Understanding of Basics of Tidal Energy

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***Abstract-* The current global energy sector needs an efficient and economic alternate of the fossil fuels as they are getting depleted and are also major sources of anthropogenic pollution. Tidal energy is one of those renewable energy sources which are almost carbon free as it does not produce any pollutants during its operation. Tidal Energy has emerged as a very promising energy source but still in the group of renewable energy sources this is not been developed on a large scale. This report aims to study the tides as an energy source, different technologies, economics and social and environmental impacts. The two types of tidal technologies, Tidal Range and Tidal Stream, are discussed in detail in the report. The economical review of both the types is mentioned in detail. The critical study on the social and environmental impacts has been carried out in the report.**

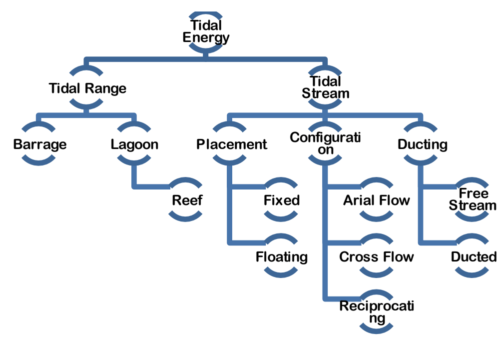
I. INTRODUCTION

Tides are the form of the hydro-energy, which are the result of combine effect of the rotations of earth around the sun and the gravitational effect of the moon, sun and other planets on earth in the solar system. The tidal energy is only renewable energy which can be predicted very accurately. Most spots in the oceans undergo usually two high tides and two low tides in the day, which are known as semi-diurnal tides spots; but the areas where just one high and one low tide in a day are experienced in a day is known as diurnal tides spots. The classification of the tides in an open sea can be done by as little difference as 1 m. The effects of tides on the shore area are different than the effect of them in the ocean currents. The above phenomena decide which method of the power generation is to be used and where.

The early days of the technology had focused on the estuaries, where certainly the very large volume of the water passes through narrow channels with a high velocity. The kinetic energy of the stream of water can be used in very efficient way to drive the turbine and apparently to generate the electricity. Many experiments and pilot plants have been designing to understand and prove the idea. The biggest success in the history of the tidal energy is the La Rance tidal power plant. The plant runs on 24 turbines of rated capacity 10 MW; which generates almost 600 GWh electricity every year (La Rance Tidal Power Plant, 2009).

Depending on the location of the tidal power plant, the working mechanism and type of the turbine can be chosen. The power generating methods can majorly be classified in two methods as follow.

II. TECHNOLOGY



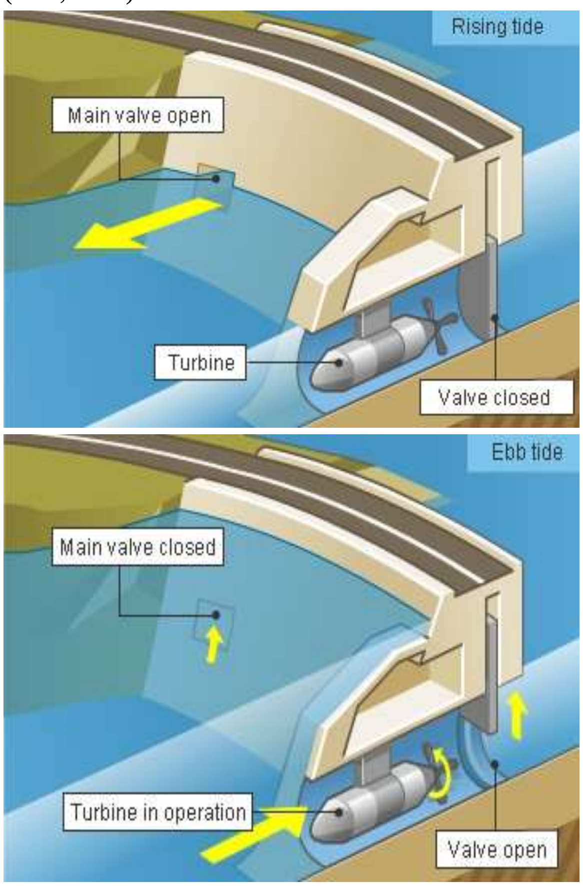
(Entec, 2007)

A. TIDAL RANGE

The rise and fall of the tides cause water flow in and out in estuaries, and this creates the height difference at two different points in estuary. A barrage or dam can be built to utilise this height difference to generate the electricity. Thought the tidal range has to be more than 5 m for the barrage to be beneficial. (ESRU, University of Strathclyde, No date)

(a) Tidal Barrage:

This is a conventional method of the electricity generation using tidal energy, which employs the dam or barrage as its name suggests. The dam or barrage is built to serve the purpose of water flow thought the turbine it into the basin and vice versa. The flow of the water can be controlled by the means if the gate (sluice gate) at the entrance of the barrage to trap that in the basin or estuary during high tide, this creates the hydrostatic head. The hydrostatic head helps to release the water back into the water body during low tide, which passes through the turbine and generates the electricity. The advantage of the system is that it is simple to design if one-basin-system or slightly complicated if two-basin-system, but the electricity can be generated for comparatively short period of time if. This disadvantage can be overcome using cross-flow turbine. This method is known as the EBB GENERATION method. Diagrammatic representation of the system is shown in figure 1. (ICIT, 2011)



(Image Taken from http://www.icit.hw.ac.uk/student_project/sweyn4.htm)

In the FLOOD GENERATION method, the sluice gates are kept closed during the flood tide to keep the water level high outside the barrage. At the right time the water is allowed to flow through the turbines into the barrage to drive it and generate electricity eventually. This method is unfavourable because of its adverse effect on shipping. (ICIT, 2011)

The combination of the flood and ebb generation method can eliminate many of the disadvantages of the stand-alone generation system. During the flood tide the sluice gate is kept closed and water is allowed to flow into the basin driving the turbine to generate the electricity. When the hydrostatic head is incapable of driving the turbine the sluice gate are opened and kept open until the next high tide. This makes the water flow out the basin and drives the turbine. This method almost eliminates the non-generation stage of electricity and hence increases the efficiency of the power plant. (ICIT, 2011)

If the combine generation method is not suitable for any reason, the provision of the two-basin system is the best solution. This system basically works on the same principle as one-basin system with some variation in design. Variety of the turbines can be employed for the application depending upon the requirements.

The energy produced by turbine at any particular instance can be calculated using below equation.

$P = \rho * g * C_d * A * [2 * g * (Z_1 - Z_2)^3]^{0.5}$ (ESRU, University of Strathclyde, No date)

Where P = Power, ρ = density (Kg/m3), g = gravity constant = 9.81, C_d = Discharge Coefficient, A = Cross section area (m^2), Z_1 and Z_2 = Height (m) of water level in sea and in basin respectively.

(b) Tidal Lagoon:

This system is similar to the barrage design system, but the only difference is that they are not built all over the estuary instead just consists a part of it only. The idea of building the tidal lagoons (also termed as impounded walls) is to create independent structure on a seabed which provides better environmental and economic renewable energy approach as it avoids blocking off the shoreline. Tidal lagoons are made of the loose rocks, sand and gravel to catch and hold the water during the high tide, which gets released in to the sea during the low tide cycle driving the turbine to generate the electricity. The turbines are located underwater, and the electricity is transmitted to the shore using the underwater cable connections. The best location for tidal lagoons is the shallow part of the sea where the low tide level is easy to achieve. In case of any accident, damage to the structure would not affect the associated accessories or other safety issues as a result the failure would be economic. (Entec, 2007) (ESRU, University of Strathclyde, No date)

B. TIDAL STREAM

Tidal stream or submerged turbine systems are comparatively smaller devices than the tidal range as they do not require any sort of big structures or barriers to be built. Water also has the phenomena to flow from low pressure region to the high-pressure region this pressure difference causes acceleration of the water flow and that can be used to generate the electricity. The idea is to place these devices on the seabed on monopole or fixed concrete base structure; few designs may float but fasten very securely to the seabed. Some devices are designed to be submerged while others may have some part above the water level. (Entec, 2007)

The motive of this technology is not to extract all energy from moving water rather just a part of it. It is possible to predict the maximum amount of energy that can be produced using these devices for different location in the sea.

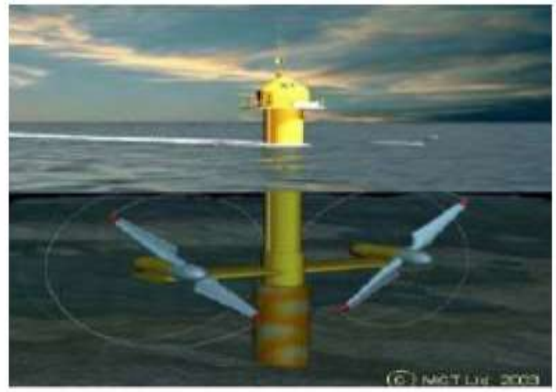
The chief advantage of this tidal stream technology is that it can be installed and operated in stages and can be expanded as required. (Entec, 2007)

(a) Placement:

It is necessary to make sure the tidal stream devices are located at specific location and not moving so that they do not affect the other utilisations of the sea and maximum energy can be produced.

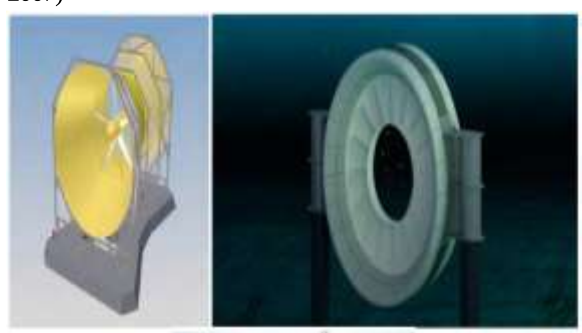
Fixed

The general approach to fix the devices on the seabed could be piling based or gravity based, and it depends on the type of the seabed. Piling (generally mono-piles) needs drilling or effective striking of the pile pillar on the seabed. This can be installed in water up to almost 40 m deep. This concept is being used in off shore wind farm widely. (Entec, 2007)



(Image Taken From http://www.sd-commission.org.uk/publications/downloads/TidalPowerUK2-Tidal_technologies_overview.pdf)

Gravity based foundation needs the seabed levelled and arranged with fine stones. The concrete float is employed to keep the structure upright and on the same location by the means of the gravity. (Entec, 2007)



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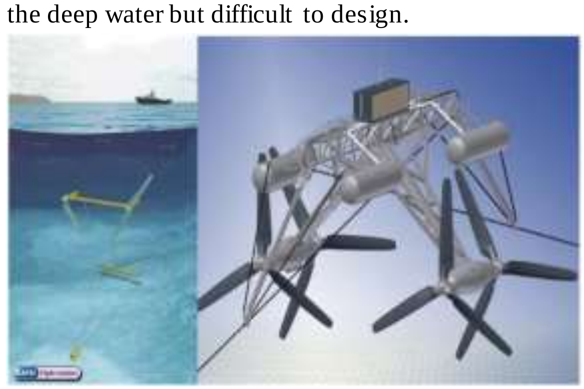
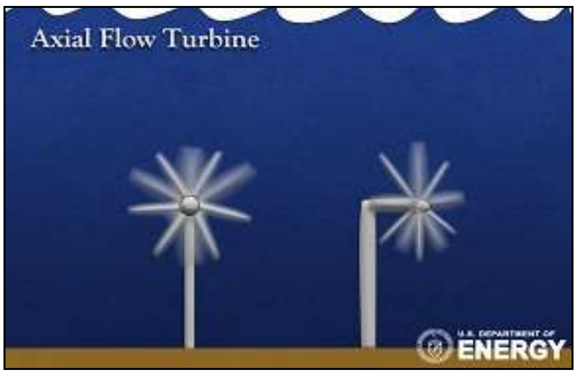
Floating

The devices are placed onto the seabed using the anchors or moors in floating foundation. This is generally a light weight system consist of single or multi-turbines on a frame that is floating at required depth in water. These systems are more suitable for the deep water but difficult to design.



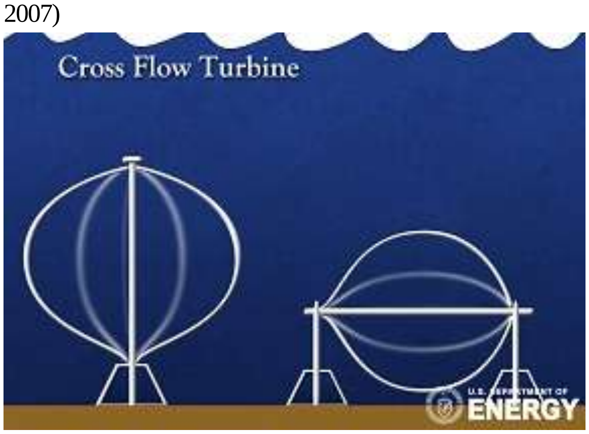
(Image Taken From http://www.sd-commission.org.uk/publications/downloads/TidalPowerUK2-Tidal_technologies_overview.pdf)
(Entec, 2007)

(b) Configuration
The efficiency of these devices directly depends on the cross-section or swept area of the rotor and hence small fundamental change in the design can make significant difference.
Axial-flow
The energy is produced using a rotor in which direction of the flow of water is in the direction of the rotation axis. This concept is very similar to modern wind turbine farms. (Entec, 2007)



(Image taken from http://www1.eere.energy.gov/windandhydro/hydrokinetic/techTutorial.aspx)

Cross-flow
Cross flow rotors produce the energy using the water flowing perpendicular to their rotation axis. (Entec, 2007)



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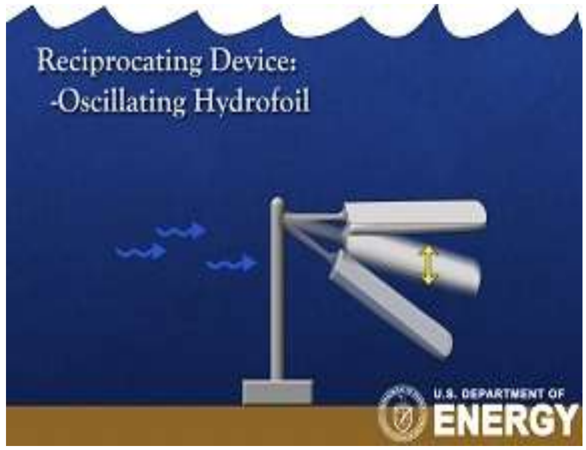
Reciprocating
These devices are designed to move up and down with the flow of the water, having a hydrofoil(s) connected to the rotating shaft which moves by either hydraulics or mechanical forces to generate the electricity. (Entec, 2007)



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(c) Ducting
The ducting is covering the turbine to improve the flow through the rotor. The change in the cross-sectional area alters the velocity of the flow and the quantity of the water. This is very effective in low speed sites or can provide the same output with the smaller rotor which is can balance the cost of the operation, although it is preferable if the ducting is cheaper than the larger rotor. (Entec, 2007)

III. DISCUSSION

Economics
The biggest huddle in execution of any renewable energy plans is the capital cost, investments and its payback time. As many of the renewable technologies are still under development, they are not as efficient as the conventional methods of energy production and hence not cost effective as well. Despite of this, looking at the current status of non-renewable energy sources and its market it is inevitable to look for the renewable energy technologies.
The initial investment and hence the capital cost for the tidal energy scheme obviously depends upon the technology used. The capital cost comprises of the materials, components, labour, manufacturing, site

preparation, connection to the onshore electric work. The capital cost varies with time as the development in technology, changes in cost of the components and other indirect expenditures. The operation and maintenance costs of tidal projects are very small compared to the capital cost e.g. constructing the tidal barrage necessitates the large capital investment, but the turbines are only required to be substituted every 30 years and the plant can run with the same efficiency for years.

The tidal barrages could be easy to build and operate because of the enough experience in the technology, which could cost more in case of the tidal lagoons and tidal stream technologies as they are not practically implemented yet on a successive scale. However, the investors have shown confidence in the new technologies and experienced and skilled persons are working on it to take it to next level and make it economically beneficial. (Kaltschmitt and Streicher, 2007) (Entec, 2007)

The initial cost of the electricity generated using the tidal energy is likely to be high respective to the non-renewable energy source but the development in the technology helps to lower the price. The Rance Tidal Power Station, owned by electricity giant EDF, works on tidal barrage technology produces electricity at a cost of the 1.8 c/kWh which is even less than the nuclear energy cost (roughly 2.5 c/kWh). The power station took almost 5 years to be built and the total construction cost was almost €95m (British-Hydro Organisation, 2009)

The tidal stream technology has no comparable projects in practice and hence it is very difficult to understand and assure the economics of it. This method would widely depend on the site of installation and the technology used. The Carbon Trust's Marine Energy Challenge developed a model to estimate the economics tidal stream devices in the UK and found that the device could up to £8000/ kW but development in the technology has delivered few systems which were built for under £4800/kW. Considering the above statistic it is estimated that first pilot production model could costs between £1,400/kW and £3,000/kW and hence this implies that first 5 MW farm would cost between £7 and £15 million. The energy cost and its payback period also depend on the installation cost which directly depends on the capacity of the plant. Installing 5 MW plant would require almost 24% less and 30 MW plant would require almost 40% less installation cost compared to 1 MW plant. (Entec, 2007)

Environmental and Social Impact

The construction of tidal barrage or tidal lagoon onshore has some social consequences on surrounding. The transportation near the coast would get affected and might affect the sea trafficking sometimes, but the barrage can be used as a road or rail link and that helps to attract the tourists which can add to the local economy. It is also possible to integrate the wind turbines to add on the power.

The general approach to build the tidal stream plant is in remote areas and hence the local communities are required to be considered. The operational part of the plant is underwater, which eliminates the possible disputes and complications related to the aesthetics of water, shipping business and navigation industry.

The tidal power plants would help the local economy as well as employment would be required during the construction and even whilst working.

It is very important to consider the environmental issues and impact while thinking about any tidal power plants as they play very significant role in ecosystems and surrounding environment. The tidal energy has no direct emission of the CO_2 or any other hazardous gases during operation and hence is one of the potential technologies to replace the fossil fuels. It is predicted that the high tides will lower to some extent but can be avoided using the pumps. Reduction in high tide can lead to the generation of farm land near coastal area as the coastal area will be covered less by the salt water. (Wyre Tidal Energy, No Date)

The construction phase and closing of the estuaries may lead to disappearance of marine flora and fauna due to the salinity fluctuation. The accidents with underwater lives are possible in case of the tidal stream plants, but there are no strong evidences available. One of the major concerns with underwater technologies is the effect of the power lines which may affect the aquatic animals that use the earth's natural magnetic field for their navigation. Many researches are under progress to understand the effect of the electromagnetic field of the devices and their effects on marine lives.

The Future of Tidal Power

The tidal energy technology is competing with many other renewable energy technologies along with nuclear energy, which has gained a major attention these days. Despite of that, full-scale prototype tidal current systems are being developed and tested worldwide. The UK government has identified almost 42 potential sites for the tidal stream generation. The findings of the DTI's Energy Technology Support Unit (ETSU), in the UK suggests that 36TWh/year energy could be produced using the most hopeful tidal stream sites in the UK. The Scottish Enterprise estimates that almost 34% of the UK's energy could be produced using tidal stream technology. There are many sites recognized all over the world including the India, South Korea, Canada, New Zealand etc. (Entec, 2007)

IV. CONCLUSION

The Tidal energy has shown a promising aspect to become a viable option for a large-scale energy production technology in the time of the depleting oil reserves and global climate crises. The research and development in the tidal stream technologies can make tidal energy low-cost and environment friendly. The tidal range and tidal stream technologies are fundamentally different and hence their viabilities on a commercial scale are also different. The tidal range technology has been proven successful at large scale and hence it catches the most of the investors' interest. Although the high investment cost, long period of time for the construction, high requirement of the raw materials and their costs have made investors look into the tidal stream. The tidal barrages have plenty of information and experience available, but they have very limited options for the sites, but it is still possible to construct large number of tidal lagoons.

The tidal stream systems are difficult to built and even more difficult to maintain and hence their maintenance cost is much higher than the tidal range, but they have wide range of sites and scales. It is expected to have more tidal stream farms having sole device to a plant of 30 or more. The significant improvements have been noticed in the technology which has made the process considerable over a period of time in terms of the efficiency and economics.

The effective environmental monitoring of the power plants is always expected to be carried out before the installation and the research programmes have been initiated to understand and avoid adverse environmental effects. The study of the effects of electromagnetic field, noise and other operational factors on marine life is being taken very seriously.

In longer term, tidal energy technology can contribute a great share in a world energy scenario as cheap as nuclear energy.

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