The Feasibility of Electrical Generation by Using Tidal Method

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Abstract: This paper proposes an offshore generation method for tidal electrical generation system. Generating electrical energy by using tidal effect is another source of a renewable energy without giving any negative impacts on environment. The theory of tidal energy is that it cycle for 24 hours without stopping. Since tidal generation depends on height, then the most critical requirement for generating electrical energy by using tidal effect is the differences between low tide and high tide. The suitable mathematical equations are used to evaluate the performance of the proposed approach compared to the conventional scheme. The simulation results show the ability of generating electrical energy by using offshore tidal generation scheme. The feasibility of this system was analyzed at Sejingkat, Sarawak. This location is chosen because it has the largest differences between low tide and high tide. Offshore generation at Sejingkat, Sarawak offers 6.257 MW as a mean of potential energy per month. Maximum potential energy can be generated in January whereas the minimum in August, which is about 6.543MW and 5.963MW, respectively. Thus, the proposed scheme shows that the offshore tidal generation system at such location is feasible based on the stable monthly potential energy.

Keywords: High tide, Low tide, Offshore, Tidal energy, Tidal generation.

1. INTRODUCTION

Tidal power technology was typically used for grinding grains into flour since tidal mills were invented in the early 1900s [1]. Recently, tidal barrage is the usual technique used for the tidal power generation. The typical model of a barrage is shown in Figure 1.
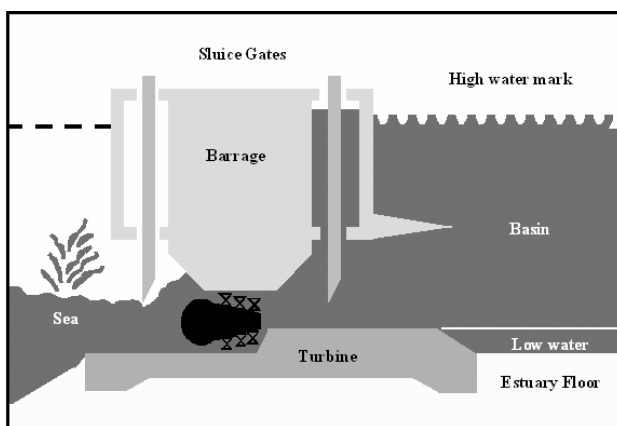

Figure 1. Layout of the barrage with the sluice gate

It is to dam a tidally affected estuary or inlet, allowing the tidal flow to build up on seaside of the dam and the generating during high tide period. After the water level reaches maximum high tide, gate valves are closed and the water is impounded and awaits low tide when it is released and produces power [2]. Even though, barrage can be managed successfully in generating electricity, it still has a several major negative environmental effect such as the navigation is blocked, fish migration is impeded and fishes are killed by passing through the turbines. In addition, the location and nature of the inter tidal zone are changing and the tidal regime is also changing downstream.

Therefore, offshore tidal generator method is proposed to overcome the barrage problems. This paper investigates the ability and effectiveness of tidal generation method for electrical generation. A new scheme of tidal generation method is proposed and its performance is studied using offshore technique to improve the barrage technique.

This paper continues with a brief introduction to the proposed approach in Section 2. Section 3 describes the tidal generation using offshore technique. The simulation results and analysis of tidal data at Sejingkat Sarawak were presented in Section 4. The conclusion of the paper was presented in Section 5.

2. OFFSHORE TIDAL GENERATION METHOD

An offshore tidal generation is a solution to overcome the barrage problems. This is because this method considers the environment preservation, minimum cost and high prospect. This scenario make tidal phenomenon as one of the energy sources that cannot be ignored. Figure 2 represents the proposed model of offshore tidal generation method.

Offshore tidal power generators use an impoundment structure, making it completely self-contained and independent of the shoreline (visualize a circular dam, built on the seabed), thereby eliminating the environmental problems associated with blocking off and changing of the shoreline [3]. Besides that, the optimal site for offshore tidal power generation is the shallow water of near-shore areas and its turbines are situated in a

powerhouse that it contained in the impoundment structure and is always underwater. Power is transmitted to shore via underground/underwater cables and connected to the grid.

Tidal power has the potential to generate significant amounts of electricity at certain sites around the world. However, entire electricity needs could never be met by tidal power alone, it can be a valuable source of renewable energy to an electrical system [4]. Although at the moment tidal technology is quite new which was discovered in 1999, it however could provide a promising prospect for clean and economical energy generation.
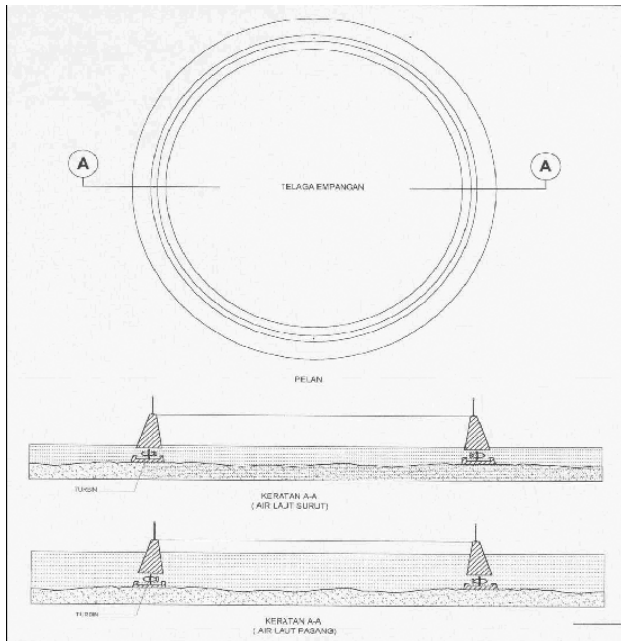

Figure 2. Schematic diagram of proposed offshore tidal generation scheme

3. SYSTEM DESIGN SPECIFICATIONS

Offshore tidal method is a new approach that requires learning from traditional barrage system. For feasibility analysis, four important items had been taken into consideration. The cost analysis is not considered in this part. We consider the following in this paper:

1. Tidal energy mathematical equation
2. Generator sizing
3. Generation scheme
4. Turbine chosen factor

3.1 Tidal Energy Mathematical Equation

Bernoulli Theorem in [5] was used to obtain the equation of tidal power. Bernoulli Theorem was assumed as:

$$BT = U^2 / 2g + p + z \tag{1}$$

where $U^2/2g$ is kinetic energy, U is water velocity per unit, p is pressure and z is potential energy or datum height from water head level. Assume that:

$$z = d - h \tag{2}$$

where d is critical passed depth and h is typical passed depth. Hence, the water passed ratio into turbine, H can be calculated as:

$$H = U2 / 2g + p + (d - h) \tag{3}$$

But, p = h, therefore:

$$H = U^2 / 2g + d \tag{4}$$

Generated energy, E is computed as:

$$E = k_1 Q \tag{5}$$

where Q is the current flow, measured in m³/s and is given by:

$$Q = Av \tag{6}$$

By substituting equation (6) into equation (5), tidal energy can be calculated as:

$$E = Ak_1 (2g(H - d))^{1/2}$$

$$E = Ak_2 (H - d)^{1/2} \tag{7}$$

where A is the area of water passed through, k is the constant value of turbine sensitivity, generator sensitivity, loss factor in transmission line, loss factor outside the transmission line, H is the water height in structure and d is the height of critical passed through. Equation (7) can be simplified as:

$$E = Ak_2 (h)^{1/2} \tag{8}$$

where h is the depth below the free surface.

3.2 Generator Sizing

The suitable size of generator was chosen base on the data obtained at identified locations. It was considered that there were 2 or 3 times of hide tides and low tides changes in 24 hours, depending on locations. The equation involved is given as:

$$Q = Av = V / t \tag{9}$$

Where V is volume and t is time in second.

3.3 Generation Scheme

There are two types of generation scheme in tidal generation system, which is namely as "One pool Generation" and "Three pool Generation. However, this paper focused on one pool generation scheme.

One pool generation use simple generation method. It has one level basin, where pumping process is utilized in this system. The purpose of pumping process is to make the generation process move faster to fulfil the demand.

3.4 Turbine Chosen Factor

Selection of tidal turbine depends on the requirement of generation or demands, operation condition and surrounding factor (erosion and inner pressure bubble).

Several factors were taken into consideration in selecting the turbine, such as:

1. Low tides level
2. Different level of water height and current flow
3. Pumping need
4. What way generation
5. Frequency of generation

3. RESULTS AND DISCUSSIONS

Energy generation by using tidal method is one of the effective way in generate electricity. This is proven by the examples of tidal generators, which were built largely around the world, where it can supply the customer's demand at their locations. This generated energy is fully depending on the difference of water height level between basin and sea level.

3.1 Simulation Results

Figure 3 shows the generated potential power by one turbine per annum for year 2002 at Sejingkat Sarawak. As can be seen from the graph, the potential energy generated each month is identical. Offshore generation at Sejingkat, Sarawak offers 6.291 MW as a mean of potential energy per month. Maximum potential energy can be generate on January whereas the minimum on August, which is about 6.543MW and 5.963MW, respectively. The difference energy generated each month is influenced by the changes of monsoon wind factor. Figure 4 depicts the simulation results of energy output for 12 months; from January until December (at Sejingkat, Sarawak). From the observation, there was three significant cases which representing the maximum, minimum and average amount of energy output.
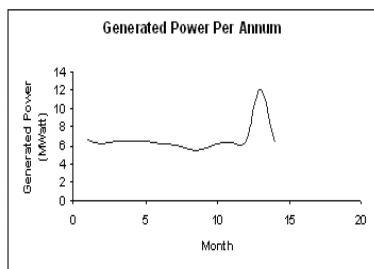

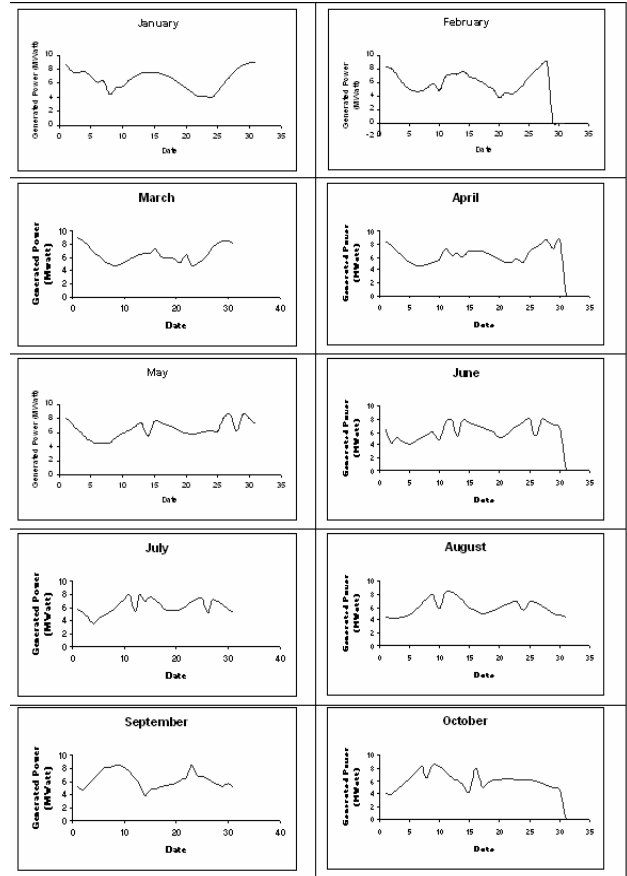
Figure 3. Generated power per annum

Figure 4. Generated power for each month

Figure 5 exhibits the maximum energy potential being generated in January. This month represents the maximum energy potential compared to others. The mean energy generated is about 6.542 MW with mean difference tide 4.304m. However, daily outputs show unstable generation rhythm due to the daily difference between the highest and the lowest tides, which is about 5.73m at 1st January and 2.6m at 24th January, respectively. This shows that the daily generations are unstable.
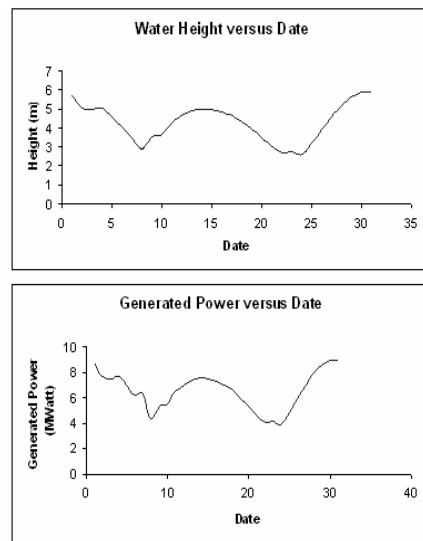

Figure 5. Generated power in January

Figure 6 represents the generated energy in August. The generated energy potential at this month is the lowest

output, approximately 5.962 MW with mean difference tide 3.902m. As data obtained in January, the difference tides also seem unstable. Minimum difference tides is 2.89m on beginning and at the end of the month, whereas the maximum on 11th with 5.48m difference in height.

Figure 7 depicts the generated energy in December. Mean potential energy at this month is about 6.478 MW with mean difference tide of 4.262m. As outputs attained in January and August, this data also had shown unstable rhythm. Minimum height is appeared on 13th December with difference height 1.75m, while maximum value appeared on 5th with difference height 5.96m. Unstable rhythm can be seen obviously at this month, with 4.21m as the highest difference between maximum and minimum height.
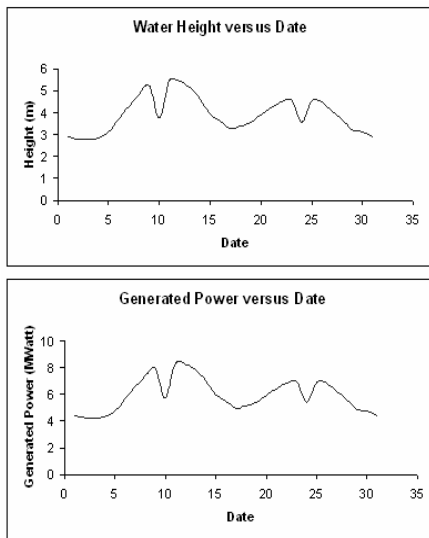

Figure 6. Generated power in August

Based on outputs data from Figure 5 to 7, it can be noticed that the difference tides show unstable. There are approximately 2 maximum and 2 minimum generation cycles per month. Hence, the one-pool and three-pool generation scheme must be considered to solve the problem.

3.2 Analysis of Generation Scheme

Tidal energy generation depends on the difference height of tides. Each generation has a constant value of energy generated. Figure 8 represents the energy output by using one pool generation scheme. The result is based on data obtained at 4th March 2002 at Sejingkat.

From the figure, it can be seen that the total power obtained is constant from 5.00a.m to 9.00a.m. By referring to Figure 9 and 10, the similar different height at each time of generation can be illustrated. However, there is a time where generation could not be done due to the meeting of water level between basin and sea.

Overall, from the obtained output in Figure 3, it can be observed that the monthly energy generated at Sejingkat Sarawak is stable. The stability of power generation is very important for industrial and tourism sectors. Since Sejingkat is located near to Kuching (industrial town), it can be conclude that offshore tidal generation method is feasible to be developed at such location.
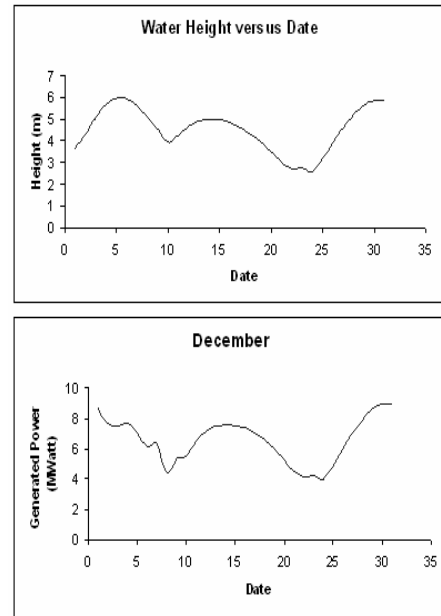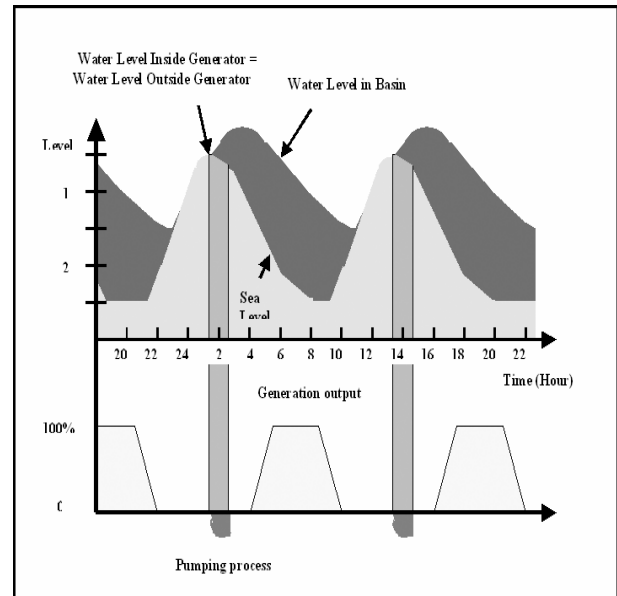

Figure 7. Generated power in December

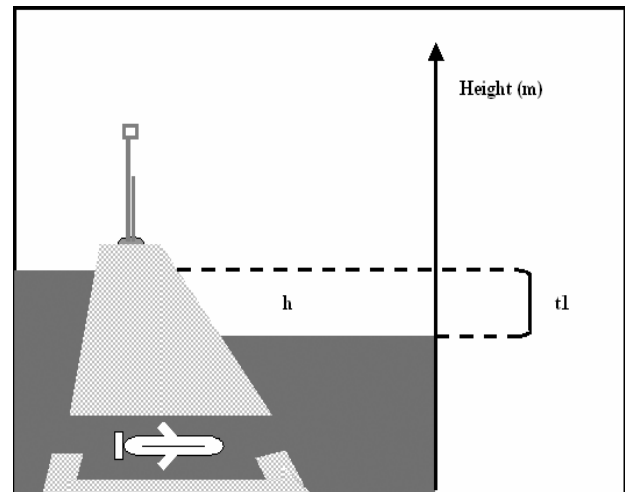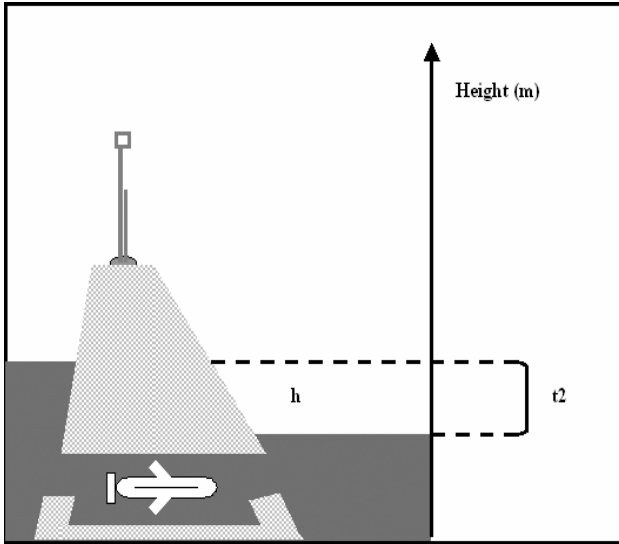Figure 8. One pool generation scheme

Figure 9. Different height at t1

Figure 10. Different height at t2

4. CONCLUSIONS

An offshore technique for new scheme of tidal generation method was proposed. The general observation from the analysis and simulation using offshore technique shows comparable offshore and barrage to tidal generation system, given a very high confident of potential. This infers to comparable confidence of the offshore with 'impoundment wall structure' scheme compared to barrage system.

The offshore tidal generation with 'impoundment wall structure" scheme promises more reliable and practical to be commercialized and it's safe from any negative impacts on environment. In addition, it can overcome the 'stopped-generation' problem in barrage system. More detailed studies are needed to investigate the viability and practicality of this approach, either for one-pool generation or three-pool generation scheme. With specialized 'small-scaled model' support, three pool generation scheme, although more complicated than one-pool generation scheme, can maintain the electrical energy generation in constant mode.

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