DESIGN AND EXPERIMENTAL STUDY OF WATER CURRENT TURBINE

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UNIVERSITI MALAYSIA SARAWAK

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ABSTRACT

Tidal energy is the renewable energy and occurs according to the change in the water level in ocean, which is caused by the gravitational effect of earth, moon and sun. This energy are appropriately used for electricity generation by building the water current turbine system which is clean and protect the environment from being destroyed.

This research studies the power produce from the water current turbine model. The prototype of water current turbine uses two types of propeller. Single blade propeller is 0.05mm in diameter and 0.05m in pitch while Triple blade propeller is 0.05mm in diameter and 0.25m in pitch. Data obtained is used to determine the effect of both the propellers.

Result from this research shows that the single blade propeller produce much power than triple blade propeller. From this study, the best propeller to produce the electricity from tidal energy is a propeller, which has a lower pitch.

ABSTRAK

Tenaga pasang surut adalah suatu tenaga yang tidak akan habis dan berlaku berikutan adanya perubahan paras air di lautan yang disebabkan wujudnya daya tarikan graviti di antara bumi, bulan dan matahari. Tenaga yang terbentuk ini adalah sesuai di gunakan untuk menjana kuasa elektrik dengan membina turbin air mengalir iaitu suatu teknologi yang selamat disamping dapat menjaga persekitaran daripada berlakunya kemusnahan.

Kajian ini dijalankan adalah untuk mengkaji kuasa yang dapat dihasilkan daripada turbin air mengalir. Oleh itu, satu model water current turbine telah di cipta dengan menggunakan dua jenis kipas yang berbeza iaitu kipas 1 di mana berdiameter 0.05mm dan 0.05m kecondongan dan kipas 2 berdiameter 0.05mm dan 0.25m kecondongan. Data yang diperolehi dapat digunakan dalam mengenalpasti kesan yang wujud di antara kedua –dua jenis kipas.

Hasil daripada kajian yang telah dibuat, didapati bahawa kipas 1 memberi jumlah kuasa yang lebih baik berbanding daripada kipas 2. Oleh itu, kajian ini menunjukkan bahawa bentuk kipas yang mempunyai kecondongan yang kecil adalah lebih baik dalam menghasilkan kuasa elektrik.

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CHAPTER 1
INTRODUCTION

1.1 Creation of tides

Tides are periodic rising and falling of large bodies of water. It's occurring caused by the combination of the gravitational interaction of the moon and the lesser extent of the sun on Earth. The gravitational attraction of the moon causes the oceans to bulge out in the direction of the moon. Another bulge occurs on the opposite side, since the Earth is also being pulled toward the moon and away from the water on the far side. Since the earth is rotating while this is happening, two tides occur each day. It can be seen in **Figure 1.1.**

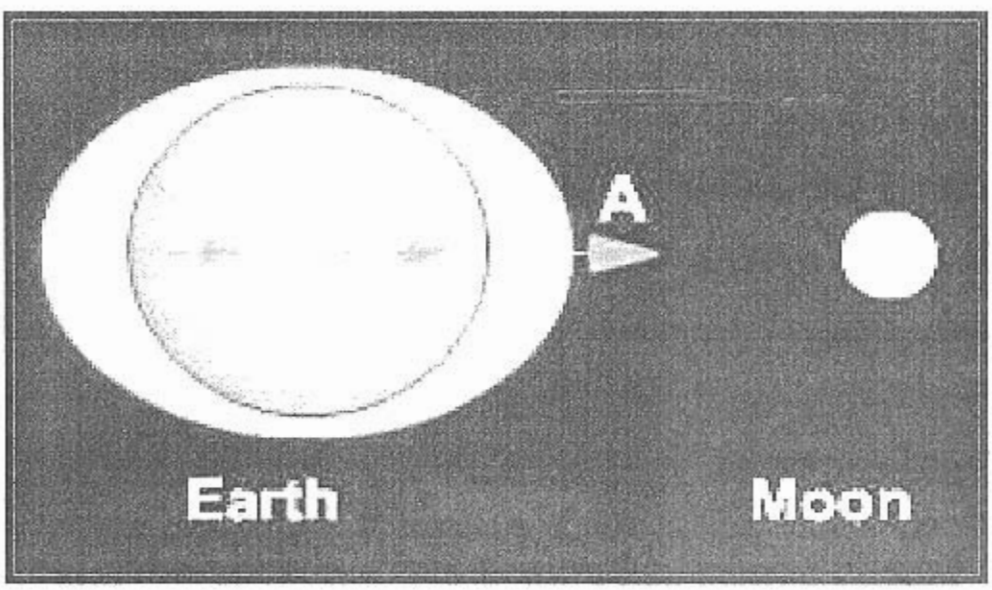

Figure 1.1: Interaction of the Moon and the Sun on Earth [Blue Planet, 2001]

The bulges remain stationary while the Earth rotates underneath them. This is why the water goes up and down on the beach twice a day. The Sun also exerts a gravitational attraction on the Earth as shown in **Figure 1.2**

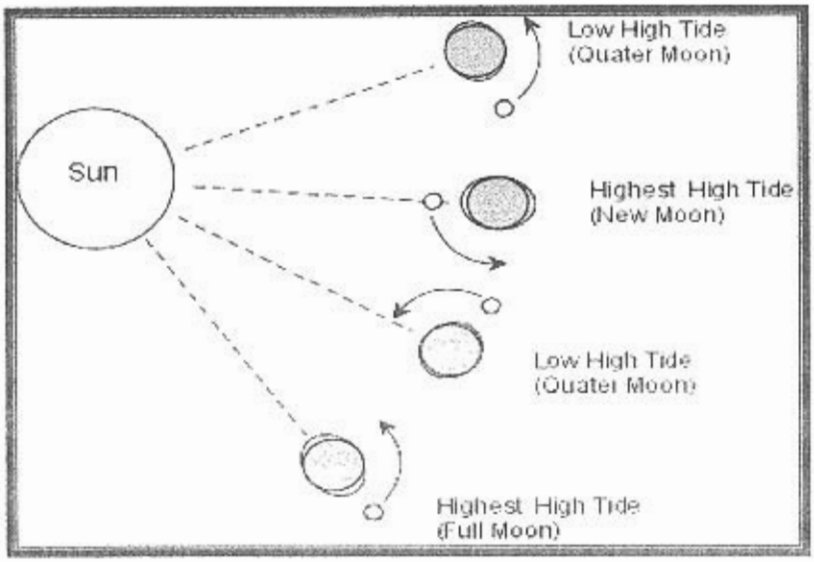

Figure 1.2: Highest high tides and lowest high tides [Blue Planet, 2001]

Highest high tides occur when the Sun and the moon are on the same side of the Earth (new moon) or on opposite sides of the Earth (full moon). The lowest high tides occur when the Sun and the moon are not opposed relative to the Earth (quarter moons). These highest high tides when combined with lousy weather are the times of greatest erosion along the beach.

Figure 1.3 show a spring tides that are especially strong tides, which they do not have anything to do with the season spring. They occur when the Earth, the Sun, and the Moon are in a line. The gravitational forces of the Moon and the Sun both contribute to the tides. Spring tides occur during the full moon and the new moon. The Proxigean Spring Tide is a rare, unusually high tide. This very high tide occurs when the moon is both unusually close to the Earth (at its closest perigee, called the proxigee) and in the

New Moon phase (when the Moon is between the Sun and the Earth). The proxigean spring tide occurs at most once every 1.5 years

Different with the neap tides, these are especially weak tides. They occur when the gravitational forces of the Moon and the Sun are perpendicular to one another mean with respect to the Earth. Neap tides occur during quarter moon.

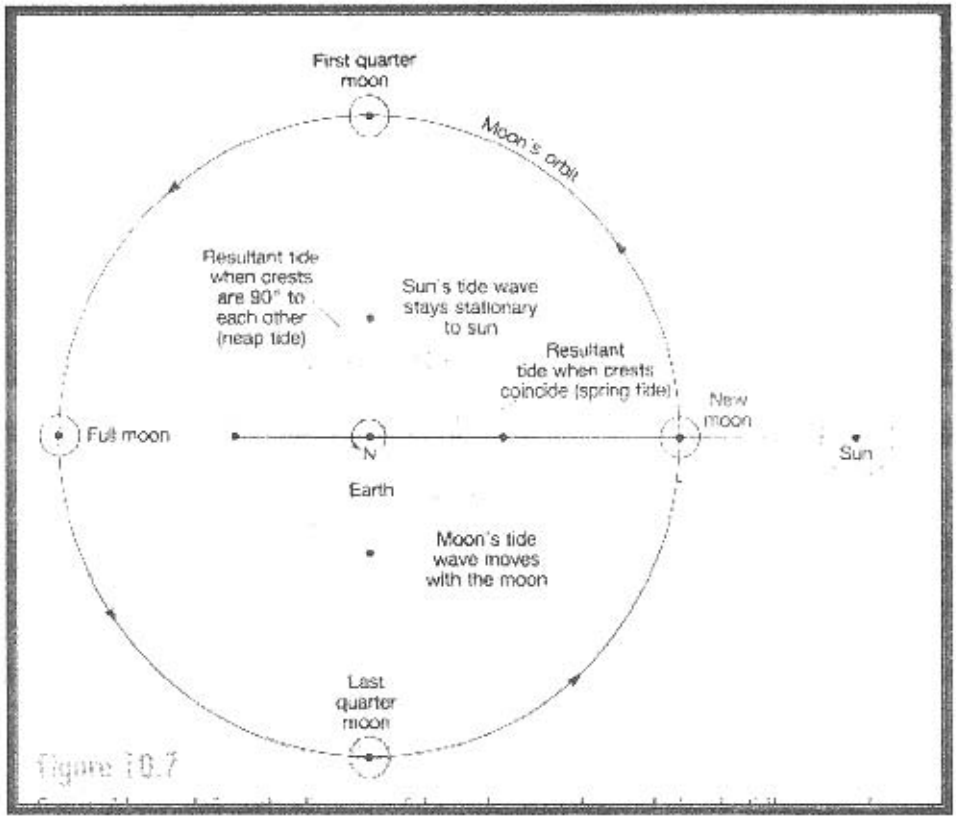

Figure 1.3: Spring tides result from the earth, the moon and the sun during the full moon and the new moon. During the moon's first and last quarters neap tides are produced. [Earth Science, 1997]

It takes 23 hours and 56 minutes long to come around the same position relative to the stars, which is as call the sidereal day. Although, when the Earth comes around to the same position relative to the sun, the solar day was occurring. The solar day is 24 hours

solar day is 24 hours long and the extra four minutes come from the fact that the Earth travels about 1 degree around the sun per day.

When the time need for the Earth to come around to the same spot relative to the moon is defined as a lunar day. Since the moon revolved around the Earth, this day is even longer than the solar day about 24 hours and 48 minutes. That's why the tides do not occur at the same time every day as the moon is not in the same location in the sky each day.

1.1.1 Tidal Pattern

A tidal movement around the world is different in different places. The area with one high tide and one low tide each day known as a *Diurnal tide. Semidiurnal tied* are two high and two low waters each lunar day. A *Semidiurnal mixed tide* may have characteristics of both of the other tides. The diurnal inequality is a characteristic of this tide and successive high and low tides will have significantly different heights. Semidiurnal tidal period occur for a days of each tidal month but it will be changed to diurnal periods.

At high tide, current velocity is zero because the water has reached its highest stage and is about to begin its outward flow. Following this high slack water, the lowering of the tide begins and the ebb current velocity increases and reaches a maximum about three hours after high slack. At low tide (low slack water), the velocity has decreased to zero and the flood tide onshore begins.

Tidal currents do have a more important effect on the shelf sea floor and on coastal configuration than permanent currents. Tides and tidal currents on continental shelves are propagated as waves from the open oceans that are partially reflected back out to

sea by the shoaling bottom. They are more pronounced in places where constrictions such as narrow entrances to large bays cause strong flows. [Ferrao, 2001]

Tidal changes have short-term cyclic effects on beach sedimentary processes. Both the tidal range and the tidal currents generated vary widely and consequently, have an effect that can range from strong in shaping the beach to almost no effect on beach processes. The primary role of tides in beach processes is exposure and submergence of the beach face, and hence changes in how effective incoming waves may be in modifying the beach. The times of low tides will leave parts of the beach above wave action, and where tidal range is large, the time of exposure to marine transport processes is reduced. In areas of low tidal range, the continually submerged features are subject to more time of exposure to surf zone processes. Low tidal areas are therefore subject to more potential erosion. The areas of low tidal range are also subject to increased erosion during intervals of raised water levels associated with storm conditions and higher than normal tide periods because these reach areas beyond the beach face development. [Nicholas, 1999]

1.1.2 Equilibrium Tidal Theory.

Sir Isaac Newton's with the universal law tell that the force of attraction between any two bodies is proportional to the product of the two mass divided by the square of the distance between the centers of the masses as:

$$F = G \frac{(m_1 m_2)}{R^2} \qquad \text{..... (1.1)}$$

Where;

G = Universal gravitational constant,

6.67 X 108 cm3/gram/sec2;

m_1 = mass of body 1 in grams;

m_2 = mass of body 2 in grams;

R = distance between centers of masses in centimeters.

This earth-moon-sun system is balanced at the earth's centers but these are not between points on the earth's surface. The force different per unit mass between a surface point and the earth's center is proportional to;

$$G\,(M/R^3) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.2)$$

Where;

G = gravitational constant;

M = mass of the sun or the moon;

R = distance between the earth and the moon.

The mass of the sun is very great, but the sun is very far away. The moon is small but it close to the earth. Hence the moon has a greater attractive effect on the water particles than the sun [Duxbury, 1997].

1.2 Introduction to Tidal Power.

Figure 1.4 shown the principle of the tidal power generation which the barrage or dam holds back the water in the estuary as the tide falls. And then, the gates are opened and

the water rushes seaward through the turbine. Later the rising tide will be held back by the barrage, and then released to flow through another turbine into a river estuary

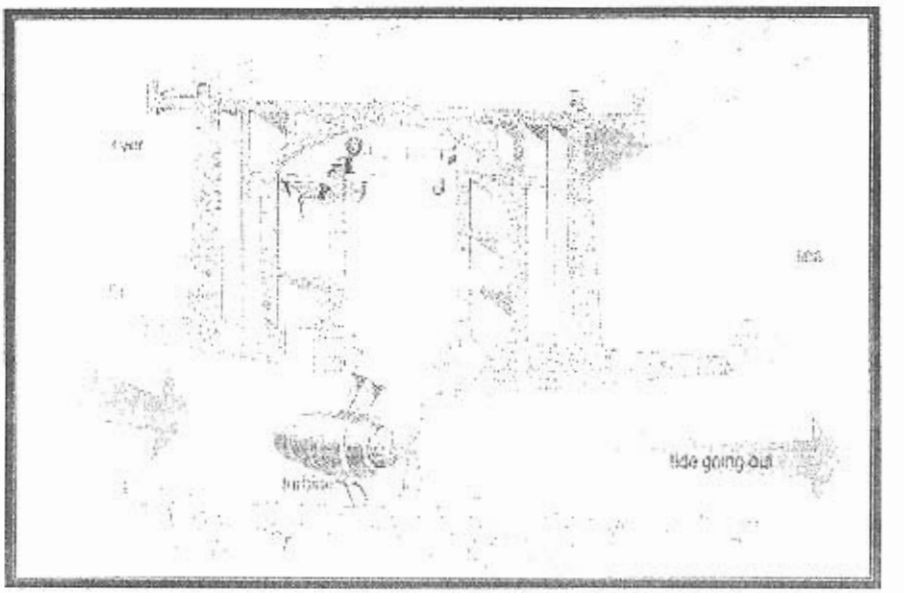

Figure 1.4: The principle of tidal power Generation

[United State Energy Atlas, 1986].

The generation electricity from tides rather like a hydroelectric generation, except that water is able to flow in both directions and this must be taken into account in the development of the generators and the dam is much bigger. A huge dam called a barrage is built across a river estuary. When the tide goes in and out, the water flows through tunnels in the dam. The ebb and flow of the tides can be used to.

1.2.1 Types of Hydropower plants

Most of the hydropower plants are building by the conventional design. It means, to generate the electricity they must use one-way water flow. So, there have two categories of conventional plants known as run river plant and storage plant.

i. *Run of River Plants*

The functional of these plants are to store water to provide water flow through the turbine. It is very useful for the weather changes especially for the seasonal changes cause some plants store a day or week's worth of water. This plant is significant fluctuations in power output.

ii. *Storage Plants*

These plants are provided a constant supply of electricity and have enough storage capacity to off set seasonal fluctuations in water flow. It uses the large dams and can store several year *worth* of water.

Different with the conventional hydropower plants, pumped storage are utilized to recycle water. After the initial water produces the electricity, it flows from the turbines into a lower reservoir located below the dam. During the periods of low energy demand or off-peak hours, some of the water is pumped into an upper reservoir and reused during period of peak-demand [China New energy, 1999].

1.2.2 Turbine uses in Power Station

Turbine is the main resource in the tidal plant Power Station. When the rising and falling of the surface water occur twice each day, it possible to generate electric with the large tide. Their have several different turbines are possible to use.

i. *Bulb turbine*

Bulb turbine, is utilized at the La Rance tidal plant near St. Malo on the Brittany coast in France, uses the water movement energy of both raising and falling tides. As the large tide, the dam's gated are opened. Water passing upstream through the gates turns 24 separate turbines to generate electricity [O'Mara 1999].

i. *Rim turbine*

Rim turbine used at Annapolis Royal in Nova Scotia similar to the Straflo turbine. This turbine is utilized to reduce problem with the generator mounted in the barrage occur at the right angles to the turbine blades. However it is quite difficult to maintains the performance of these turbines and it not suitable for pumping.

ii. *Tubular turbine*

Tubular turbine is used in the Severn tidal project in the United Kingdom. The blades are connected along the shaft.

iii. *Francis turbine*

A Francis turbine has a runner with fixed vanes, usually nine or more. The water enters the turbine in a radial direction with respect to the shaft, and is discharged in an axial direction. Francis turbines will operate from 10 feet to 2,000 feet of head and can be as large as 800 megawatts [EREN 2001].

iv. Propeller turbine

A propeller has a runner with three to six fixed blades, like a boat propeller. The water passes through the runner and drives the blades. Propeller turbines can operate from 10 feet to 300 feet of head and can be as large as 100 megawatts. A Kaplan turbine is a type of propeller turbine in which the pitch of the blades can be changed to improve performance. Kaplan turbines can be as large as 400 megawatts [EREN 2001].

v. Pelton turbine

A Pelton turbine has one or more jets of water impinging on the buckets of runner that looks like a water wheel. The Pelton turbines are used for high head sites (50 feet to 6,000 feet) and can be as large as 200 megawatts [EREN 2001].

vi. Tidal turbine

Similar to the wind turbine, it also offers significant advantages over barrage including reducing the environment effect. It is use to move between 2 and 3 m/s (4 to 6 knots) or generated between 4 and 13 kW/m^2 [FRR 200].

1.3 Operation method and requirement equipment

The tidal power stations can be divided into three types according to its operation method and requirement equipment, which are single-reservoir and single-direction type, single-reservoir and two-direction type and the two-reservoir and single-direction type.

i. *Single-Reservoir and Single-Direction Type*

Single-reservoir and single-direction type tidal power stations, the penstock will be opened during the floor tide to fill water to the reservoir; be closed during the slack tide. After the ebb tide and while there is a certain water head between the reservoir and the open sea, the penstock will be opened to drive the turbine hydraulic power generator for electricity. The advantage of such type of tidal power stations is its simple structure of the equipment and cost-efficient investment. The disadvantage is its intermittent operation. More than 65% of the time in a day is in the position of storage of water and shutdown state.

ii. *Single-Reservoir and Two-Direction Type*

There are two plan designed for single-reservoir and two-direction type tidal power station. The first plan is to utilize 2 sets of single-direction valve to control 2 pipelines for conducting water-to-water turbine. During the floor tide and ebb tide, seawater will flow to water turbine from respective conducting channel, making the single direction of rotating of water turbine to drive the engine. The second plan is to adopt two direction water turbine generation sets.

iii. *Two-Reservoir and Single-Direction Type.*

For this system, the continuous power generation by tidal energy can be realized in two reservoirs, which are associative in hydraulics. During the floor tide, the reservoir with higher level will be filled with water; while during the ebb tide, water will be discharged to the reservoir with lower level. The water head

between these two reservoirs makes water turbine continuously generating the electricity in one direction rotation. The disadvantage is to build up two reservoirs, which may be heavy in investment and may decrease working water head [CNE, 1999].

1.4 The advantages of the Tidal Power Plant

Tidal energy is a renewable source of the energy, clean and readily available. It does not produce any emission gases responsible for global warming or acid rain. Uses of tidal energy also decrease the need for fossil fuels as major source of energy.

1.5 Disadvantages of Tidal Power Plant

Tidal power plant is a clean and free resource, but it cannot become a significant resource worldwide because a few geographical have different in water level between high and low tide suitable to be harvested. Thus, it is difficult to generate constant electricity supply.

Other problem associated to tidal energy is building the dam and change the natural flow of a river. A dam will hold the water and flood the land. If reservoirs form, it could destroy the plant and animal habitat. The natural beauty of the site is affected and makes it less suitable for plant and animal.