“Tidal Energy Harvesting”

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Abstract-

Tidal power, also called tidal energy, is a form of hydro power that change the energy of tides into useful forms of power, mainly electricity. Although not yet wide used, tidal power has potential for upcoming electricity generation. Tides are more inevitable than wind energy and solar power. Among the sources of renewable energy, tidal power has regularly suffered from relatively high cost and limited availability of sites with sufficiently high tidal flow of velocities, thus constricting its total availability. However, many latest technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), indicate that the complete availability of tidal power may be much higher than previously assume, and that economic, environmental costs may be brought down to competitive levels.

Keywords- Tidal Lagoon, Tidal Barrages, Tidal range, environmental costs

I. INTRODUCTION

Generation of electrical power from ocean tides is very similar to traditional hydroelectric power generation. The simplest generation system for tidal plants involves a dam, known as a barrage, across an inlet. Usually, a tidal power plant consists of a tidal pond created by a dam, a powerhouse containing a turbo-generator, and a sluice gate to allow the bidirectional tidal flow. The rising tidal waters fill the tidal basin after opening the gate of the dam, during the flood tide. The gates are closed, when the dam is filled to capacity. After the ocean water has receded, the tidal basin is released through a turbo-generator. Power can be generated during ebb tide, flood tide, or both. Ebb tide occurs when the water is pulled back, and flood tide occurs when the water level increases near the shore. Studies demonstrate that the tidal power will be economical at sites where mean tidal range exceeds 16 ft.

One of the advantages of tidal energy harvesting is that the tidal current is regular and predictable. Furthermore, tidal current is not affected by climate change, lack of rain, or snowmelt. Environmental and physical impacts and pollution issues are negligible. In addition, tidal power can be used for water electrolysis in hydrogen production and desalination applications. However, tidal power generation is a very new technology, which needs further investigations and developments. Similar to the wind turbines, tidal turbines can be used for tidal energy harvesting. Tidal turbines and wind turbines are similar in both appearance and structure, to some extent. Tidal turbines can be located in river estuaries and wherever there is a strong tidal flow. Since water is about 800 times as dense as air, tidal turbines have to be much stronger than wind turbines. They will be heavier and more costly however, they will be able to capture more energy at much higher densities usually, tidal fences are mounted in the entrance of ocean channels.[1]

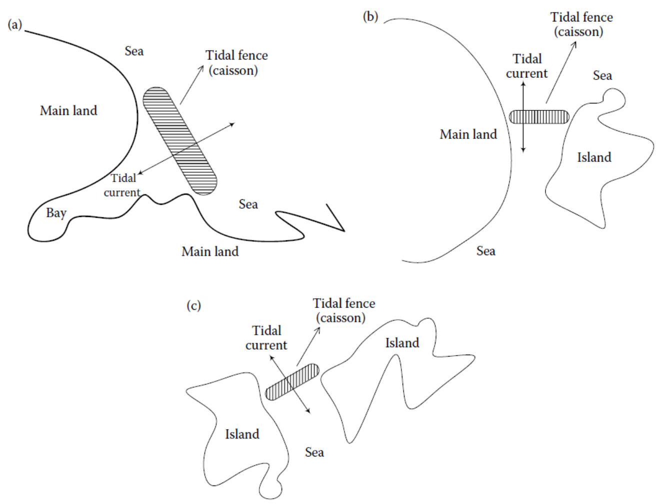

Fig 1.1 Tidal fences can be mounted (a) at the entrance of bays, (b) between the main land and an island (c) between two islands.

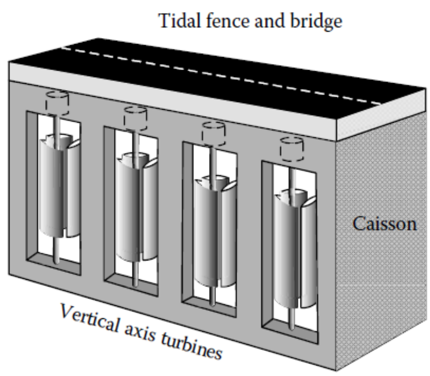

Fig1.2Tidal fence and bridge structure

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II.HISTORY OF TIDAL ENERGY HARVESTING

The earliest evidence of the usage of the oceans' tides for power conversion dates back to about 900 A.D., in Britain and France. Much later, American colonists built tidal-powered mills in New England. Naturally occurring tidal basins are used by Americans to construct tidal power plants by building a barrage across the opening of the basin and allowing the basin to fill with the rising tide, impounding the water as the tide falls down. The impounded water could be released through an energy conversion device like a waterwheel or a paddle wheel. The power was used quite widely for grinding grains and corn.

The idea of generating electric power from exploiting the power of the tides in estuaries was proposed in 1920.In 1967; the world's first tidal electric plant was successfully completed on the Rance Estuary in Brittany, France. The enclosed estuary of the Rance River has very large tides with 13.5m difference between high tide and low tides during the equinox. The 740-m-long barrage is simultaneously used as a road and it also contains a ship lock. This 240mWpower plant has 24 two-way 10mW turbines, and it is sufficient to power 4% of the homes in Brittany. So far it is still the largest operating commercial tidal facility in the world. It attracts large numbers of visitors and students every year

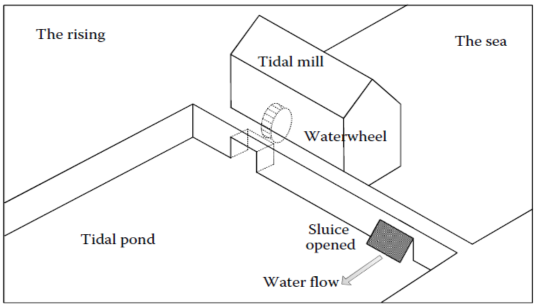

Fig 2.1 Water flows inside to the tidal pond.

III.PHYSICAL PRINCIPLES OF TIDAL ENERGY

Gravitational interaction between the moon, the sun, and the earth attributes the rhythmic rising and lowering of tidal height. The attraction force exerted by the moon or the sun on a molecule of water can be calculated as

$$f = KMm/d2 ,$$

Where f is the attraction force, K is the universal constant of gravitation, M is the mass of the moon or sun, m is the mass of a water molecule, and d is the distance from a water molecule to the moon/sun. Due to the less distance between the moon and the earth, the moon exerts 2.17 times greater force on the tides as compared to the sun . As a result, the tide closely follows the moon during its rotation around the earth, bulging along the axis pointing directly at the moon. When the sun and the moon are in line, whether pulling on the same side or on the opposite side, their gravitational forces are combined together and this results in a high "spring tide" . When the moon and the sun are located at 90◦ angle to each other, their gravitational force pulls the water in different directions, causing the bulges to eliminate each other's effect. This results in a smaller difference between high and low tides, which is known as a "neap tide" . The concepts of spring tide and neap tide. The period between the two spring tides or neap tides is around 14 days, half of the lunar cycle. The range of a spring tide is commonly about twice as that of a neap tide, whereas the maximum period cycles impose smaller perturbations.

The amplitude of the tide wave is very small in the open ocean. The typical tidal range is about 50 cm in the open ocean. However, the tide height can increase dramatically, when it reaches coasts or continental shelves, bringing large masses of water into narrow bays and river estuaries along a coastline. At some sites, the tidal flow can be heightened to more than 10m by the complex resonance effects. Bay of Fundy, in Canada, where the greatest tides in the world can be found, and the Severn Estuary, in England, are famous examples of this effect. In these areas, two high tides occur in one day, called semidiurnal tide, with a tidal cycle of about 12 h and 25. This daily variation is quasisinusoidal. Tidal wave can also be reinforced by reflections between the coast and the shelf edge, and funneling effect (due to the shape of the coastline as the tidal bulge progresses into a narrowing estuary), In addition, tide can also be diurnal (one tidal cycle per day with a period of 24 h and 50 min) or mixed (with a tidal cycle intermediate between a diurnal tide and a semidiurnal tide).[2]

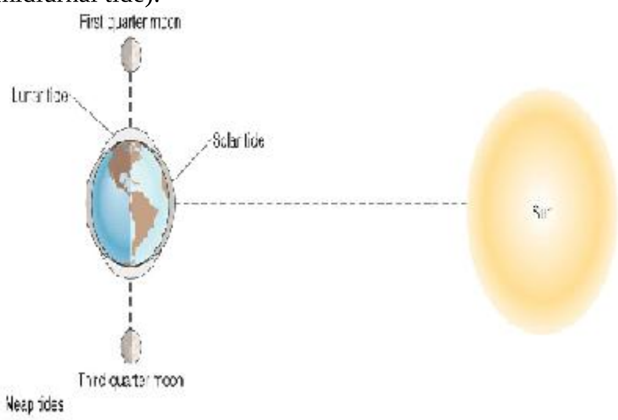

Fig 3.1 Gravitational effect of the sun and the moon on tidal range.

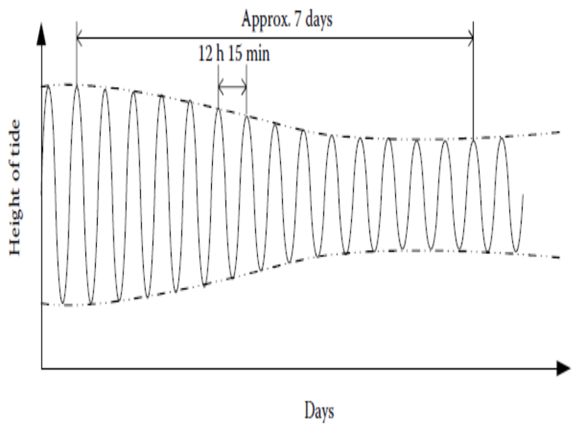

Fig 3.2 Tidal variation during a week.

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IV. TIDAL BARRAGES APPROACH

Tidal barrages approach is a conventional method, where a barrage is placed across an estuary with a large tidal range to create a pressure difference, and operate a hydroelectric power plant with intermittent flow. The Rance River Estuary plant is a well-known example of this approach. The basic elements of a barrage are caissons, embankments, sluices, turbines, and ship locks., turbines, and ship locks are housed in caisson (very large concrete blocks). Where it is not sealed by caissons. There are three main operation patterns in which power can be generated from a barrage: ebb generation, flood generation, and two-way generation.

1] EBB GENERATION

In ebb generation, first the basin is filled by the incoming tide through the sluice gate, and then the sluice gates are not opened. The turbine gates are kept closed until the sea level falls to create sufficient head across the barrage, and then they are opened so that the water passes through the turbines to generate power until the water level inside the basin is again low. This process is expressed in Figure 4.1.Ebb generation takes its name because generation occurs as the tide ebbs.

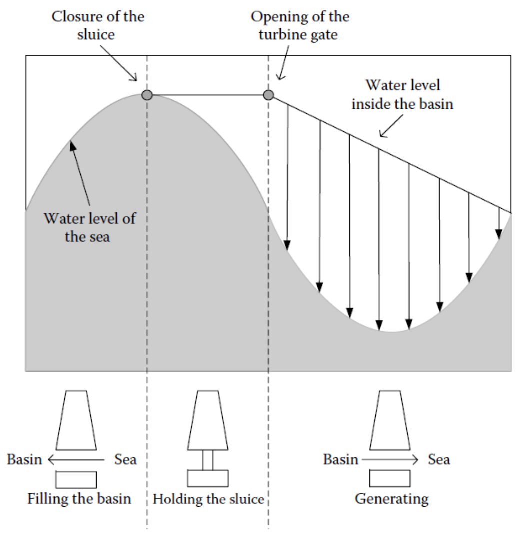

Fig 4.1 Process of the ebb generation approach.

2] FLOOD GENERATION

The flood generation method uses incoming tide to generate power, when water passes through turbines. When the tide is coming, the sluices and the turbine passages are closed so that the water level on the ocean side of the barrage rises. When sufficient head is created, the turbine gates open and the generators start to work. The process of this approach is presented in Figure 4.2. Generally, its efficiency is a little lower than that of ebb generation method, because the surface area of the estuary decreases with depth, which means less water can be contained. Flood generation is less flavored due to problems such as more severe potential ecological problems for the basin and reduced access of shipping.

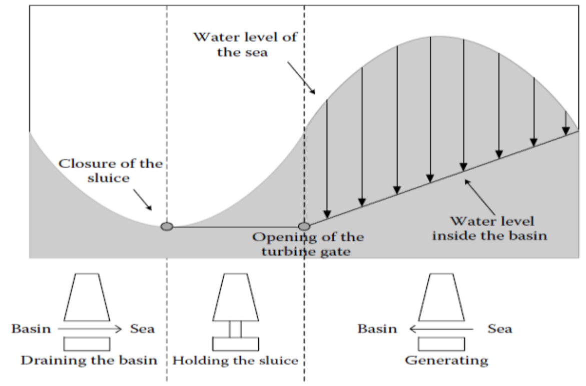

Fig 4.2 Process of the flood generation approach.

3] TWO-WAY GENERATION

Two-way generation approach combines the ebb generation and flood generation methods. Generation occurs as the tide both ebbs and floods in every cycle. The process of this approach is expressed in Figure 4.3. This method can extract more energy than ebb or flood generation. However, practically, it cannot significantly improve the efficiency due to several facts. First, the turbines have to be designed to operate in both directions, which results in less efficiency and more cost. Second, the water passage has to be longer, in order to capture energy from both water flow directions, which is another issue in two way generation. In addition, it also has the potential ecological and shipping problems associated with the flood generation method[1]

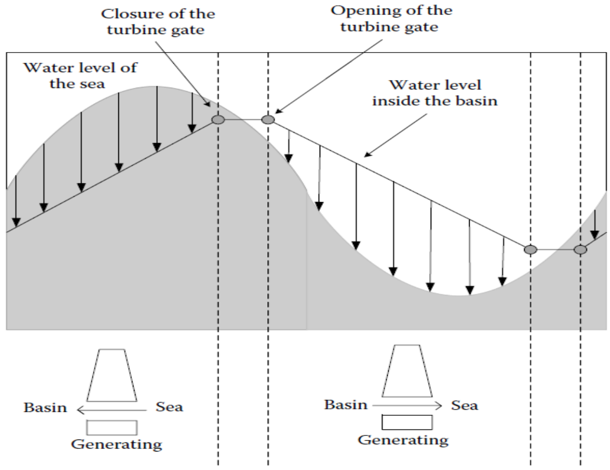

Fig 4.3 Process of the two-way generation approach.

V. TIDAL LAGOONS CONCEPT

The tidal lagoon, as shown in Figure 5.1, is an offshore tidal power conversion approach. It may relieve the environmental and economic problems of the tidal barrage method. This concept was proposed by the Tidal Electric Ltd. Tidal lagoons can be built of loose rock, sand, and gravel. A 60MW project has been proposed for Swansea Bay, UK, which covers $5km^2$ in one mile offshore area. In comparison to barrages constructed at estuary, offshore tidal lagoon can utilize both the ebb and the flood tides for generation, since the environmental and shipping problems are much smaller. Its

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generation cycle is illustrated in Figure 5.2 Conventional low-head hydroelectric generation equipment and control systems are proposed to be utilized in this concept. This concept uses mixed-flow reversible bulb turbines[1]

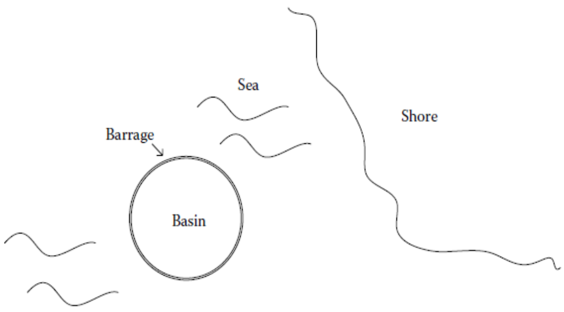

Fig 5.1 Schematic diagram of a tidal lagoon.

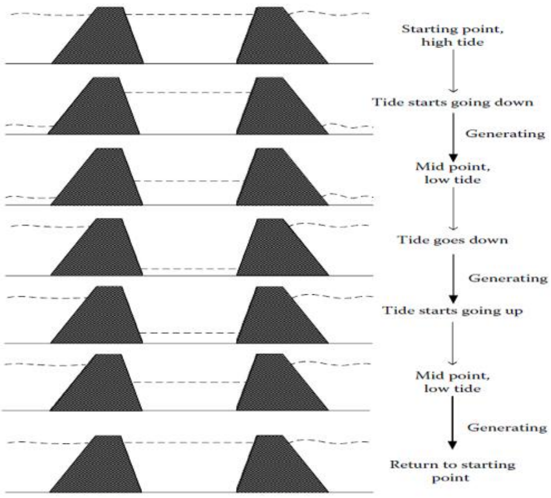

Fig 5.2 Operation process of a tidal lagoon.

VI.GRID CONNECTION OF TIDAL ENERGY

SeaGen, the world's first commercial-scale tidal turbine, situated in Northern Ireland's Strangford Lough and developed by British tidal energy company, Marine Current Turbines (MCT), has delivered electricity into the grid for the first time. The tidal current turbine has briefly generated 150kW of power onto the grid as part of its commissioning work, ahead of it achieving total capacity in a less weeks time. SeaGen's power is being intentionally constrained to 300kW during the commissioning phase, but once totally operational, it will generate 1.2MW of power, supplying neat and green electricity to the equivalent of 1000 homes.

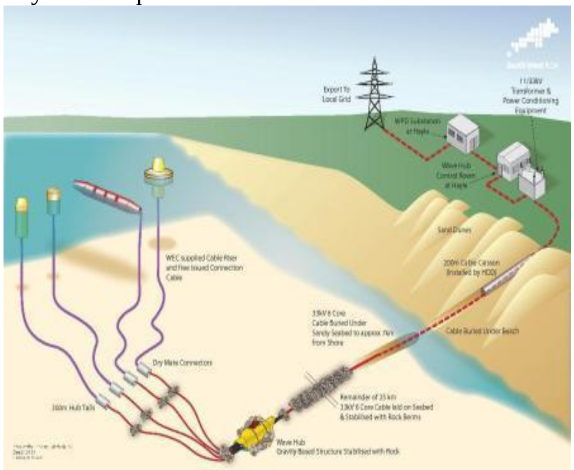

Fig.6.1 Grid connection.

Fig.6.2 Grid cables.

1] TIDAL POWER STATIONS THAT ARE IN OPERATION IN INDIA

a) Kuchchh Tidal power project (West Coast)

- It was identified in 1970 by CEA, more than twelve specialized organizations of Govt. Of India and Govt. Of Gujarat will be involved in the field of investigations for sea bed analysis The proposed Tidal power scheme envisages as installation of 900 MW project biggest in the world, located in Hansthal creek. It comprises of the following.
- The main tidal rock fill barrage of 3.25 Km length was proposed for construction across Hansthal creek which is accommodate the power house, sluice gate & navigational locks It envisages installation of 900 MW capacity comprising 36 geared bulb type turbo-generators units of 25 MW each & 48 sluice gates of 10M*12M.Size would generate 1690 Gwh energy annually, Unfortunately, execution of this project has not been taken up so far because of unknown reasons In Jan 2011, the state of Gujarat announce plans to install Asia's first commercial-scale tidal current

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power plant; the state government approved the construction of a 50 MW project in the Gulf of Kutch.

b) Durgaduani Creek (East Coast)

The country's first Tidal power generation project is coming up at Durgaduani Creek of the Sundarbans. The 3.75 MW total capacity durgaduani creek tidal energy project is technology demonstration Project and will span over an area of 4.5 Km

VIII. ENVIRONMENTAL IMPACTS.

- Tidal energy has significant environmental benefits. It is nonpolluting and replaces coal and hydrocarbon fuels. A barrage, sometimes, can also provide protection over coastal areas during very high tides by acting as a storm surge barrier or breakwater. However, any proposed large-scale energy project has environmental impacts that must be weighed and considered.

1) Sediment

- Estuaries often have high volume of sediments moving through them, from to the rivers to the ocean. The introduce to a barrage into an estuary may result in sediment accumulation within the barrage, which requires more frequent dredging

2) Fish

- Fish migration is also affected heavily by tidal barrages. Some fishes such as the salmon must migrate from saltwater to freshwater to spawn and migrate back, multiple times in their lifespan. When the sluices are open, they can get through. Otherwise they have to seek way out through the turbines, which may end their life. Marine mammal's migration may also be affected in some regions and, therefore, fishing industry will be affected.

3) Salinity

- Barrages may also cause less water exchange between the sea and the basin. Result of this will be the decrease in the average salinity inside the basin, which may affect the food chain of the creatures inside the basin.

IX. TIDAL BARRIERS: PROBLEMS FACED IN EXPLOITING TIDAL ENERGY

- Intermittent supply - Cost and environmental problems, for particular barrage systems are less attractive than some other forms of renewable energy. Global estimates put the cost of generation at 13-15 cents/kWh (no Indian estimates available)
- Cost - The disadvantages of using tidal and wave energy must be considered before jumping to conclusion that this renewable, neat resource is the answer to all our problems. The main detriment is the prize of those plants.
- The altering of the ecosystem at the bay - Damages like less flushing, winter icing and erosion can change the vegetation of the area and disrupt the balance. Similar to other sea energies, tidal energy has several prerequisites that make it only available in a small number of areas. For a tidal power plant to produce electricity effectively (about 85% efficiency), it requires a basin or a gulf that has a mean tidal amplitude (the differences between spring and neap tide) of 7 meters. It is also desirable to have semi-diurnal tides where there are two high and low tides every day. A barrage across an estuary is very expensive to build, and affects a very wide area - the environment is changed for many miles upstream and downstream. Many birds rely on the tide not covering the mud flats so that they can feed. There are less suitable sites for tidal barrages.[3]
- Only provides power for near around 10 hours each day, when the tide is actually moving in or out.
- Present designs do not produce a lot of lights, and barrages across river estuaries can change the flow of water and, coit will be, the habitat for birds and other wildlife
- Expensive to construct
- Power is often generated when there is small demand for electricity
- Limited construction locations
- Barrages may block outlets to flow of water. Although locks will be installed, this is often a slow and costly process.

X.CONCLUSION

Tidal energy is a result of the orbital kinetic energy of the moon, earth, and sun. It provides zero gas, solid, or radiation pollution and is an inexhaustible supply of energy. As a kind of green energy, tidal energy has some significant merits. Tidal power energy does not depend on the season or the weather type, so it is more predictable, compared to other sources of energy such as wind or solar energy

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