Study of tides prediction for Malaysia electricity generation purposes using Matlab Simulink

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Abstract - Renewable energy has become a phenomenon in where the usage of natural energy such as water, solar, wind, wave and tides is increasing year by year. This initiative is driven by the increasing of oil prices and concerns about climate change caused by reliance on using fossil fuel or coal that encourage the emissions of greenhouse gasses with increasing of electricity demand. Tidal energy is one of the natural sources that have not yet been studied extensively in Malaysia. Thus, this project provides an investigation information in order to provide suitable locations for the implementation of tidal energy in Malaysia which specify only at Malacca Straight. It also focuses on designing a simulation for tidal energy installation in Malaysia electricity generation purposes using Matlab Simulink. As results of this project, tidal energy can be fully implemented and reduces the usage of coal and fossil fuel in future which can preserve the earth with clean environment.

Keywords - Renewable Energy, Tidal Energy, Matlab/Simulink.

I. INTRODUCTION

Electricity generation is an important process before transmitting and distributing the electricity to consumers, where there are many alternative sources of energy to generate electricity. Nowadays, the green technologies are frequently used, spreading and expanding in terms of generation for power utilities. This technology consists of renewable energy sources such as solar, wind, geothermal and wave. In Malaysia, fossil fuel or coal was heavily used to fulfill the electricity demand and happen to increase the emissions of greenhouse gases. In addition, the energy consumption and electricity demand was increased proportional to the rising of population in Malaysia year by year. Recently, the researches of harnessing energy from the ocean are being actively carried out. Moreover, tidal energy that comes with few advantages such as lower environment impact and highly predictable than wind or solar energy seems suitable and expected to be the most reliable alternative energy than wind and solar in the future.

Basically, tidal energy was extracted from moving masses of water which was known as tides. According to previous published paper; ocean energy is one of the sources with huge potential to generate electricity where it was abundance as almost 70% of our Earth covers with waters which are best describe as a huge reservoir with many kind of energy that can be extracted from it such as waves, thermal differences, tides, salinity gradient and marine current [1].

Generally, there are three methods or approach that were often used in order to harness the energy and generate electricity from the ocean sources, which are tidal barrage, tidal stream and dynamic tidal power.

A. Tidal Barrage

Tidal barrage as shown in figure 1 is a popular method that was builds across a bay or an estuary at high tides differential at least five to ten meters of tidal ranges, to achieve valuable and worth value of electrical power generation. The bottom of the barrage is located on the sea floor and the top is above the highest level that the water can get at high tide. The estuary was characterized by narrow, shallow channels with a relatively constant width and depth. [7] It applies the same principle as hydroelectric generation except that tidal currents flow in both directions. [8]
During high tide, the water level on sea side was increased and only then the sluice gates opened and the water was forced to flow through the narrow openings and flow into the basin that create forces. The forces create speeds that rotate the turbines and generating the electricity. After the basin was filled with water, the sluice gates will close and this process was repeated everyday to generate electricity. That is why the tidal energy is said to be abundance and highly predictable. By using equation 1 below, the potential energy of a tidal turbine can be calculated [4][5]:

\[
E_p = \frac{1}{2} C_p (\lambda) g \rho A H^2 \tag{1}
\]

Where:
- \(E_p\) = Potential Energy (J)
- \(C_p\) = power coefficient
- \(\lambda\) = tip speed ratio
- \(g\) = acceleration due to gravity (ms\(^{-2}\))
- \(\rho\) = density of the water (seawater is 1025 kgm\(^{-3}\))
- \(A\) = the sweep area of the turbine (m\(^2\))
- \(H\) = tide amplitude (m)

B. Tidal Current

Tidal current or stream is an energy that was extracted from free flowing water. [3] It extracts the energy from currents in similar way with wind turbines but in different density where water is 832 times denser than air which means it will harness the same amount of power although the water speeds are slower (one-tenth) than wind speed in meter per second (m/s) for same size of turbine. [4]

Currently, there are two types of turbines which are horizontal and vertical axis turbines. Figure 2 illustrates the types of turbines blade for tidal stream approach.

\[\text{(a) Horizontal axis turbine} \quad \text{(b) Vertical axis turbine}\]

Fig. 2. Types of tidal stream turbines [2]

In order to harvest tidal stream energy, the conversion systems are required to convert water kinetic energy into motion of mechanical system which can drive the generators [2]. Thus, equation 2 was used to assume the output power from capture kinetic energy [9][10]:

\[
P = \frac{\xi \rho A V^3}{2} \tag{2}
\]

Where:
- \(P\) = the power generated (W)
- \(\xi\) = the turbine efficiency
- \(\rho\) = density of the water (seawater is 1025 kgm\(^{-3}\))
- \(A\) = the sweep area of the turbine (m\(^2\))
- \(V\) = the velocity of the flow (ms\(^{-1}\))

There are a numbers of most desirable locations to harness tidal energy which fulfill the requirement of narrow straits between land masses or are adjacent to headlands where large tidal currents were developed.

II. METHODOLOGY

The basic diagram of tidal energy conversion and transmission system as shown in figure 3 is chosen. Since the tidal energy system is huge to be build, the focus in this project is to design the simulation from tidal turbine until machine side converter or rectifier.

\[\text{Fig. 3. Tidal energy system [6]}\]

MATLAB/Simulink program is the practical software that can ever design and used to simulate the system. Since there are three approaches that have been introduced earlier in the previous topic, tidal streams are the most suitable for Malaysia Sea and river condition. In order to find the suitability of the location, the data of tidal observation is available at National Hydrographic Center where the books of tides prediction were obtained. It contains data where the tide predictions were tabulated for the whole months throughout year 2012. There are three locations that were selected for this research which are off One Fathom Bank, Off Raleigh Shoal and Off Tanjung Segenting. Figure 4 shows the block diagram of the proposed system designed of the simulation from tidal turbine until machine side converter.

\[\text{Fig. 4. Block diagram of designed system}\]

The input of the system is tidal currents or tidal streams that were obtained from books of tides prediction using equation 3. The tidal ranges however are using equation 4.
Tidal stream (knots) = \frac{\text{Positive tidal streams}}{2} - \frac{\text{Negative tidal streams}}{2} \quad (3)

Tidal range (m) = \frac{\text{High Tide}}{2} - \frac{\text{Low Tide}}{2} \quad (4)

Equation 2 (discuss earlier) was used as a basic in the tidal turbine to obtain the output power. The Simulink block that was designed in MATLAB/Simulink was illustrated in figure 5, 6 and 7 below.

The designed system was originally creates with requirement of figure 4. There are four subsystems that contain the four important elements in harnessing tidal energy. They are the turbine, generator, control circuit and machine side converter (rectifier).

![Fig. 5. Tidal Turbine and Generator Designed](image)

![Fig. 6. Control circuit of the system](image)

![Fig. 7 Tidal Energy Rectifier Designed](image)

III. RESULTS AND ANALYSIS

The simulation results and analysis was presented in table and graph to compare the output of the system. In order to achieve the objectives of the project, the values from the simulation were varied to fulfill the requirement of a generation output. Thus, the system was validated to be tested either it was right or wrong and make sure the results is in range and sensible.

A. Simulation System via MATLAB Simulink

The condition according to the tidal stream results was used for this simulation of tidal energy. The tidal streams were converted into meter per second (m/s) unit by applying the conversion calculation using equation 4 [1][11] below:

$$Tidal\ stream\ (ms^{-1}) = tidal\ stream\ (knots) \times 0.51444\ ms^{-1}$$

Where:

One Fathom Bank = 2.1 knots x 0.51444 ms⁻¹
= 1.080324 ≈ 1.08 ms⁻¹

Off Raleigh Shoal = 2.05 knots x 0.51444 ms⁻¹
= 1.054602 ≈ 1.05 ms⁻¹

Off Tanjung Segenting = 1.85 knots x 0.51444 ms⁻¹
= 0.951714 ≈ 0.95 ms⁻¹

Therefore, the tidal streams were completely converted into the m/s unit. For the tidal range, the location of the Malacca Straits was obtained where the One Fathom Bank was located at Selangor. Therefore, tidal range of Pelabuhan Klang was selected and recorded in the table. The other two locations use the same method of selection the tidal range. Table 1 below shows the values for all of the simulation condition.

<table>
<thead>
<tr>
<th>Locations</th>
<th>Off One Fathom Bank</th>
<th>Off Raleigh Shoal</th>
<th>Off Tanjung Segenting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal stream</td>
<td>1.08</td>
<td>1.05</td>
<td>0.95</td>
</tr>
<tr>
<td>Tidal range</td>
<td>3.05</td>
<td>1.33</td>
<td>2.02</td>
</tr>
<tr>
<td>Water density</td>
<td>1025</td>
<td>1025</td>
<td>1025</td>
</tr>
<tr>
<td>Area covered</td>
<td>$1 \times 10^6$</td>
<td>$1 \times 10^6$</td>
<td>$1 \times 10^6$</td>
</tr>
<tr>
<td>Rotor Radius</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tidal power coefficient, $C_p$</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
</tbody>
</table>

The water density is fixed, 1025 kg/m³. The area covered and rotor radius was selected for initial value at 1 x 106 meter (1km x 1 km) and 1 meter respectively. The tidal coefficient was chosen as 0.45 because it was the minimum number of coefficient for tidal energy. The
coefficients vary from 0.45 until 0.9 but still the 0.45 or 0.5 coefficients were used but there were no specific measurement to calculate tidal power coefficient.

B. Tidal Energy System

The results of simulation test of tidal energy system were recorded in Table II below:

Table II. The results of simulation test of tidal energy system

<table>
<thead>
<tr>
<th>Locations</th>
<th>One Fathom Bank</th>
<th>Off Raleigh Shoal</th>
<th>Off Tanjung Segenting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Potential Power Generation (kW)</td>
<td>974.4</td>
<td>185.3</td>
</tr>
</tbody>
</table>

As expected, One Fathom Bank with high tidal range and speed was generating high potential power generation than the others. This value may be seen as relevant because in EHV system in terms of electrical engineering, the capacity for transmission is greater than 275kV. So, the value in electricity generation part should be higher than transmission part to reduce the energy lost in long distance transmission. It is because the tidal turbine was situated in the deep sea, far from the shore and being converted into direct current only when it arrived onshore. The conversion of AC voltage was necessary since the distance to the load was far. This situation was solved by using HVDC transmission line to deliver the electricity to the consumer as it is stable compared to HVAC transmission. Thus, these values were assumed to be valid.

C. Machine Side Converter (Rectifier)

As the transmission of the electricity that has been done by using HVDC, the conversion was needed to convert AC voltage into DC voltage. Figure 8, 9 and 10 show the rectification graph of machine side converter (rectifier). The simulation result of machine side converter however was recorded and tabulated in Table III:

Table III. The simulation results of DC voltage

<table>
<thead>
<tr>
<th>Locations</th>
<th>One Fathom Bank</th>
<th>Off Raleigh Shoal</th>
<th>Off Tanjung Segenting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Frequency (Hz)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Output Voltage DC</td>
<td>$1.201 \times 10^{19}$</td>
<td>$1.967 \times 10^{18}$</td>
</tr>
</tbody>
</table>

From Table III, the outputs voltages DC were in very high state. The values also did not have a comparison with others as it has limitation of journal with voltage specifications. Furthermore, tidal energy usage in Malaysia was being investigated long time ago but not being implemented yet and it is still in infant stage compared to the other countries with high tidal range and speed where they depend on this renewable energy in many years ago. This is because, this renewable energy was being developed earlier along with nowadays advanced of technologies. Therefore, the focus was on the innovation of this renewable energy, and yet Malaysia only done the investigation. Thus, this simulation was not going to be compared and considered to be an experiment as it was only an implementation to use the tidal energy. This value was assumed to be valid and further improvement on the values was encouraged.
IV. CONCLUSION

In a conclusion, tidal energy will be a great impact for Malaysia’s electricity generation if the scheme is implemented. It is environment friendly as it not going to emit any gases. Compare to other renewable sources such as wind and solar, tidal is predictable as the tides occur two times per day without any affection from the weather such as climate change, melting snow, low of rain or storm. In addition, it is abundance where the earth is majority covered with water. Furthermore, it is a trend to try out anything new for the facilities generation where it can be combined with other energy known as hybrid technology. Hence, it can compliment each other as a backup and it is believed to be a reliable and operate efficiently.

Thus, this problem had solves as it reflects the problem statement previously to reduce the usage of coal and fossil fuel while fulfilling the increasing of electricity. Furthermore, all of the proposed objectives were achieved with intermediate level in providing relevant results.

REFERENCES