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GB 2587316 B

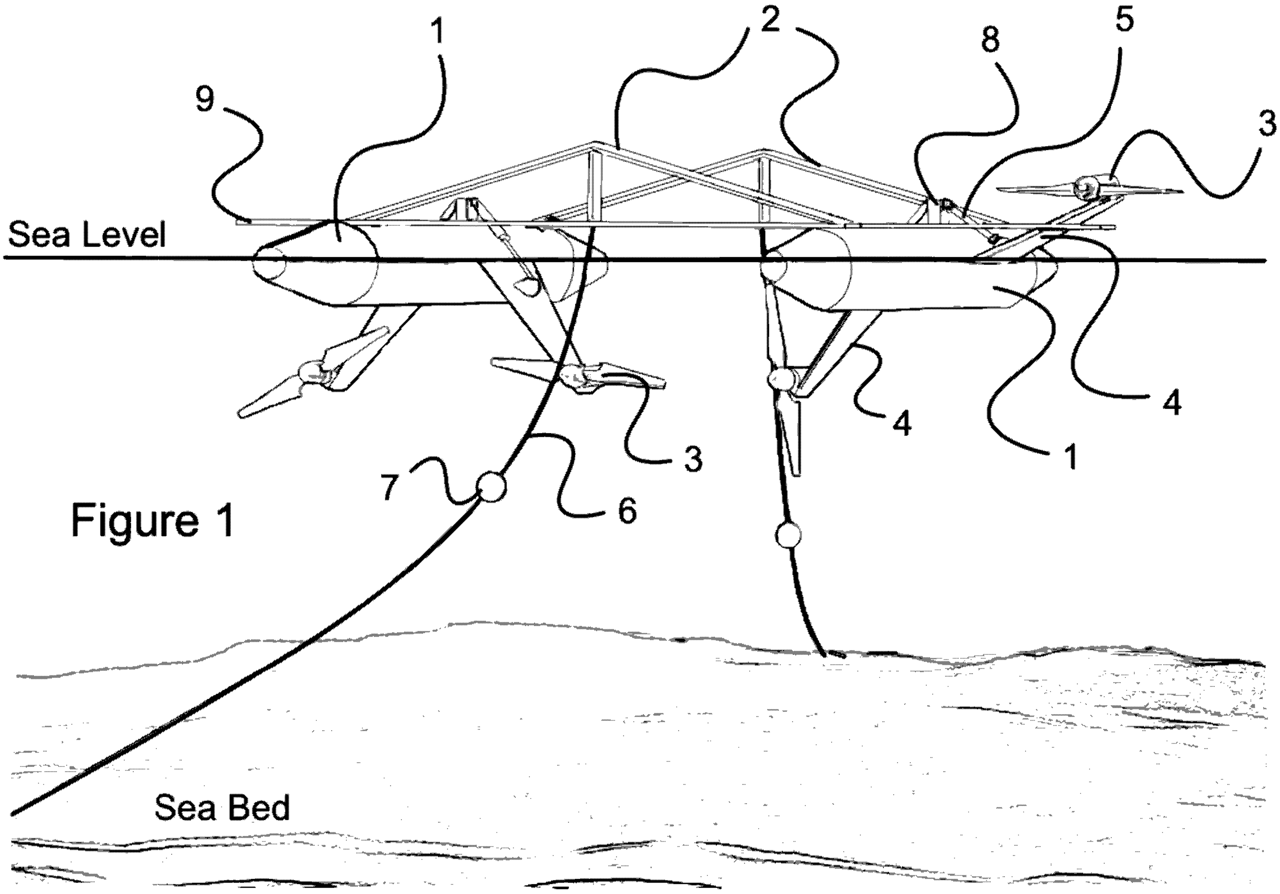

Figure 1

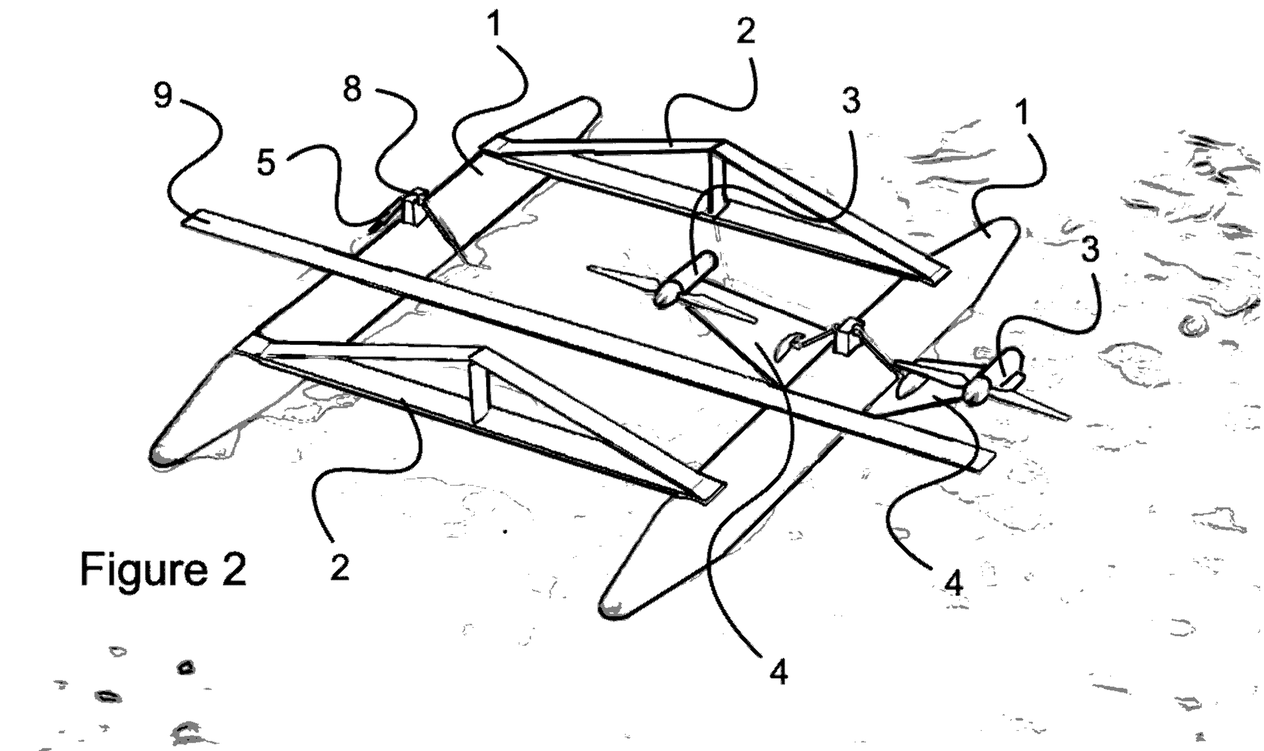

Figure 2

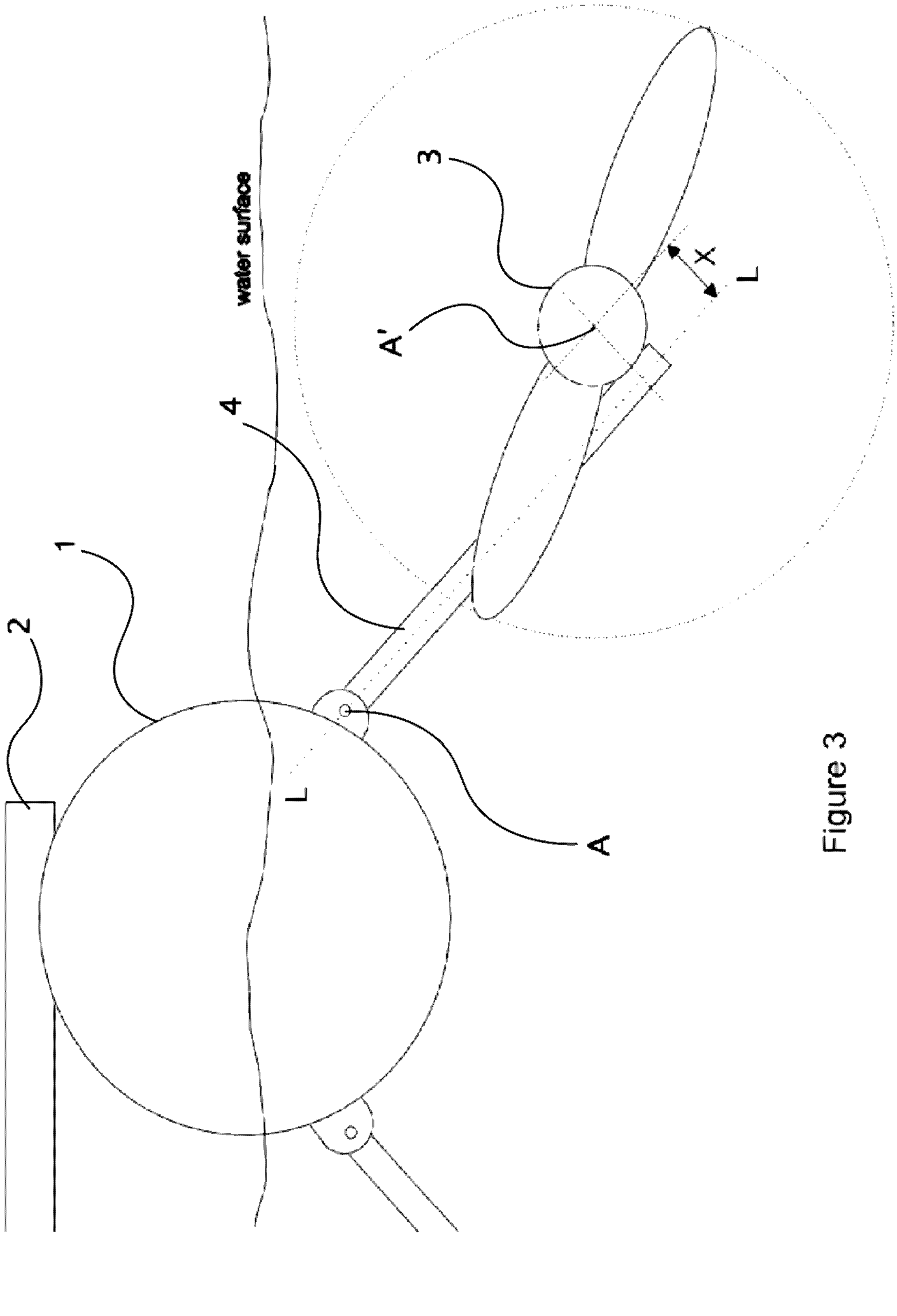

Figure 3

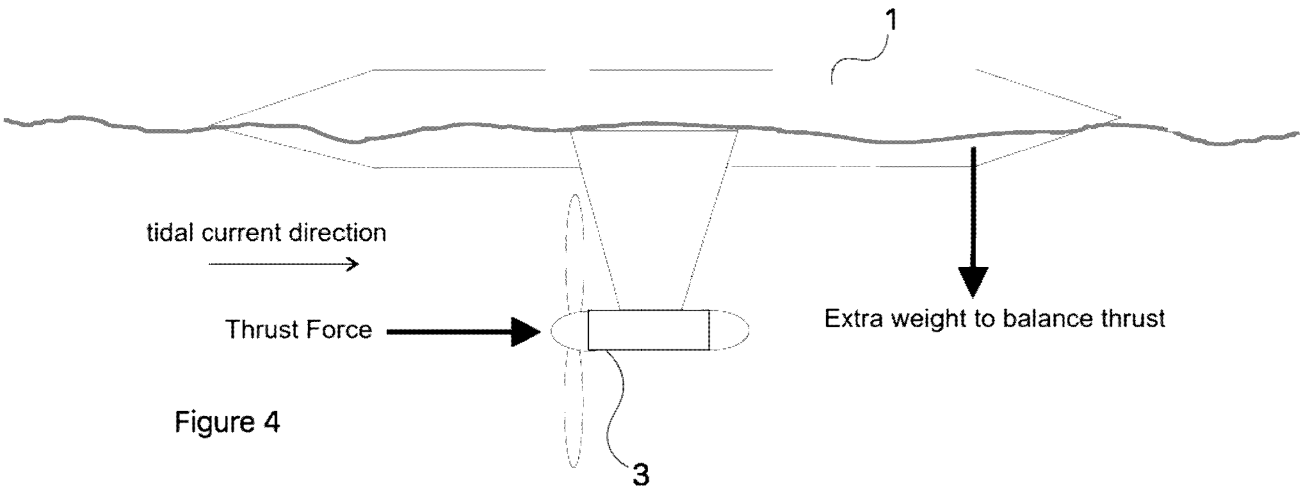

Figure 4

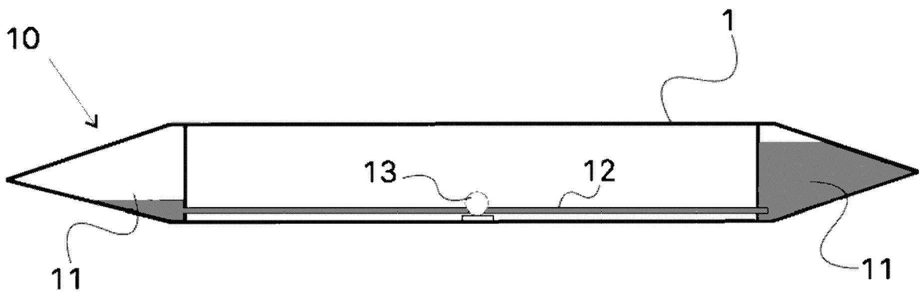

Figure 5

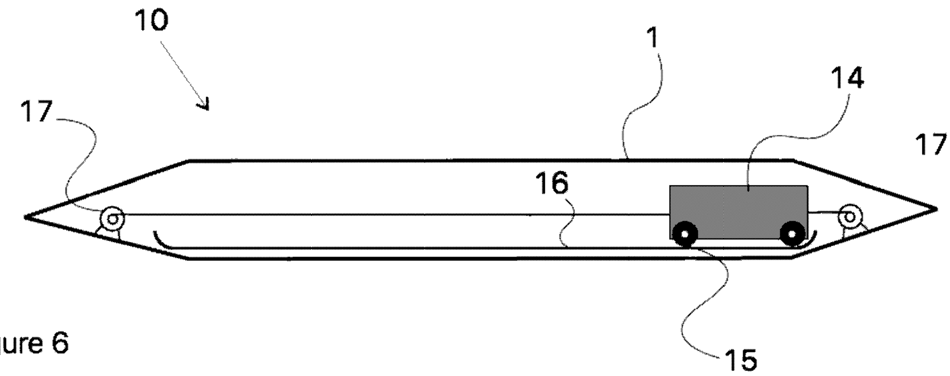

Figure 6

Floating Apparatus for Extracting Energy from Fluid Currents

This invention relates to apparatus capable of interacting with a flow of water, in such a manner as to transfer energy from the fluid to a mechanically driven device. This invention relates more particularly to turbines or other such devices arranged to be driven by the action of a flow of water and capable of extracting kinetic energy from water currents flowing naturally in the seas, estuaries or rivers for the purposes of utilising such energy to produce either electricity, shaft power or for pumping water or transporting other liquids or gases for a required useful purpose.

It is known how to use turbines and rotating machinery for the purpose of extracting energy from flowing water currents. Such constructions pertaining to water drivable turbines where one or preferably two or more rotors may be arranged such that they are supported on a fixed structure embedded in, or carried on a foundation set in the sea, river or estuary bed.

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It should be noted that water drivable devices will generally be axial flow (propeller-like) rotors or possibly cross flow (sometimes known as Darrieus) rotors capable of being propelled by large lift forces and small drag forces in order to achieve a high level of efficiency of kinetic energy conversion. However any mechanism capable of extracting energy from flowing water may in principle be applied through the use of this invention.

Water drivable devices will necessarily be connected mechanically, hydraulically or pneumatically to a power train capable of absorbing the available energy from the relatively slow rotational speed of the device in response to relatively slow moving but forceful water movements and converting it to a more usable form such as electricity or pressurised fluid which may be readily transferred by way of cables or pipes (respectively) to a point of application to be usefully exploited. The power train may typically consist of a geared speed increaser coupled to an electrical generator or to a hydraulic pump or in some cases the rotor may be directly coupled without recourse to a mechanical speed-increaser to a specially designed and matched slow-speed generator or pump.

Tidal turbine development appears to have slowed down in recent years. Thus far, there are a number of prototypes being tried and tested, all sized at around 1MW, (the SeaGen turbine of Marine Current Turbines Limited being the only one so far to consistently exceed 1MW and then only by a small amount). There is not a single array of turbines operating commercially, although one is planned. The existing technology appears to be too expensive to be able to generate at a commercially competitive cost compared, for example, with offshore wind turbines, and it seems likely that this is inhibiting investment in this new, otherwise promising tidal technology. Tidal turbines, unlike wind turbines, can of course deliver electricity to a predictable timetable and potentially they should become smaller and therefore less costly than equivalent rated power wind turbines, but their advantages will never be realised unless they can become cost-competitive with wind turbines.

The wind industry has found that it is not commercially viable to deploy wind turbines rated at much less than 3MW, especially offshore. This is because the high fixed overhead costs (i.e. costs that are independent of the rated power) make small systems disproportionately costly. Indeed, the offshore wind industry favours wind turbines of at least 5MW.

Tidal turbines share not only similar physical principles to wind turbines, other than using sea water rather than air as their working fluid, but also share similar project costs, especially the fixed overhead costs such as site survey work, environmental impact studies, consenting, offshore project management, connection costs, mobilisation of installation vessels and of course similar operations and maintenance requirements and costs. Therefore, it seems hardly surprising that 1MW (or even 2MW) tidal turbines have much higher costs of generation than competing 5 to 8MW wind turbines where the energy capture is 5 to 8 times greater and therefore fixed overhead costs are spread 5 to 8 times more thinly.

According to a first aspect of the present invention, there is provided apparatus comprising at least one surface floating hull device, a plurality of water-drivable devices connected to the at least one surface floating hull device by respective hinged struts whereby each water-drivable device is moveable independently between a first, submerged, position and a second, non-submerged, position on either side of the hull device and arranged to be stopped at an oblique angle to the horizontal, wherein an axis of rotation of each hinged strut, about which each water-drivable device is moveable between the first and second positions, is substantially horizontal and substantially aligned with a direction of flow of water, and the hull device includes stabilizing means comprising a mass transfer device for transferring a mass from one position of the hull to another position of the hull.

According to a second aspect of the invention, there is provided a method of stabilizing a surface floating hull device having a plurality of water-drivable devices connected thereto by way of respective hinged struts, each water-drivable device being moveable independently between a first, submerged, position and a second, non-submerged, position on either side of the hull device and arranged to be stopped at an oblique angle to the horizontal, wherein an axis of rotation of each hinged strut about which each water-drivable device is moveable between the first and second positions is substantially horizontal and substantially aligned with a direction of flow of water, and transferring a mass from one position of the hull device to another position of the hull device by way of a mass transfer device thereby balancing buoyancy of the hull device against the direction and force of a fluid flow acting upon the hull device.

Owing to these two aspects, it is possible to provide a stable floating water drivable system.

Advantageously, the water-drivable device is hingedly mounted to hull device for pivotal movement about a hinge axis from a first position to a second position, the hinge axis being substantially horizontal and substantially aligned with a water flow. In addition, the water-drivable device is arranged to pivot between the first position which is submerged and the second position which is a raised non-submerged position. In this way, the apparatus is relatively easily deployable and maintainable.

Preferably, the water-drivable device is mounted to the respective hinged strut, wherein an axis of rotation of the water-drivable device is offset from a longitudinal axis of the hinged strut. In this way, there will, owing to the offset, be less interference from the effect of the rotor blade cutting through the strut wake flow because the rotor blade axis never aligns with the strut axis but cuts across it at an angle.

The floating hull device needs to be moored to anchor points so as to engage with the ground over which the water flows (i.e. the sea, the estuary or a river bed), such that the moorings can resist the strong reaction forces resulting from the extraction of kinetic energy from the flow together with additional environmental loads caused by turbulence in the water, waves or wind, for example. In other words, means must be provided to ensure the structure cannot move significantly under even the most severe loads caused by either the reactions from operating the power system, or from extreme storm conditions that may occur from time to time in most offshore locations.

In another preferred embodiment, there are a plurality of floating hull devices connected together by a support structure framework, each floating hull device, of which there are preferably two, comprising a plurality of water-drivable devices.

Even greater economies of scale are possible by mooring an array of the aforementioned apparatus and, in some cases as will be explained, they may be linked so as to span the width of a fast-moving current.

The apparatus preferably comprises a catamaran (or possibly also a trimaran) barge with two (or three) floating hull devices or pontoons linked by an above-water framework of struts, beams or other such structural components bridging the space between the pontoons. The structural framework is designed so as to link the pontoons and ensure they are maintained substantially parallelly and level with each other. It could be possible to use underwater structural links, but generally there is a need to minimize the drag of the barge so that underwater structural components spanning the gap between the hulls are to be avoided if possible.

The above-water structure bridging the gap between the hull devices can also carry deck structures aligned such that when the rotors are in the raised position, personnel may readily gain access to facilitate rapid and safe maintenance and repair operations.

The preferred embodiment includes a twin-hulled catamaran barge. Each hull device carries a pair of turbine rotors and their power trains, each mounted on a streamlined strut aligned with the water flow direction and hinged to the respective hull device from a substantially horizontal hinge axis such that when the strut is inclined downwards the entire rotor is in the submerged position in the flowing water current and to one side and below the hull device. The struts carrying the rotors will generally, but not necessarily, be symmetrically arranged on each side of the respective hull device approximately “amidships”; i.e. half way along the length of the hull device. The hinged mounting may be any appropriate mechanism to permit the strut in the form of a large flat wing-like member to have a hinged attachment to a fixed structure such as the hull devices, for example trunnions set into sockets, plummer block type bearings (attached to the hull device with a shaft through them attached to the strut or vice-versa) or an actual hinge.

Means will be provided to raise the struts and their attached rotors and power trains from the lower submerged position to the raised non-submerged position above the water level, by lifting them such that they pivot about the substantially horizontal hinge axis and can be raised so that the rotors and power trains are positioned entirely above the surface of the water. This process can of course be reversed to lower them into the operational submerged position. With an axial flow rotor this can be facilitated by using twin bladed rotors and arranging for the blades to come to rest substantially horizontally when clear of the water so that the distance they need to be raised can be minimized.

The methods for raising the struts can be for example through the use of hydraulic, pneumatic or electrical jacking mechanisms, or alternatively winches pulling cables or chains may be used or indeed any other suitable actuation device.

In the case where this apparatus is applied in a unidirectional flow, such as a river or ocean current it may be moored by attaching a mooring line to the centre of the support structure on the upstream side or paired mooring lines can be attached to the upstream (bow) end of each catamaran hull. The mooring lines may be cables, ropes, chains or rigid universally hinged struts which are attached to an anchor point upstream of the device. In most cases two or more parallel moorings will be preferred to ensure redundancy in the event of a line becoming damaged or worn. The anchor point may be an anchor such as those used for mooring ships, with flukes that engage with the ground, a heavy weight such that the frictional drag of the weight exceeds the thrust forces produced by the drag of the rotors and the device, or more probably a pile drilled and usually grouted into a socket in the bed of the river, the sea or the ocean. The pile can be immersed or may extend above the surface to provide a visible mooring point. Clump weights may be added to the mooring lines to prevent said moorings going slack and then snatching under the influence of turbulence or other varying loads.

In the case of tidal turbines, where the apparatus is exposed to a bi-directional flow, then it requires to be moored to withstand drag in opposite directions during ebb tide and flood tide conditions. This requires two anchor points and two sets of moorings; one set to be upstream of the device during the ebb tide and the other upstream during the flood tide. In this case, only one mooring at a time, the upstream one, is tensioned and the other is slack. Clump weights may be used to maintain some tension in the unloaded slack mooring or alternatively, provision may be made on the deck structure spanning the catamaran hull devices to tension the moorings against each other using winches or similar mechanisms as a means for maintaining tight moorings even when the tide rises and falls. This is primarily to stabilize the positional accuracy of the apparatus and to ensure there is no possibility of entanglement of the mooring lines with the rotors during slack tide conditions.

If axial flow rotors are used it will generally be necessary to modify the rotor geometry to cope with reversing flows. Fixed geometry bi-directional rotors are being used in some cases on existing tidal turbines, but these invariably involve considerable loss of efficiency compared with rotor geometry properly optimized for flow direction (i.e. rounded leading edge, sharp trailing edge and some degree of camber for the rotor foil). Therefore, the preferred solution is either to pitch the rotor blades through 180 degrees every time the flow reverses, or to provide means for yawing the rotor about the hinged strut to which they are mounted. An alternative arrangement in bi-directional flows will be to attach the catamaran barge to a single point mooring so that it can swing around in its entirety when the current reverses. The single point mooring can be external and upstream of the catamaran barge or it could be a tall pile embedded in the sea, estuary or river bed that extends above water level and engages with a yaw bearing attached to said barge, so that the barge may yaw about the tall pile. Yawing could be passive by having the pivot point upstream of the centre of drag or it could be active using suitable servo actuators.

It is also possible to utilise cross-flow or Darrieus rotors. This type of rotor works equally well with the flow in either direction, so no method is needed for orientating them when the tide reverses. The added simplicity of this option has to be weighed against a loss of efficiency compared with axial flow rotors. The above-mentioned pitch-controllable axial flow rotors of the kind proposed for use with this invention can have their output modulated by varying their pitch and can even be stopped in full flow conditions whereas fixed pitch rotors and Darrieus rotors cannot be controlled in this way.

The stabilizing means of the hull device(s) are provided in order to stabilize the floating hull device(s). When there is a current driving the water-drivable device(s), this generates a large thrust force which will tend to make the supporting hull device pitch downwardly in the direction from which the current is approaching because the centre of buoyancy is much higher than the centre of thrust. The stabilizing means is arranged to counteract the asymmetric thrust force in order to keep the hull device reasonably level in the water.

The water-drivable device(s), hereafter referred to as “rotor(s)” are preferably but not necessarily axial flow pitch-controlled rotors, on a single floating support structure which has been devised to achieve a number of beneficial requirements; namely:

- to carry the rotors immersed in the flow but as near to the surface as possible so as to take advantage of the fastest moving water (which due to velocity shear effects is always near the surface)

- to carry rotors that can be individually as large as possible to benefit from economies of scale (there is an optimum size of rotor to maximize cost-effectiveness as diminishing returns eventually limit the maximum size)

- to carry two rotors per floating hull device to achieve the highest practicable power level which is necessary to maximize the energy capture and hence to minimize the fixed cost overheads in order to minimize energy costs

- to enable the rotors and all the mechanical and electrical components that are submerged when operational to be quickly, reliably and easily raised above the surface of the water to facilitate maintenance and repairs on site and at relatively low cost.

- to enable the entire floating system to be able to be towed to (and from) the operational location by relatively small low cost vessels such as tugs as a result of the ability to raise the fluid drivable devices or rotors above the water level thereby reducing the draft of the vessel so as to avoid the very high installation costs prevalent with many of the seabed or riverbed mounted water current energy conversion devices presently under development which have to be transported to a site and installed rather than being able to be simply towed to the site and anchored.

- to include a relatively low cost mooring and anchoring system capable of being installed quickly and easily from a relatively low cost installation barge.

In order that the present invention can be clearly and completely disclosed, reference will now be made, by way of example only, to the accompanying drawings, in which:-

Figure 1 illustrates a floating apparatus for extracting energy from water in a perspective view sectioned at the water level so that both the above water and the below water arrangements are made visible,
Figure 2 is an aerial perspective view looking down onto the apparatus of Figure 1 showing it with two rotors raised above sea level and visible and the other two are deployed in a submerged position,
Figure 3 is a schematic end elevation of part of the apparatus,
Figure 4 is a schematic side elevation of part of the apparatus of Figure 1,
Figure 5 is a sectional view of one version of a mass transfer device, and
Figure 6 is a view similar to Figure 5, but of a second version of the mass transfer device.

Referring to the Figures, a floating apparatus for extracting energy from water currents comprises first and second floating pontoon hulls 1 connected by a bridge-like framework support structure 2. The shape and form of the hulls 1 and the support structure 2 is shown by way of example as variations in the shape, proportions and structural arrangements may be made. In fact, it will be important to minimize drag so as to economise with moorings and the cost of installation, and for this reason it may be preferable to utilize modern bow designs such as the “X-Bow” and to vary the hull aspect ratio (water level length to beam ratio). An alternative embodiment which may be beneficial would be a so-called “SWATH hull” (Small Water Plane Area Twin Hull) form where the two hulls 1 are completely submerged with a relatively slender vertical member above each hull carrying the superstructure spanning the two hulls 1. Such hulls have potentially low drag compared with conventional hulls, which are at their maximum width on the water line. There are also considerations of optimizing the hull length in relation to the lateral spacing to minimize drag.

Each hull 1 carries a pair of rotors or turbines 3, which in the example shown are illustrated as two-bladed axial flow (propeller) type turbines, although other types of turbine may be applied. The turbines 3 are mounted at outer end regions of hinged, streamlined wing-like struts 4, which are hingedly attached at their inner end regions to the pontoon hulls 1. The hinge attachment may be at the water line, but may also be below or above the water line with variations of the invention. The axis A of the hinge is substantially horizontal and substantially aligned with the flow of water or current. In Figure 1, three of the turbines 3 are shown operationally deployed in a first, lowered submerged position with its blades rotating whereas the turbine 3 on the extreme right-hand side is shown in a second, raised non-submerged position with the turbine 3 out of the water and with its blades 'parked' as it would be when being maintained or repaired or while the apparatus is being towed to or from the operational site.

Means are provided for actuating the raising or lowering of the struts 4 and in the Figures a hydraulic ram 5 is shown reacting against a pillar 8 built into the top of the pontoon hull 1. Other means including pneumatic or electrical actuators or the use of winches can be applied for this purpose.

The raising and lowering of the turbines 3 facilitates towing of the apparatus on deployment or recovery. With the turbines 3 raised, the apparatus becomes a vessel with a relatively shallow draft, preferably only about 4m. It also allows access to the turbines whilst at sea for routine maintenance and/or repairs. The large majority of faults that cause a shut-down and loss of availability tend to be minor, so the ability to fix most faults at sea without a need to recover the entire apparatus to shore will greatly reduce operation and maintenance costs and improve the availability compared with the submerged systems that have mainly been developed so far. In addition, if each turbine 3 has independent power electronics, which is the preferred arrangement, then a faulty system can be shut-down and raised out of the water pending repairs while the other turbines 3 continue to operate. Therefore, a single fault will generally cause only a 25% reduction in output rather than 100% as with single turbine systems.

The Figures show an example of the apparatus intended for use in bidirectional currents such as tidal flows. Therefore, there is a double catenary mooring 6 arranged so that the upstream mooring (on the left Figure 1) is tensioned and the down stream one is slack. Clump weights 7 are illustrated as a means to keep the moorings 6 sufficiently tensioned to prevent them getting caught in the rotors at slack tide.

The tension in the mooring system may be measured by sensors so that if the mooring tension exceeds some predetermined and allowable value owing to, for example, unusually high currents, or flotsam catching on the floating structure, then the turbines can be automatically stopped and raised from the water to minimize drag and a corresponding signal sent to the management ashore.

Anchors are deployed upstream and downstream of the device (not illustrated) to provide means to attach the moorings 6 and prevent the apparatus from being moved away by the current. In a uni-directional current, such as in a river or some ocean currents, then as outlined previously, only one mooring will of course be necessary. A number of different methods of mooring the device may be used and have not been illustrated; for example tensioned moorings, a spread of multiple moorings, or a rigid strut mooring. The anchor points also can be provided in different forms, such as a conventional ship type anchor, a massive gravity foundation relying on friction to hold the device in place or piles driven or drilled into the sea or river bed. If the shore is nearby then the apparatus may alternatively be attached to one or more onshore anchor points.

Referring specifically to Figure 2, both turbines 3 on the right-hand pontoon 1 (as viewed) are shown in the raised non-submerged position out of the water and both turbines on the left hand pontoon 1 are in the submerged position. The hydraulic ram 5 and pillar 8 lifting arrangement can be more clearly seen. An access deck 9 is also shown spanning the two pontoon hulls 1 and extending outwardly to near the outermost extremity of the rotor blades. This allows easy access for maintenance personnel boarding the apparatus and, in practice, will likely have safety railings around it. The deck 9 can also to accommodate power electronics, control systems, transformers, spare-parts, tools, etc., in order to facilitate easy maintenance. In addition, when the rotors are submerged, this access deck 9 extends to their outermost limits to prevent deep draft vessels coming close enough to make contact with the moving rotors. This should make it more readily acceptable to have the rotors located as near to the surface of the water as possible since it mitigates the risk of damaging other vessels.

The preference is to use two-bladed turbines as the blades can be parked substantially horizontally when raised out of the water in the non-submerged position which reduces the height they need to be raised compared, for example, with a three-bladed rotor. In order to minimise the overall width of the apparatus, i.e. spacing between the hulls 1, the struts 4 carrying the turbines 3 are stopped from being raised to a horizontal position but are instead raised to an oblique angle to the horizontal, for example about 30 degrees from horizontal, if they require raising at the same time, so that when the inner pair of turbines 3 between adjoined hulls 1 on a catamaran or multi-maran arrangement are raised, their adjacent blades do not clash. This is because the centre of rotation or shaft of each turbine 3 moves through an arc when being raised such that they move closer together than when they are deployed in the submerged position. An alternative solution is to have the blades in spaced apart substantially vertical planes, so that, for example, the blades of one turbine 3 are arranged to rotate in one substantially vertical plane a suitable distance from the blades of another turbine 3. Thus, when raising the inner turbines 3, their blades will pass each other without clashing, even if parked substantially horizontally.

As previously mentioned, when there is a current driving the turbines 3 this generates a large thrust force which will tend to make the supporting pontoon pitch downwardly in the direction from which the current is approaching owing to the centre of buoyancy being much higher than the centre of thrust. A stabilizing means 10 to counteract the asymmetric thrust force, in order to keep the pontoon hull 1 approximately level in the water, is provided by a mass transfer device 11 to transfer sufficient weight at end region of the pontoon hull 1 to the other end region to counteract the thrust force. During operation, the stabilizing means 10 compensate for this pitching movement which seriously hampers the efficiency of the turbines 3.

The stabilizing means 10 can be in the form of ballast tanks 11 fore and aft of the hulls 1 and a transfer pipe 12 connecting the tanks 12 at each end of the pontoon hull 1, as shown in Figure 5. A pump 13 connected to the pipe 12 is also provided and is capable of moving a liquid, advantageously water, from one tank 12 to the other when the tide changes direction to accommodate the change in direction of the pitching force. Automatic controls can be provided to activate the pump 13 either from a sensor device that detects the direction of the current or by having strain sensors that can respond to thrust loads.

In bi-directional tidal flows, “fore and aft” will swap around when the tide flow direction changes so that fore and aft regions of the hull 1 are relative to the direction of the current flow – fore meaning the first end which the current is approaching.

Alternatively, the stabilizing means 10 can be in the form of a heavy weight 14 with rollers which run on a track 16 internally or externally of the hull 1 which gets positioned when the tide changes, as shown in Figure 6. In this version, a dense heavy weight 14, possibly fabricated from steel or some other dense material, is mounted on a wheeled chassis 15 or trolley which can run on the track 16. The wheeled trolley 15 will preferably be positioned by being pulled by a winch device 17 connected to it by way of a cable 18 or the like. Two winches 17 are provided, one at each end region of the hull 1, in order that the trolley 15 with the weight 14 can moved from one position to another. The weight 14 could alternatively be mounted externally on top of the pontoon hull 1 rather than inside it.

The same effect may be provided by hanging the dense weight 14 from a rail set along the inside top surface of the hull 1, that is the ceiling within the hull.

As with the stabilizing means 10 shown in Figure 5, the weight system of Figure 6 may be controlled by sensors that can detect the pitch angle of the hulls or change in direction or force of the current.

Referring specifically to Figure 3, the pontoon hull 1 (of circular cross-section in this example) has the attached turbine 3 immersed in its operational position. The substantially horizontal hinging axis A is substantially parallel with the water surface and, as shown in this example, is a small distance below the water surface. However, in some instances the axis A may be substantially at or be a small distance above the water surface. The strut 4 is thin in the direction of flow in order to minimize its drag, but nevertheless will naturally produce a strut wake caused by the flow of surrounding water around the strut 4. Attached to an upper surface of the outer end region of the strut 4 is the turbine 3 with its central axis of rotation A' of the rotor blades being offset from the longitudinal axis L of the strut 4 by a small distance X.

As a result, the central axis A' does not align with the longitudinal axis of the strut 4, which would otherwise happen if there was no offset distance X.

Owing to this offset, when the flow is, for example, bi-directional as in a tidal environment, and when the flow approaches from upstream of the strut 4 (i.e. in Figure 3 from the direction towards the viewer) then the flow wake of the strut 4 will not align with the blades of the turbine 3 and, in effect, the blades “scissor” through the strut wake in such a way that only part of the blades, rather than their whole radial length, are in contact with the strut wake at any moment in time. As a result, there will be less interference from the effect of the blades cutting through the strut wake which will be beneficial in terms of helping the turbines 3 be more efficient and in terms of minimizing vibration.

The offset X as shown may alternatively be on the lower (opposite) surface of the strut 4, as the same principle will apply.

A possible issue when the rotors are in the raised non-submerged position out of the water is that displacement buoyancy is reduced and the topside weight is increased which will cause the respective pontoon hull 1 to sink lower into the water. In most cases there will be sufficient surplus hull buoyancy to make the lower freeboard (that is the distance from the waterline to the upper deck level) unimportant. By way of the stabilizing means 10, it is possible to maintain the freeboard dynamically to balance the buoyancy.

A twin-hulled configuration, such as that shown in Figures 1 and 2, seems the most practical option. However multiple twin hulled apparatus as illustrated could be moored side-by-side across the current and the access decks 9 could be connected by walkways to permit personnel to walk from one apparatus to the next. A closely coupled array of moored turbines could cause hydrodynamic blockage of the current, which could also considerably enhance the energy capture.

The stabilizing means 10 are applicable to many forms of floating tidal turbine whether a mono-hull, catamaran or multi-maran. It may also be installed within a floating wind turbine as a means for counteracting the leaning effect caused by wind thrust.

The floating apparatus of the Figures would have sufficient stability and resistance to overturning in order to permit a wind turbine to be installed on the structure to enhance the energy capture at relatively marginal extra cost. In such a case, a mooring spread may be needed to cater for lateral thrusts from the wind turbine.

The export of power generated by the turbines 3 is by way of a flexible marine cable.

The primary advantage of the preferred embodiment is that it conveniently enables four rotors to be used on a single apparatus, which makes it potentially twice as powerful as the largest tidal turbines hitherto demonstrated, the largest of which can only deploy two rotors. Another major advantage is the low cost of access and of removing to shore and replacing the entire apparatus compared to most existing technologies. Finally, the weight of material required in relation to the rotor swept area is potentially lower than for virtually all other tidal turbines so far demonstrated and hence there is a greater power/energy capture capability per unit of weight, which implies improved cost-effectiveness.

Two further advantages of a floating apparatus of the kind herein described are, firstly, that the rotors can be located near the surface. Since the system is visible to shipping, having the rotor submerged to a depth of about 3m from the rotor top is usually considered acceptable, which allows something like 20% more energy to be captured than would be available from a similarly sized rotor located about 10m below the surface as is generally considered necessary for systems that are completely submerged and out of sight. Secondly, the apparatus can be moved at relatively low cost if the positioning proves to be less than optimal. Since energy capture is a function of the cube of the velocity, any positioning error resulting in less velocity than expected can cause a considerable loss of energy; eg. a 10% lower velocity results in a 30% lower level of energy capture and hence of revenue. Thus, being able to move the apparatus at relatively low cost could make the difference between financial success and failure.

CLAIMS

1. Apparatus comprising at least one surface floating hull device, a plurality of water-drivable devices connected to the at least one surface floating hull device by respective hinged struts whereby each water-drivable device is moveable independently between a first, submerged, position and a second, non-submerged, position on either side of the hull device and arranged to be stopped at an oblique angle to the horizontal, wherein an axis of rotation of each hinged strut, about which each water-drivable device is moveable between the first and second positions, is substantially horizontal and substantially aligned with a direction of flow of water, and the hull device includes stabilizing means comprising a mass transfer device for transferring a mass from one position of the hull to another position of the hull.

2. Apparatus according to claim 1, and further comprising a second surface floating hull device having a plurality of water-drivable devices connected thereto.

3. Apparatus according to claim 1 or 2, wherein an axis of rotation of the water-drivable device is offset from a longitudinal axis of the respective hinged strut.

4. Apparatus according to claim 3 as appended to claim 2, wherein the water drivable devices include rotatable blades and wherein the blades of respective water-drivable devices lie in spaced apart substantially vertical planes.

5. Apparatus according to any preceding claim, wherein the stabilizing means comprises ballast tanks at fore and aft regions of the hull device, a transfer pipe connecting the ballast tanks and a pump device connected to the transfer pipe.

6. Apparatus according to any one of claims 1 to 4, wherein the stabilizing means comprises a heavy weight with rollers for running on a track extending between fore and aft regions of the hull device.

7. Apparatus according to claim 6, wherein the stabilizing means can be located internally or externally of the hull device.

8. Apparatus according to claim 5 or any one of claims 6 or 7, wherein the stabilizing means are controlled by one or more sensors that can detect the change in pitch angle and/or direction and/or force of a water flow acting upon the hull device.

9. Apparatus according to any preceding claim, and further comprising a double catenary mooring.

10. Apparatus according to claim 9, and further comprsing clump weights attached to the double catenary mooring.

11. A method of stabilizing a surface floating hull device having a plurality of water-drivable devices connected thereto by way of respective hinged struts, each water-drivable device being moveable independently between a first, submerged, position and a second, non-submerged, position on either side of the hull device and arranged to be stopped at an oblique angle to the horizontal, wherein an axis of rotation of each hinged strut about which each water-drivable device is moveable between the first and second positions is substantially horizontal and substantially aligned with a direction of flow of water, and transferring a mass from one position of the hull device to another position of the hull device by way of a mass transfer device thereby balancing buoyancy of the hull device against the direction and force of a fluid flow acting upon the hull device.

12. A method according to claim 11, wherein the stabilizing comprises pumping along a transfer pipe a liquid between ballast tanks at fore and aft regions of the hull device relative to the direction of the fluid flow.

13. A method according to claim 11, wherein the stabilizing comprises moving a heavy weight with rollers along a track between fore and aft regions of the hull device.

14. A method according to any one of claims 11 to 13, and further comprising controlling the stabilizing means by one or more sensors that detect the change in direction and/or force of the fluid flow acting upon the hull device.

15. A method according to any one of claims 11 to 14, and further comprising a second surface floating hull device and respective hinged struts by way of which further respective water-drivable devices are hingedly mounted to

the second floating hull device, wherein the water-drivable devices include rotatable blades and wherein the blades of respective water-drivable devices lie in spaced apart substantially vertical planes.

16. A method according to any one of claims 11 to 15, wherein an axis of rotation of each water drivable device is off-set from a longitudinal axis of the respective hinged strut.