The Development of a Preliminary Design for a Tidal Energy Plant

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Abstract—Renewable energy sources are considered a part of the future of energy production in Malaysia. The main objectives of this research are to append a new energy extraction technique that harvests energy from tides and to develop a preliminary design for a tidal energy plant at Kuching Barrage. Knowing the diameter of the turbine, the dimensions of the powerhouse are achieved in conjunction with site conditions. The centerline should be at least below the low water tide so that the tide is at all times guaranteed to be submerged. Based on this, the powerhouse has a 24.61m length, is about 100m in distance across, and its elevation is 36.39m. The construction is located downstream and the centerline habitation at -1.15 and below LSD. The calculated tidal energy plant is comprised of four bulb-type turbines installed at each barrage gate. The bulb-type turbine blades would face the sea site with 11.32m length of the draft tube. This study detailed feasibility study can be implemented.

Keywords-tidal range; powerhouse; renewable energy; Malaysia; Kuching Barrage

I. INTRODUCTION

Renewable energy in Malaysia is considered a great source of energy and a factor of the green energy revolution in Malaysia. The Malaysian government is working on various renewable power plants across the country. The most significant renewable energy sources in Malaysia are solar energy from photovoltaic (PV) panels, biogas, biomass, and small hydro. In the upcoming four years, the Malaysian government proposes to generate 2080MW of electricity from renewable energy. On the other hand, the Sustainable Energy Development Authority [1] in Malaysia is skeptical about achieving this target by the year 2020, since from 30th September 2015, the verified renewable energy creation was only about 319.5MW. Malaysia ought to restore its responsibility regarding accomplishing the target of electricity generation from renewable resources. The current research project is expected to raise awareness regarding renewable energy in Malaysia, particularly tidal range technologies, as at present there is no tidal energy plant in Malaysia. Unlike other known renewable energy resources, tidal range energy harvesting is an expectable phenomenon. Energy production from a tidal range power can be assessed appropriately [2]. More than 80% of energy production comes from non-renewable energy resources such as fossil and coal and they are slowly depleting [3].

About 40 sites have been recognized in the world as ideal sites for the harvesting of tidal range technology [4]. However, this site number is relatively low and no Malaysian site is included among these suggested sites. The reason may be the lack of research on this area and the lack of interest of the Malaysian authorities. This lack of research in Malaysian tidal range energy can be overcome with further studies on the Malaysian ocean and with expected technological improvements. The states Sabah and Sarawak have isolated regions near the coastline which have a shortage in the supply of electric power. There are various modes of electricity used to disband electricity to far-flung locales, such as grid-based and diesel-based generators which are well-known modes of electricity disband. One of the common modes of electricity is grid extension, however, it is costly, takes time, is not economically viable in certain remote areas that are not easily accessible, and often requires sophisticated technologies. It is considered that as a not very feasible mode. Hence, renewable energy sources are being patronized as a green, trustworthy, and economical solution, for the far-flung areas. Among various available green energy options, tidal range energy and tidal stream energy have the best potential due to the reason that they are in sheer abundance, have high density, and they are powerful and predictable and void of any weather conditions, in contrast to solar and wind that are highly subject to metrological conditions. Also, their impact on environmental and human activity is less [5, 6].

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In previous studies conducted at the coast of Sarawak Malaysia, researchers argued that no site in the coast of Sarawak state is meeting the standards of peak speed (more than 1.5m/s) [7, 8], except Pulau Triso at Batang Lupar where maximum speed of 2.06m/s was recorded. Therefore, this is a potential area to generate renewable energy from the tidal range at the East Coast of Peninsular Malaysia that covers Kelantan and Terengganu [9]. According to [9], power could be generated from the existing or new barrage. Worldwide, there are many barrage plants in the operation process. The Sihwa dam in Korea and La Rance in France have mounting energy capability of 254MW and 240MW respectively [10, 11]. Resource mapping is the initial stage in the development of tidal range and tidal stream schemes [11]. Tidal range power generation requires power calculations using real data (tidal range and area of barrage) from the region. The real data can be displayed with the help of resource mapping by indicating the potential sites for the development of tidal energy plants. The aim of this research is to investigate the potential of coastal areas around the East Malaysian states for generating tidal range power plants and also to develop a preliminary design for a tidal energy plant at the chosen areas.

II. LITERATURE REVIEW

A. *Designing the Tidal Range Energy Plant*

The design of a tidal power plant at the Saemangeum project in South Korea was developed in [13]. In the first step, the final measurements of the turbines were calculated. The final measurements of the turbine are the diameter and centerline of the turbine. With the measurement information of the turbines, the powerhouse's dimensions can be calculated with the combination of specification site realities [13]. Dimensions of the powerhouse are the draft tube and turbine bay. The powerhouse is to be constructed at the space required of barrage gates.

B. *Dimensions of the Tidal Range Energy Plant*

The calculation of the powerhouse at Saemangeum was done through empirical formulas and the design process was proposed in [14, 15]. The height of the powerhouse is mainly determined by water levels. Other factors may also influence the structural design, such as a projected road on the barrage and spaces for operation and maintenance. The applied experimental procedure measurements of the future site of this study are concluded. The total length, width, and elevation of the power plant for the future site can be calculated [16].

III. DEVELOPMENT OF THE PRELIMINARY DESIGN OF THE TIDAL RANGE ENERGY PLANT

The development of a preliminary design of a tidal energy plant at the potential site might be established on the basis of the Saemangeum tidal power plant in Korea [13]. Knowing the diameter of the turbine, the dimensions of the powerhouse are achieved in conjunction with the specific site conditions. The centerline should be at least below the Low Water Tide so that the turbine is at all times guaranteed to be submerged. The design of the tidal energy plant is based on the selected turbine of the chosen site. Future power generation sites will be developed accordingly. CAD software such as AutoCAD is an important tool to be imparted in this ongoing project. The development of preliminary designs of tidal energy plants is also proposed. In order to achieve the novelty of this research project, a structured research flow chart with distinct phases and sets of objectives is to be established. It will comprise the development of the tidal energy plant and the generation of electricity by means of constructed barrage or new processes.

Experimental procedures were applied to conclude the measurements of the Saemangeum powerhouse in Korea [14]. It is important to know that the turbine should not disturb the LSD level and not cross the lowest tide level and the Kuching Barrage gate. The LSD at Kuching Barrage gate is –8.0m, the lowest tide level is –3.3m, so the space between LSD and the lowest tide is 4.7m. Logically, the Kuching Barrage turbine diameter should be 2.35m. For the turbine to be under water at all times, the centerline should be at least at the depth of –1.15m. The calculated parameters and plan drawing are shown in Figure 1. The measurement information of the turbine and powerhouse dimensions are calculated with the combination of specification site data and the selected bulb type turbine to be installed at Kuching Barrage are shown in Figure 1. The total length of the Kuching Barrage power plant is 18.37m. Since Kuching Barrage's low tide is at –3.30m and if the turbine diameter is 2.35m, the centerline should be at least at the depth of –1.15m.

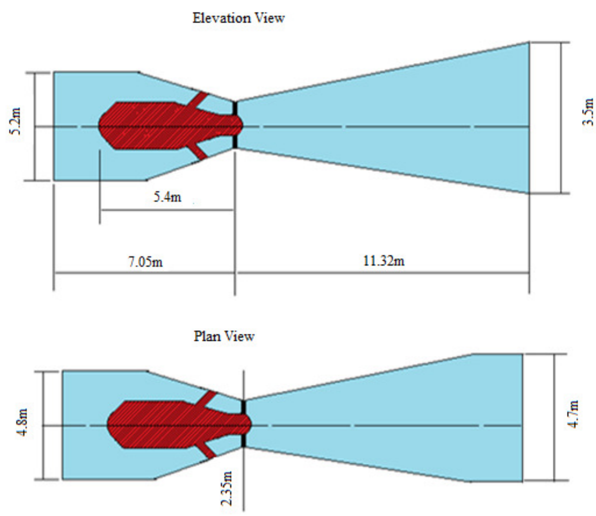

Fig. 1. Kuching Barrage tidal energy plant powerhouse dimensions.

The proposal of the Kuching Barrage powerhouse is exhibited in Figure 2. The powerhouse is to be constructed at the downstream of the Kuching Barrage opening. This would faceplate the flushing process of the present barrage. The proposal in Figures 1 and 2 is drawn according to the reported design. The further construction length is 24.61m, its width is 100m, and its elevation is 36.39m, as presented in Figures 2 and 3. In Figure 2, the powerhouse is comprised of two stop logs at the bay and the exit of the turbine. The main purpose of the stop logs is to support short-term block of water flow during maintenance works. At Kuching Barrage, the structure of the powerhouse and the fixing of fish screens at each gate of the barrage is important. Furthermore, the centerline of the powerhouse is positioned at LSD (–1.15m) to ensure that the turbine is plunged all the time. Fish screens are needed to be fixed at the upstream (basin) to avoid fish incoming to the turbine area. Figure 3 shows that the total width of the barrage is 125m and its length is 37m. However, the width of the Barrage is taken as 100m. The four bulb-type turbines are installed at each gate of Kuching Barrage except gate five, which is reserved for emergencies.

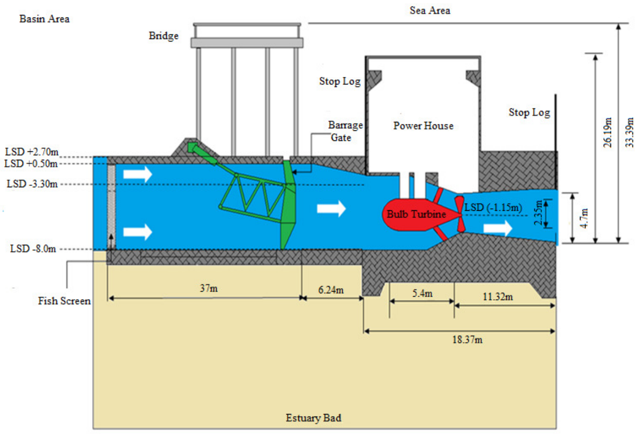

Fig. 2. Powerhouse layout of Kuching Barrage tidal energy plant.

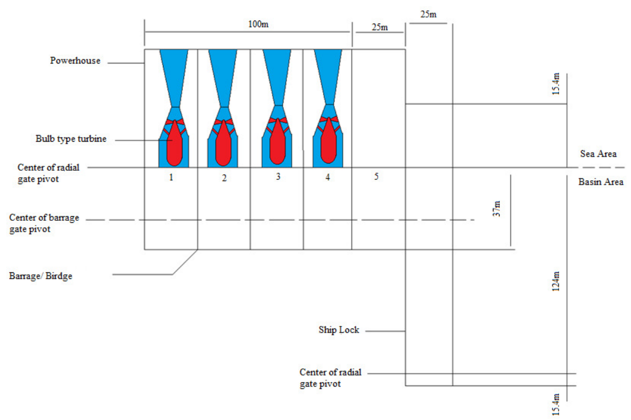

Fig. 3. Plan view of Kuching Barrage tidal range energy plant scheme at four gates.

Figure 4 illustrates the proposal of a selected bulb-type turbine at one gate of Kuching Barrage. It is required that the turbine must be installed below low tide level. When the hydrodynamic pressure is below the vapor pressure of the liquid, there is a formation of the vapor phase (bubbles). The formation of bubbles and their subsequent collapse is called the cavitation problem. The right hand is a basin and the left-hand shows the seaside (upstream-downstream).

IV. PROPOSED OPERATION

Kuching Barrage is located in Sarawak and was built to mitigate the floods in Kuching city. It also has the potential for the development of a tidal energy station. If the Kuching Barrage is being used for tidal energy harnessing, then the tidal energy plant would function during the daily flushing operation. The Kuching Barrage is a one-way process in which the turbine will only work at flushing times.

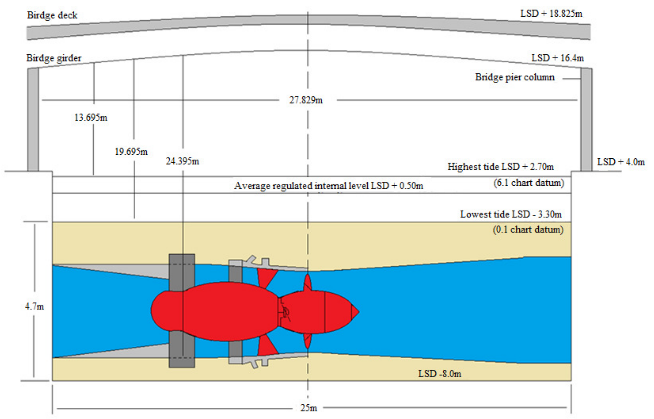

Fig. 4. Schematic diagram of one gate of bulb turbine for Kuching Barrage.

A. *Power Generation by Ebb Generation*

The Kuching Barrage tidal energy plant will produce energy by ebb generation. Figure 2 reports the cross-section of the suggested tidal energy plant arrangement at Kuching Barrage. The barrage gates are locked at all times in order to maintain the river water level and also to avoid saltwater pass into the river. The gates are unlocked for the period of daily flushing process at the ebb tide. In order to accommodate the barrage process, it is suitable to produce energy in the flushing process. Furthermore, out of the three mentioned processes of power generation, ebb generation is the most suitable. The water would flow into the turbine bay, moving the turbine blades and it would flow out of the draft tube. At that time, the shaft would transfer the kinetic energy to the generator and the movement of the coil in the moving magnetic field inside the generator would produce energy.

B. *One-way Operation with Single Basin System*

The calculated tidal energy plant consists of four bulb-type turbines installed at each barrage gate. The bulb-type turbine blades would face the seaside with the 11.32m length of the draft tube for a turbine diameter of 2.35m as shown in Figures 1 and 2. The nominated bulb-type turbine is a one-way process, in which the turbine will only work during flushing. The one-way operation is better since reversible turbines are challenging and costly [2]. The Kuching Barrage gate will be closed, so the turbine will not be able to run. During the implementation of turbines at Kuching Barrage gates, flushing operation with pumping would also be supported.

V. CONCLUSION

Kuching Barrage already exists in the pending site. Therefore, it is identified as a potential site that could yield 10.23GWh/year of energy. The design of a powerhouse tidal energy plant at Kuching Barrage is proposed. The plant will produce power by ebb generation. The data collected from

Kuching Barrage will be also helpful in future studies. The development of the preliminary design of the tidal energy plant scheme can serve as a benchmark or reference for project proposals of similar nature. This project plays a catalyst role in the promotion and introduction of energy harnessing from tides. The proposed powerhouse length is about 24.61m, across in 100m distance, and the elevation is 36.39m. The construction is located downstream and the centerline habitation at −1.15m below LSD. The calculated tidal energy plant consists of four bulb-type turbines installed at each barrage gate. The bulb-type turbine blades would face the seaside with the 11.32m length of the draft tube. The proposed bulb-type turbine is a one-way process, in which the turbine will only work during the flushing process. The one-way operation is better since reversible turbines are challenging and costly.

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