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HOW TO GENERATE ELECTRICITY BY APPLICATION OF TIDAL ENERGY POWER CONVERSION SYSTEM

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ABSTRACT:

The purpose of this paper is to provide a technology specification of the present state of the art of marine wave and tidal energy technologies. Tidal Energy (TE) represents one of the largest renewable resources available on the planet. TE is an emerging industry that has a potential to satisfy world-wide demand for electricity, water and fuels, when coupled with secondary energy conversation principles. This energy transfer provides a natural storage of tidal energy in the water near the free surface. This article is about tidal power. It describes tidal power and the various methods of utilizing tidal power to generate electricity. It briefly discusses each method and provides details of calculating tidal power generation and energy most effectively. The paper also focuses on the potential this method of generating electricity has and why this could be a common way of producing electricity in the near future.

Keywords: **-** Principal and Aspects of Tidal Energy Conversion, Tidal Power Generation Systems Work, Advantages and Disadvantages of Tidal Power Generation

1. Introduction

Tidal power, also called tidal energy, is a form of Hydropower that converts the energy of tides into Electricity or other useful forms of power. Tides are more predictable than wind energy and solar power. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However many recent 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 total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels. Tidal power along tidal shores has been used for centuries to run small tidal mills. Generating electricity by tapping tidal power proved to be very successful only in the last century through the tidal power plant constructed in 1967 in La Rance, France. This used a large barrier to generate the sea level head necessary for driving turbines. Construction of such plants evolved very slowly because of prohibitive costs and concerns about the environmental impact. Developments in the construction of small and inexpensive underwater turbines admit the possibility of small scale operations that will use local tidal currents to bring electricity to remote locations. Since the generation of such electricity is concerned with the tidal energy in local water bodies, it is important to understand the site- specific energy balance, i.e., the energy owing in through open boundaries, and the energy generated and dissipated within the local domain. The question is how to tap the tidal energy while keeping possible changes in the present tidal regimes to a minimum. The older approach of constructing barrages may still be quite useful in some locations. The basics of such tidal power plants constructed in a small bay are analyzed in order to understand the principal parameter for tidal plant evaluation, i.e., the power produced. At present, tidal power plants (TPP) use both potential (tidal sea level) and kinetic energy (tidal currents). Both uses have their roots in the small tide mills constructed along tidal shores. The older use of tidal power by blocking the entrance to a bay with a dam was implemented very slowly, because of the prohibitive costs of such a construction. The new approach is to use tidal currents in a way similar to that in which windmills are used to tap wind energy. the same amount of energy generated by a wind can be achieved by a relatively much slower water movement.

2. History

Tidal energy is one of the oldest forms of energy used by humans. Indeed, tide mills, in use on the Spanish, French and British coasts, date back to 787 A.D. but it is likely that there were predecessors lost in the anonymity of prehistory. Tide mills consisted of a storage pond, filled by the incoming (flood) tide through a sluice and emptied
during the outgoing (ebb) tide through a water wheel. The tides turned waterwheels, producing mechanical power to mill grain and power was available for about two to three hours, usually twice a day. The power requirements of the industrialized world dwarf the output of the early tidal barrages and it was not until the 1960’s that the first commercial-scale modern-era tidal power plant was built, near St. Malo, France. The hydro mechanical devices such as the paddlewheel and the overshot waterwheel have given way to highly-efficient bulb-type hydroelectric turbine/generator sets.

3. Principal and Aspects of Tidal Energy Conversion

3.1 Tidal Range Energy

The technology required to convert tidal range energy into electricity is very similar to the technology used in traditional hydroelectric power plants. The first requirement is a dam or "barrage" across a tidal bay or estuary. At certain points along the dam, gates and turbines are installed. When there is an adequate difference in the elevation of the water on the different sides of the barrage, the gates are opened. The "hydrostatic head" that is created, causes water to flow through the turbines, turning an electric generator to produce electricity. Tidal range energy conversion technology is considered mature, but, as with all large civil engineering projects, there would be a series of technical and environmental risks to address. One major environmental risk is associated with the changes of water levels which would modify currents, and sediment transport and deposit. However, there are regional development benefits as well, for example the La Rance plant in France, the only commercial sized tidal range conversion scheme so far, includes a road crossing linking two previously isolated Communities and has allowed further development of the distribution network for raw materials and developed products.

3.2 Tidal amplitude

The theoretical amplitude of oceanic tides due to the Moon is about 54 cm at the highest point, which corresponds to the amplitude that would be reached if the ocean possessed a uniform depth, there were no landmasses, and the Earth were not rotating. The Sun similarly causes tides, of which the theoretical amplitude is about 25 cm (46% of that of the Moon) with a cycle time of 12 hours. At spring tide the two effects add to each other reaching a theoretical amplitude of 79 cm. The total amplitude changes as a result of the varying Earth-Sun and Earth-Moon distances. This causes a variation at neap tide: the theoretical level is reduced to 29 cm. Since the orbits of the Earth about the Sun, and the Moon about the Earth, are elliptical, the tide amplitudes in the tidal force and theoretical amplitude is of about ±18% for the Moon and ±5% for the Sun. If both the Sun and Moon were at their closest positions and aligned at new moon, the theoretical amplitude would reach 93 cm. Real amplitudes differ considerably from the theoretical ones, because of the variations n ocean depth and of the presence of continents.

3.3 Tidal constituents

The various frequencies of astronomical forcing which contribute to tidal variations are alled constituents. In most locations, the largest constituent is the principal lunar emidiurnal (M2). Its period is about 12 hours and 27 minutes, exactly half a tidal lunar ay, the average time separating one lunar zenith from the next, and thus the time required for the Earth to rotate once relative to the Moon. constituents other than M2 arise from factors such as the gravitational influence of the un, the tilt of the Earth's rotation axis, the inclination of the lunar orbit and the llipticity of the orbits of the Moon about the Earth and the Earth about the Sun. variations with periods of less than half a day are called harmonic constituents. Long period constituents have periods of days, months, or years.

3.4 Tidal forces

Tidal forces can be analyzed from the point of view of a reference frame that translates with the centre of mass of the Earth. Consider the tide due to the Moon (the Sun is similar). At first observe that the Earth and Moon rotate around a common orbital centre of mass with a 27.3 day period, as determined by their relative masses. The orbital centre of mass is 3/4 of the way from the Earth's centre to its surface.

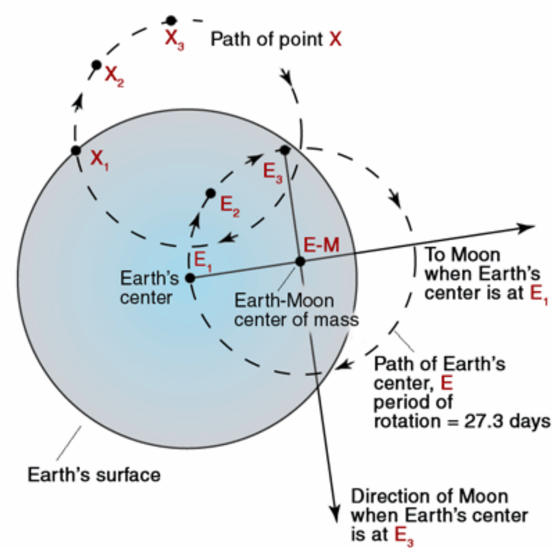


Fig.3.4 - Earth-moon centre of mass and period of rotation (Naval Postgraduate School. Monterey, California).

The second observation is that the Earth's centripetal motion is the averaged response of the entire Earth to the Moon's gravity and it is exactly the correct motion to balance the Moon's gravity only at the centre of the Earth; but every part of the Earth moves along with the centre of mass and all parts have the same centripetal motion, since the Earth is rigid. On the other hand each point of the Earth experiences the Moon's radially decreasing gravity differently; the near parts of the Earth are more strongly attracted than is compensated by inertia and experience a net tidal force toward the Moon; the far parts have more inertia than is necessary for the reduced attraction, and thus feel a net force away from the Moon.

3.5 Two ways of generating electricity from tides

There are basically two ways of generating electricity from marine and tidal currents: by building a tidal barrage across an estuary or a bay in high tide range areas, or by extracting energy from free flowing water. In the first case tidal barrage harnesses the energy in a similar way as run-of-river hydro power plants and was the first ocean energy technology to be used in a large scale project. The barrage traps a water level inside a basin; this leads to a decrease of tidal range inside the basin or lagoon, implying a reduced transfer of water between the basin and the sea. The reduced transfer of water accounts for the energy produced by the scheme. The second ocean energy technology is capturing the energy in free flowing water, meaning much less civil engineering work and less environmental impact at the site. A great deal of attention was drawn to marine and tidal currents as a possible source of energy during the oil crisis in the 1970s, but all in all the abundant resources of tidal energy have remained untapped. However, recent developments in power electronics, in the offshore industry and in wind power technology have brought tidal energy much closer to an introduction on the electricity market. At present, there are a number of promising and more or less innovative concepts for Marine Current Energy Converters.

3.6 Barrage tidal power

3.6.1 Introduction

A barrage is built across an estuary or a bay that experiences an adequate tidal range. The purpose is to create a basin where water level raises and falls with a time law different from that of the open sea, in order to create a hydrostatic head. The turbines placed along the barrage generate power as water flows in and out the bay. The system is then similar to a low head hydro dam. The construction of a barrage requires a very long civil engineering project. It will have environmental and ecological impacts, not only during construction, but will change the affected area forever. Just what these impacts will be is very hard to measure as they are site specific, and each barrage is different.

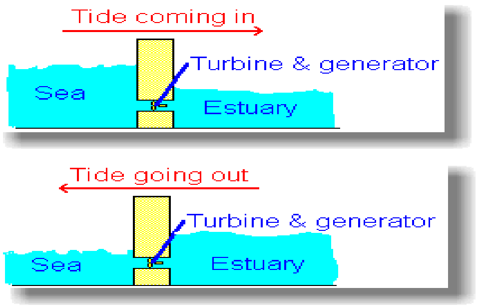


Fig. 3.6.1 - Simple draw of the operating condition of a two-ways barrage tidal power plant (Andy Darvill,

Broadoak Community School).

Ebb generation:

It also known as outflow generation, it takes its name because generation occurs as the tide ebbs. The basin is filled through the sluices until high tide. Then the sluice gates are closed. At this stage there may be pumping to raise the level further. The turbine gates are kept closed until the sea level falls to create sufficient head across the barrage, and then are opened so that the turbines generate until the head is again low. Then the sluices are opened, turbines disconnected and the basin is filled again. The cycle repeats itself.

Flood generation:

The basin is filled through the turbines, which generate at tide flood. This is generally less efficient than ebb generation, because the volume contained in the upper half of the basin (which is where ebb generation operates) is greater than the volume of the lower half; so the difference in levels between the basin side and the sea side of the barrage, and therefore the available potential energy, is less than it would otherwise be.

Pumping:

The turbines in the barrage can be used to pump extra water into the basin at periods of low demand. This usually coincides with cheap electricity prices, generally at night when demand is low. The company therefore buys the electricity to pump the extra water in, and generates power at times of high demand when prices are high so as to make a profit. This has been used in Hydro Power, and in that context is known as pumped storage.

Two way power generation:

Electrical power is generated from both the ebb and the flood tides. Ebb generation starts at a basin level that is less then that of a single generation (towards the end of the generating cycle, the sluice gates are opened to allow flow from the basin to the sea and hence drop the water level in the basin). This is necessary to achieve a sufficient difference in water height during the flood generation phase. At low tide, the sea and basin levels become equal and the gates are closed. Once the sea has risen to the optimum height, generation begins by operating the turbine in the opposite direction.

***Two-basin schemes*:**

Another form of energy barrage configuration is that of the dual basin type. With two basins, one is filled at high tide and the other is emptied at low tide. Turbines are placed between the basins. Two-basin schemes offer advantages over normal schemes because generation time can be adjusted with high flexibility and it is also possible to generate almost continuously. In normal estuarine configuration, however, two-basin schemes are very expensive to construct due to the cost of the extra length of barrage. There are some favourable geographical settings, however, which are well suited to this type of scheme.

3.6.2 Tidal stream power

Introduction

Useful energy can be generated from marine currents using completely submerged turbines consisting of rotor blades and generator. They are called Water Current Turbines, that are defined as systems that convert hydro kinetic energy from flowing waters into electricity, mechanical power, or other forms of energy, such as hydrogen. This approach offers many additional advantages:

1. it does not require the construction of a dam: hence, it is considered much less costly and more environmentally-friendly; moreover further cost-reductions are realized from not having to dredge a catchments area;

2. vertical-axis tidal generators may be stacked and joined together in series to span a passage of water such as a fiord and they offer a transportation corridor (bridge), essentially providing two infrastructure services for the price of one;

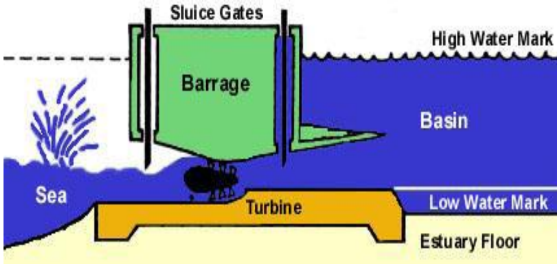
3. vertical-axis tidal generators may be joined together in series to create a ‘tidal fence’ capable of generating electricity on a scale comparable to the largest existing fossil fuel based, hydroelectric and nuclear energy generation facilities;

4. tidal current energy, though intermittent, is predictable (at least its astronomical part) with exceptional accuracy many years in advance. In other words, power suppliers will easily be able to schedule the integration of tidal energy with backup sources well in advance of requirements. Thus, among the emerging renewable energy field, tidal energy represents a much more reliable energy source than wind, solar and wave, which are not predictable;

5. present tidal current, or tidal stream technologies are capable of exploiting and generating renewable energy in many marine environments that exist worldwide.

3.7 How Tidal Power Generation Systems Work

In very simple terms a barrage is built at the entrance of a gulf and the water levels vary on both sides of the small dam. Passages are made inside the dam and water flows through these passages and turbines rotate due to this flow of water under head of water. Thus, electricity is created using the turbines. A general diagram of the system. What follows will be a description of a general tidal power station with its components. Also, many systems of power generation will be described.



The components of a tidal power station are:

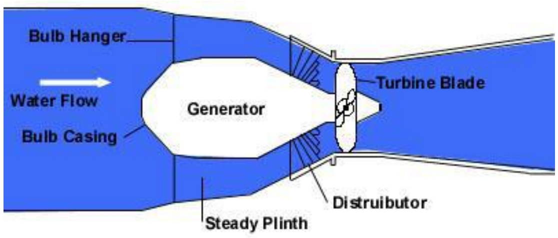
1- **A barrage:** a barrage is a small wall built at the entrance of a gulf in order to trap water behind it. It will either trap it by keeping it from going into the gulf when water levels at the sea are high or it will keep water from going into the sea when water level at the sea is low.

2- **Turbines:** they are the components responsible for converting potential energy into kinetic energy. They are located in the passageways that the water flows through when gates of barrage are opened. There are many types of turbines used in tidal power stations:

1. Bulb turbines: as shown in Fig. 4 these are difficult to maintain as water flows around them and the generator is in water.

2. Rim turbines: as shown in Fig. 5 these are better maintained than the bulb turbines but are hard to regulate as generator is fixed in barrage.

3. Tabular turbines: as shown in figure 6 these turbines are fixed to long shafts and thus solve both problems that bulb and rim turbines have as they are easier to maintain and control.



3- **Sluices:** sluice gates are the ones responsible for the flow of water through the barrage they could be seen.

4- **Embankments:**

They are caissons made out of concrete to prevent water from flowing at certain parts of the dam and to help maintenance work and electrical wiring to be connected or used to move equipment or cars over it.

3.8 Advantages of Tidal Power Generation

There are many advantages of generating power from the tide; some of them are listed below:

1. Tidal power is a renewable and sustainable energy resource.

2. It reduces dependence upon fossil fuels.

3. It produces no liquid or solid pollution.

4. It has little visual impact.

5. Construction of large-scale offshore devices results in new areas of sheltered water, attractive for fish, sea birds, seals and seaweed.

6. Tidal power exists on a worldwide scale from deep ocean waters.

7. It offers short time scale between investing in the modular construction and benefiting from the revenue

8. Tidally driven coastal currents provide an energy density four times greater than air, meaning that a 15-m diameter turbine will generate as much energy as a 60m-diameter windmill.

9. Tidal currents are both predictable and reliable, a feature which gives them an advantage over both wind and solar systems. Power outputs can be accurately calculated far in advance, allowing for easy integration with existing electricity grids.

10 The tidal turbine offers significant environmental advantages over wind and solar systems; the majority of the assembly is hidden below the waterline, and all cabling is along the seabed.

3.9 Disadvantages and Constraints to Tidal Power Generation

Unfortunately, there are also disadvantages and limitations to generating tidal power. Some of these are:

1. At the present time both tide and wave energy are suffering from orientation problems, in the sense that neither method is strictly economical (except in few locations throughout the world) on a large scale in comparison with conventional power sources.

2. Tidal power systems do not generate electricity at a steady rate and thus not necessarily at times of peak demand, so unless a way can be found of storing energy efficiently - and any storage devices currently available incur a considerable loss - they would not help in reducing the overall need for fossil power stations, but only allow them to run at a lower rating for a certain amount of the time.

3. Tidal fences could present some difficulty to migrating fish.

4.0 Reference

[1] Ocean Energy: Tide and Tidal Power by Roger H. Charlier

[2] Ocean Wave Energy: Current Status and Future Prespectives (Green Energy and Technology) by Joao Cruz

[3] Ocean Wave Energy Conversion by Michael E. McCormick

[4] The Analysis of Tidal Stream Power by Jack Hardisty

[5] Developments in Tidal Energy: Proceedings of the Third Conference on Tidal Power, Institution Of Civil Engineers (Contributor)

[6] Ocean, Tidal, and Wave Energy: Power from the Sea (Energy Revolution) by Lynne Peppas

[7] National Energy Authority. (2009). *Raforkuspa 2009-2030.* Reykjavik: National Energy Authority of Iceland.

[8] Shpolyanskij, Y., Usachev, I., & Istorik, B. (2009). Russian tidal and wave poer development: experiance of the Kislogubskaya tidal plant. *Marine Energy. The International Journal on Hydropower & Dams, special supplement.*, 5-9.

[9] Henry R. F., Foreman M. G. G., 2001, *A representation of tidal currents based on energy ux*, Mar. Geod., 2493, 139{152.

[10] Lawton F. L., 1972. *Economics of tidal power*, [in:] *Tidal power*, T. J. Gray & O. K. Gashus (eds.), Plennum Press, New York, 105{130.

[11] United States Coastal Pilot, 1995, *Paci_c and Arctic Coasts of Alaska*, NOAA, Washington, DC, 334 pp.

[12] Bahaj, A S and Myers, L E (2003), Fundamentals applicable to the utilization of marine current turbines for energy production, Renewable Energy 28, 2205-2211.

[13] E. Goldwag and R. Potts, "Energy production," Developments iri Tidul Etiergy, Pro(.. 3rd Cor$ Tidal Power, London, U.K., Nov. 1989.