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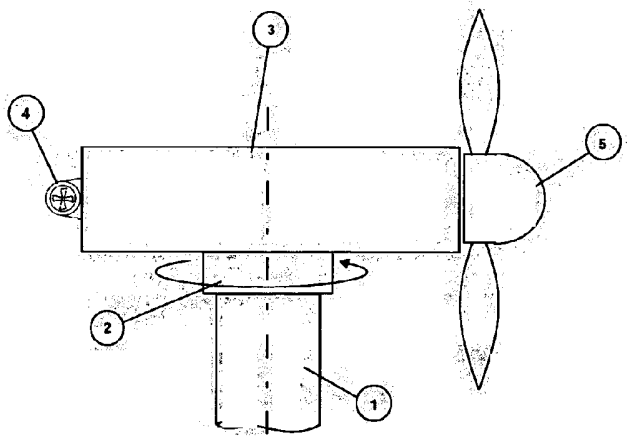

(57) Abstract: A water current generating device consisting of a main body (3) and a horizontal axis rotor (5) is attached by a mechanical connection (2) to a fixed support structure (1). Under the action of one or more hydrodynamic thrusters (4) the main body of the turbine is rotated about a desired axis of rotation to face the oncoming current flow. The mechanical connection incorporates an appropriate degree of freedom to allow this re-orientation to take place.

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WATER CURRENT POWER GENERATING DEVICES

The present invention relates to water current power generating devices, for extracting energy from water currents. Specifically, the invention provides a means of aligning a water current power generating device with the current flow, such that it can accommodate changes in current direction on a periodic basis.

BACKGROUND OF THE INVENTION

The direction of current flow in estuaries and tidal races usually changes according to a prescribed periodic pattern. As an example, tidal currents typically reverse direction by approximately 180deg roughly every six hours when the flood or ebb tides turn. As the tide is turning the current speed is very low or stationary for a short period of time around slack water. This invention seeks to take advantage of such a period of slow moving or stationary flow to re-orientate a water current power generating device.

Proposed methods that allow a water current power generator to accommodate significant changes in current direction on a periodic basis include:

- *Mechanical Yaw drive*: This is the technique used by the wind industry where there is a requirement for the rotor to face the wind blowing from any direction, but it can also be adopted for use on a water current turbine. The turbine rotor is yawed around using a mechanical friction or geared drive mounted on the turbine nacelle, which reacts against the tower (or vice-versa). Due to the relatively small radius at which the yaw drive is typically mounted (usually equivalent to the support tower radius), a high reaction force is required to provide adequate torque to re-orientate the turbine. Water born particles and debris could cause fouling or wear of such a drive unless it is sealed from the external environment (which is expensive on a large diameter yaw bearing). The design requires tight control of mechanical tolerances between the moving gear/friction drive unit and the stationary reaction gear/surface.

- *Fixed rotor with full span pitch control:*. This technique can be used where the current changes direction by approximately 180deg each current cycle. When the current direction changes each rotor blade is rotated 180deg about its respective lengthwise axis to face the opposite direction. In hydrodynamic

terms this has the same effect as yawing the rotor through 180deg. This scheme has the drawback that the rotors must operate in the wake of the support structure for one direction of current flow. It also introduces efficiency losses and asymmetric rotor loading if the two current directions are not 180 deg apart.

- *Fixed rotor employing fixed pitch reverse flow blades:* The rotor blade aerofoil section is designed to allow the blades to operate with flow coming from opposite directions without adjusting their pitch or turning the rotor in any way. This can be achieved using a blade aerofoil section profile which is symmetric about both the local blade cord and vertical axes (an example would be a flattened ellipse profile). There will be significant efficiency losses associated with this design of blade section. Such a fixed blade pitch rotor will rely on hydrodynamic stall control to limit the output power, which does not provide a very controllable means of power regulation.

- *Positively buoyant rotor tethered to seabed:* A fully submerged positively buoyant rotor (or group of rigidly connected rotors) is tethered to the seabed. When the rotors are generating, they are supported mid water column by the balancing forces of turbine thrust, buoyancy, and the resultant tension in the mooring tethers. The level of the rotors in the water column changes with the current speed and amount of thrust generated. When the current reverses direction, the rotors flip vertically over the point the other direction. The main disadvantage of this system is the potential for undesired dynamic response of the entire main body of the water current generating device on its flexible moorings. This is of particular concern if there is any significant turbulence or wave induced fluctuations in the current flow. The tethered mooring arrangement also makes it more difficult to protect electrical power cables running from the turbines to the seabed.

SUMMARY OF THE PRESENT INVENTION

According to one aspect of the present invention, there is provided a water current power generating device including a water current power generating device including:

a support structure which is located on, and affixed to, a bed of a body of water;

a main body located on the support structure by way of a mechanical connection with the support structure, the mechanical connection being adapted to enable rotation of the main body with respect to the support structure about an axis of rotation, the main body including a rotor device operable to generate power from a water current; and

at least one hydrodynamic thruster, separate to the rotor device and mounted on the main body, the or each hydrodynamic thruster being operable to exert a torque on the main body of the device, thereby to cause rotation of the main body about the axis of rotation.

According to another aspect of the present invention, there is provided a method of re-orientating a water current power generating device to face an oncoming water current flow, the water current generating device including at least one hydrodynamic thruster and a mechanical connection between its main body and its support structure allowing a degree of freedom about an axis of rotation, the method including:

waiting until the speed of the water current flow is sufficiently low that a hydrodynamic moment exerted by the water current flow on the main body of the water current generating device about the axis of rotation is less than the moment that can be exerted by the at least one hydrodynamic thruster on the main body about the axis of rotation; and

under such water current flow conditions, powering the or each thruster to provide sufficient net torque to re-orientate the main body of the water current generating device about the axis of rotation until it faces a new current flow direction.

The thruster(s) may be powered electrically, hydraulically or pneumatically. Power for the thruster(s) may provided from systems onboard the water current power generating device, from a separate sea or river bed mounted unit, or directly from the shore.

The thrusters would typically be used during periods when the flow was stationary or slow moving, thereby reducing the hydrodynamic forces acting on the main body of the water current generating device due to the current flow. This would reduce the thrust requirement on the thrusters, which would be designed to overcome only bearing friction, inertia and, in certain cases, weight and buoyancy forces acting on the water current generating device.

In a preferred embodiment, the water current power generating device employs a horizontal axis rotor.

In a preferred embodiment, the main body of the water current power generating device is attached to the support structure by a single vertical axis yaw bearing.

In a preferred embodiment, more than one thruster is used, being mounted either side of the yaw bearing to generate a yaw moment whilst creating a minimal net sideforce.

In a preferred embodiment, the thrusters employed are of the bow and stern thruster type, as used on ships or submarines.

In a preferred embodiment, a separate means of locking and releasing the main body of the water current generating device in the new orientation is provided. This locking device is released whenever the thrusters are being used to re-orientate the turbine, then the locking device is re-engaged to hold the turbine in the new orientation.

In a preferred embodiment, mechanical position stops are included in order to ensure that the turbine is re-orientated to the desired angle without the need for accurate feedback control of orientation.

Advantages of the invention

The principle advantages of the invention are:

- The main body of the water current power generating device can always generate power upstream of its support foundation, minimising the influence of the turbulent wake of the support structure on the main rotor.
- The main body of the water current power generating device can be attached to its foundation in a robust manner using a high structural integrity rotational bearing. This improves the survivability of the power generating device.
- A thruster positioned at the end of the main body of the water current power generating device has a much greater moment arm than a mechanical yaw drive acting on the much reduced radius of the rotational bearing. Less reaction force is therefore required to provide a given net torque about the axis of rotation compared to a mechanical yaw drive.
- The potential problems of debris entrapment in an open geared or friction mechanical yaw drive are overcome by this invention.

- The hydrodynamic thrusters are compact. The concept of aerodynamic yaw thrusters would not be practical for use on a wind turbine for example, due to the low density of air compared to water.

BRIEF DESCRIPTION OF THE DRAWINGS

Different versions of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a side elevation of a device embodying the present invention;

Figure 2 is a side elevation of another device embodying the present invention;

Figure 3 is a front elevation of another device embodying the present invention;

Figure 4 is a side elevation of another device embodying the present invention;

Figure 5 is a side elevation of another device embodying the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to Figure 1, a horizontal axis rotor 5 is mounted on the end of a main body 3 of a water current power generating device. The main body is attached to a fixed support structure 1 by a vertical axis yaw bearing 2. Current flows horizontally across the page from left to right or right to left. When a hydrodynamic thruster 4 is powered, the main body rotates in a horizontal plane about the yaw bearing to face the desired direction.

Referring to Figure 2, the horizontal axis rotor 5 is mounted on the end of the main body 3 of the water current power generating device. The main body is attached to the fixed support structure 1 by a horizontal axis pitch bearing 2. The current flows horizontally across the page from left to right or right to left. When the hydrodynamic thruster 4 is powered, the main body rotates in a vertical plane about the pitch bearing to face the opposite direction. This arrangement only provides a +/- 180 deg change in orientation of the device. The thruster is sufficiently powerful to overcome any weight or buoyancy moments acting on the main body + rotor about the axis of rotation.

Referring to Figure 3, the horizontal axis rotor 5 is mounted within an annular housing which forms the main body 3 of the water current power generating

device. The main body is attached to the fixed support structure 1 by two horizontal axis pitch bearings 2. The current flows into and out of the page. When the hydrodynamic thrusters 4 are powered, the main body rotates in a vertical plane about the pitch bearing to face the opposite direction. This arrangement only provides a +/- 180 deg change in device orientation.

Referring to Figure 4, the horizontal axis rotor 5 is mounted on the end of the main body 3 of the water current power generating device. The main body is attached to the fixed support structure 1 by a vertical axis yaw bearing 2. The current flows horizontally across the page from left to right or right to left. When the hydrodynamic thrusters 4 are powered, the main body rotates in a horizontal plane about the yaw bearing to face the desired direction. In this arrangement the two thrusters can be arranged to provide a pure yaw moment about the yaw bearing with no set sideforce.

Referring to Figure 5, the horizontal axis rotor 5 is mounted on the end of the main body 3 of the water current power generating device. The main body is attached to the fixed support structure 1 by a vertical axis yaw bearing 2. The current flows horizontally across the page from left to right or right to left. When the hydrodynamic thrusters 4 are powered, the main body rotates in a horizontal plane about the yaw bearing to face the desired direction. In this arrangement the three thrusters can be arranged not only to provide a pure yaw moment on the main body of the water current turbine, but also to control its orientation in the water when disconnected from the support structure during maintenance retrieval operations.

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgement of any form of suggestion that such prior art forms part of the common general knowledge.

It will be understood that the term "comprise" and any of its derivatives (eg. comprises, comprising) as used in this specification is to be taken to be inclusive of features to which it refers, and is not meant to exclude the presence of any additional features unless otherwise stated or implied.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A water current power generating device including:

a support structure which is located on, and affixed to, a bed of a body of water;

a main body located on the support structure by way of a mechanical connection with the support structure, the mechanical connection being adapted to enable rotation of the main body with respect to the support structure about an axis of rotation, the main body including a rotor device operable to generate power from a water current; and

at least one hydrodynamic thruster, separate to the rotor device and mounted on the main body, the or each hydrodynamic thruster being operable to exert a torque on the main body of the device, thereby to cause rotation of the main body about the axis of rotation.

2. A device as claimed in claim 1, wherein the mechanical connection between the main body and the support structure is a rotational bearing.

3. A device as claimed in claim 1 or 2, wherein a source of power for the or each hydrodynamic thruster is provided from a device located in a location chosen from one or more of: onboard the water current generating device, a surface vessel, a separate sea or river bed mounted unit, and directly from the shore.

4. A device as claimed in any one of the preceding claims, further including position stops for control of a final orientation of the main body relative to the support structure.

5. A device as claimed in any one of the preceding claims, further including a clamp device operable to clamp or mechanically lock the main body relative to the support structure, after the main body has been re-orientated.

6. A device for re-orientating a water current generating device substantially as hereinbefore described with reference to accompanying drawings.

7. A method of re-orientating a water current generating device to face an oncoming water current flow, the water current generating device including at least one hydrodynamic thruster and a mechanical connection between its main body and its support structure allowing a degree of freedom about an axis of rotation, the method including:

waiting until the speed of the water current flow is sufficiently low that a hydrodynamic moment exerted by the water current flow on the main body of the water current generating device about the axis of rotation is less than the moment that can be

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exerted by the at least one hydrodynamic thruster on the main body about the axis of rotation; and

under such water current flow conditions, powering the or each thruster to provide sufficient net torque to re-orientate the main body of the water current generating device about the axis of rotation until it faces a new current flow direction.

8. A method as claimed in claim 7, further including:

powering the or each thruster in a direction of rotation until the main body of the water current generating device reaches a position stop which prevents further movement in that direction.

9. A method as claimed in claim 7 or 8, further including:

clamping or mechanically locking the main body of the water current generating device relative to its support structure after the re-orientation is complete for the purposes of maintaining a constant orientation whilst generating electricity; and

releasing or mechanically unlocking the main body of the water current generating device again to effect subsequent further changes in its orientation.

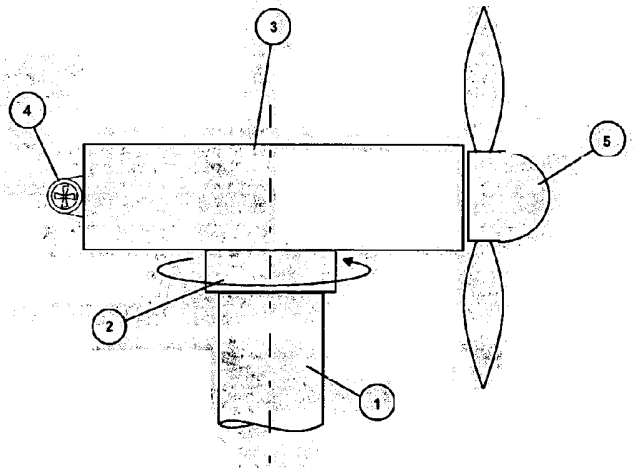

Figure 1

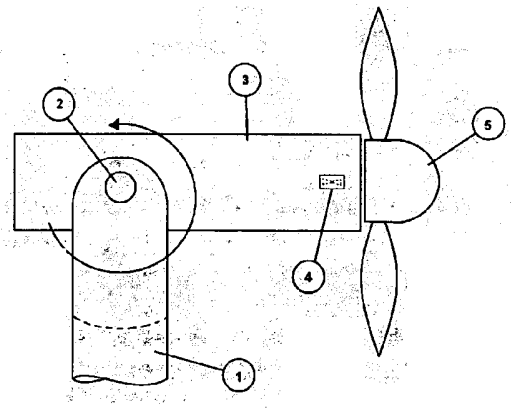

Figure 2

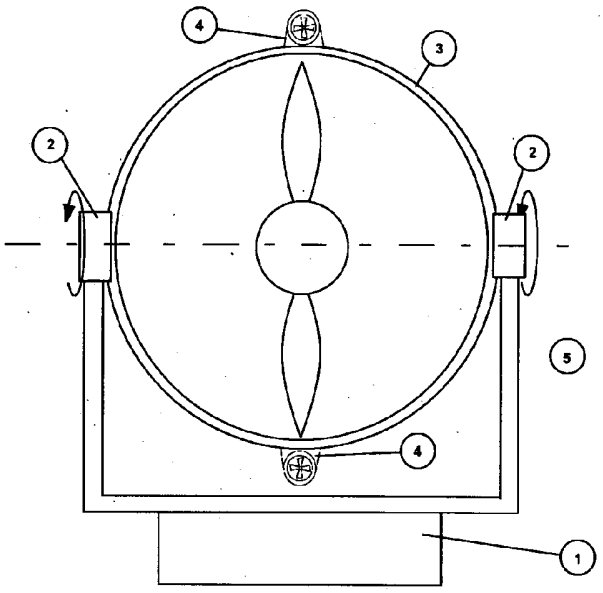

Figure 3

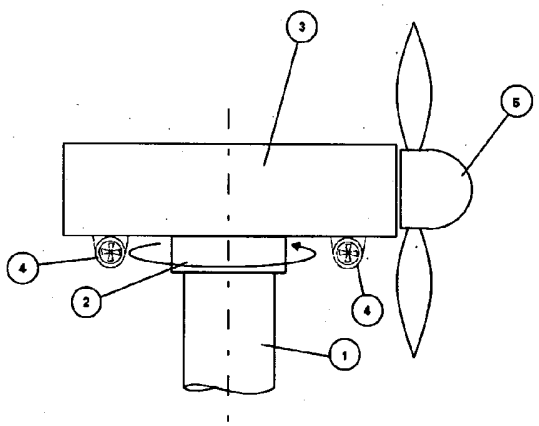

Figure 4

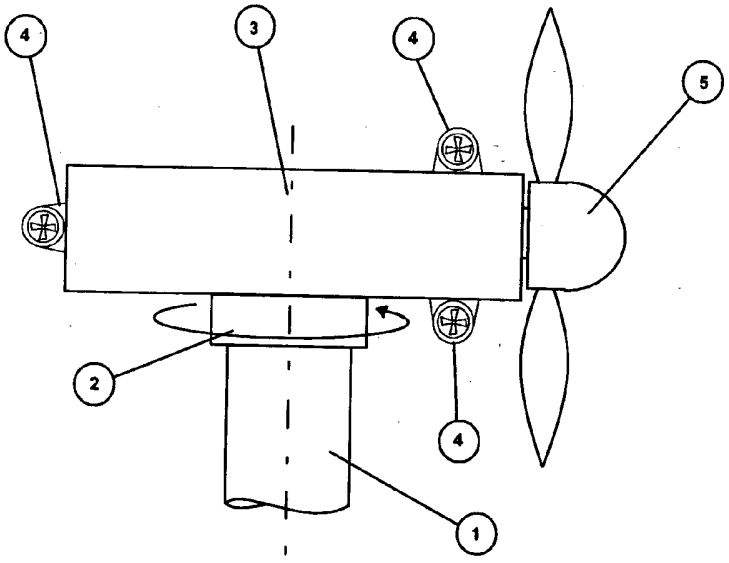

Figure 5