ELECTRICITY GENERATION SYSTEM

The current application relates to an electricity generation system.

The potential opportunity for sustainable marine energy technologies is enormous. Tidal hydrokinetic energy in particular, is a potentially unlimited renewable source for energy generation, due to its complete predictability and availability. This vast resource enables tidal energy converting devices to help meet energy demands globally.

It is however a complicated technological challenge and is therefore a relatively late comer to the renewable energy market. The European Union and the United Kingdom were the first to recognize the potential and provided government funding for tidal energy development. The focus was on developing large scale 1MW systems to provide utility scale power.

However, this requires very large expensive turbines and installation structures and very fast tidal flows, ranging from 3 m (meter)/s (second) or above, for the systems to be viable. However, there are very few sites in the world that offer these flows and where available, are mostly located in deep ocean waters.

WO 2016/145477 A1 discloses a rotor for an electricity generator.

It is an object of the present specification to provide an improved electrical energy generation system.

An improved electricity generation system comprises:

at least one electricity generation device being removably fixed to a mounting device formed as a floating body or as a fixed infrastructure by means of a retaining device, wherein the electricity generation device is bidirectionally symmetric and comprises a water turbine being functionally connected to a generator, wherein the generator comprises a helical gearbox, wherein the generator is a permanent magnet synchronous motor, wherein the generator comprises an incremental encoder, wherein a rotation of the generator is monitorable by a signal generated from the incremental encoder, wherein electrical energy is conductible via a power line being guided from the generator via an outside of the mounting device, wherein the electrical energy is conductible from the mounting device to a power station, wherein the nose and tail cones is coated by at least two layered bio fouling coatings, wherein blades of the turbine are sensitive to a bi-directional water flow, wherein a power line entry point is arranged at a top of an enclosure, wherein the electricity generation device comprises a control panel, wherein the electricity generation system is functionally connectable to the web.

In this way, electrical energy can be generated through the water flow below the mounting device. The mounting device can be for example a bridge pier in a river or in a bay or a floating body attached thereto. By means of the helical gear, rotation speed between the turbine and the generator can be matched, so that rotation speeds are attached properly. By means of the symmetrical design of the enclosure, electrical energy can be generated to consciously release both directions of the flow of the tide.

In one embodiment, the mounting device is a bridge or a floating body. In this way, the electrical energy system can be

fixed both to a fixed infrastructure as well as to a movable object.

In further embodiments, the floating body is one of the following: barge, catamaran, mooring platform, existing fixed infrastructure, mobile platform, watercraft.

In a further embodiment, the electricity generation device is mountable to a railing of the floating body. In this way, several electricity generation devices can detachably be fasted to the floating body.

According to yet a further embodiment, the electricity generation device is mountable to an opening located at a bottom of the floating body.

In yet a further embodiment, electrical energy of the electricity generation system is conductible via a power line being guided from the generator via an outside of the mounting device. A power line routing through a bottom of the floating body can be avoided in this way. For example, each power line from the turbines is directed to the top of the barge and into the control panels.

In one or more embodiments, the electricity generation system further comprising a control system, the control system adapted to control the electricity generation system in accordance with specified control parameters.

In one or more embodiments control parameters of the electricity generation system consider at least one of the following circumstances:

- begin and/or end of tidal cycle;
- cut out of tidal velocity;

- specified threshold of rotor speed;
- emergency case;
- marine mammal/fish activity.

In one or more embodiments, by means of the control system pitch control units are controlled, wherein the pitch control units are arranged in the blade hub, wherein the pitch control units are adapted to control pitch angles of the blades.

In one or more embodiments, the control system is adapted to be remotely controlled by means of a control unit.

In one or more embodiments, the control system is adapted to control the electricity generation system in dependence of at least one of the following:

- tidal current speed;
- motions in six degrees of freedom;
- wave height and period;
- rotor torque and/or rotor speed and/or thrust;
- mooring line load;
- electric power generation.

In one or more embodiments, the control system is adapted to control the electricity generation system in dependence of at least one of the following:

- equipment space temperature and/or humidity;
- generator temperature;
- generator voltage and/or generator current;
- leak detection alarm.

In one or more embodiments, the control system is adapted to control a shutdown of the electricity generation system in accordance in at least one of the following ways:

- Manual shutdown;

- Automated shutdown;
- Emergency shutdown;
- Emergency stop.

In one or more embodiments, the electricity generation system comprises a communication unit, adapted to provide a communication to an external control unit.

In one or more embodiments, the communication unit is based on at least one of the following communication technologies: WLAN, 4G, 5G, GSM, satellite link.

In yet a further embodiment, a material of an enclosure of the improved electricity generation device named the nacelle is manufactured in stainless steel (SS316L) and at least one of the following for the nose and tail cone sections: fiberglass, fibre reinforced plastics.

In yet a further embodiment, a nacelle of the electricity generation system does not require any additional coating. This can reduce environmental impact.

In yet a further embodiment, the nose and tail cone is coated by at least two layered bio fouling coatings.

In yet a further embodiment, cathodic protection will be implemented by utilizing sacrificial anodes mounted on the turbine.

In yet a further embodiment, blades of the tidal turbine are sensitive to a bi-directional water flow. An optimized energy utilization is supported in this way.
In yet a further embodiment, a material of the blades comprises at least one of the following: Aluminium Alloy, Carbon

Fibre, Glass reinforced plastics, composite materials, recycled plastic materials.

In yet a further embodiment, a power line entry point is arranged at a top of the enclosure. An improved and comfortable power line routing is supported in this way.

In yet a further embodiment, the electricity generation device comprises a control panel. A performance monitoring and control of the whole system is supported in this way.

In yet a further embodiment, the electricity generation system is functionally connectable to the web. In this way a centralized operation of the system is supported.

An inner end of the respective blade can be provided between two opposing discs. The inner end is placed next to the two opposing discs such that the disc acts to prevent the blade from bending.

The disc and the blades are intended to rotate about an axis. Under the tidal current, the blade of the turbine experiences thrust loads causing them to bend in the direction of the flow of the tidal current. As the flow reverses every six hours, the forces on the blades also reverse causing them to undergo fatigue. The two circular plates harness the blades on both sides to minimize or eliminate the deformation of the blades.

The disc can also comprise at least one rib to prevent the disc from bending.

The rib refers to an elongated ridge with a cross-section that has a shape of an arc. The rib is formed on the disc and can be straight or circular.

The rib acts to strengthen the disc, thereby preventing the disc from bending. The rib also serves to reduce the weight of the disc in the sense that a disc with a rib can have the same resistance to bending as a thicker disc - and thus heavier disc- without the rib.

The subject matter of the present specification will now be explained in more detail with respect to several figures, wherein:

Fig. 1 shows a side view of an embodiment of an improved electricity generation system,

Fig. 2 shows a top view of a further embodiment of the electricity generation system of Fig. 1,

Fig. 3 shows an exploded view of an embodiment of an electricity generation device of the electricity generation system of Fig 1,

Fig. 4 shows different views of an improved circular plate support for the blades,

Fig. 5 shows ribs of the plates to minimize the plate deformation,

Fig. 6 shows data of the deployment of one implementation of the electricity generation system 100 at Sentosa Boardwalk, the data relates to monthly generation, and

Fig. 7 shows the results of a computational simulation or calculation for one implementation of the improved turbine of the electricity generation system 100.

In the following description, specific features are provided to describe embodiments of the electricity generation system. It shall be apparent to a skilled person, however, that the embodiments may be practised without such specific features and/or other corresponding features.

It is noted that in the following description numerical values of embodiments are merely exemplary. Hence, a skilled person will use other numerical values for systems, devices, components, elements, diameters, materials, etc. without departing from the scope of the electricity generation system.

Some parts of embodiments, which are shown in figures, may have similar parts. Similar parts may have same names or similar part numbers with a primary number and/or with a letter. The description of such similar parts also applies by reference to other similar parts, where appropriate, thereby reducing repetition of text without limiting the disclosure.

The small and versatile tidal turbine of the improved electricity generation system supports multiple deployent options, such as below a bridge, on a mooring platform, existing fixed infrastructures, mobile platforms, and watercrafts, arranged in arrays. The disclosed small scale tidal turbine can harness mechanical flow energy from low flow velocity resources, which are predominantly located in coastal waters and/or in remote island locations and in rivers of suitable depths and current speed.

By means of the improved electricity generation system, a huge opportunity for smaller affordable devices is provided that can be operated in low tidal flow sites, which are usually found in coastal waters within approximately 10 km (kilometre)

off the shoreline. Flow speeds in such sites range from approximately 0.6 m/s to approximately 3.0 m/s or higher. In this way there is provided renewable marine energy to end users in a plug-and-play operating system, covering a wide range of customizable products and services.

Proposed is an affordable small scale improved tidal turbine which may exploit marine energy, either deployed single or in arrays and detachably fixed to a mounting device, which may be built as a bridge, a floating body, or to an existing infrastructure, etc. In this way means to exploit a specific form of renewable energy (hydrokinetic energy) to largely untapped non-utility markets, such as off-grid islands, fast streams under bridges, rivers, irrigation canals, after-flows in hydro dams, is provided, all of those locations with flow rates from approximately 0.6 m/s to approximately 3 m/s.

Fig. 1 shows a side view of a first embodiment of an improved electricity generation system 100. The electricity generation system 100 comprises a mounting device 10 formed as a floating body, preferably formed as a barge, to which at least one electricity generation device 20, 20´ is removably fixed, wherein each electricity generation device 20, 20´ comprises a turbine with blades 21a…21n, 21a´…21n´ and an enclosed generator 24, which may be driven by the turbine. In such way a tidal turbine is provided. Several electricity generation devices 20 may removably be fastened to a railing 11 of the floating body.

The blades 21a…21n, 21a´…21n´of the tidal turbine are sensitive to a bi-directional water flow. “Sensitive” in this context means that a rotation of the blades 21a…21n, 21a´…21n´ can be caused by various water flow directions, in particular

by flow directions A and B. An optimized energy utilization is supported in this way.

One recognizes a streamlined, preferably symmetrical design, which can reduce water drag and thus enables incoming water to rush past the electricity generation device 20 easily. An incoming water flow direction A, B is aligned with a longitudinal axis of the axial-flow tidal turbine. This is mainly because any change in angle of attack may reduce the power generation at design condition.

The floating body may for example be formed as a boat, a catamaran, a floating platform, a mooring platform, watercraft, etc. The mobile and transportable floating body can transport the attached tidal turbine to any site where a usable tide with corresponding water flow is present. The tide may be used to drive the tidal turbine with the generator 24, thereby generating electricity.

The electricity generation devices 20, 20´ are fixed to the mounting device 10 by means of retaining elements 13, 13´ which can also be used to lead power lines 15, 15´ of the electricity generation devices 20, 20´. Power line entry points 27, 27´are arranged on top of enclosure 25, 25´of the electricity generation devices 20, 20´. By means of folding devices 14, 14´ each electricity generation device 20, 20´can separately be pulled in and pulled out from the mounting device 10. In this way the system 100 is operable also in the case that one of the electricity generation devices 20, 20´ is missing due to exchange, service, repair, etc. In order to conduct electric energy from the electricity generation system 100 to a remote power station 50, electrical current can separately be conducted via each power line 15, 15´ or via a single power line 15, 15´.

By means of a control panel 30, which can be connected to the web 40, an operation of the electricity generation system 100 can be controlled.

In an alternative arrangement, the mounting device 10 may be built as a fixed bridge or existing infrastructure in a jetty (not shown). In this way it is possible that at least one, preferably several electricity generation devices 20, 20´ may be fastened to the fixed bridge, thereby exploiting a water flow beneath the bridge for the purposes of generation of electricity.

In the above explained way there is provided a cost-effective tidal turbine energy solution which is applicable for example to conditions in Southeast Asia. Southeast Asia represents different tidal energy resources than those available for example in Europe or North America. The resources in Southeast Asia consist of slow to medium peak velocity tidal flows (from approximately 0.6 m/s to approximately 3 m/s) that are present in near-to-shore and shallower sites.

Its tidal turbines are usable in these areas to convert hydrokinetic energy both in fast flowing streams and in low tidal flows at sea into electricity.

In contrast thereto, larger tidal turbines (e.g., MW-scale per unit turbines) having been designed for high flows deployed in other regions of the world are therefore unfavourable in Southeast Asia, have had poor track records of failed deployments and do most likely not achieve the required cost of energy to be viable in those sites.

The electricity energy generation system 100 possesses various properties which are listed below merely exemplary:

- Simple to manufacture with a low number of elements to assemble

- Focus on unit turbines with electric power output from approximately 7kW to approximately 100kW, achieved in device sizes of approximately 1.5 m to 5 m in length and approximately 400 kg to 1000 kg in weight

- In-house software developed for control and system optimization, which supports Internet-of-Things

- Small compact design allows ease of installation on support structures

- Customizable for a placement of turbines on barges, platforms, bridges, wharfs, rivers, canal walls, watercrafts etc. Larger scale units can also be deployed, e.g., on the seabed

- Cost effective fabrication, assembly, and logistics

- Cost savings in use near existing infrastructure and at sea, as there is no requirement for heavy-lift vessels for the purpose of transportation

- The tidal turbines of the electricity generation system can achieve large electrical power output using a horizontal scale-out architecture of multiple tidal turbines in arrays
- This is more cost-effective and mitigates the risk of unit failures as compared to scaling-up a single turbine to a much larger size

- Further cost savings may be attained by sharing a common electrical infrastructure, such as drives, inverters, power connections.

The electricity generation system 100 is able to produce clean renewable energy at sea and represents a turnkey solution for clean tidal energy supply to offshore islands, microgrids and the emerging blue economy. This includes e.g., design, construction, deployment, electrical connection, metering, operation, maintenance, etc.

The electricity generation system 100 comprises a mounting device 10 with several, preferably four to six 10kW tidal turbines being detachably fixed to the mounting device 10. A mounting device 10 built as a floating body may be formed as a barge or a catamaran or other kind of watercraft.

In this way, also other possible designs of mounting devices 10 will enable a deployment of an increased number of tidal turbines. Electricity generated by the tidal turbines may initially be supplied to end users via marine power lines. Energy storage on the floating platform at sea and distribution to the local island grid may easily be implemented with the electricity generation system 100.

An operation of the electricity generation system 100 may be performed at least partially or fully autonomous and its performance may be remotely monitored on the mainland, e.g., via web-based tools. An end user receives thus a plug-and-play electric energy station at sea which provides a complete solution for clean marine energy generation, storage, and distribution.

A control system 70 for the electricity generation system 100 may be designed to be automated via an embedded computer-based system, where a software controller will have total control of the system. This component will monitor the operating state of the turbine devices, reading information from the different

sensors and other components and manipulate this information in order to keep the system working within specified operational limits.

The operation of the electricity generation system 100 may be monitored and controlled remotely via a control unit (e.g. a Supervisory Control and Data Acquisition (SCADA) system) which may, preferably permanently run on a dedicated PC located onshore at offices. This SCADA system will be able, amongst other things, to show the instantaneous state of the electricity generation system 100, acknowledge warnings and alarms from it, give the operator the option to record them or not and print reports when necessary, etc.

The control system 70 may include systems necessary to control the extraction of energy from the tide. Various sensors (not shown) are adapted to monitor different environmental parameters and how the device responds to environmental inputs. This may include e.g.:

- tidal current speed;
- motions in the six degrees of freedom;
- wave height and period;
- rotor torque, speed and thrust;
- mooring line loads;
- electrical power generation.

As part of the control system 70, certain parameters may be monitored solely for the safe and reliable operation of the system 100. These parameters may e.g. include:

- Equipment space temperature/humidity
- generator temperature
- generator voltage and current
- leak detection alarms.

The operation and monitoring of the electricity generation system 100 may be undertaken remotely, largely over the internet, by connecting to the SCADA computer located inside the turbine. This configuration minimizes the communication issues between the PLCs (programmable logic controllers) and the SCADA.

A HMI (human-machine) interface (not shown) will allow operators to perform different operational and safety related actions over the electricity generation system 100 depending on the security level that each operator is given. The SCADA system will generate information about the general status of the system via process variables, alarms, reports, etc.

Integrated with the main control system 70 may be several instruments which will gather important data to be used during the real time operation of the machine and to assess the performance of the electricity generation system 100 during the post-processing of the data. Apart from the main sensors that will give feedback from several parts of the system 100, the following instrumentation will help with safety and environmental tasks:

- Doppler Current Profiler to measure the tidal speed: This will be used during operation to control power generation and to make safety decisions

- MRU (Motion Reference Unit): provides information about the motion of the mounting device 10 and can also be useful for safe operations

- GPS (Global Positioning System): Monitors the position of the electricity generation system 100 and helps to set geofencing alarms

- Turbine variables (e.g. torque, speed, thrust, etc.): Sensors give information which can be used to control generation and work within safety limits

- Temperature sensors: These will ensure that equipment is working within limits and that the environment inside the turbine is safe for possible access

- Fire alarm system: This system will inform about fire alarms, ensuring that operation and access are safe

A control of the electricity generation system 100 can be fully automated, wherein the following exemplary control scenarios are conceivable:

- Planned at the end of each tidal cycle

- Planned at cut out tidal velocity (the velocity above which generation of power is stopped due to the increased loads and strain on the structure and control system)

- Survival shutdown of rotor above critical sea state
- In case of an emergency

- In case of marine mammal/fish activity input from the sonar control bring the turbines to a controlled stop until operational area is clear.

There are a number of different shut down processes depending on the circumstances of the shut-down outlined below:

- Manual shutdown: in this case the operator decides to cease turbine operation or decides what state they want

the turbine to be in e.g., transport mode during maintenance operations

- Automated shutdown: the turbine control system, based on environmental information, decides if it can keep generating or not and whether to go into a controlled stop stage

- Emergency shutdown: the device, again based on environmental information, decides that it is dangerous to operate and shuts down automatically, going into survival mode (legs up).

Emergency stop: the device detects a risky or dangerous situation and stops the rotors, disables the drives and trips any other equipment involved in the movement of the rotors, applying the brakes and waiting for the operator to decide what to do next.

The proposed electricity generation system 100 may functionally be connected to extern, e.g. to the web 40 via a communication unit 60. The communication unit 60 may be used to control the electricity generation system 100 and may be based one at least one of the following wireless communication technologies:

- Wireless LAN (WLAN): A communication link based on WLAN connects the tidal turbine with a router installed on shore via long range access points as the backup communications link

- 4G/5G: There may be at least one 4G modem installed in the tidal turbine which can be used as the primary communication link

- GSM: There will be a GSM system which allows the tidal turbine to send and receive SMS texts. This system may be used to alarm duty managers about safety related issues in the event of a failure on the internet connection and can receive commands from the duty managers to perform actions on the electricity generation system 100. The GSM system may be backed up by an UPS (Uninterruptible Power Supply) to ensure that it remains operational in the event of a power failure

- Satellite link: Where no suitable wireless connection can be engineered, or no mobile telephony network connectivity exists, then the communications by means of the communication unit 60 will be established utilising a satellite link.

Fig. 2 shows a top view of the electricity generation system 100 with another removable mounting option of the electricity generation devices 20, 20´ at the mounting device 10 built as a floating body. One realizes that the electricity generation devices 20, 20´ (shown with dotted lines) may be attached to openings 12, 12´ in the bottom of the floating body. In this way, numerous electricity generation devices 20 may removably be fixed to the floating body and may comfortably be submerged into and lifted out from the water, for example for the purposes of servicing, exchange, repair, etc.

Fig. 3 shows an embodiment of an electricity generation device 20 in more detail in an exploded view and highlights a sealed casing of the generator 24. Wake dynamics is closely linked to a design of a tail section 20b of the electricity generation device 20. A design of the improved tidal turbine design does not depend solely on the efficiency of a single tidal turbine

but also on an interaction between several tidal turbines during operation.

An amount of electrical energy available for each tidal turbine strongly depends on energy fluxes from the flow passing the tidal turbine and the fluxes are affected by the flow topology in the turbines' wakes. The tail section 20b is preferably designed keeping those aspects in mind to strive a smaller wake zone with less unsteady vortex shedding.

The electricity generation device 20 comprises a mounting member 25a and two eye hooks (not shown) by means of which the electricity generation device 20 may be lifted to a transport means (e.g., truck, ship, airplane, etc.).

Fiberglass or fibre reinforced plastics may preferably be used as a choice of material of the nose and tail cones, preferably at least of the front section 20a and the tail section 20b of the electricity generation device 20.

Said preferred materials are low-maintenance and can comprise optionally a marine coating as a base coating (not shown) and a gel-coating on the surface (not shown), in this way supporting a long service life. Regular cleaning such as washing off bio fouling and reapplying the gel-coating may help to maintain efficiency of flow of water and to drag forces to the blades 21a…21n.

For a blade design, a key consideration includes a variation in a turning angle along blade length. At the blade root, the radial velocity is lower and thus requires larger turning angle. At the tip of the blades 21a…21n radial velocity and also turning angle are at its maximum. This is to avoid any occurrence of mixing flow along the blade length to maximize the

harnessing of energy available from incoming tides. The blades 21a…21n are preferably designed to capture tides in both flow directions A, B. In other words, the blades 21a…21n are sensitive in a "bi-directional" way.

The blades 21a…21n of the improved tidal turbine may be manufactured using preferably one of the following materials:

- Aluminium Alloy, which is tried and tested for turbine blades (wind turbines and hydro)

- Carbon fibre, which is the normal choice for wind turbines but is rather costly

- Glass Reinforced plastics (GRP)

Cheaper and/or other alternative materials to the above-mentioned materials are also possible.

The blade hub 22, to which the blades 21a…21n are fastened, may e.g., be fabricated with two identical 3mm stainless steel (SS316L) circular plate reinforced with circular ribs and flat bars of approximately 3mm thickness. An overall diameter of the blade hub 22 may preferably range from approximately 650mm to approximately 750mm, preferably approximately 700mm. The blade hub 22 is designed to withstand a thrust force of up to approximately 20kN on both directions of the blade hub 22. The blades 21a…21n may be secured to the blade hub 22 e.g., with a specially designed Delrin material mounting. Delrin is not hydrophobic and does not impact the environment negatively.

The tidal turbine blades 21a…21n may be subject to large, highly dynamic fluid forces. System performance over the expected life time of the turbine by way of rapid, passive pitch

control can reduce hydrodynamic instabilities and improve load shedding and structural performance. This may be achieved by passive or active pitch control units 22a…22n arranged in the blade hub 22. By means of said pitch control units 22a…22n, individual blades 21a…21n may increase pitch to, in effect, bleed off excess energy when subjected to current speeds above design limits for short periods. In this way it is possible that loads and their effects on the blades 21a…21n of the turbine support structures can be reduced.

A conceptual propeller tapered designed mounting implements a mounting element 23 which is used to fix the tidal turbine rotor's shaft to the blade hub 22. A mechanical seal 26 is used to fix the mounting element 23 to a geared motor 24.

A perpendicular ring (not shown) of e.g., approximately 20 mm in width is fabricated to a front circular plate of the blade hub 22 and may be used for a mounting of the front section 20a to the blade hub 22.

The enclosure 25 is foreseen to enclose the tidal turbine with the generator 24. The enclosure's flange mounted body may e.g., be fabricated with a schedule 10 stainless steel (SS316L) pipe of overall diameter of approximately 500 mm. The front of the enclosure 25 is preferably a standard blind flange of approximately 700 mm. The back of the enclosure 25 is extended with a schedule 10 stainless steel (SS316L) pipe of overall diameter of approximately 400 mm. The flange mounted geared generator 24 is sealed and protected within the enclosure 25 by means of a mechanical seal.

An electric power line (e.g., marine cable) entry point 27, 27´ is realized preferably at the top of the enclosure body. A perpendicular ring of approximately 20 mm in width fabricated

to the back of the turbine enclosure 25 is used for a mounting of the tail section 20b at the enclosure 25.

A material of the enclosure 25 can e.g., be a 316L stainless steel grade, wherein the generator 24 with its gearbox are all sealed and protected in the enclosure 25 with such material. 316L stainless steel is a type of metallic alloy of stainless steel that is austenitic and contains nickel and molybdenum, which make the steel corrosion resistant. This enables a significant reduction of operation maintenance and coatings for the enclosure 25.

The enclosure's body may comprise a top standard flange to act as a mounting interface 25a between the turbine and a support structure 25b. The mounting interface 25a provides flexibility for a design of the support structure 25b that holds the tidal turbine for any deployments but utilizing a standard flange size which is convenient for any end user.

The generator 24 is preferably built as a permanent magnet synchronous servo geared motor with a flange mount. The flange mount may be used to attach the generator 24 to a mounting element 23, which is attached to the blade hub 22. The permanent magnet synchronous servo geared motor comprises a gearbox, which is preferably a helical gearbox filled with environmental pollution oil. By means of said gearbox, the rotational speed of the blade hub 22 with the blades 21a…21n may be applied to the generator 24, such that rotational speeds of the blade hub 22 and the generator 24 appropriately fit together. The helical gearbox is used to adjust a transmission ratio of the rotational speeds of the blade hub 22, a rotational speed of the generator 24 is preferably monitored by an encoded signal, being generated by an incremental encoder.

A shaft seal of the generator 24 may be fitted with a 50mm diameter mechanical seal and covered with seal end 'O' ring protector. Mechanical seals are devices that are used to provide a seal at the point of entry or exit of a rotating shaft. The mechanical seals are used to prevent the leakage of one high pressure fluid into a lower pressure fluid. In this way, the tidal turbines can be submerged in the sea exerting the tidal turbine to a pressure around one bar, where a reliable mechanical seal performance is useful. The selected mechanical seal focuses on higher performance characteristics and is able to operate the tidal turbine under the most arduous conditions.

Optionally, temperature sensors (not shown) are built within the generator 24. Furthermore, also at least a vibration sensor and/or at least a leak detector (not shown) may be built within the generator 24. Other condition monitoring sensors include at least a humidity-, and/or radial- and/or axial vibration sensor.

The mentioned sensors allow a sensor-based data collection which supports a monitoring of a condition of the tidal turbine during operation. These collected data may support a planning for future maintenance schedules and smart anomaly detections.

The tidal turbine may be fitted with a waterproof bulkhead threaded connector for a connection to a control panel 30.

A control system of the improved tidal turbine comprises a Variable Frequency Drive (VFD, programmable logic controller (PLC) and a supervisory control and data Acquisition (SCADA) unit. To this end, a VFD-controller may be used for the turbine control. The electrical power generated by the tidal turbine is conducted to a power grid via an Active Front-End

(AFE) controller, an overall electric power generation may be controlled via the programmable logic controller PLC.

Moreover, also a web base access may be foreseen with control and monitoring functions. Preferably, the tidal turbine is designed with capabilities of remote monitoring and accessibility. All collected data can be stored for example in a cloud server, wherein necessary information can be processed and shared with customers and relevant authorities.

A marine monitoring system for the electricity generation system 100 may comprise at least one of the following items:

- subsea camera
- hydrophones
- CTD (conductivity, temperature, and density)
- Turbulence
- ADCP
- Active Fish finding sonar
- real time monitoring tools
- ‘Best Practice’ principles for monitoring during deployment

The data collected from the subsea camera and the hydrophone may be used to monitor the electricity generation system 100 and further to monitor any fish and mammal interactions (e.g., by utilizing an AI-platform) with the electricity generation system 100.

By means of the electricity generation system 100 there may be harnessed mechanical flow energy from both upstream and downstream flows.

The electricity generation system 100 may provide various data such as performance data, site condition data, eco system protection monitoring data, wherein these data can be used for an

analysis of usage and improvement of the electricity generation system 100.

A special embodiment of the electricity generation system 100 is described below.

This embodiment is intended to operate in an environment, wherein, the speed in waters with low flows, ranging from about 0.5 m/s to about 2 m/s, produces a lower operational rotation range from about 25 to about 120 RPM (revolution per minute).

To operate in this environment, the electricity generation system 100 is configured or selected as follows.

Referring to the gearbox of the special embodiment of the electricity generation system 100, it is selected on the following criteria to interface the blade hub with the servo motor at optimum or improved generating speed.
Axial force or thrust force from the impact of flowing water on the gearbox can be about 10kN (kilonewton) according to calculations. For safety and assuming an additional load factor for wind-induced currents and wave loading, the thrust force is assumed to be about 20kN. The gearbox is selected to withstand a thrust or axial load of about 20kN.

Due to the above, a special bearing with reinforcement is selected to withstand this thrust force.

As for radial force, which is a force exerted in a radial direction, shaft diameter and bearing are then selected to withstand a radial load that will be exerted during operations up to a water or sea depth of 15 meters.

As for gear ratio, it is selected as 1.0:17.5 based on matching high accuracy servo motor.

As for the weight and size of the gearbox, it is selected to enable the overall turbine to be lightweight and compact which supports easy deployment and installation.

As for mechanical interface and mounting, a flange-type mounting for the gearbox is selected in order to align the shaft, mechanical seal, gearbox, and servo motor. The gearbox interface, flange type, is aligned with the blade hub by attaching to the turbine enclosure flange 23. A key consideration for the turbine enclosure flange 23 selection (ANSI 150# Standard flange) included the seawater pressure at the depth of 15 meters (1.5 bar). This prevents the turbine enclosure flange 23 from deforming and provides an additional watertight mechanical seal.

As for gear oil, a mineral high-performance gear oil (Oil CLP ISO VG220) is selected. Modern high-performance gear oils based on specially selected base oils show excellent thermal stability, good ageing stability as well as extraordinary wear-protecting properties while being an environmentally acceptable lubricant. The gearbox only houses some 2 litres of oil. This also reduces the environmental impact should there be any leak into the water.

Referring to the servo geared motor of the generator 24 of the special embodiment of the electricity generation system 100, the gearbox and servo geared motor are selected from the same manufacturer, Siemens, for better reliability and compatibility.

In detail, a servo-geared motor that has precision control with high accuracy is selected.

With the natural tidal flows, which result in fluctuating speed, the selected servo-geared motor is then able to control the speed of the turbine with high accuracy.

The servo-geared motor also has a lightweight and is smaller in size as compared to the standard low-speed permanent magnet motor, which is about five times heavier and bigger. The standard low-speed permanent magnet motor is unable to achieve high accuracy in speed control.

The servo-geared motor is designed for operation without external cooling and the heat is dissipated through the motor surface and the gearbox mounting surface. The natural sea water temperature should be sufficient to cool the enclosure surface, where the heat from the motor is dissipated too.

Referring to the mechanical seal 26 of the special embodiment of the electricity generation system 100, the seal 26 is mounted inside the turbine enclosure flange and on the shaft. Most turbines have double O rings, and the seals 26 are placed on the exterior of a shaft exposed to seawater.

By placing the mechanical seal 26 within the enclosure, the seal 26 is protected from corrosion, biofouling, and degradation. Importantly, this prolongs its life span and prevents leakage.

A turbine hoisting and lowering mechanism is provided for the special embodiment of the electricity generation system 100.

The platform can be provided with two moon pools although we can use one moon pool. This enables the turbine to be lowered and hoisted from the deck of the platform to the water. A davit system coupled with a support structure and an option to use A-frame is provided on the deck for this procedure.

For efficient deployment and retrieval, an electric wire rope hoisting mechanism is provided on all the davit systems coupled with the support structures. The same applies to the A-frame on the deck.

The option to hoist and lower the turbine manually by cranking is included as a backup solution.

All provided wire ropes are approved for usage in sea environments. The wire ropes include either stainless steel or marine-grade wires.

A further embodiment of the improved blade hub 22 is provided for the special embodiment of the electricity generation system 100 and is described below.

The tidal turbine system includes three blades with individual holders and two circular discs 28, as shown in Figs. 4 and 5. An inner end of each blade is attached to a holder. Each holder is placed between the two opposing circular discs 28 and is fixedly attached to both circular discs 28. The discs 28 also include ribs 29 as shown in Fig. 5.

The rib 29 has an elongated ridge with a cross-section that has a shape of an arc.

Functionally, the blade hub serves as a circular disc support system for the blades. The circular disc 28 and the blades are

intended to rotate about a horizontal axis. Each holder acts to support the respective blade.

Under the tidal current, the tidal turbine blades experience excessive thrust loads causing them to bend in the direction of flows. As flow reverses every six hours, the forces on the blades also reverse causing them to undergo fatigue.

This water flow acts to exert bending loads that cause the blades to bend along the flow direction producing loss of power and reduction in power generation in the tidal turbine. The two circular plates harness the blades on both sides to minimize the deformation of the blades.

The ribs 29 of the disc 28 also act to strengthen the disc 28, thereby preventing the disc 28 from bending while reducing its weight.

One implementation with a single side plate with very high thickness undergoes a deformation of more than 14 mm. But with two stainless steel circular plates on both sides of the blades, the plates having a 3 mm thick stainless steel circular plate, the deformation is reduced to 0.8 mm.

Referring to the tidal turbines of the special embodiment of the electricity generation system 100, the turbines are designed to extract power during the onward flow direction. This allows the turbine to extract energy only during the onward motion. The tidal turbines have a unique improved geometry that has a symmetric aerofoil in both the leading and trailing edge of the blade 21a...21n which enables the blade 21a...21n to cause a positive lift in both onward and reverse flow causing increased energy generation in a tidal flow condition.

This when implemented in the tidal turbine enables the extraction of energy in both ebb and flood directions in an open sea.

The blade 21a...21n includes the variation in turning angle along the blade length. At the blade root, the radial velocity is lower and thus requires a larger turning angle. At the tip of the blade 21a...21n, radial velocity is at its maximum and thus turning angle reduces. This is to avoid any occurrence of mixing flow along the blade length to maximise the harnessing of energy available from the incoming tides.

The blades 21a...21n are also designed to capture tides in both directions.

Referring to the enclosure 25 of the special embodiment of the electricity generation system 100, the stainless-steel material is selected such that it allows the enclosure 25 have excellent corrosion resistance as well as good stability, appearance, durability, lustre, strength, and stiffness.

Referring to the front section 20a and the tail section 20b of the special embodiment of the electricity generation system 100, they have lower manufacturing cost and maintenance allowing for lower life cycle cost overall and reduced weight whilst providing the hydrodynamic performance required.

Referring to the control panel 30 or system for the tidal turbines of the special embodiment of the electricity generation system 100, the control panel 30 is designed to be automated via an embedded computer-based system, where a software controller will have total control of the tidal turbines. This component will monitor the operating state of the turbine devices, reading information from the different sensors and

other components and manipulate this information in order to keep the system working within specified operational limits.

The variable voltage output from each generator is fed to the control panel 30, where it is passed through its own converter and converted to a dc voltage and then through an inverter into a grid-tied 415-volt AC, three-phase output. This 415-volt AC, three-phase AC output is fed ashore via the subsea cable to the onshore equipment which is project-specific equipment.

With the above-mentioned environment, and with the improved turbine design, power production and thrust load from flowing water can be simulated or calculated utilizing computational simulations or calculations.

Fig. 6 shows data on the deployment of one implementation of the electricity generation system 100 at Sentosa Boardwalk, the data relates to monthly generation.

Fig. 7 shows the results of a computational simulation or calculation for one implementation of the improved turbine of the electricity generation system 100.

Itemized list of embodiments:

The embodiments can also be described with the following lists of features or elements being organized into an item list. The respective combinations of features, which are disclosed in the item list, are regarded as independent subject matter, respectively, that can also be combined with other features of the application.

1. Electricity generation system (100), comprising:
   - at least one electricity generation device (20, 20´) being removably fixed to a mounting device (10) by means of a retaining device (14, 14´, 15, 15´), wherein the electricity generation device (20, 20´) is bidirectionally symmetric and comprises a water turbine being functionally connected to a generator (24), wherein the generator (24) comprises a helical gearbox, wherein the generator (24) is a permanent magnet synchronous servo geared motor, wherein the generator (24) comprises an incremental encoder, wherein a rotation of the generator (24) is monitorable by a signal generated from the incremental encoder.

2. Electricity generation system (100) according to item 1, wherein the mounting device (10) is a bridge or a floating body.

3. Electricity generation system (100) according to item 2, wherein the floating body is one of the following: barge, catamaran, mooring platform, existing fixed infrastructures, mobile platforms, watercrafts.

4. Electricity generation system (100) according to item 2 or 3, wherein the electricity generation device (20, 20´) is mountable to a railing (11) of the floating body.

5. Electricity generation system (100) according to one of items 2 to 4, wherein the electricity generation device (20, 20´) is mountable to an opening (12) located at a bottom of the floating body (10).

6. Electricity generation system (100) according to one of the preceding items, wherein electrical energy is conductive via a power line (15, 15´) being guided from the generator (24) via an outside of the mounting device (10).

7. Electricity generation system (100) according to one of the preceding items, wherein a material of an enclosure (25) of the electricity generation device (20, 20´) is at least one of the following: stainless steel, fiberglass, fibre reinforced plastics.

8. Electricity generation system (100) according to item 7, wherein the nose and tail cones (20a, 20b) is coated by at least two layered bio fouling coatings.

9. Electricity generation system (100) according to one of the preceding items, wherein blades (21a…21n, 21a´…21n´) of the turbine are sensitive to a bi-directional water flow (A, B).

10. Electricity generation system (100) according to item 9, wherein a material of the blades (21a…21n, 21a´…21n´) comprises at least one of the following: Aluminium Alloy,

Carbon fibre, Glass reinforced plastics, recycled materials.

11. Electricity generation system (100) according to one of the items 7 to 10, wherein a power line entry point (27, 27) is arranged at a top of the enclosure (25´, 25´).

12. Electricity generation system (100) according to one of the preceding items, further comprising a control system (70), the control system (70) adapted to control the electricity generation system (100) in accordance with specified control parameters.

13. Electricity generation system (100) according to item 10, wherein the control parameters consider at least one of the following circumstances:
- begin and/or end of tidal cycle;
- cut out of tidal velocity;
- specified threshold of rotor speed;
- emergency case;
- marine mammal/fish activity.

14. Electricity generation system (100) according to item 12 or 13, wherein by means of the control system (70) pitch control units (22a…22n) are controlled, wherein the pitch control units (22a…22n) are arranged in the blade hub (22), wherein the pitch control units (22a…22n) are adapted to control pitch angles of the blades (21a…21n, 21a´… 21n´).

15. Electricity generation system (100) according to one of items 12 to 14, wherein the control system (70) is adapted to be remotely controlled by means of a control unit.

16. Electricity generation system (100) according to one of items 12 to 15, wherein the control system (70) is adapted to control the electricity generation system (100) in dependence of at least one of the following:
- tidal current speed;
- motions in six degrees of freedom;
- wave height and period;
- rotor torque and/or rotor speed and/or thrust;
- mooring line load;
- electric power generation.

17. Electricity generation system (100) according to one of items 12 to 16, wherein the control system (70) is adapted to control the electricity generation system (100) in dependence of at least one of the following:
- equipment space temperature and/or humidity;
- generator temperature;
- generator voltage and/or generator current;
- leak detection alarm.

18. Electricity generation system (100) according to one of items 12 to 17, wherein the control system (70) is adapted to control a shutdown of the electricity generation system (100) in accordance in at least one of the following ways:
- Manual shutdown;
- Automated shutdown;
- Emergency shutdown;
- Emergency stop.

19. Electricity generation system (100) according to one of the preceding items, comprising a communication unit (60) with at least one communication unit (61) being arranged on the electricity generation system (100) and at least

one communication unit (62) being arranged external of the electricity generation system (100).

20. Electricity generation system (100) according to item 19, wherein the communication unit (60)is based on at least one of the following communication technologies: WLAN, 5G, 4G, GSM, Satellite link.

21. Electricity generation system (100) according to one of the preceding items, wherein the electricity generation device (20, 20´) comprises a control panel.

22. Electricity generation system (100) according to one of the preceding items, wherein the electricity generation system (100) is functionally connectable to the web (40).

23. Electricity generation device (20, 20´) being adapted to be removably fixed to a mounting device (10) in the form of a floating body (10) or a fixed infrastructure, wherein the electricity generation device (20, 20´) is bidirectionally symmetric and comprises a water turbine being functionally connected to a generator (24), wherein the generator (24) comprises a helical gearbox, wherein the generator (24) is a permanent magnet synchronous motor, wherein the generator (24) comprises an incremental encoder, wherein a rotation of the generator (24) is monitorable by a signal generated from the incremental encoder.

24. Electricity generation system (100) according to one of the preceding items, wherein
an inner end of the respective blade (21a…21n, 21a´…21n´) is provided between two opposing discs and placed next to

the two opposing discs, wherein the disc acts to prevent the blade from bending.

25. Electricity generation system (100) according to item 24, wherein
the disc comprises ribs to prevent the disc from bending.

REFERENCE LIST

10	mounting device
11	railing
12	opening
13, 13´	retaining element
14, 14´	folding device
15, 15´	power line
20, 20´	electricity generation device
20a	front section
20b	tail section
21a…21n	blades
21a´…21n´	blades
22	blade hub
22a…22n	pitch control unit
23	mounting element
24	generator
25	enclosure
25a	mounting interface
25b	support structure
26	mechanical seal
27, 27´	power line entry point
28	disc
29	rib
30	control panel
40	web
50	power station
60	communication unit
70	control system
100	electricity generation system
A, B	flow direction

CLAIMS

1. Electricity generation system (100), comprising:

at least one electricity generation device (20, 20´) being removably fixed to a mounting device (10) formed as a floating body or as a fixed infrastructure by means of a retaining device (14, 14´, 15, 15´),

- wherein the electricity generation device (20, 20´) is bidirectionally symmetric and comprises a water turbine being functionally connected to a generator (24),
- wherein the generator (24) comprises a helical gearbox,
- wherein the generator (24) is a permanent magnet synchronous motor,
- wherein the generator (24) comprises an incremental encoder,
- wherein a rotation of the generator (24) is monitorable by a signal generated from the incremental encoder,
- wherein electrical energy is conductible via a power line (15, 15´) being guided from the generator (24) via an outside of the mounting device (10),
- wherein the electrical energy is conductible from the mounting device (10) to a power station (50),
- wherein the nose and tail cones (20a, 20b, 20a´, 20b´) is coated by at least two layered bio fouling coatings,
- wherein blades (21a…21n, 21a´…21n´) of the turbine are sensitive to a bi-directional water flow (A, B),
- wherein a power line entry point (27, 27´) is arranged at a top of an enclosure (25, 25´),
- wherein the electricity generation device (20, 20´) comprises a control panel (30),
- wherein the electricity generation system (100) is functionally connectable to the web (40).

2. Electricity generation system (100) according to claim 1, wherein
the mounting device (10) is a bridge.

3. Electricity generation system (100) according to claim 1, wherein
the floating body is one of the following: barge, catamaran, mooring platform, mobile platform, watercraft.

4. Electricity generation system (100) according to claim 3, wherein
the mounting device (10) is mountable to a railing (11) of the floating body.

5. Electricity generation system (100) according to claim 3 or 4, wherein
the electricity generation device (20, 20´) is mountable to an opening (12, 12´) in a bottom plate of the floating body (10).

6. Electricity generation system (100) according to one of the preceding claims, wherein
a material of an enclosure (25, 25´) of the electricity generation device (20, 20´) is at least one of the following: stainless steel, fiberglass, fibre reinforced plastics.

7. Electricity generation system (100) according to one of the preceding claims, wherein
a material of the blades (21a…21n, 21a´…21n´) comprises at least one of the following: aluminium alloy, carbon fibre, glass reinforced plastics, recycled materials.

8. Electricity generation system (100) according to one of the preceding claims, wherein an inner end of the respective blade (21a…21n, 21a´…21n´) is provided between two opposing discs (28) and is placed next to the two opposing discs (28), wherein the discs (28) acts to prevent the blade from bending.

9. Electricity generation system (100) according to claim 8, wherein the disc (28) comprises at least one rib (29) to prevent the disc (28) from bending.

10. Electricity generation system (100) according to one of the preceding claims, further comprising a control system (70), the control system (70) adapted to control the electricity generation system (100) in accordance with specified control parameters.

11. Electricity generation system (100) according to claim 10, wherein the control parameters consider at least one of the following circumstances:
- begin and/or end of tidal cycle;
- cut out of tidal velocity;
- specified threshold of rotor speed;
- emergency case;
- marine mammal/fish activity.

12. Electricity generation system (100) according to claim 10 or 11, wherein by means of the control system (70) pitch control units (22a…22n) are controlled, wherein the pitch control units (22a…22n) are arranged in the blade hub (22), wherein the pitch control units (22a…22n) are adapted to control pitch angles of the blades (21a…21n, 21a´… 21n´).

13. Electricity generation system (100) according to one of claims 10 to 12, wherein the control system (70) is adapted to be remotely controlled by means of a control unit.

14. Electricity generation system (100) according to one of claims 10 to 13, wherein the control system (70) is adapted to control the electricity generation system (100) in dependence of at least one of the following:
- tidal current speed;
- motions in six degrees of freedom;
- wave height and period;
- rotor torque and/or rotor speed and/or thrust;
- mooring line load;
- electric power generation.

15. Electricity generation system (100) according to one of claims 10 to 14, wherein the control system (70) is adapted to control the electricity generation system (100) in dependence of at least one of the following:
- equipment space temperature and/or humidity;
- generator temperature;
- generator voltage and/or generator current;
- leak detection alarm.

16. Electricity generation system (100) according to one of claims 10 to 14, wherein the control system (70) is adapted to control a shutdown of the electricity generation system (100) in accordance in at least one of the following ways:
- Manual shutdown;
- Automated shutdown;
- Emergency shutdown;
- Emergency stop.

17. Electricity generation system (100) according to one of the preceding claims, comprising a communication unit (60) adapted to provide a communication to an external control unit.

18. Electricity generation system (100) according to claim 17, wherein the communication unit (60) is based on at least one of the following communication technologies: WLAN, 4G, 5G, GSM, satellite link.

19. Electricity generation device (20, 20´) being adapted to be removably fixed to a mounting device (10) in the form of a floating body (10) or a fixed infrastructure, wherein the electricity generation device (20, 20´) is bidirectionally symmetric and

comprises a water turbine being functionally connected to a generator (24),

- wherein the generator (24) comprises a helical gearbox,
- wherein the generator (24) is a permanent magnet synchronous motor,
- wherein the generator (24) comprises an incremental encoder, wherein a rotation of the generator (24) is monitorable by a signal generated from the incremental encoder.