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GB 2409885 A **GB 2348249 A**
WO 2005/103484 A2 **US 4864152 A**

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UK CL (Edition X) **B7A, E1H, F1T**
INT CL **B63B, F03B**
Other: **EPODOC, WPI**

(54) Abstract Title: **Underwater turbine mounting**

(57) An underwater turbine mounting 100 comprises a variable buoyancy frame 1, 6 having at least one horizontal axis turbine 2 mounted thereon. One end of a rigid arm 3 is pivotally connected to the frame 1, 6, and the other end of the rigid arm 3 is pivotally connected to an underwater anchorage 4. An adjustable length tether 11 is provided between the opposite end of the rigid arm 3 to that which is connected to the frame 1, 6, and a part on the frame 1, 6 away from the connection point of the rigid arm 3, so as to provide a moment arm about the connection point of the rigid arm 3. The variable buoyancy of the frame 1, 6 may be provided by water-tight chambers having means to vary the air/water ratio therein. The mounting 100 may be towed into position and then deployed as illustrated in figure 2 or 3.

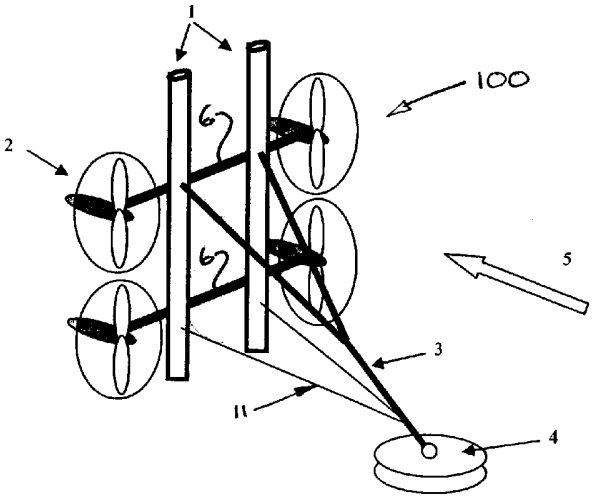

Fig1

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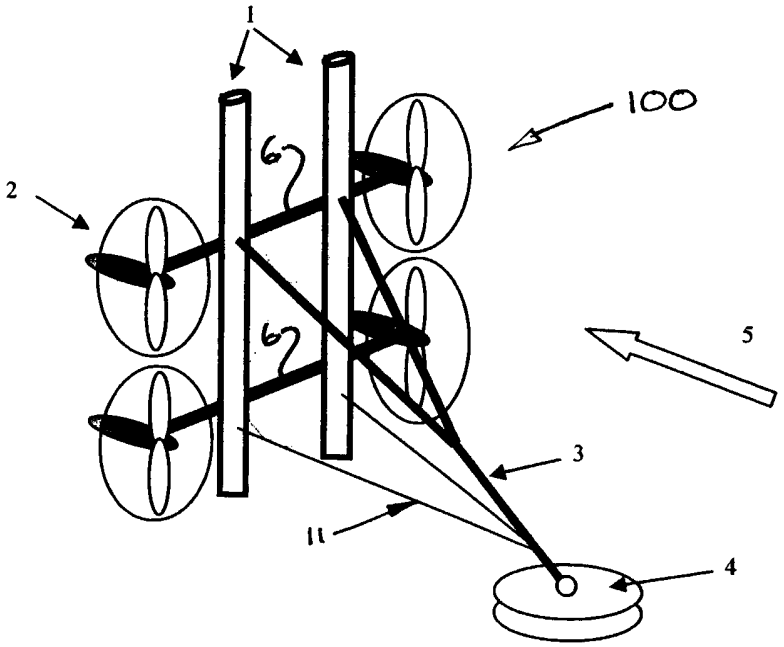

Fig1

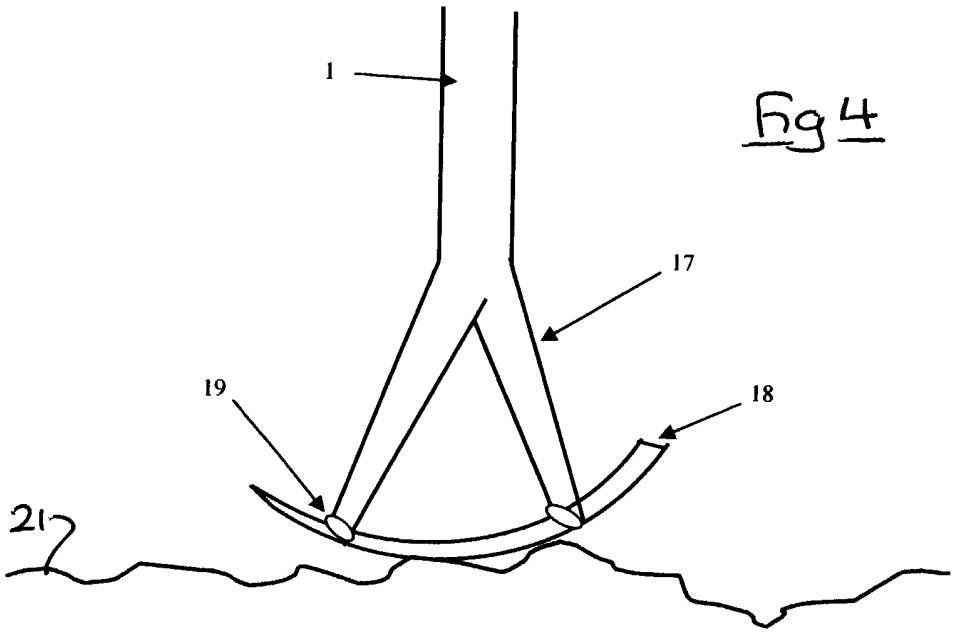

Fig 4

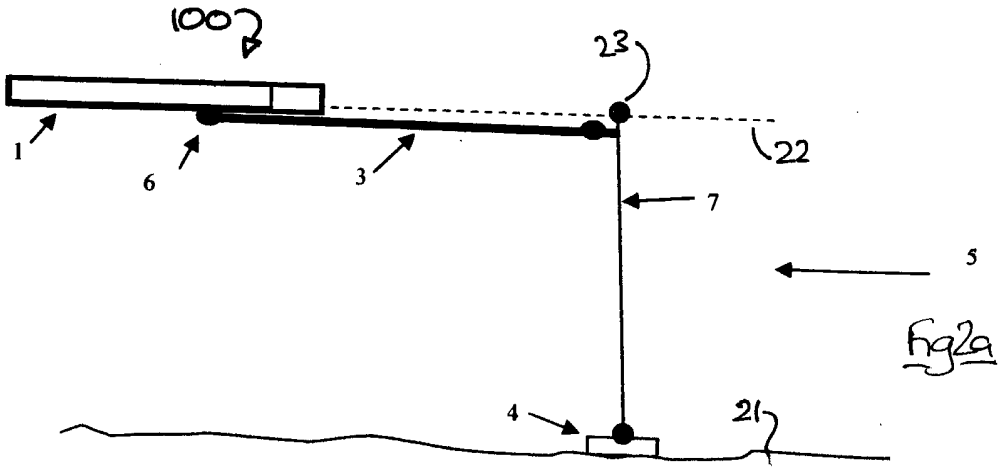

Fig2a

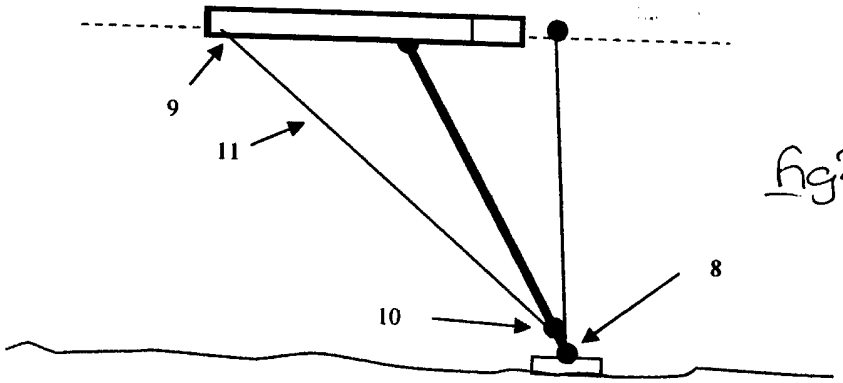

Fig2b

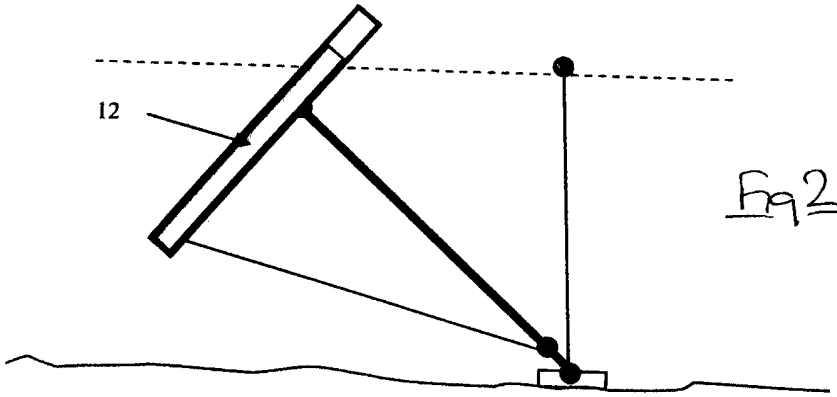

Fig2c

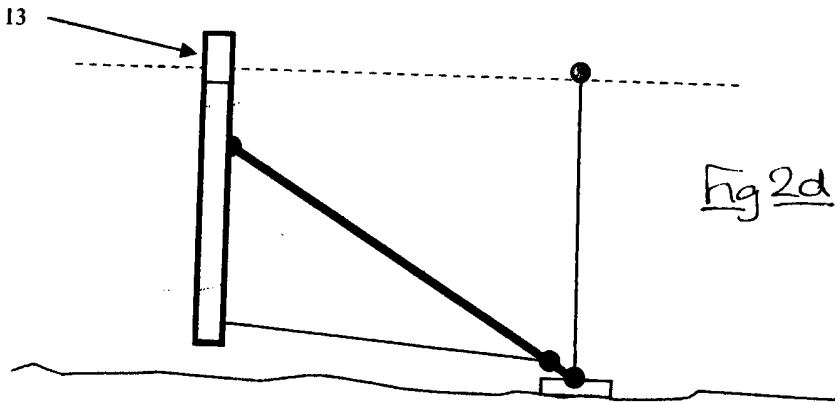

Fig2d

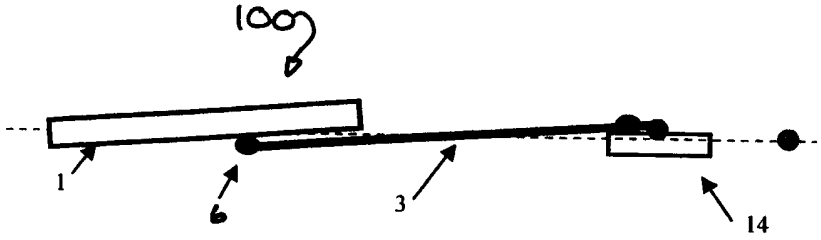

Fig 3a

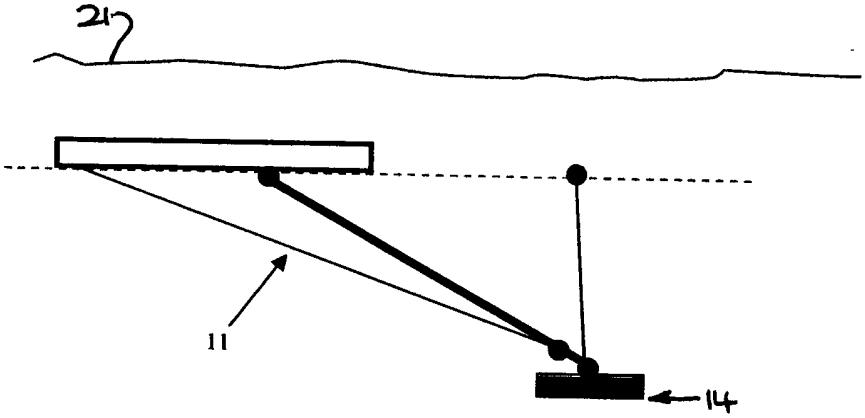

Fig 3b

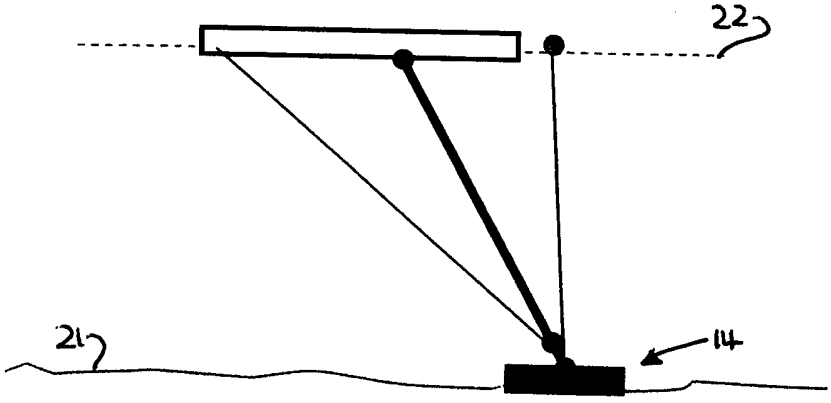

Fig 3c

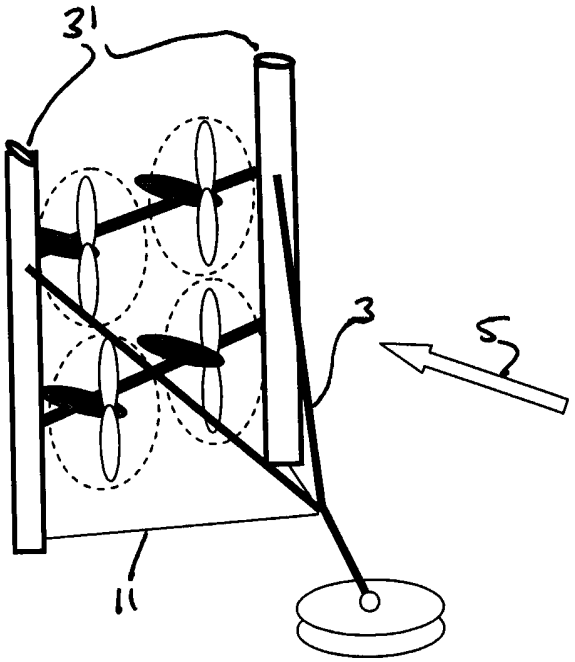

Fig5

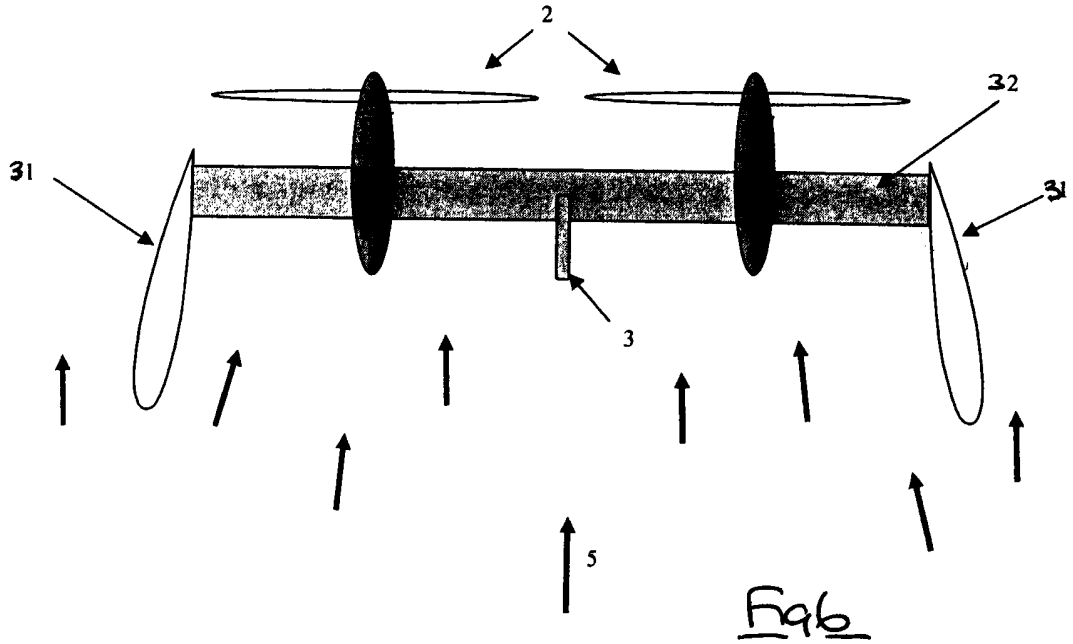

Fig6

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DEEP WATER TURBINE AND MOUNTING THEREFOR

This invention relates to deep water turbines, particularly those intended to be located in costal regions or river estuaries at a depth of 20 metres or more.

Many systems have been proposed for the generation of electricity from water turbines. Such turbines harness the stream energy of rivers and tides, and in the case of tides are bi-directional so as to generate electricity both on a rising and a falling tide.

In order to maximise generation of electricity it is of course desirable to site such turbines in regions of deep fast flowing water, but practical difficulties arise concerning deployment positioning and maintenance.

According to a first aspect of the invention there is provided an underwater turbine mounting comprising:

a frame adapted to mount one or more horizontal axis water turbines thereon;

a rigid arm pivotally connected at one end in said frame, the other end being adapted for pivotal connection to an underwater anchorage;

variable buoyancy means on said frame and adapted to pivot said frame about said arm in use;

a depending moment arm of said frame;

a flexible tether connected between the other end of said rigid arm and said moment arm; and

means to vary the length of said tether to vary the orientation of said frame, in use.

Such a mounting is adapted for deployment in a fast water stream by being towed to the installation site in a configuration in which the frame is substantially horizontal

and on the water surface. At the site, the free end of the rigid arm is connected to a suitable anchorage on the river/sea bed, and the tether is reduced in length to pivot the frame to an orientation in which turbines of the frame are correctly positioned in the water stream. It will be understood that by virtue of the pivotal connection to the anchorage, the mounting will trail the anchorage and be self-aligning with the water stream, thus maintaining the tether taut. Fine adjustment of turbine rotational axis with respect to stream direction can be achieved by adjusting the length of the tether. The depth of the frame in the stream may be adjusted by varying the buoyancy means, if desired. The pivotal connections, in one embodiment, are hinges.

It will be appreciated that turbines mounted above the frame when in the horizontal condition are accessible for maintenance and repair. Thus a straightforward lengthening of the tether will allow the frame to pivot in use under the action of the buoyancy means, from an active generating condition to passive surface condition in which the turbines are exposed above the water surface. In this passive condition, the frame may be towed to the installation site.

In a preferred embodiment, the frame is adapted for mounting a plurality of turbines transversely to the stream direction. Such an arrangement allows a balanced symmetrical assembly. The frame may be adapted to mount a plurality of turbines one above another in the active condition, so as to maximise generating potential in deep water without recourse to excessively large turbine diameters. In a preferred embodiment the frame is adapted to a symmetrical array of four turbines arranged in respective upper and lower groups of two, about an upright axis in the active condition.

The frame may comprise a cruciform structure in which the transverse (in use) limb(s) comprise turbine mountings, and the upright (in use) limb(s) comprise a moment arm to which the flexible tether is attached. In a preferred embodiment the

frame has two such upright limbs and said tether comprises one strand from each limb. In this embodiment, the rigid arm may be forked for connection at one end to a respective upright limb of the frame. Preferably the rigid arm is connected to the frame in the region of an upper (in use) transverse limb, and most preferably, substantially on the axis thereof.

The variable buoyancy means preferably comprise a water-tight chamber having means to vary the air/water ratio thereof. In this way by increasing or reducing relative air volume, the floating depth of the chamber, and hence the frame may be adjusted. Relative air volume may be adjusted by pumping air or water. Preferably the frame comprises a buoyancy chamber, and in the preferred embodiment said chamber comprises the or each moment arm.

In a preferred embodiment the frame may extend upwardly, so that in use, it can be arranged to be above the water surface and act as a marker for ships and the like. In a preferred embodiment the upward extension may comprise one or more sails adapted to respond to prevailing winds so as to urge the mounting in a desired direction with respect to the stream direction. Such an arrangement may be particularly effective in maximising the generation potential of the turbines. In the preferred embodiment said upward extension comprises the upright limbs of the frame. Any suitable sail may be employed, including but not limited to fabric sails and rotating cylinders.

The mounting of the invention may further include an anchorage connected to the rigid arm. In a preferred embodiment said anchorage includes a buoyancy chamber to permit deployment by towing to the installation, and sinking. One suitable embodiment comprises a closed chamber of concrete, the chamber being progressively flooded to lower the anchorage at the installation site.

An embodiment of the invention comprises a ready to deploy assembly comprising a turbine mounting of the afore-mentioned kind, and turbines assembled thereto.

The turbines may be arranged inboard or outboard of the limbs which are in use upright, or maybe both inboard and outboard. The upright limbs may be aerodynamically profiled to reduce drag and accelerate water flow towards the turbines.

According to a second aspect of the invention there is provided a method of deployment of a mounting assembly according to the first aspect of the invention, said method comprising shortening of said tether to pivot said turbines through substantially 90° into an active condition.

Other features of the invention will be apparent from the following description of a preferred embodiment illustrated by way of example only in the accompanying drawings in which:

Fig.1 is a schematic view of an embodiment of an underwater turbine incorporating the invention;

Figs.2a-2d illustrate deployment of the embodiment of Fig.1.

Figs.3a-3c illustrate an alternative deployment technique.

Fig.4 illustrates a foot or skid for the assembly of Fig.1.

Fig.5 illustrates an alternative embodiment of the invention.

Fig.6 is a plan view of the embodiment of Fig.5.

With reference to Fig.1 an underwater turbine assembly 100 comprises a cruciform frame having two sets of parallel limbs at right angles. In the active in-use condition two of the limbs 1 are substantially upright whereas the other two limbs 6 are substantially horizontal and transverse to the direction of the water stream 5. Mounted on respective ends of the limbs 6 are four electricity generating turbines 2. The upright limbs 1 comprise hollow chambers which can be partially flooded to

vary the buoyancy thereof, as will be described. In addition, or alternatively, the horizontal limbs and rigid arm may also comprise buoyancy chambers.

Pivotally connected between the turbine frame and an underwater anchorage 4 is a rigid arm 3 which is forked at the frame end to provide a connection to each upright limb 1, as illustrated.

A flexible tether 11 is connected between the turbine frame and anchorage end of the rigid arm 3, and as illustrated comprises two strands, connected one to a respective lower end of the upright limbs 1.

In use the frame is deployed as illustrated in a water stream with the tops of the upright limbs protruding just above the water surface. The pivotal connections of the arm 3 ensure that the turbines self align with the water stream 5. In the event that the water stream reverses, due to tides, the turbine assembly swings through 180° about the anchorage so that electricity is generated for both directions of stream.

Electricity is conveyed from the turbines in any suitable manner, for example by cable to the anchorage, and hence to the surface or shore. Suitable means for preventing cable wind-up during tidal movement of the assembly are included if required.

Figs.2a-2d indicate a method of deployment to an existing anchorage on the water/sea bed 21. The anchorage has a marker buoy 23 on the surface 22.

A turbine assembly 100 is towed on the water surface to the installation site. The buoyancy chambers of the limbs 1 support the assembly which includes turbines (not shown). The rigid arm 3 is relatively light and may be supported by a tug and act as a tow bar (Fig.2a).

At the site the arm 3 is connected to the anchorage by, for example, using the buoy cable 7 as a guide. A means of automatically latching the arm to a pre-prepared socket of the anchorage may be provided (Fig.2b).

The pre-attached tether 11 is then shortened, in conjunction with a variation in the buoyancy of the limbs 1, to deploy the assembly at the desired depth and orientation (Figs.2c & 2d). The pivot connections 9,10 facilitate positioning of the frame, as illustrated. The respective volumes of water 12 and air 13 are shown by way of example, and may be varied by conventional means typically comprising valves and a source of air under pressure. Alternatively water may be pumped in or out to vary buoyancy.

An alternative gravity deployment of an anchorage 14 is illustrated in Figs.3a-3c. Common parts carry the same reference numerals.

The anchorage 14 is pre-attached to the assembly 100 and towed by the tug to the desired position (Fig.3a). The anchorage is preferably a buoyant device having an internal chamber which can be flooded to cause it to sink (Fig.3b).

Once in position (Fig.3c), and further ballasted if desired, the turbine frame is deployed in the manner described with reference to Figs.2c and 2d.

It will be appreciated that the assembly 100 can be deployed and serviced from a boat or tender without necessity for a human diver to attend. Accordingly the risks associated with working in deep fast flowing water are mitigated to a considerable extent. The means of modulating the length of the tether may for example comprise an hydraulic or electric winch or rack and pinion, operated remotely from a shore station or via a connection carried by the buoy 23 or upright 1. The length of the tether may be adjusted in use accordingly to stream flow rate and direction in order

to optimise generation of electricity. The means of varying tether length may be at the anchorage or on the frame.

By lengthening the tether the turbines can be brought out of the water to the position of Fig.2b for servicing and repair.

Fig.4 illustrates an arcuate foot 18 of the upright limb(s) 1 and attached by welding 19 to a bifurcated leg 17. Alternative means of connection may be compliant, and/or incorporate a damping medium. Such arrangements allows grounding of the upright in use whilst minimising the risk of damage thereto. Grounding may for example occur during tidal surges or during reversal of the assembly 100 about the anchorage.

As an alternative to gravity deployment of an anchorage 14, with or without subsequent ballasting, a further embodiment of the invention provides an anchorage having explosive ground-penetrating anchors thereon. For example three such anchors provided at the periphery in an equi-spaced array may be actuated remotely to drive spikes into the water bed or the sea bed 21. This arrangement permits a less massive anchorage and/or a more secure anchorage to resist tangential and sideways movement. Alternatively a remotely operated drill and anchorage system may be mounted on the anchorage whereby holes may be drilled in the ground and anchors secured in the holes.

The protruding portion of the upright limbs 1 may have the effect of a sail with respect to the prevailing wind, which may not coincide with the stream direction. In an alternative embodiment suitable sails, of any kind, may be provided on or as part of the upright in a steerable manner so as to allow the direction of the turbine mounting to be adjusted. Thus the sails may be adjusted to counteract an adverse influence of the protruding uprights, or to better align the turbines to maximum generation potential. Such sails, if provided, are under control of a suitable

command apparatus, which may also modulate tether length in accordance with prevailing wind and stream conditions.

With reference to Fig.5 and 6, the upright limbs 31 are provided at opposite ends of respective horizontal spars 32, and one or more turbines 2 are provided between the upright limbs 31. Four turbines are illustrated, but more or fewer turbines and/or more or fewer horizontal spars 30 may be provided, as required.

Fig.6 illustrates that the upright limbs 31 are hydrodynamically shaped to reduce drag in the flow direction 5, and may be inclined to accelerate water flow in the region therebetween; thus the generation potential of the turbines is maximised.

In use the arrangement of Figs. 5 and 6 is displayed in the manner previously described. The upright limbs 31 comprise variable buoyancy chambers to facilitate movement from the active generation condition illustrated, to the generally horizontal passive condition for maintenance. The wide spacing of the limbs 31 ensures a stable floating platform during maintenance operations.

CLAIMS:

1. An underwater turbine mounting comprising:

a frame adapted to mount one or more horizontal axis water turbines thereon;

a rigid arm pivotally connected at one end on said frame, the other end being adapted for pivotal connection to an underwater anchorage;

variable buoyancy means on said frame and adapted to pivot said frame about said arm in use;

a moment arm of said frame;

a tether connected between the other end of said rigid arm and said moment arm; and

means to vary the length of said tether to vary the orientation of said frame, in use.

2. A mounting according to claim 1 wherein said frame is adapted for mounting a plurality of turbines transversely and symmetrically.

3. A mounting according to claim 2 wherein said frame is adapted to mount a plurality of turbines one above another in the active condition.

4. A mounting according to claim 3 wherein said frame is adapted to a symmetrical array of four turbines arranged in respective upper and lower groups of two, about an upright axis in the active condition.

5. A mounting according to any preceding claim and comprising a cruciform structure in which a transverse limb comprises turbine mountings, and an upright limb comprises a moment arm to which said flexible tether is attached.

6. A mounting according to claim 5 wherein said frame has two upright limbs and said tether comprises one strand from each limb.

7. A mounting according to claim 6 wherein said rigid arm is forked for connection at one end to a respective upright limb of the frame.

8. A mounting according to claim 7 wherein said rigid arm is connected to the frame in the region of the topmost transverse limb in use.

9. A mounting according to claim 8 wherein said rigid arm is connected to the transverse limb substantially on the axis thereof.

10. A mounting according to any preceding claim wherein said variable buoyancy means comprises a water-tight chamber having means to vary the air/water volume ratio therein.

11. A mounting according to claim 10 wherein said frame comprises a buoyancy chamber.

12. A mounting according to claim 11 wherein said chamber comprises a moment arm.

13. A mounting according to any preceding claim and adapted to extend upwardly, so that in use, it is above the water surface.

14. A mounting according to claim 13 wherein the upward extension comprises one or more sails adapted to respond to prevailing winds so as to urge the mounting in a desired direction with respect to the stream direction.

15. A mounting according to claim 14 wherein said upward extension comprises an upright limb of the frame.

16. A mounting according to any preceding claim and further including an anchorage connected to said other end of said rigid arm.

17. A mounting according to claim 16 wherein said anchorage includes a buoyancy chamber to permit deployment by towing and sinking.

18. An underwater turbine mounting substantially as described herein with reference to the accompanying drawings.

Application No: GB0601014.4 **Examiner:** Alex Swaffer

Claims searched: 1-17 **Date of search:** 9 May 2007

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 relevance
A	-	WO2005/103484 A2 (Weir Strachan & Henshaw): See figure 2 in particular.
A	-	GB2348249 A (Armstrong): See figure 1 in particular.
A	-	GB2409885 A (Marine Current Turbine Ltd): See figure 1 in particular.
A	-	US4864152 A (Pederson): See figures 1 and 2 in particular.

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[X] :

B7A; E1H; F1T

Worldwide search of patent documents classified in the following areas of the IPC

B63B; F03B

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

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
F03B	0017/06	01/01/2006
B63B	0035/44	01/01/2006
F03B	0013/26	01/01/2006