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(56) Documents Cited:
EP 0761964 A1 **WO 2003/069156 A1**
WO 1998/032968 A1 **FR 002752443 A1**

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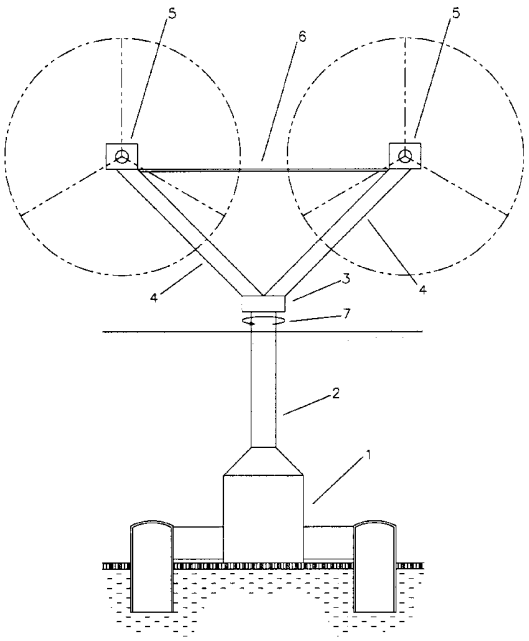
(54) Abstract Title: **Multiple turbine offshore support structure**

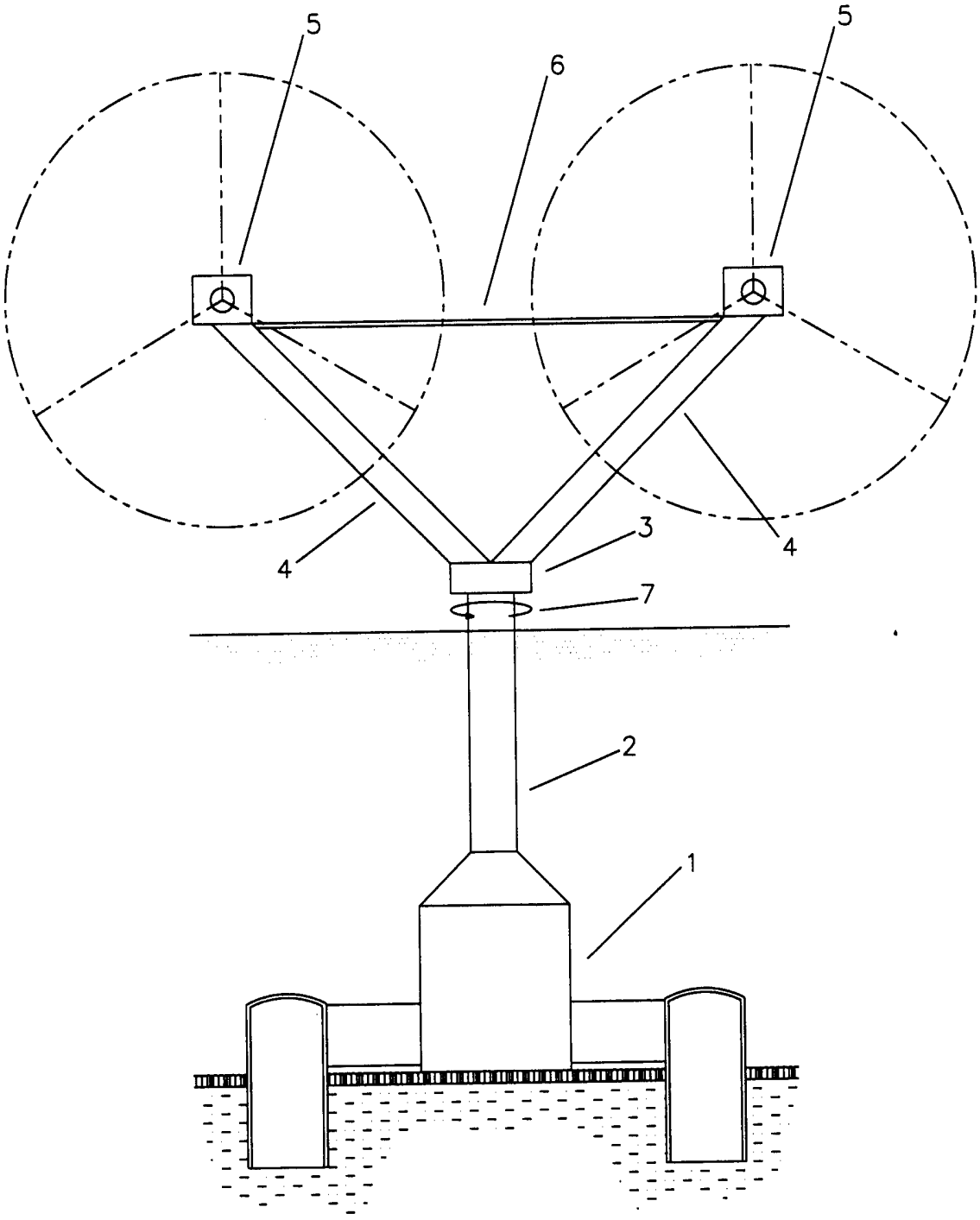
(57) A multiple turbine offshore support structure has a foundation 1 fixed to the seabed or a watertight hull floating above the seabed and flexibly connected to it. A shaft 2 extends upwardly from the foundation or hull, with a rotatable hub 3 located on the shaft, which can rotate about the vertical axis. Two or more structural arms 4 are connected to the hub and are inclined symmetrically across a diameter drawn through the vertical axis of the shaft. The structural arms are of sufficient size and strength to support a wind turbine 5 at the free upper end. The structural arms are connected to the hob by hinged or rigid joints.

Figure 1



GB 2 402 109 A

Figure 1



MULTIPLE TURBINE OFFSHORE SUPPORT STRUCTURE

This invention relates to offshore support structures for wind turbines.

Currently foundation structures for offshore wind turbines, where the foundation is rigidly fixed to the seabed become increasingly uneconomical as the water depth increases. This has created a need for floating support structures in deeper water. Stability requirements during installation and dynamic requirements during operation make it difficult to produce a floating support structure that can support more than one wind turbine. Current solutions tend to provide one support structure for one wind turbine, so that wind farms typically consist of multiple single turbine support structures. The use of a single turbine mounted on a tower on either a fixed or floating support structure results in a high tower structure for a given power output. This in turn results in very high bending moments (hence greater costs) in the tower construction, and in the case of the floating turbine support structure difficult stability problems.

We have now devised a fixed or floating offshore windtower support structure that alleviates the above problems.

According to the present invention there is provided a multiple turbine offshore support structure comprising a foundation fixed to the seabed or a watertight hull floating above the seabed and flexibly connected to it, a shaft extending upwardly from said foundation or hull, a rotatable hub located on said shaft and capable of rotating around the vertical axis, and two (or more) inclined (symmetrically across a diameter drawn through the vertical axis of the shaft) structural arms connected by hinged or rigid joints to said rotatable hub, said structural arms being of sufficient size and strength to support a wind turbine at the free upper end, and with sufficient vertical adjustability to allow clearance for safe operation of adjacent turbines.

The rotatable hub allows the turbine blades to be aligned optimally to the wind direction obviating the need to rotate the whole structure via its moorings.

In an alternative embodiment the structural arms are arranged so that they are each inclined by the same angle normal to an initial incline (in a backward extension) said initial incline being symmetrically across a diameter drawn through the vertical axis of the shaft and are balanced using an additional structural arm with a counter balance weight in the horizontal plane at 180 degrees around the vertical plane of the shaft bisecting the other structural arms (in a forward extension). The structural arm with counter balance is configured so as to provide a balance of forces about the vertical plane of the shaft. Each structural arm including the counter balance arm may be capable of supporting a turbine rotor. The structural arms can be lowered or rotated to suit wind conditions. Also, the backward extension of the structural arms permits the rotatable hub to self-align the rotors to the optimal wind direction by weathervaning and thus obviates the need for powered drive or computer control systems.

In a further embodiment using the inclined arms with counter balance configuration, the structural arms are designed with an aerofoil or streamlined type shape to reduce wind loading on the structure. It is possible to do this because of the smaller load capacity required normal to the airflow when using this structural configuration with intermediate tie member.

The narrower arms further improve airflow and lower wind resistance thus resulting in less load on the structure. The improved airflow also allows better rotor blade efficiency.

Also, because of an improved airflow the backward extension and streamlining effects allows use of rear mounted turbine blades, or two bladed rotors, which give better efficiency than front mounted or three blade rotors.

Preferably the floating embodiment is taut moored to the seabed (or seabed foundation device) with flexible connectors that are pre-tensioned due to the watertight hull being installed at a draught which causes excess buoyancy.

The floating embodiment preferably has a watertight hull comprising one or more chambers spaced for stability and inter-linked with structural braces.

Preferably the structural arms are transported in the horizontal position to improve stability and hence aid installation of the support structure and turbines. An A frame and cables can be utilised to assist lowering and raising of the arms. Also, the shaft may be telescopic to aid installation and transportation.

Preferably, once in the desired position, the structural arms are linked at the top by a cable or rigid brace to assist holding them in position and to aid distribution of structural forces away from said arms.

The use of pin-jointed arms and cable stays lowers the structural weight when compared to single turbine support structures. By this means the estimated weight of a support structure for two turbines will be about 1.5 times the weight for a single turbine support structure. Hence, an overall weight saving of 25% is achieved, and hence cost savings.

A specific embodiment of the invention will now be described by way of example only and with reference to the accompanying drawing in which: -

Figure 1 shows in vertical cross section the multiple turbine offshore support structure on location with the shaft extended and the structural arms in the operating position.

Referring to Figure 1 the structure comprises a watertight foundation 1 from which protrudes a telescopic shaft 2, a rotatable hub 3 attached to the shaft 2, and adjustable structural arms 4. The turbines 5 are attached to the end of the structural arms 4. A cable brace 6 is used to link the structural arms 4 at the top ends.

The structural arms 4 are connected to the rotatable hub 3 with pin joints, thus allowing the arms 4 to be held in the horizontal position during transportation and installation. When the structure is in position the arms 4 are raised to the desired position as shown. The rotatable hub 3 (with axis of rotation indicated by arrow 7) allows the turbines 5 (and arms 4) to be manoeuvred into any desired orientation in order to maximise wind energy available.

CLAIMS

1. A multiple turbine offshore support structure comprising a foundation fixed to the seabed or a watertight hull floating above the seabed and flexibly connected to it, a shaft extending upwardly from said foundation or hull, a rotatable hub located on said shaft and capable of rotating around the vertical axis, and two (or more) inclined (symmetrically across a diameter drawn through the vertical axis of the shaft) structural arms connected by hinged or rigid joints to said rotatable hub, said structural arms being of sufficient size and strength to support a wind turbine at the free upper end, and with sufficient vertical adjustability to allow clearance for safe operation of adjacent turbines..

2. A multiple turbine offshore support structure as claimed in Claim 1 wherein the rotatable hub allows the turbine blades to be aligned optimally to the wind direction obviating the need to rotate the whole structure via its moorings.

3. A multiple turbine offshore support structure as claimed in Claim 1 or Claim 2, wherein the structural arms are arranged so that they are each inclined by the same angle normal to an initial incline (in a backward extension) said initial incline being symmetrically across a diameter drawn through the vertical axis of the shaft and are balanced using an additional structural arm with a counter balance weight in the horizontal plane at 180 degrees measured around the vertical plane of the shaft bisecting the other structural arms (in a forward extension).

4. A multiple turbine offshore support structure as claimed in any preceding claim, wherein the structural arm with counter balance is configured so as to provide a balance of forces about the vertical plane of the shaft.

5. A multiple turbine offshore support structure as claimed in any preceding claim, wherein each structural arm including the counter balance arm may be capable of supporting a turbine rotor.

6. A multiple turbine offshore support structure as claimed in any preceding claim, wherein the structural arms can be lowered or rotated to suit wind conditions.

7. A multiple turbine offshore support structure as claimed in any preceding claim, wherein the backward extension of the structural arms permits the rotatable hub to self-align the rotors to the optimal wind direction by weathervaning and thus obviates the need for powered drive or computer control systems.

8. A multiple turbine offshore support structure as claimed in any preceding claim, wherein using the inclined arms with counter balance configuration, the structural arms are designed with an aerofoil or streamlined type shape to reduce wind loading on the structure.

9. A multiple turbine offshore support structure as claimed in any preceding claim, wherein the improved airflow from the backward extension and streamlining effects allows use of rear mounted turbine blades, or two bladed rotors, which give better efficiency than front mounted or three blade rotors.

10. A multiple turbine offshore support structure as claimed in any preceding claim, wherein the floating embodiment is taut moored to the seabed (or seabed foundation device) with flexible connectors that are pre-tensioned due to the watertight hull being installed at a draught which causes excess buoyancy.

11. A multiple turbine offshore support structure as claimed in any preceding claim, wherein the floating embodiment has a watertight hull comprising one or more chambers spaced for stability and inter-linked with structural braces.

12. A multiple turbine offshore support structure as claimed in any preceding claim, wherein the structural arms are transported in the horizontal position to improve stability and hence aid installation of the support structure and turbines.

13. A multiple turbine offshore support structure as claimed in any preceding claim, wherein the shaft may be telescopic to aid installation and transportation.

14. A multiple turbine offshore support structure as claimed in any preceding claim, wherein once in the desired position, the structural arms are linked at the top by a cable or rigid brace to assist holding them in position and to aid distribution of structural forces away from said arms.

15. A multiple turbine offshore support structure substantially as herein described and illustrated in the accompanying drawings.

Application No: GB0411754.5 **Examiner:** Richard Collins

Claims searched: 1 to 15 **Date of search:** 27 July 2004

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular reference
X,E	1,2,6	WO03/069156 A1 (WOBBEN) see all figures.
X	1,2,6	WO98/32968 A1 (VAN DEIJL) see figure 1 and related description.
X	1,2,6,14	EP0761964 A1 (ALEXANDROFF) see figure 11 especially.
X	1,2,6	FR2752443 A1 (ALEXANDROFF) see all figures.

Categories:

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

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{W} :

B7A; E1H; F1T

Worldwide search of patent documents classified in the following areas of the IPC^{07}

B63B; E02B; F03D

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

EPODOC, JAPIO, WPI