to generate electricity and it is also known for these wind turbines to be positioned offshore. Known systems may be fixed or may float but each incorporates a fixed platform that can introduce difficulties. Difficulties exist in terms of establishing structures of this type at sea, particularly in deep water. Furthermore, they are prone to fatigue because a rigid fixed structure will attract and absorb vibrations induced by wind and turbine operation. The introduction of this fatigue will reduce the operational lifespan of the device.

It is also known that a fixed structure must be fixed or tied to the seabed, such that it will require substantial deep foundations, thereby limiting positions where systems of this type may be installed.

BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention, there is provided an

apparatus for generating electricity, an apparatus for generating electricity, comprising: a generating sub-assembly; a support structure for supporting said generating sub-assembly; and a support mechanism for securing the generating sub-assembly to said support structure; wherein: said generating
5 sub-assembly has a wind-responsive turbine and an electrical generator; said support structure includes a buoyancy portion for submersion in water and a mast portion extending from said buoyancy portion to extend the generating sub-assembly above a water line; said support structure is buoyant and free to roll when floating in water; said support mechanism is
10 hinged so as to allow the generating sub-assembly to maintain an operational angle during the rolling of said support structure; and said mast portion comprises: an elbow; a first section below said elbow inclined at a first angle away from said turbine; and a second section above said elbow inclined at a second angle towards said turbine.

15 In an embodiment, the centre of gravity of the generating sub-assembly is below the position of the hinge.

According to a second aspect of the present invention, there is provided a method of generating electricity, a method of generating electricity, comprising the steps of: locating a buoyant support structure in
20 water, such that said buoyant support structure is free to roll in said water; and supporting a generating sub-assembly upon said support structure by a hinged mechanism, so that said generating sub-assembly is rotatable about said hinge so as to maintain an operational angle for a turbine forming part of said generating sub-assembly during the rolling of the buoyant support
25 structure; wherein said support structure includes a mast portion comprising an elbow; a first section below said elbow inclined at a first angle away from said turbine; and a second section above said elbow inclined at a second angle towards said turbine.

BRIEF DESCRIPTION OF THE DRAWINGS

30 Figure 1 shows an apparatus for generating electricity;

Figure 2 shows an alternative view of the apparatus of Figure 1;
Figure 3 shows the apparatus of Figure 1 performing a backwards roll;
Figure 4 shows the apparatus of Figure 1 performing a forwards roll;
and
5 Figure 5 shows an array of electricity generating devices.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

Figure 1

An apparatus for generating electricity is shown in Figure 1. The apparatus has a generating sub-assembly **101** a support structure **102** for supporting the generating sub-assembly **101** and a support mechanism **103** for securing the generating sub-assembly to the support structure.
10

The generating sub-assembly **101** has a wind-responsive turbine **104** and an electrical generator **105**.

The support structure **102** includes a buoyancy portion **106** for submersion in water; water level is indicated at **107**. The support structure **102** also includes a mast portion **108** extending from the buoyancy region **106** to extend the generating sub-assembly **101** above waterline **107**. In this way, the support structure **102** is buoyant and free to roll when floating in water. Furthermore, the support mechanism **103** is hinged so as to allow the generating sub-assembly to maintain an operational angle during the rolling of said support structure. Thus, the generating sub-assembly **101** is free to roll in a direction indicated by arrow **109**.
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The embodiment shown in Figure 1 addresses issues of rigidity by introducing a free floating system that is free to move or rotate. It is therefore far less prone to fatigue damage. Furthermore, the embodiment also addresses difficulties in relation to the installation of foundations by presenting a floating system that is not sitting on, or tied rigidly to, the seabed. The apparatus of Figure 1 is able to rotate freely in a manner that may be described as a pendulum floating in water. It has been identified as
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“free floating” or “rotationally free floating”.

The inverted pendulum apparatus of Figure 1 is self adjusting with respect to its vertical position; its vertical alignment is based on the principle of buoyancy, with its centre of gravity being lower than its centre of buoyancy.

The generating sub-assembly is supported on a substantially horizontal hinge system, while being self adjusting with respect to the vertical alignment; so as to maintain the correct heading to the horizontal, based on the counterweight. It is also stabilised, when rotating, due to the gyroscopic effect.

Figure 2

The generating sub-assembly **101** includes a rotor ballast **201**, in this embodiment, to ensure that the centre of gravity of the generating sub-assembly is below the position of its supporting hinge. Thus, the hinge of the support mechanism **103** locates the generating sub-assembly at a first position **202** and at a second position **203**. Thus, in this embodiment, the rotor ballast **201** provides an extension that descends below hinge positions **202** and **203** so as to lower the centre of gravity of the generating sub-assembly **101**.

Figure 3

The apparatus of Figure 1 is shown in Figure 3, having rolled such that a central axis **301** now defines a roll angle **302** with respect to a vertical axis **303**.

In this embodiment, the generating sub-assembly includes three rotor blades, including rotor blade **304**. The rotor blades rotate within a plane that should be perpendicular to the direction of the wind. Thus, a rotor axis **305**, perpendicular to the plane of the rotor blade **304**, defines the attitude of the rotors.

In the example shown, due to roll, the mast portion **108** has swung

backwards in the direction of arrow **109**. To compensate for this, while maintaining attitude, the generating sub-assembly **101** has rotated in the direction of arrow **307**.

To facilitate the backward roll, as shown in Figure 3, the mast portion **108** is substantially J-shaped; thereby allowing rotation to occur while maintaining clearance between the mast and the rotating blades.

In the embodiment of Figure 3, the mast portion includes an elbow **308**. The mast portion therefore defines a first section **310** below the elbow **308** and inclined at a first angle **311** taking the mast portion away from the position of the turbine blade **304**.

Above elbow **308**, the mast portion defines a second section **312** that is inclined at a second angle **313** returning the mast portion **108** back towards the turbine blade **304**.

Figure 4

The apparatus of Figure 1 is shown in Figure 4, after the support structure **108** has rolled forward in the direction of arrow **401**. In response to this roll, the generating sub-assembly **101** has rotated in the direction of arrow **402**, such that the attitude of rotor blade **304** is maintained in horizontal axis **305**.

As illustrated in Figure 4, the mast portion includes a vertical section **403** extending between the buoyancy portion **106** and the first section **310**.

The buoyancy section **106** includes a buoyancy tank **404**. In this embodiment, the buoyancy tank contains air; although other gases could be used or the buoyancy area could be filled with lightweight material such as polystyrene. The buoyancy tank **404** may be defined by inflatable structures. In the embodiments described, the overall structure is defined by steel sheeting. However, in alternative configurations, more of the substructure could be defined by inflatable units.

In the embodiment shown in Figure 4, the buoyancy portion **106** also

includes a ballast tank **405**, located below the buoyancy tank **404**.

To establish a structure of the type described with reference to Figures 1 to 4, to perform a method of generating electricity, the buoyant support structure is located in water, such that it is free to roll in the water. The structure supports a generating sub-assembly, secured upon the support structure by a hinged mechanism. In this way, the generating sub-assembly is rotatable about the hinge to maintain an operational angle for a turbine (forming part of a generating sub-assembly) during the rolling of the buoyant support structure.

In an embodiment, a tether **406** is attached to the buoyant support structure to maintain the location of the structure, while still permitting the structure to roll.

Structures of this type, subject to vibrations, usually require a reliable and sufficient level of damping. In this application, substantial damping is achieved by the presence of the water surrounding the floating structure.

As illustrated in the Figures, a substantial proportion of the structure is located below the surface of the water and hence below any waves; the overall exposure to waves is therefore minimal.

As a floating object, the structure will have a natural frequency for overall movement, far lower than resonant frequencies for fixed structures. Given the low value of this natural frequency, it will not interact with turbine frequencies and will therefore have minimum effect on turbine operation.

Figure 5

As illustrated in Figure 5, it is possible to arrange the support structures in an array **501**. Thus, individual units may be restrained vertically and/or horizontally by means of a tie anchor; either to the ground or to adjacent structures. Thus, in the configuration shown in Figure 5, many of the devices are held in place by being tied to adjacent structures within the array.

In the example, an anchor point may be made to a first structure at

location **502** and again at a location connected to a second structure **503**. In the example, oncoming wind is shown blowing in the direction of arrow **504**. Each turbine thereby presents its rotors towards the wind and these positions are maintained while the support structures roll, as described previously.

5 During installation, ballast may be added, for retention in ballast tank **405**, in order to provide the required level of buoyancy and effectively move the centre of buoyancy; this being the centre of the volume of water that the device displaces when floating.

10 To summarise, the system may be considered as a floating inverted pendulum; therefore it may rotate or move freely to some degree around the point of equilibrium, as distinct from having a ground-fixed foundation. The structure, the ballast and the buoyancy tank can be partially or wholly inflatable, thereby facilitating fabrication and installation.

15 The apparatus described reduces fatigue problems by introducing an inherently flexible support that is a floating system; the flexible system experiences lower loads compared to a similar rigid system.

20 The approach overcomes many problems associated with the installation of a foundation on the seabed. The floating pendulum (or inverted pendulum) is self adjusting with respect to vertical alignment, because the centre of gravity is lower than the centre of buoyancy.

25 The rotor blade sub-assembly is hinged on a horizontal axis and is self adjusting with respect to the horizontal heading. Thus, it remains horizontal to the wind while the supporting floating structure may roll significantly away from vertical alignment. The overall performance is achieved by the presence of the counterweight, in combination with the gyroscopic effect when the rotor blades are operating.

 The preferred J-shape introduces a new aesthetic but it also introduces the functionality of ensuring that the blades clear the structure when the structure rolls away from verticality.

Claims

What we claim is:

1. An apparatus for generating electricity, comprising:
a generating sub-assembly;
5 a support structure for supporting said generating sub-assembly; and
a support mechanism for securing the generating sub-assembly to
said support structure; wherein:
said generating sub-assembly has a wind-responsive turbine and an
electrical generator;
10 said support structure includes a buoyancy portion for submersion in
water and a mast portion extending from said buoyancy portion to extend the
generating sub-assembly above a water line;
said support structure is buoyant and free to roll when floating in
water;
15 said support mechanism is hinged so as to allow the generating sub-
assembly to maintain an operational angle during the rolling of said support
structure; and
said mast portion comprises: an elbow; a first section below said
elbow inclined at a first angle away from said turbine; and a second section
20 above said elbow inclined at a second angle towards said turbine.
2. The apparatus of claim 1, wherein the centre of gravity of the
generating sub-assembly is below the position of said hinge.
- 25 3. The apparatus of claim 1, wherein said generating sub-
assembly has an extension that descends below said hinge to lower the
centre of gravity of the generating sub-assembly.
- 30 4. The apparatus of claim 1, wherein said mast portion further
comprises a vertical section extending between said buoyancy portion and

said first section.

5. The apparatus of any of claims 1 to 4, wherein said buoyancy portion includes a buoyancy tank.

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6. The apparatus of claim 5, wherein said buoyancy tank contains air.

7. The apparatus of claim 5 or claim 6, wherein said buoyancy portion includes inflatable structures.

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8. The apparatus of any of claims 1 to 7, wherein said buoyancy portion includes a ballast tank.

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9. The apparatus of claim 8 when dependant on any of claims 5 to 7, wherein said ballast tank is located below said buoyancy tank.

10. A plurality of the apparatus of claim 1, said plurality being arranged in an array.

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11. A method of generating electricity, comprising the steps of:
locating a buoyant support structure in water, such that said buoyant support structure is free to roll in said water; and
supporting a generating sub-assembly upon said support structure by a hinged mechanism, so that said generating sub-assembly is rotatable about said hinge so as to maintain an operational angle for a turbine forming part of said generating sub-assembly during the rolling of the buoyant support structure; wherein

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said support structure includes a mast portion comprising an elbow; a first section below said elbow inclined at a first angle away from said turbine; and a second section above said elbow inclined at a second angle towards

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said turbine.

5 **12.** The method of claim 11, further comprising the step of attaching a tether to said buoyant support structure to maintain the location of said structure while still permitting said structure to roll.

13. The method of claim 11, further comprising the step of arranging a plurality of support structures in an array.

10 **14.** The method of any of claims 11 to 13, further comprising the step of adding ballast to provide the required degree of buoyancy.

15. An apparatus for generating electricity, substantially as herein described with reference to the accompanying drawings.

15

16. A method of generating electricity, substantially as herein described with reference to the accompanying drawings.

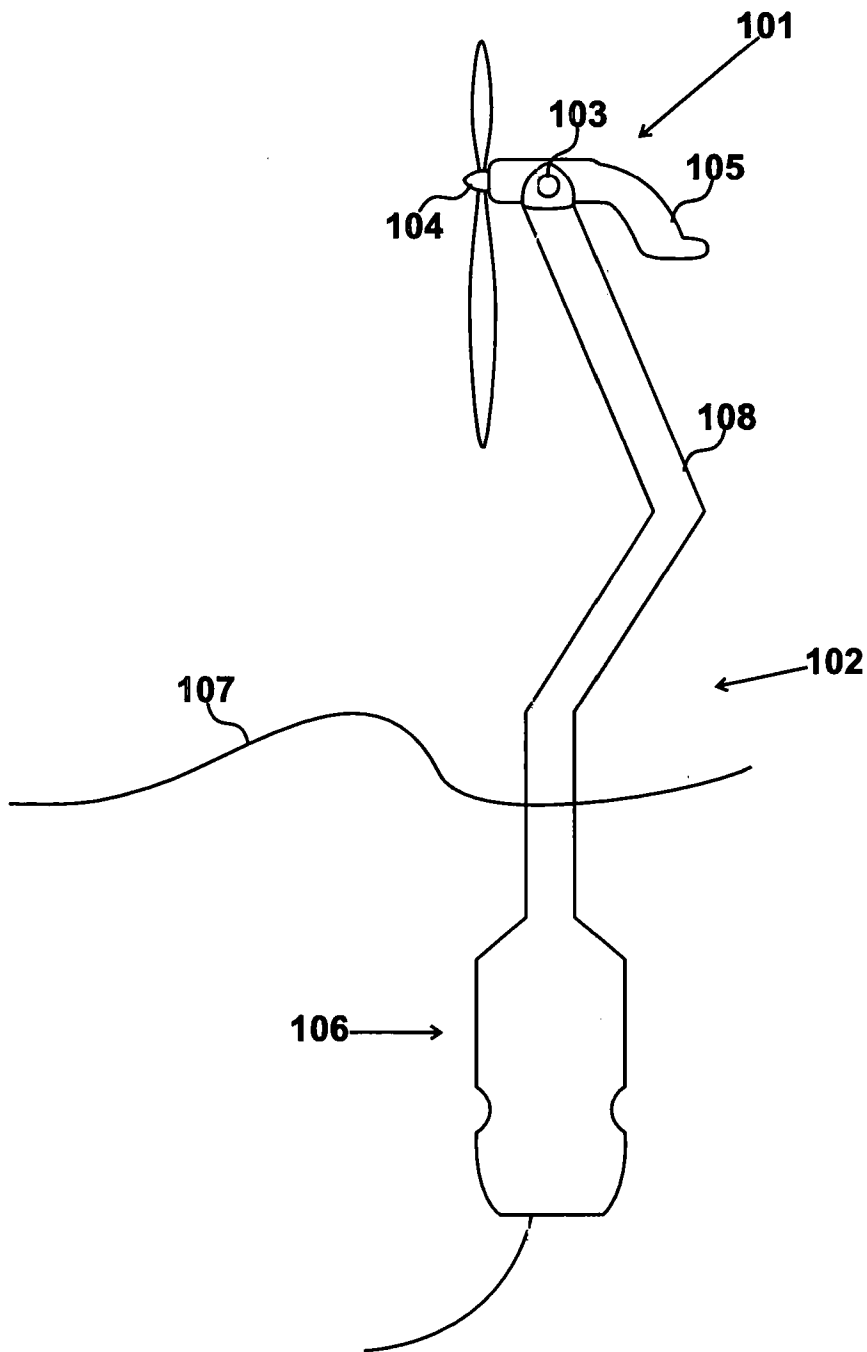


Fig. 1

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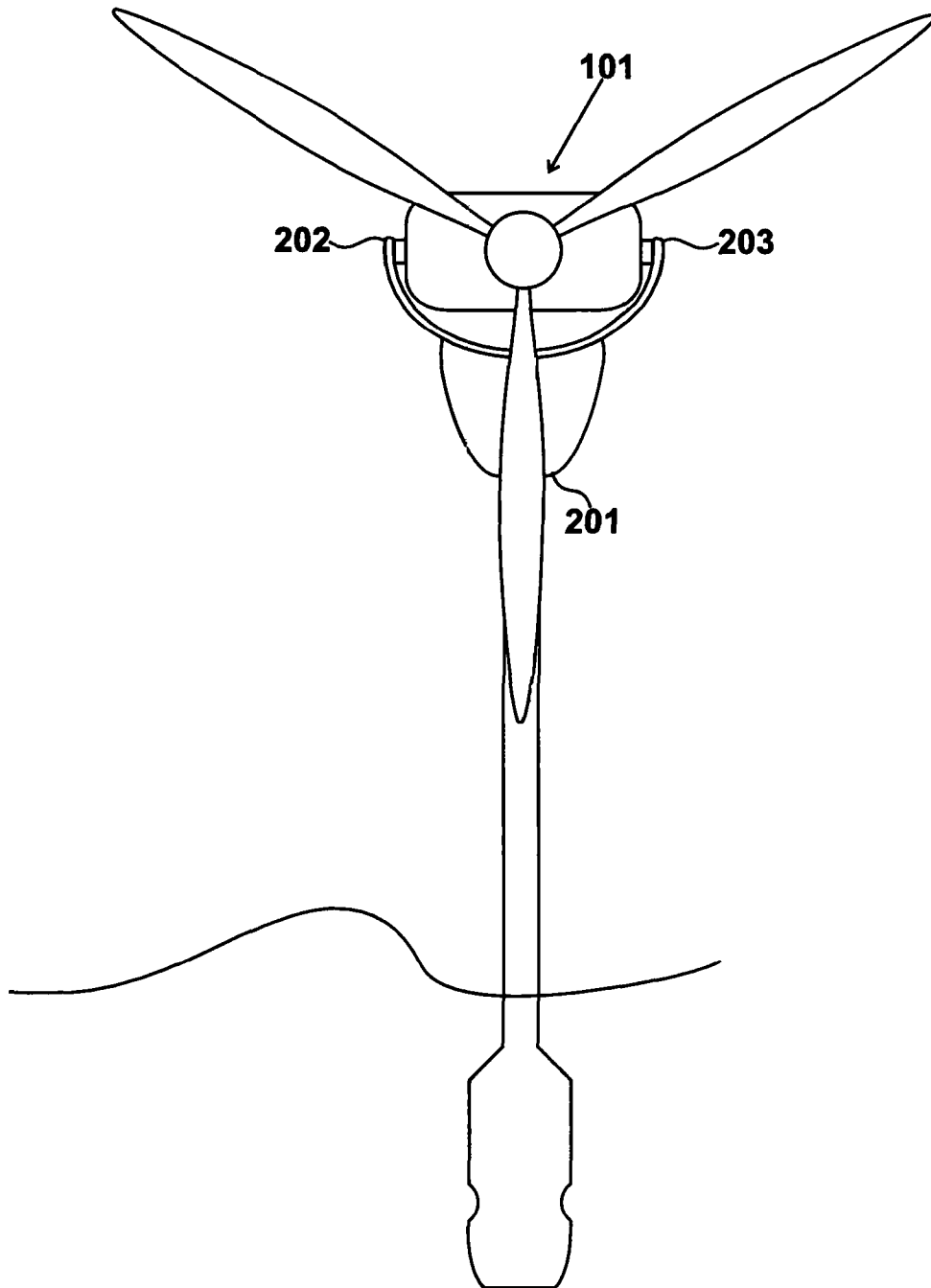


Fig. 2

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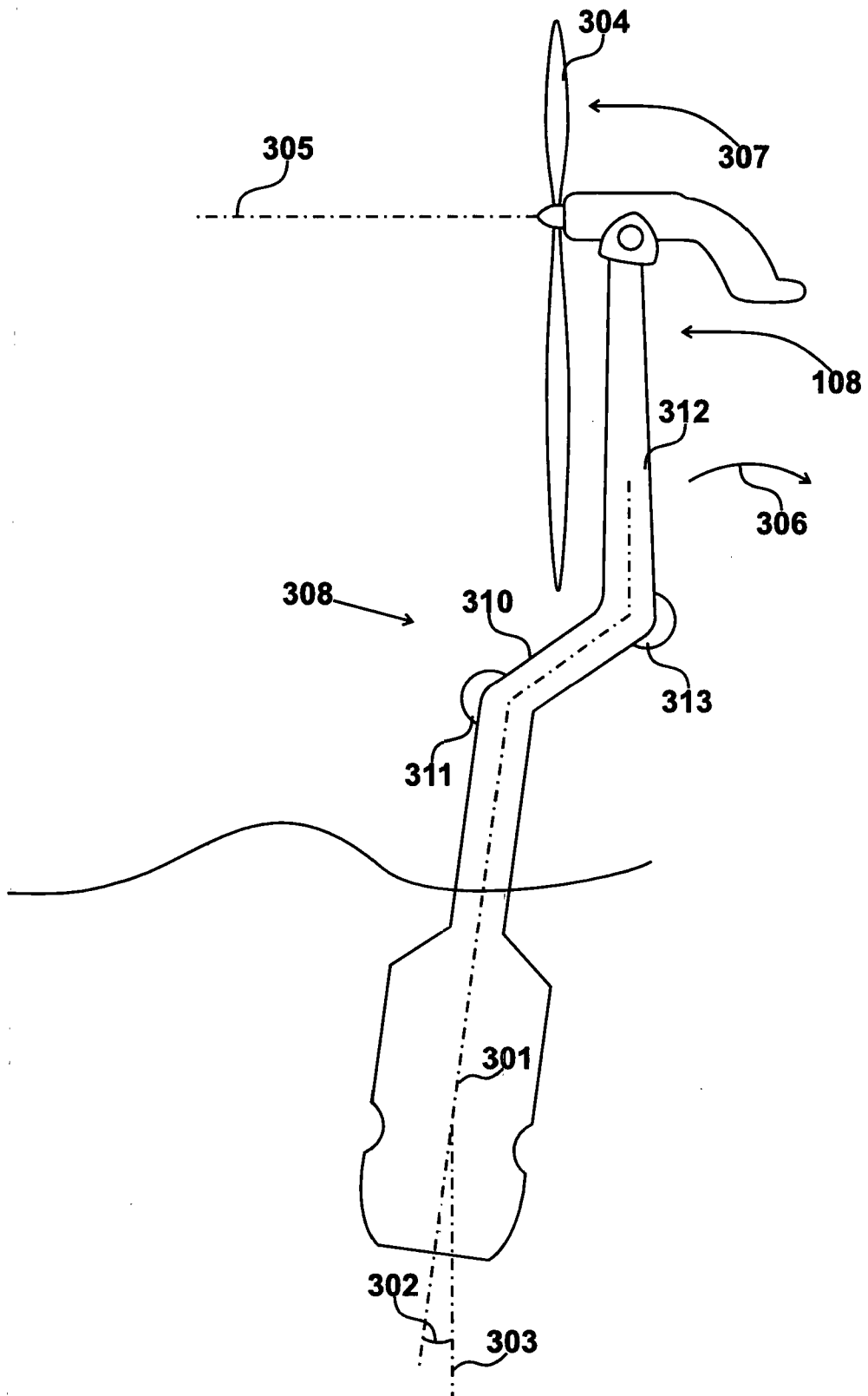


Fig. 3

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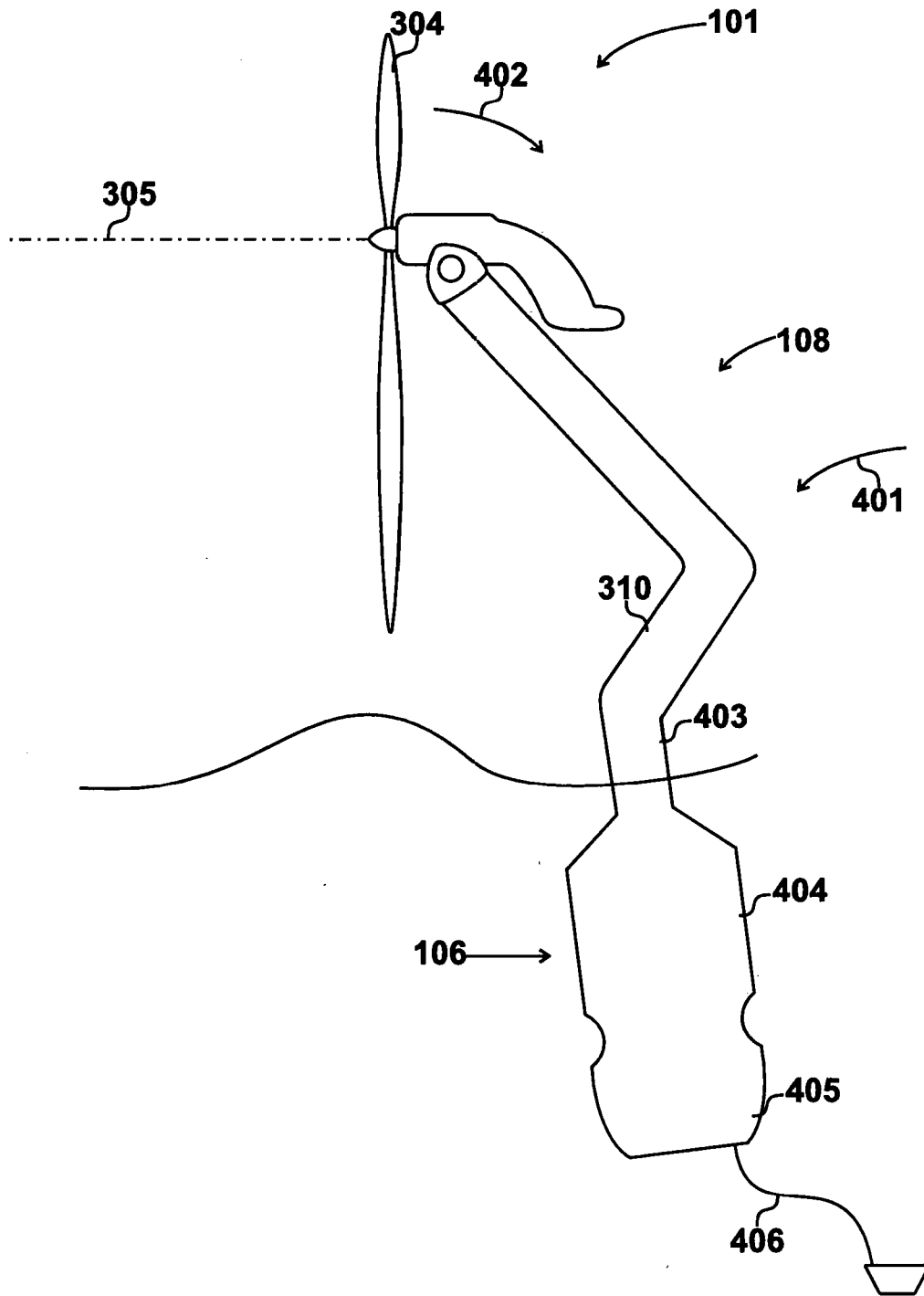


Fig. 4

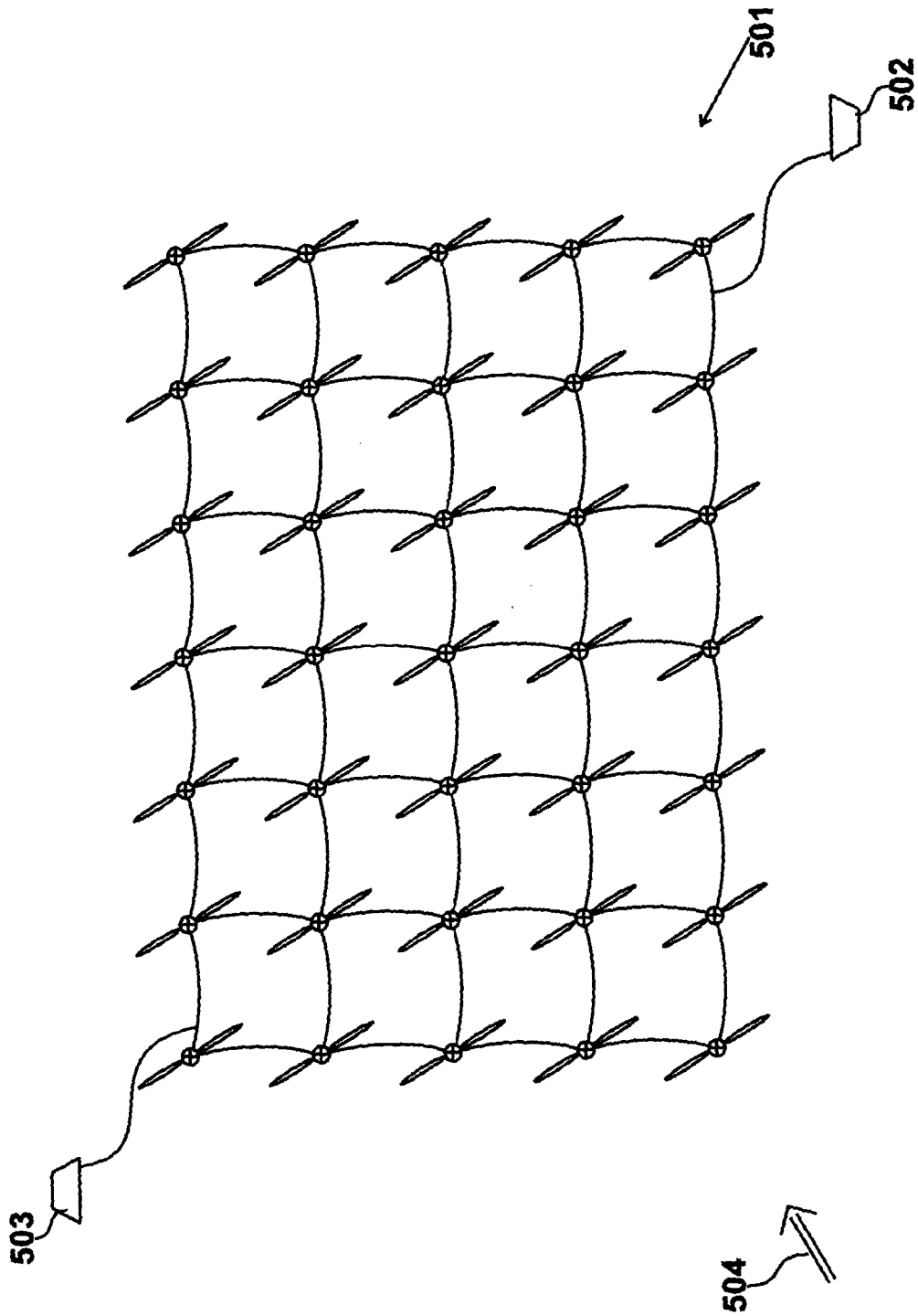


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/000524

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D11/04 F03D1/00
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
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

| C. DOCUMENTS CONSIDERED TO BE RELEVANT | | |
|--|--|-----------------------|
| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| X | WO 2010/098814 A1 (ENER2 LLC [US]; MOSER GEORGE [US]; LINN RANDY W [US]; WALWORTH VAN [US]) 2 September 2010 (2010-09-02) claims 13,20; figures 10-12,16,17,21-23 ----- | 1,3-14 |
| X | FR 2 984 968 A1 (IFP ENERGIES NOUVELLES [FR]) 28 June 2013 (2013-06-28) figures 4a)-5b) ----- | 1,3-14 |

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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- "O" document referring to an oral disclosure, use, exhibition or other means
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- "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
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2014/000524

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|--|------------------|-------------------------|------------------|
| WO 2010098814 | A1 | 02-09-2010 | NONE |
| FR 2984968 | A1 | 28-06-2013 | NONE |