Tidal Power-Future Wave of Power Generation

[1]*Mayur Shelar*, [2]*Asad Shaikh*, [3]*Shyam Mishra*, [4]*Roopali Patil*
[1,2,3]*UG Student*, [4]*Assistant Professor*
Department of Electrical Engineering
Sandip Institute of Engineering and Management, Nashik

Abstract - Renewable energy can be used to decrease global dependence on natural resources, and tidal power can be the primary form of renewable power utilized. Built upon steam turbine knowledge, tidal turbines draw on innovative technology and design to operate on both the inflow and outflow of water through them. Two case studies, Annapolis Royal and La Rance, prove that tidal power plants are capable of producing reliable and efficient power. Problems, such as initial cost and power transportation hinder future implementation of tidal power plants. This paper emphasizes the possibilities of utilizing the power of the oceans by pollution free, tidal Power generation. Tidal power utilizes twice the daily variation in sea level caused primarily by the gravitational effect of the Moon and, to a lesser extent by the Sun on the world's oceans. The Earth's rotation is also a factor in the production of tides.

I. INTRODUCTION

The sources for 90% of the electric energy generated today are non-renewable. Natural resource emissions are over 120 times greater than that of renewable emissions. The depletion of the finite resources, environmental pollution, global warming became more apparent near the end of the 20th century. World energy consumption is expected to rise 60 per cent by 2020. In order to meet that demand, while limiting production of greenhouse gases, renewable energy sources considered as an alternative to traditional forms of energy production. Renewable sources of energy are necessary because the Earth will eventually run out of the resources to create non-renewable energy. There are three types of renewable energy sources: solar, wind, and waterpower. Both solar and wind power are drastically affected by weather variations, while tidal power varies little when the weather changes power. Over the last fifty years, engineers have begun to look at tidal and wave power on a larger, industrial scale. However, until the last few years, wave power and tidal power were both seen as uneconomic. Although some pilot projects showed that energy could be generated, they also showed that, even if cost of the energy generated was not considered, there was a real problem making equipment which could withstand the extremely harsh marine environment.

Tidal energy is an essentially renewable resource which has none of the typical environmental impacts of other traditional sources of electricity such as fossil fuels or nuclear power. Changing the tidal flow in a coastal region could, however, result in a wide variety of impacts on aquatic life, most of which are poorly understood.

II. OPERATING PRINCIPLE OF TIDAL POWER GENERATION

Tidal power works because of the Moon's constant rotation around the Earth. This is very convenient because scientist's can predict the electricity production on a daily basis hydrostatic head or adequate water height difference on either side of the turbine. The simple idea of utilizing hydrostatic head to power turbines will be the crux of our article.

A. Wave Power I - Sea-Based devices: A recent review has shown that there are new types of wave power devices which can produce electricity economically. The "Salter" Duck is the device which can produce electricity for lower cost. `The "Salter" Duck was developed in the 1970s by Professor Stephen Salter at the University of Edinburgh in Scotland and generates electricity by bobbing up and down with the waves. Although it can produce energy extremely efficiently it was effectively killed off in the mid-1980s when a European Union report miscalculated the cost of the electricity it produced by a factor of 10. In the last few years, the error has been realized, and interest in the Duck is becoming intense.

The "Clam" is another device which, like the "Salter" Duck can make energy from sea swell. The Clam is an arrangement of six airbags mounted around a hollow circular spine. As waves impact on the structure air is forced between the six bags via the hollow spine which is equipped with self-rectifying turbines. Even allowing for cabling to shore, it is calculated that the Clam can produce energy for around $US0.06kW/hr.

B. Wave Power II- Shore based systems: Where the shoreline has suitable topography, cliff-mounted oscillating water column (OWC) generators can be installed. OWC systems have a number of advantages over the Clam and the Duck, not the least of which is the fact that generators and all cabling are shore -based, making maintenance much cheaper. The OWC works on a simple principle. As an incoming wave causes the water level in the unit's main chamber to rise (see diagram), air is forced up a funnel which houses a Well's counter-rotating turbine. As the wave retreats, air is sucked down into the main chamber again.

The Well's turbine has been developed to spin in the same direction, whichever way air is flowing, in order to maximize efficiency. Although most previous OWC systems have had vertical water columns that in LIMPET is angled at 45° - which wave tank test show to be more efficient.

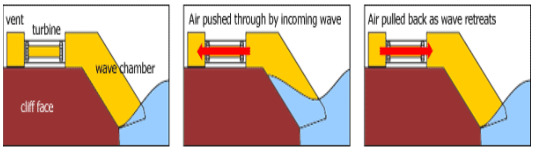

Fig.1. Schematic diagram of OWC Systems

III. CURRENT TECHNOLOGIES TO HARNESS TIDAL FLOW ENERGY

A. Drag Devices Water wheels: This device is insufficient compared to other modes of generation and the blades speed cannot be exceeded as much as the tidal current.

B. Lift Devices Turbines: This wind mill technology is applied to liquid environment only and it is more efficient then drag devices. Also, refined propeller achieves the speeds which is several times higher than that of the tidal current.

Certain coastal regions experience higher tides than others. This is a result of the amplification of tides caused by local geographical features such as bays and inlets. In order to produce practical amounts of power (electricity), a difference between high and low tides of at least five meters is required. There are about 40 sites around the world with this magnitude of tidal range. In Canada, the only practical site for exploiting tidal energy is the Bay of Fundy between New Brunswick and Nova Scotia. The higher the tides, the more electricity can be generated from a given site, and the lower the cost of electricity produced. Worldwide, approximately 3000 Giga-watts (1 Giga-watt = 1 GW = 1 billion watts) of energy is continuously available from the action of tides. Due to the constraints outlined above, it has been estimated that only 2% or 60 GW can potentially be recovered for electricity generation.

Electricity can be generated by water flowing both into and out of a bay. As there are two high and two low tides each day, electrical generation from tidal power plants is characterized by periods of maximum generation every twelve hours, with no electricity generation at the six hour mark in between. Alternatively, the turbines can be used as pumps to pump extra water into the basin behind the barrage during periods of low electricity demand. This water can then be released when demand on the system its greatest, thus allowing the tidal plant to function with some of the characteristics of a "pumped storage" hydroelectric facility.

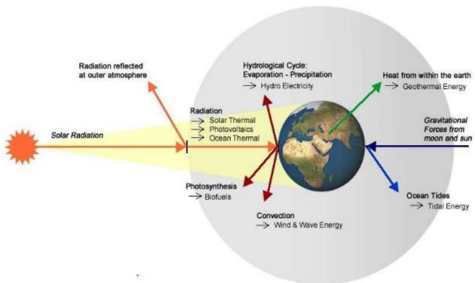

Fig.2. Concept of Tidal Currents

i. Tidal stream generator:

Tidal stream generators (or TSGs) make use of the kinetic energy of moving water to power turbines, in a similar way to wind turbines that use wind to power turbines. Some tidal generators can be built into the structures of existing bridges or are entirely submersed, thus avoiding concerns over impact on the natural landscape. Land constrictions such as straits or inlets can create high velocities at specific sites, which can be captured with the use of turbines. These turbines can be horizontal, vertical, open, or ducted and are typically placed near the bottom of the water column where tidal velocities are greatest.

No standard tidal stream generator has emerged as the clear winner, among a large variety of designs. Several prototypes have shown promise with many companies making bold claims, some of which are yet to be independently verified, but they have not operated commercially for extended periods to establish performances and rates of return on investments.

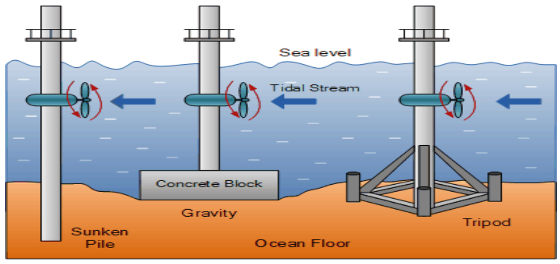

Fig.3. Tidal Stream Generator

ii. Tidal Barrage:

The barrage method of extracting tidal energy involves building a barrage across a bay or river that is subject to tidal flow. Turbines installed in the barrage wall generate power as water flows in and out of the estuary basin, bay, or river. These systems are similar to a hydro dam that produces static head or pressure head (a height of water pressure). When the water level outside of the basin or lagoon changes relative to the water level inside, the turbines are able to produce power.

The basic elements of a barrage are caissons, embankments, sluices, turbines, and ship locks. Sluices, turbines, and ship locks are housed in caissons (very large concrete blocks). Embankments seal a basin where it is not sealed by caissons. The sluice gates applicable to tidal power are the flap gate, vertical rising gate, radial gate, and rising sector.

Only a few such plants exist. The first was the Rance Tidal Power Station, on the Rance River, in France, which has been operating since 1966, and generates 240MW. A larger 254MW plant began operation at Sihwa Lake, Korea, in 2011. Smaller plants include one on the Bay of Fundy, and another across a tiny inlet in Kislaya Guba, Russia. A number of proposals have been considered for a Severn barrage across the River Severn, from Brean Down in England to Lavernock Point near Cardiff in Wales. Barrage systems are affected by problems of high civil infrastructure costs associated with what is in effect a dam being placed across estuarine systems, and the environmental problems associated with changing a large ecosystem.

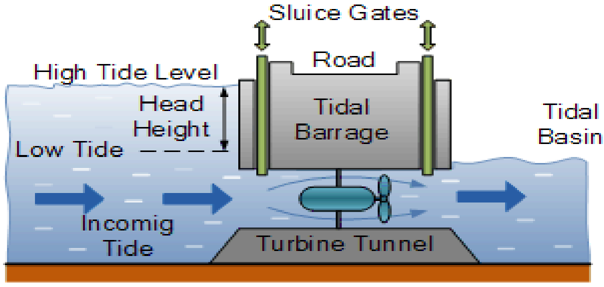

Fig.4. Tidal Barrage

iii. Blue energy

The Blue Energy Ocean Turbine acts as a highly efficient underwater vertical -axis windmill. Sea water is 832 times denser than air and a non-compressible medium, an 8 knot tidal current is the equivalent of a 390 km/hr wind. Developed by veteran aerospace engineer Barry Davis, the vertical-axis turbine represents two decades of Canadian research and development. Four fixed hydrofoil blades of the Blue Energy Ocean Turbine are connected to a rotor that drives an integrated gearbox and electrical generator assembly.

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 readily 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. Computer optimized cross-flow design ensure that the rotation of the turbine is unidirectional on both the ebb and the flow of the tide.

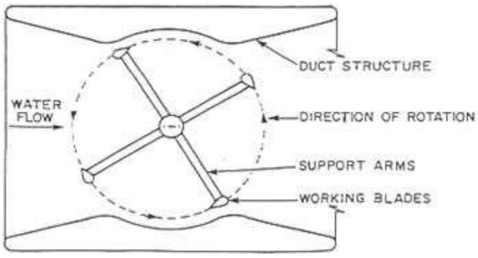

Fig.5. Design of Blue Energy

The design of the Blue Energy Ocean Turbine requires no new construction methodology: It is structurally and mechanically straightforward. The transmission and electrical systems are similar to thousands of existing hydroelectric installations. Power transmission is by submersible kV DC cabling and safely buried in the ocean sediments with power drop points for coastal cities and connections to the continental power grid. A standardized high production design makes the system economic to build, install and maintain.

IV. BENEFITS AND CHALLENGES

A. Benefits: A single dam can accommodate over 8 GW (8000 MW) of installed capacity, with a capacity factor of about 30%, for an estimated annual power production of each dam of about 23 billion kWh (83 PJ/yr). To put this number in perspective, an average European person consumes about 6800 kWh per year, so one DTP dam could supply energy for about 3.4 million Europeans. If two dams are installed at the right distance from one another (about 200 km apart), they can complement one another to level the output (one dam is at full output when the other is not generating power). Dynamic tidal power doesn't require a very high natural tidal range, so more sites are available and the total availability of power is very high in countries with suitable conditions, such as Korea, China, and the UK (the total amount of available power in China is estimated at 80 - 150 GW).

B. Challenges: A major challenge is that a demonstration project would yield almost no power, even at a dam length of 1 km or so, because the power generation capacity increases as the square of the dam length (both head and volume increase in a more or less linear manner for increased dam length, resulting in a quadratic increase in power generation). Economic viability is estimated to be reached for dam lengths of about 30 km shipping routes, marine ecology, sediments, and storm surges. Amidst the great number of challenges and few environmental impacts the method of utilizing tidal power to generate electricity has great potential and is certainly a technology most of the countries will try to harness in near future.

V. CONCLUSION

The Department of Energy has shown great enthusiasm regarding tidal power as a future energy source than any other renewable energy sources. Our philosophy regarding energy will change drastically from the present into the future. In a society with increasing energy demands and decreasing supplies, we must look to the future and develop our best potential renewable resource. Tidal power fits the bill, a natural source of energy with many benefits. The planet's tidal capability greatly exceeds that of the world's entire coal and oil supply. It is an ideal source of energy with great potential. When developed, tidal power could be a primary provider for our future energy requirements.

VI. REFERENCES

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