Marine power generation system

The present invention relates to marine systems, e.g. for generating power from flowing water. Some embodiments are surface-based, while others are underwater or submersible. In particular, some aspects relate to the installation, control, adjustment (e.g. of position and/or orientation) and maintenance of such assemblies, whether such assemblies are surface-based or submersible/underwater assemblies.

Turbine-based power generation systems can be submerged in order to extract power from flowing water. The water flow in a given location may be unidirectional, such as in a river, or bidirectional, for example where local flow is dominated by tidal effects. Alternatively, turbine-based power generation systems can be arranged to operate on the surface of a body of water. Much the same principles apply in either of these cases.

The invention is defined in the independent claim. Further embodiments of the invention are defined in the dependent claims.

According to a first aspect, there is provided a turbine assembly having: a support structure; and a first turbine system, supported by the support structure, the first turbine system having a centre of mass and being pivotally connected to the support structure so that the first turbine system is rotatable, relative to the support structure, about a centre of rotation; wherein the first turbine system includes a first flowing-water driveable turbine for generating power from water flow, the first turbine having an operational axis, and being designed for optimum power output when local water flow is aligned with the operational axis; and wherein the centre of rotation is spaced away from the centre of mass of the first turbine system in a direction parallel to the operational axis of the turbine.

This arrangement allows turbines to be mounted on the assembly and to passively flip to maximise their power output. Passive flipping means that no external input is required to rotate the turbines to achieve this effect. Instead, the water flow itself causes the turbines to come closer to alignment with the water flow. This arrangement does not require complex actuator systems to implement the flipping, and the device is therefore simpler, and less prone to mechanical failures. Such a passive flipping system will result in the turbine system operating

in a downstream flow mode in which the part of the turbine which produces the greatest hydrodynamic drag, usually the turbine blades, is the most downstream

above the surface of the water in normal operations. In some surface-based designs, the assembly may nonetheless be substantially submerged, with only a small portion of the assembly being above the water surface in normal use. The common features of turbine assemblies configured for operation at a water surface is that a portion is intended to be above the water surface in normal operation, and that the turbines are arranged to extract power from water flow near the surface, i.e. in the top third of the water column. Surface based devices can be simpler to install, operate and maintain than submersible assemblies. Even when surface based, the turbines may me mounted low enough that the turbine blades do not emerge from the water at any point during a revolution. This can improve efficiency of the assembly, as the blades are driven by the local water current at all points during their rotation.

The first turbine system may be rotatable independently of the parts of the support structure to which the first turbine system is directly connected. This allows fewer parts of the assembly to rotate, consequently simplifying the design.

Optionally, the first turbine system has a centre of mass and is pivotally connected to the support structure so that the first turbine system is rotatable about a centre of rotation; and wherein the centre of rotation is spaced away from the centre of mass of the first turbine system in a direction parallel to the operational axis of the turbine. In this arrangement, in the absence of external forces acting on it (e.g. from local current flow), the turbine system will align its operational axis with the local gravitational field, that is to say, vertically. This provides a stable position when there is no current flow. In addition, since current flow is typically horizontal, that is to say it is dominated by a component perpendicular to the local gravitational field, the stable, vertical, position does not naturally favour any particular direction of current flow, and therefore allows the turbine system to rotate to align itself with local water flow when this changes, unimpeded by its orientation prior to the change in water flow. This effect may be particularly advantageous when the assembly extracts power from water flow driven primarily by tidal flow patterns, as the local flow will cycle between strong flow in a first direction; no flow; strong flow in a second direction opposite to the first direction; no flow; and then the cycle repeats, starting again with strong flow in the first direction. In these

conditions, the turbine system may rotate towards aligning

Figure 1 is a perspective view of an embodiment of an assembly of the present disclosure;

Figure 2 is a perspective view of another embodiment of an assembly of the present disclosure;

Figure 3 is a detailed perspective view of a portion of the assembly of Figure 2, showing a turbine;

Figure 4 is a side view of an embodiment of an assembly of the present disclosure.

Figure 5 is a perspective view of an onboard control module according to an embodiment of the present disclosure;

Figure 6 is a sectional view of the onboard control module of Figure 5 shown mounted on an embodiment of a submersible assembly according to the present disclosure;

Figure 7A is a perspective view of an embodiment of the module of the present disclosure;

Figure 7B is a perspective view of the module of Figure 7A viewed from another angle;

Figure 7C is a side view of the module of Figures 7A and 7B;

Figure 8 is a detailed view of a portion of the module of Figures 7A-7C;

Figure 9 is a perspective view of the arrangement of some of the components of the module shown in Figures 1A-1C, with the outer casing removed;

Figure 10A is a perspective view of the docking point of a submersible assembly according to an embodiment of the present disclosure in which a protective door is closed;

Figure 10B is a perspective view of the docking point of the submersible assembly of Figure 4A in which a protective door is open;

Figure 11A is a sectional view of the beginning of an exemplary docking procedure in which the module docks with the submersible assembly, according to the present disclosure;

Figure 11B is a sectional view of an intermediate phase of an exemplary docking procedure in which the module docks with the submersible assembly, according to the present disclosure; and

Figure 11C is a sectional view of a later part of a docking procedure according to the present disclosure.

Figure 1 shows a perspective view of an assembly 100 according to an embodiment. A series of anchoring points 102 are provided on the water bed to which primary anchoring lines 106 are attached. The anchoring lines bifurcate into upper 108 and lower 110 anchoring lines, each of which attaches to the assembly 100 at a different location. It is not necessary for the anchoring system of the present disclosure to bifurcate in this way, and a single anchoring line is possible.

The assembly 100 is buoyant in water, with the buoyancy being provided by buoyancy devices 126. These may simply be fixed buoyancy devices such as air-filled tanks, or foam based buoyancy devices. Or they may be variable buoyancy devices which can be selectively flooded with water to reduce their buoyancy or filled with air and sealed to increase their buoyancy. The assembly 100 is held in a state of floating equilibrium by the combination of the upward buoyant force from the buoyancy devices 126 and the downward component of tension in the anchoring lines 106, 108, 110. It is not necessary for the present technique to be anchored in this way. It is possible, for example, for the whole assembly to be a rigid structure permanently affixed to the water bed.

In some cases, the floating equilibrium holds the assembly on, at or near the water surface, while in other cases the assembly is substantially or entirely submerged in the body of water. In particular, the assembly may be held in a position of floating equilibrium in a fully submerged position.

The assembly 100 has a support structure 112 in the form of a series of beams linking the buoyancy devices together. These beams provide support to a turbine system 114, which comprises a turbine 116 rotatably mounted to the support structure 112. The turbines 116 are arranged to rotate in response to external forces from a local water flow. This is discussed in more detail below.

Turning now to Figure 2, another assembly 200 according to an embodiment of the present disclosure is shown. The anchoring system is omitted from this Figure, but the anchoring systems discussed above in relation to Figure 1 could be used in this embodiment too. The assemblies shown in Figures 1 and 2 are each suitable for situating at the surface of a body of water or submerging in the body of water.

The assembly 200 has a set of four buoyancy devices 226, two at each end. Each of these may be fixed or variable, as described above. Each pair of buoyancy devices is spaced apart from one another by a pair of vertical support members 230. The support structure further includes a plurality of horizontal trusses 228 spanning the width of the assembly and connecting the lower buoyancy device 226 at one end of the assembly 200 to the lower buoyancy device 226 at the other end. These trusses 228 may be simple trusses, or they may be hollow and selectively floodable to alter the buoyancy of the assembly. Rising from the trusses 228 are a pair of intermediate vertical supports 232. Between the vertical supports 232, and also rising from the trusses 228, is a central pontoon 234. The central pontoon 234 may be hollow, and may further be air-filled, water filled, or selectively floodable to achieve variable buoyancy, depending on the buoyancy requirements of the system.

A beam 224 spans between the upper buoyancy device 226 at one end of the assembly 200 to central pontoon 234, and a second beam spans between the upper buoyancy device 226 at the other end of the assembly and the central pontoon 234. Each of these beams is supported approximately at its midpoint by one of the intermediate vertical supports 232.

Four turbines 216 are mounted on the beam 224 in pairs (each pair being referred to in this embodiment as a turbine system) with one turbine 216 from each pair being located between an intermediate support 232 and a buoyancy device 226, and the other turbine of the pair being located between the intermediate support 232 and the central pontoon 234. Both turbines 216 have their blades facing in the same direction, as explained in more detail below. In this case, the turbine systems are each arranged to rotate independently of the parts of the support structure 226, 232, 234 to which they are directly connected. That is, the

Figure 3 shows a single turbine 316 mounted on a beam 324, along with a second, adjacent beam. The adjacent beam may also have a turbine mounted on it, and both turbines may be arranged to rotate in a pair, along with their respective beams. This may be achieved, for example, by forming the hydrodynamic foil as a covering on a generally cylindrical beam. The fairing may then extend up to the intermediate support 332 which separates the two portions of fairing from one another. The intermediate support 332 may further have an aperture comprising bearings to allow the cylindrical beam to pass through and rotate. The second portion of fairing and second turbine may then be provided on the other side of the intermediate support 332 in a similar manner.

The turbine 316 in Figure 3 is shown mounted on top of the beam 324, although clearly when the turbine 316 rotates to adapt to a change in current flow direction, this may change, and the turbine 316 may later located below the beam. It is entirely possible to mount the turbine 316 in such a way that the nacelle 320 extends as equally as far above and below the beam 324. This arrangement may be preferred for systems in which turbines 316 may rotate independently of any other turbines on the assembly, including single turbine assemblies. This is because a turbine 316 can only align its operational axis 322 vertically by using gravity alone, if the centre of mass is spaced apart from the centre of rotation along a line parallel to the operational axis 322. Clearly this requires that the axis about which the turbine 316 rotates intersects the operational axis 322, which further requires that the beam 324 supports the turbine 316 in such a way that it intersects the nacelle 320, rather than passing above or below it. Allowing the operational axis 322 to self-orient vertically in the absence of external forces means that the turbine 316 is not biased towards a particular direction of current flow.

As described above, turbine 316 may be arranged to rotate together with a second turbine, by virtue of sharing a common beam 324. In this arrangement, both turbines 316 and the beam 324 are collectively known as a turbine system. The turbine 316 shown in Figure 3 is mounted above the beam. In order to reduce torques on the support structure, and also to allow the turbine system to orient the operational axes of the two turbines vertically, the second turbine should be mounted below the beam with its operational axis parallel to that of the first turbine,

and separated from the common axis of rotation (as defined by the beam 324 with

Finally, it should be noted that the support structure could also be designed in such a way that there was sufficient clearance for the blades that the turbines can rotate in any direction, in which case the above considerations are less important.

Turning now to Figure 5, there is shown an embodiment of a centralised onboard control module 536 according to a second aspect of the present disclosure. This design comprises an upper torispherical dome portion 338 and a lower generally cylindrical portion 540. These are joined together by a watertight seal 542.

The control module 536 contains electronic control systems for the turbine assembly, for example to control actuators or brakes on the turbines of the assembly to change their rotational status. In principle, this allows these water-sensitive components to be sealed on dry land, to protect them from water damage, and subsequently the module 536 can be attached to the turbine assembly and submerged. In the event of accidental damage, the centralised nature of these control systems allows them to be easily removed and repaired.

The control module 536 is provided with a mounting bracket 544 or similar means so that it can be simply mounted and/or detached as the need arises. In particular, the control module 536 may be removable in its entirety form the assembly. For example, in the event that the module develops a fault, or needs an upgrade, the assembly may be raised to the surface, the module removed, and repairs or replacement of the module can be made, as appropriate.

In addition, other systems such as hydraulic actuators, mechanical actuators, pneumatic systems, and high power electrical equipment may also be housed in the module 536. This allows easy and centralised access to these key systems, while keeping them safe in a dry space. Centralising in this way means that fewer spaces need be sealed, and monitored to ensure safe working of the apparatus.

Externally, the module is provided with cable feedthroughs 546 for outputting control signals (in the form of electronic, or other suitable, e.g. fibre optic, signals) or electrical power as required, or for receiving electrical power e.g.