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A Review on Under Water Windmill

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Abstract -: *We are living in a world where almost 80% of energy in demand is supplied by sources such as natural gas, coal or oil, which are quickly waning. International treaties for the climate control have boosted the research in the field of Renewable energy from oceans. Thus alternative source of energy will prove to be highly efficient with high energy density, provided economical and technical problems are solved. Tidal stream turbines play a major role in generation of energy by renewable sources. They are driven by the kinetic energy of moving water, the generator is placed in moving water that typically result when water being flowing underwater currents around the world to make this form of marine renewable energy worth pursuing. Therefore, several demonstration projects in tidal power are scheduled to capture the tidal generated coastal currents. This is promising area of research and this review mainly focuses on the important and main projects all over the world. It involves the most successful project of a 1 MW twin axial-flow rotor system, called 'Seagen' which is installed. The installation and testing of 'Seagen' marked a remarkable progress in the field of Tidal stream turbines.*

Key Words: **Horizontal axis turbine, Marine Current turbine, Seagen, Tidal Stream turbines, Vertical Axis turbine**

1.INTRODUCTION

Renewable energy generation is growing in relevance due to the dual issues of continuing global warming and national security of electrical supply. A largely untapped potential with global potential to supply 170 TW of electricity annually resource is ocean energy. There are sufficient numbers of such fast-flowing underwater currents around the world to make this form of marine renewable energy worth to be harnessed. Tidal stream turbines are described as underwater windmills. They are driven by the kinetic energy of moving water like the way that wind turbines use moving air. The generator is placed into a marine current that typically results when water being moved by tidal forces comes up against, or moves around, an obstacle or through a constriction such as a passage between two masses of land. Tidal stream turbine can majorly help in producing the energy in hand by hand similarly to the other technologies.

Fig. 1. Introduction to Underwater Windmill

1.1 History

The first offshore tidal stream turbine was installed by researchers on Monday. The rotor uses the power of the tides to generate electricity on the English coast. Just the beginning: The first "farm" of tidal turbines could spring up off the English coast within years. Taking a windmill, turning it on its side and sinking it in the ocean is worth remarkable. That, in effect, is what done by engineers in the Bristol Channel in England. The aim is to harness the energy the tide produces day in, day out. On Monday, the world's first prototype tidal energy turbine was launched. The "Sea flow" installation was built into the seabed about one and a half kilometers (one mile) off the Devon coast. Above the surface, only a white and red-striped tower is visible. Beneath, 20 meters down, the single 11-meter long rotor turns up to 17 and a half times a minute at a maximum speed of 12 meters per second, drawing energy from the water. The "Sea flow" installation was built into the seabed about one and a half kilometers (one mile) off the Devon coast. Above the surface, only a white and red-striped tower is visible. Beneath, 20 meters down, the single 11-meter long rotor turns up to 17 and a half times a minute at a maximum speed of 12 meters per second, drawing energy from the water.

1.2 Technology in Tidal Range.

Tides play a crucial role in power generation. In-stream tidal devices are designed to capture the horizontal motion of the tide, tidal range technology exploits the vertical motion of the tidal cycle. A dam is constructed across a bay or estuary which experiences a large tidal range. Sluice gates at the dam base control fluid flow; these are kept closed until a sufficient head is built up across the dam wall. The gates are opened and water flows from the high side to the low side and in doing so passes through turbines which spin to produce electricity. Power is generated following both the flood and ebb tides with the high water being on the ocean side of the dam during flood tides and water being held within the bay during the ebb tide. Variations on the scheme include tidal lagoons, reefs and tidal fences, all of which operates using the same principle.

1.3. Tidal level and Parameter description:

The regular rise and fall of the water level of the ocean is principally caused by gravitational and centrifugal forces which are a result of the proximity of the Earth to the Moon and the Sun. When the water flows towards the shore it is called a flood tide while the receding water is called the ebb tide. This occurs on at least a diurnal (daily) basis in all areas of the world and for coastal areas in northwest Europe the tide exhibits strongly semi-diurnal (twice daily) behavior. High tide on earth occurs "in line" with the Moon and conversely low tide is + experienced at +/−90° relative to the Moon. When the Earth, Moon and Sun system is in alignment the gravitational effects of the Moon and Sun are combined to form a high tidal range (a spring tide), when the Moon and Sun are at 90˚ to one another, as viewed from Earth, the gravitational effects of the Moon are counteracted by those from the Sun, leading to an exceptionally low tidal range.

1.3. Principle:

A flow of fluid moves a set of blades creating mechanical energy which is then converted to electrical energy. They are equally troublesome for environmentalists, as wind turbines interrupt bird flights just as water turbines can disturb underwater life. One advantages water turbine enjoy over other sources of renewable energy is a predictable tide table. Ocean energy device works on the same principles as a windmill, where large underwater rotors, shaped like propellers, are driven by the huge mass of flowing water to be found at certain places in the sea. The technology consists of rotors mounted on steel piles (tubular steel columns) set into a socket drilled in the seabed. The rotors are driven by the flow of water in much the same way that windmill rotors are driven by the wind, the main difference being that water is more than 800 times as dense as air, so quite slow velocities in water will generate significant amounts of power. The energy generated, being derived from tides has the added significant advantage of being predictable.

2. Working of Under Water Windmill:

In Underwater windmill the tides push water against the blade, causing them to spin. These turbines can be placed in natural bodies of water, such as harbors and lagoons that naturally feature fast-moving flows of water. These turbines must be able to swivel 180 degrees to accommodate the ebb and flow of tides, as demonstrated by the Sea Gen prototype turbine in Ireland. As the blades spin, a gearbox turns an induction generator, which produces an electric current. In addition to being renewable, another key advantage of ocean power is that it's reliable and predictable, said Daniel England, an analyst at Green tech underwater wind mill.

3. Turbine Technology and concepts:

The harnessing of the energy in a tidal flow requires the conversion of kinetic energy in a moving fluid, in this case water, into the motion of a mechanical system, which can then drive a generator. It is not too surprising, therefore, that many developers propose using technology that mirrors that which has been successfully utilized to harness the wind, which is also a moving fluid. Therefore, most devices can be characterized as belonging to three fundamental types

These are

– Horizontal axis systems that has been installed in the Bristol Channel between England and Wales, or in Hammerfest Strom, in Norway

– Vertical axis systems such as the device that was tested in the Strait of Messina between Sicily and the Italian mainland.

– Variable foil systems such as the device that has been tested in Yell Sound in Shetland, which lies to the North of Scotland and Orkney.

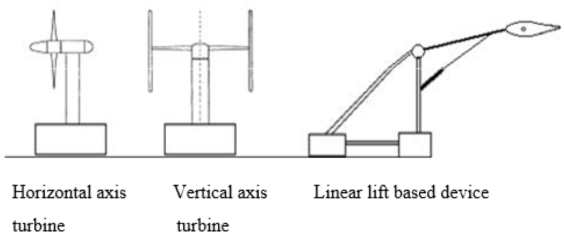


Fig. 2. Tidal turbine Fundamental types

3.1 Horizontal Axis Turbines

The Marine Current Turbine (MCT) project: Figure shows hybrid illustrations of the Seaflow turbine. It has a single 11 m diameter rotor, with full span pitch control, and is installed in a mean depth of seawater of 25 m approximately. It has exceeded its 300 kW rated power under favorable flow conditions with a 15 rpm rotor speed. A key feature is that it is mounted on a steel tubular pile, 2.1 m in diameter, set in a hole drilled in the seabed and tall enough to always project above the surface of the sea. The entire rotor and power system can be physically raised up the pile above the surface to facilitate maintenance or repairs from a boat. MCT Second project was Seagen**.** The Seagen turbine has its rotors mounted at the outer ends of a pair of streamlined wing-like arms projecting either side of the supporting pile. Each rotor drives a power-train consisting of a gearbox and generator each rated at around 500 kW. The total rated power is approximately 1 MW. Essentially the Seagen turbine produces three times the power of Seaflow. The Seagen project will be followed by an array of similar systems (farm) to be installed in an open sea location. Three turbines will be added to provide a total capacity up to 5 MW.

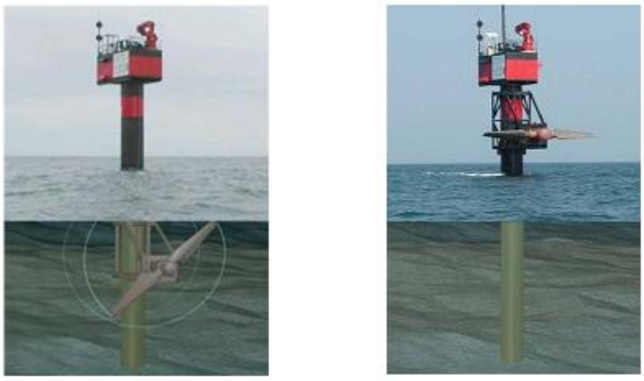
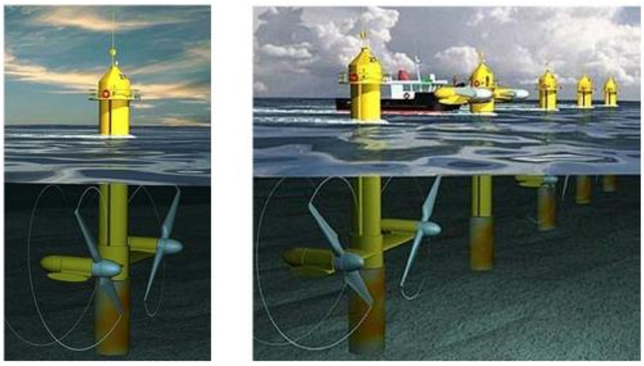


Fig.3. Hybrid illustration of Seaflow turbine



(a) (b)

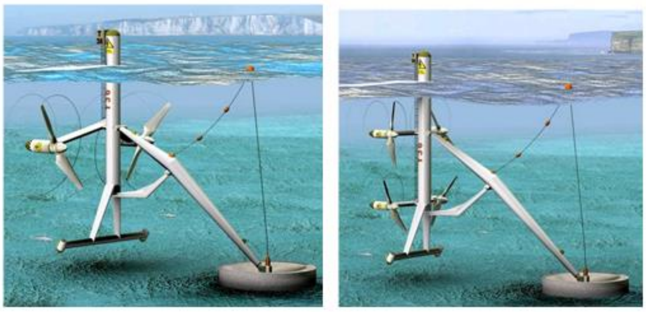
Fig.3. The Seagen system Illustration

The E-Tide Project (Norway) Hammerfest Strom has developed the so called Blue *or* E-Tide Concept in Kvalsund (Northern Norway) in 2003. The Blue Concept device is a tidal current turbine that can be installed on the seabed offshore or near shore depending on the tidal current strength. A 300 kW system was tested and the concept proven during the installation and a larger design is being developed for the same location that will provide 750-1000 kW of power. The turbine blades of 15-16 m are able to rotate on their own axes, allowing the turbine to be optimized to current conditions and also operate in both directions of the tide (pitch control).

(a) E-tide turbine. (b) Installation

Fig.4. The Blue or E-tide concept

The Tidal Stream Energy Project (UK*)*. The Tidal Stream turbine is shown in Fig.7. This configuration is designed for the site of Pentland Firth between the North of Scotland and the Orkney Islands. In the first design, the twin turbine carries two 20 m rotors, is rated at 1-2 MW depending on current speed, and operates in 30-50 m water depths. Each rotor runs in clean water upstream of its support arm. The seabed anchorage is now shown with a gravity base, and the swinging arm ball-joint is attached to the base by a three-axis swivel assembly. The swinging arm is hinged at its upper end to the main spar buoy so that it can be stowed easily for installation/removal. During operation it is held in place by a cranked strut. In today's design of Pentland Firth turbine, the 60 m deep water flow is covered by four 20 m rotors rather than a pair, in order to keep blade loads within practical limits. The whole turbine power output is 4 MW. Once rolled over into its maintenance position, the main swing-arm can be stowed for float-out removal/installation.



(a) (b)

Fig.5. The Tidal stream concept

The SMD Hydro vision TiDEL Project (UK) The TiDELconcept consists of a pair of contra-rotating 500 kW turbines, mounted together on a single crossbeam. The complete assembly is buoyant and tethered to the seabed by a series of mooring chains. The mooring system allows the turbines to align themselves downstream of the prevailing tidal flow without requiring any external intervention. As the system requires no support structure, it can be fitted in any reasonable coastal water depth. Each of the turbine powertrains are driven by 15 m diameter fixed pitched blades and are housed within a pod. The 1 MW units are designed to be mounted in an offshore tidal environment with a peak tidal velocity of 5 knots (2.5 m/sec) or more and a water depth of greater than 30 m.

Fig.6. Illustration and Front view of TiDEL.

The Lunar Energy Project (UK) and the Hydro Helix Energies Project (France). These systems have a ducted turbine, fixed to the seabed via gravity foundation. In principle, the duct captures a large area of the tidal stream and accelerates the flow through a narrowing channel into the turbine. Thus, a smaller turbine can be used for a given power output, or alternatively, a larger amount of power can be generated by a turbine of given blade diameter. The Lunar Energy tidal turbine is of a symmetrical design and capable of bi-directional operation obviating the need for a pitch or yaw control thus keeping the design simple and more cost effective. The tidal flow can be offset by 40 degrees to the duct axis without affecting the performance. A 1/20th model was tested, and a 1 MW prototype is expected soon.

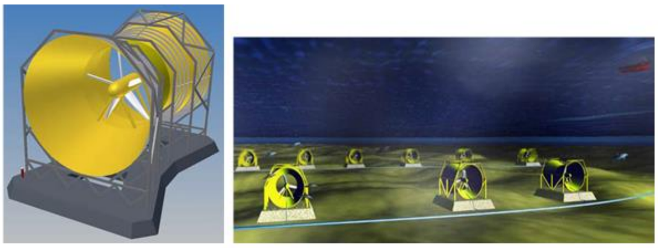


Fig.7. The lunar System illustration

3.2. Vertical Axis turbine

Turbines Vertical axis turbines that operate in marine currents are based on the same principles as the land based Darrieus turbine. The Darrieus turbine is a cross flow machine, whose axis of rotation meets the flow of the working fluid at right angles. The vertical axis design permits the harnessing of tidal flow from any direction, facilitating the extraction of energy not only in two directions, the incoming and outgoing tide, but making use of the full tidal ellipse of the flow. In this kind of turbines as in the horizontal axis ones the rotation speed is very low (around 15 rpm).

The Enermar Project (Italy). The core of the Enermar project is the Kobold turbine which is patented. Among its main characteristics, the main reason why kobold turbine starts even in high load condition is its starting torque. A pilot plant is moored in the Strait of Messina, close to the Sicilian shore in Italy, in an average sea tidal current of about 2 m/sec. With a current speed of about 1.8 m/sec, the system can produce a power of 20 kW.

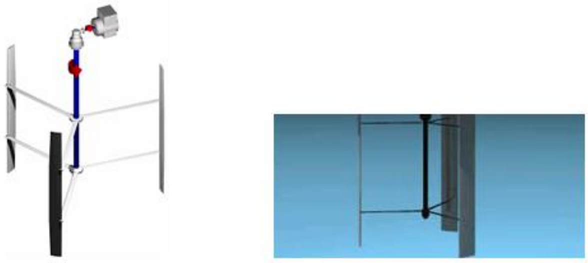
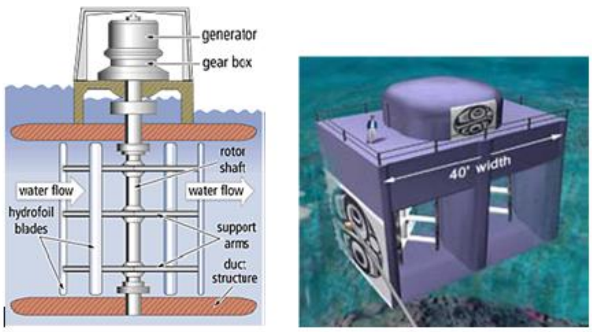


Fig.8. The Enermer project.

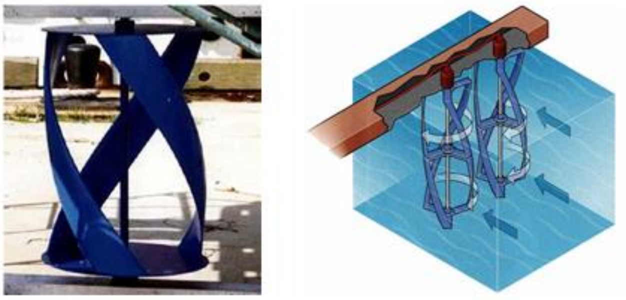
The Blue Energy Project (Canada). Four of the fixed hydrofoil blades of the Blue Energy tidal turbine are connected to rotor that drives a gearbox and electrical assembly of generator. The turbine is mounted in a durable concrete marine caisson which anchors the unit to the ocean floor, directs flow through the turbine further concentrating the resource supporting the coupler, gearbox, and generator above it. These sit above the surface of the water and are accessible for maintenance and repair. The hydrofoil blades employ a hydrodynamic lift principal that causes the turbine foils to move proportionately faster than the speed of the surrounding water. The rotation of the turbine is unidirectional on both the ebb and the flow of the tide. A unit turbine is expected to be about 200 kW output power. For large scale power production, multiple turbines are linked in series to create a tidal fence across an ocean passage or inlet.



(a) Blue Energy turbine. (b) Turbine platform.

Fig.9. The Blue energy project

The Gorlov Helical Turbine (USA). The Gorlov Helical Turbine (GHT) is shown in Figure Below. The turbine consists of one or more long helical blades that run along a cylindrical surface like a screw thread, having a so-called airfoil or airplane wing profile. The blades provide a reaction thrust that can rotate the turbine faster than the water flow itself. The GHT is self-starting and can produce power from water current flow as low as 1.5 m/sec with power increasing in proportion to the water velocity cubed. Because of its axial symmetry, the GHT always rotates in the same direction, even if the tidal currents reverse direction. This is an important advantage that simplifies design and allows exploitation of the double action tidal power plants. The standard model (1 m diameter, 2.5 m length) can be installed either vertically or horizontally to the water current flow. A single GHT rated power is 1.5 kW for 1.5 m/sec water speed and 180 kW for 7.72 m/sec. A pictorial view of a floating tidal power plant with two vertically aligned triple-helix turbines is shown in Figure Below.



(a) Gorlov turbine. (b) Expected power plant.

Fig.10. The Gorlov Helical Turbine

Oscillating Hydrofoil: The Stingray concept, developed by Engineering Business (UK), is illustrated by figure below. It consists of a hydroplane that has an attack angle relative to the approaching water stream varied by a simple mechanism. This results the supporting arm to oscillate, which in turn forces hydraulic cylinders to extend and retract. This produces high-pressure oil that is used to drive a generator. The 150 kW rated demonstrator produced 250 kW at the peak capacity and averaged 90 kWatt in a 1.5 m/sec measured current during its initial power cycles.

(a) The Stingray turbine. (b) Deployment for submerged testing.

Fig.11. The String Ray Tidal Turbine

The authors can acknowledge any person/authorities in this section. This is not mandatory.

4. Case Study:

MCT'S 1.2 MW 'SEAGEN' PROJECT

Fig.12. Location of SeaGen Project.

Country	Northern Ireland, United Kingdom
Location	Strangford Narrows between Strangford and Portaferry
Coordinates	54°22′7.2″N 5°32′45.8″W

SeaGen was the world's first large scale commercial tidal stream generator. Seaflow proved technically feasible, Seagen is needed to prove the economic and commercial feasibility. The Seagen system has its rotors mounted at the outer ends of a pair of streamlined wing-like arms projecting either side of the supporting pile. Each rotor is 16 m in diameter and drives a 600 kW power-train consisting of a gearbox and generator. the total rated power per installed unit is up to 1200 kW(e) (depending on siting conditions). The reasons for the twin rotor configuration are primarily that this permits bidirectional operation with the rotors clear of the pile wake when the rotors are downstream of the pile; 1808 rotor blade pitch control allows efficient operation when the current reverses. Also, two rotors clearly deliver twice as much energy as one would, but at less than twice the cost, so enhanced cost-effectiveness is another reason. Essentially, Seagen produces three times the power of Seaflow at around twice the cost, giving a significant 4 improvements in cost-effectiveness. It generates 1.2 MW for between 18 and 20 hours a day while the tides are forced in and out of Strangford Lough through the Narrows.

Seagen is a £10 million project. It is also supported by new shareholders of MCT and strategic partners, EDF Energy (the UK subsidiary of one of the largest utilities in the world–Electricite´ de France), by Guernsey Electricity (the Channel Island utility which happens to have strong currents around its coast), and by Bank Invest (a Danish specialist investment bank focusing on innovative and clean-energy technologies). The UK government, through the DTI, is again supporting MCT's R&D, having committed to provide a grant worth £4.3 million

4.1 Seagen technical Details:

Seagen has inherited most of the successful features from Seaflow, but it also differs in quite a number of respects. It still has full-span pitch control with carbon/glass fiber composite rotor blades. The power-train is again submersible, with a pair of planetary gearboxes driving induction generators. The main support structure is again a rolled-steel monopole although this time 3 m in diameter. The cross arm structure, such as a pair of wings, to carry the power trains either side of the pile, far enough apart for the rotors not to cut into the pile wake. Thecross-arm wings have some dihedral primarily to help raise the power trains higher out of the water for a given collar lift. The dihedral also ensures that the rotor blades cut the cross-arm wakes in a scissor like manner so that only part of a rotor blade is in the wake at any moment. The cross-arm wing section is elliptical and designed to minimize the wake thickness; some CFD analysis was carried out for MCT by QinetiQ at Hassler to optimize the cross-arm geometry. The rotors and power trains are held by three point mountings under the side wings and designed so that when raised above the water, a flat-top barge may be positioned underneath and the power-train and rotor can be lowered as a complete unit onto the barge before being replaced by reversing this process.

4.2 Technology

SeaGen generator weighs 300 tonnes. Each driving a generator through a gearbox like a hydro-electric or wind turbine. These turbines have a patented feature by which the rotor blades can be pitched through 180 degrees allowing them to operate in both flow directions – on ebb and flood tides. The company claims a capacity factor of 0.59 (average of the last 2000 hours). The power units of each system are mounted on arm-like extensions either side of a tubular steel monopile some 3 meters (9.8 ft.) in diameter and the arms with the power units can be raised above the surface for safe and easy maintenance access. The SeaGen was built at Belfast's Harland and Wolff's shipyards.

Fig.13. Artist's impression of arrayed Seagen turbines showing one raised for maintenance

4.3 Some key features: Rotors and nacelles raised above sea level for maintenance,2 x 600kW rotors:16m diameter Installed on steel pile, Transformer and electrical connection to grid in accessible and visible housing at top of pile, Deployment in arrays or "farms" of hundreds of turbines

Fig.14. Rotor Assembly at Harland and Wolff.

The power system is variable speed, variable voltage, and variable frequency with a control system able to vary both the frequency converter's parameters and the rotor blade pitch angles in order to optimize performance. The control strategy is to achieve a successful startup by initiating rotation without generation and then under the correct conditions starting the generation process at a current velocity of about 0.7 m/s. The system then seeks to maximize the power until the current speed reaches a level where rated power is achieved, which will typically be at about 2–2.3 m/s depending on the local site conditions. For higher current velocities, the pitch-control mechanism sheds power by reducing the angle of attack of the blades to maintain as close to rated power as possible. When the tidal stream velocity starts to reduce, the control system maintains rated power as long as the velocity is high enough and thereafter, as the speed ramps down, it maintains maximum power for the conditions, until the velocity falls below 0.7 m/s, at which time the system cuts out and the rotor is parked with its blades 'feathered'. When the tide turns and the flow direction reverses, the control system pitches the rotor blades 1808 ready for operation in the reverse direction once the velocity again exceeds the cut-in speed. Other design features of interest are that the collar and cross-arm, carrying the pair of rotors and their power trains, can be lifted by a pair of hydraulically activated vertical struts driven by rams, situated in the above water housing. This housing also provides a control centre where the control PCs are located and where ancillary equipment such as a hydraulic power pack, a small air compressor, safety equipment, and a dehumidifier are located. Transformers, to deliver power into a marine cable at 11 kV, and power-conditioning equipment are located in the top of the pile on three levels and the interior water-cooled pile surface is used to provide cooling, with a fan to circulate the internal air and the aforementioned dehumidifier to take out condensation. The interior of the pile and housing are sealed to minimize ingress of moisture and sea salt.

Fig.14. Installation of Seagen.

It is planned to carry through an extremely thorough testing programme where possible prior to installation to ensure bought-in items are to specification. The turbine will then be commissioned and tested firstly to obtain performance data and then to try various control strategies, before seeking to obtain operational reliability of the highest possible order. A continuous environmental monitoring programme will be run in parallel with the main programme, to confirm that the system is not causing significant adverse environmental impacts, and that if any such impacts are detected, steps can rapidly be taken to identify any such problem and develop effective mitigation measures.

5. Conclusion:

More and more people have recognized the importance of the renewable energy, the vast coastal and offshore areas contributes one of renewable resources, i.e. the tidal stream energy, to the entire energy consumption. The emphasis has been put on tidal turbine concepts. Indeed, it has been described the strength and the weakness of the major tidal turbine technologies. Moreover, attempts have been made to highlight current trends and alternative issues for generator topologies. MCT believes it is well on track to delivering commercial tidal stream technology with the potential to supply electricity on a large-scale, at low cost and without pollution. It is believed that the concepts under development by MCT will become one of the primary techniques for extracting energy from the seas.

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