Mapping of Tidal Energy Potential based on High and Low Tides for Sabah and Sarawak

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Abstract. Tidal energy is one of the best predictable and reliable source of renewable energy. Therefore, this paper aims to map extractable tidal energy, and to determine potential locations to generate electricity from tidal power along the coastline of Sabah and Sarawak states of Malaysia. The data was obtained from Sarawak Marine Department, and analyzed by using ArcGIS version 10.3. There are two potential locations, namely Tawau in Sabah, and Pending in Sarawak, where 67.0kW and 115.4kW of optimum power generated were obtained respectively.

1 Introduction

The oceans around the world are a bountiful and reliable source of renewable energy [1]. Electricity generation from the ocean power offers a numerous advantages over other sources of renewable energies [2]. The sea energy has a vast potential in its operation and developments [3]. Sea energy can be categorized broadly into two main types, namely tidal and wave power. The specific forms of sea current are surface waves, tides, salinity, thermal gradients and circulation [1]. In general, the waves were produced by the interface of wind with the sea surface, and potential to deliver a boundless source of renewable power [4]. As soon as the wind blows across huge starches of sea, then the ocean waves were created [5]. The wave power can be extracted and transformed into electricity through wave power technologies and devices [4] [6].

The tidal power is more predictable than wave energy and wind power. The tidal power activities ebb and flow of the coastal tidal waters affected by interface of gravitational fields of the moon, sun and the earth [4, 7]. The tidal water levels follows a periodic highs and lows which were related with variations of water levels, and hence the tidal currents. Stronger tides were form, due to either in water level height or tidal current velocities [8]. The tidal generator uses this phenomenon to produce power. Tidal power is a method of non-pollution energy production, which has a vast potential [9]. Besides, growing awareness in the enhancement of tidal power, potentially support to shift use of fossil fuel in the generation of electricity. However, tidal power is not a new idea and several barrage type plants were working, the biggest existence 240 MW in Larance, Farance [10]. The tidal power comprises both potential energy and kinetic energy components [6, 7]. Hence, either utilizing the kinetic energy for tidal stream energy or constructed a barrage to generate the electricity using the potential energy by storage of water [11].

Till the year 1990, for utilization of tidal power required a basin with an appropriate water level variation as comparative to the outside body of water, as an existing turbine required a significant hydraulic head to work [12]. The tidal energy involved ocean waters at high tide and low tide, although its waves show the movement of its flow horizontally [7]. The diurnal tides, semidiurnal tides and the mixed tides are main types of tide. These tides have varying tidal periods, for example the diurnal tides have about 24 hours and 48 minutes whereas a period of 12 hours and 24 minutes reported for semidiurnal tides. The combination of the diurnal and the semi diurnal tides were known as a mixed tide, exists in the most different locations. Some of mixed tides were dominant on the diurnal and the semidiurnal tides. When the diurnal tides were dominant, the maximum tidal current arises at the greater declination of the moon and last current at the zero declination. While the semidiurnal tides were dominant, then the maximum tidal current arises at spring tide and the last tidal current at neap tides [13, 14, and 15].

The principle of tidal energy usage as a renewable energy source has a key role in the improvement of the human society by serving it to control and adapt to the environment [16]. Its utilization depends on the state of the technology and local characteristics of potential regions. For example, some of the challenges were often found with the operating principles, status, and efficiency and cost of generating energy related with each technology [17].

The barrages were constructed through the river estuary. The water level would flow in and flow out through the channel by which turbine rotates as soon as the forces applied onto the turbine (example shown in figure 1) [7].
has low environmental impact as compared to tidal barrage [26]. Tidal stream technology requires very low cost and its predictability and greater water density as related to air stream technology is extra suitable than the windmills as of stream as windmills gain power from the wind [25]. Tidal [24]. The TISEC devices extracts power from the tidal and decrease of the tides [22] [23]. As the water flow stores intermittent of horizontal water flow convoying increase and decrease of the tides [22] [23]. As the water flow stores a huge quantity of power, which can be extracted with the support of tidal in stream energy conversion (TISEC) plans [24]. The TISEC devices extracts power from the tidal stream as windmills gain power from the wind [25]. Tidal stream technology is extra suitable than the windmills as of its predictability and greater water density as related to air [26]. Tidal stream technology requires very low cost and has low environmental impact as compared to tidal barrage technology [27, 28].

2 Methodology

The data was collected from the Sarawak marine department (SMD), Malaysia. The data was acquired, hourly high and low tides tables and nautical charts were used for tidal energy resource valuation and mapping of potential locations. These tables illustrate the usage of hourly tidal energy flows according to the moon age (depicted by the symbols). Data was obtained from twelve locations of the year 2015 data as published by the directorate of marine, Sarawak, Malaysia. The Nautical charts were used to describe the physical features of the selected locations. The generated powers by the wave, dam of water tidal and tidal water energy were described in the following sections.

2.1 Power generated by the wave

The potential power from the dam determined through the volume of water stored. The amount of potential energy in water volume is given by Eq. (1):

\[ E = hMg \]  

(1)

Where; \( h \) = height of tidal water, \( M \) = mass of water \( (1025 \text{ kg/m}^3) \), \( g \) = gravitational force \( (9.81 \text{ m/s}^2) \).

This method was considered together with area of barrage and also ocean tidal 4 times in a day. This resultant method is used to estimate the produced energy [7].

\[ W = \frac{(E \times (A \times H) \times 4)}{T} \] 

(2)

Where; \( E \) = potential energy (Joule), \( A \) = area of barrage \( (\text{m}^2) \), \( H \) = difference of tidal height and \( T \) = duration in one day (Second).

For a most appropriate location to construct the barrage is at great amplitude tidal wave. Since, the tidal energy shown was 80% to variation energy of water to electricity generation [7].

2.2 Dam of water tidal

The barrage technology build to apply this method but construction of barrage involves capital cost and also have environmental impact to the huge area [7]. The potential energy of water head in the barrage facilitates to produce power from different tidal conditions [29]. A barrage was constructed through an estuary or bay so as to allow water to flow into basin as the tide comes in. The barrage has gates which let the water to permit through, thus filling basin. The gates are locked when the tide has stopped coming in, signifying the beginning of ebb. The level of water outside the basin continues to drop in ebb while the level of water inside the basin leftovers high. Alteration of water level produces a head. Water in the basin is then free into the sea through a set of turbines [30].

Power is generated by turbines, which happens during ebb and continues till tide floods and increasing water decreases head to the smallest operating point. The water is then taken again and repeats procedure. Power generation takes place during ebb and then this method of procedure is called ebb generation. Through flood tide, gates and turbines are kept locked till a significant hydrostatic head is developed through the barrage. When adequate hydrostatic head is reached, turbine gates are opened permitting water to flow through them into the basin. Electricity is generated by flood tide method is termed as flood generation [30].
3 Result and discussion

3.1 Tidal water energy

The tidal energy mapping of potential sites was done after the analysis of tidal energy resources. The data of low and high tide energy extraction have been analysed and processed it with the help of an excel program. A maximum height of 6.2 m was identified at Pending location which has low and high tide among the other analysed locations. There are twelve identified locations to perform tidal water investigation, positions of these potential locations from the coastline of Sabah and Sarawak were as shown in figure 2.

![Map showing potential locations for tidal energy along Sabah and Sarawak coastline](image)

Figure 2: Map showing potential locations for tidal energy along Sabah and Sarawak coastline

The twelve locations of low and high tide data have been presented by utilizing ArcGIS software version 10.3. The energy mapping was carried out by using ArcGIS and the corresponding data as represented in excel spreadsheets.

The river widths of these locations were assumed at about 200 meters, as proposed by Maulud et al. [7]. In this study, calculation was concluded using the tidal barrage technology and has been applied to produce tidal water to region. Tidal barrage area is about 200 m x 200 m. This was assumed according to department of irrigation and drainage, Malaysia [7].

The data in tide table (2015), for a height of either inward measure or outward measure of tide specified by time. Power was considered from the difference between height of inward and outward measure of tidal power. Graph shows the result from calculation water energy location have been plotted from the values shown, to categorize the areas where water tidal energy is maximum and reliable throughout the year. It is to determine maximum value realized at a certain locations. The parameters used for determining the potential locations for tidal energy were tabulated in table 1.

<table>
<thead>
<tr>
<th>Locations</th>
<th>Lat N</th>
<th>Long M</th>
<th>Height (m)</th>
<th>E (Energy)</th>
<th>P_{max} (kW)</th>
<th>P_{min} (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuala Santubong</td>
<td>01 43</td>
<td>110 19</td>
<td>5.0</td>
<td>50276.2</td>
<td>93.1</td>
<td>80.1</td>
</tr>
<tr>
<td>Pending</td>
<td>01 33</td>
<td>110 23</td>
<td>6.2</td>
<td>62342.5</td>
<td>115.4</td>
<td>100.6</td>
</tr>
<tr>
<td>Palau</td>
<td>01 45</td>
<td>110 30</td>
<td>4.8</td>
<td>48265.20</td>
<td>89.4</td>
<td>76.3</td>
</tr>
<tr>
<td>Lakei</td>
<td>02 09</td>
<td>111 15</td>
<td>5.7</td>
<td>57314.9</td>
<td>106.1</td>
<td>91.2</td>
</tr>
<tr>
<td>Kuala Rajang</td>
<td>02 09</td>
<td>111 22</td>
<td>5.8</td>
<td>58320.4</td>
<td>108.0</td>
<td>95.0</td>
</tr>
<tr>
<td>Manis Palau</td>
<td>02 08</td>
<td>111 37</td>
<td>5.5</td>
<td>55303.8</td>
<td>102.4</td>
<td>91.2</td>
</tr>
<tr>
<td>Sarakei Labuan</td>
<td>05 17</td>
<td>115 15</td>
<td>2.2</td>
<td>22121.5</td>
<td>41.0</td>
<td>27.9</td>
</tr>
<tr>
<td>Kota Kinabalu</td>
<td>05 59</td>
<td>116 04</td>
<td>1.9</td>
<td>19104.9</td>
<td>35.4</td>
<td>24.2</td>
</tr>
<tr>
<td>Kudat Sandakan</td>
<td>06 52</td>
<td>116 50</td>
<td>2.0</td>
<td>20110.5</td>
<td>37.2</td>
<td>26.1</td>
</tr>
<tr>
<td>Lahad Datu</td>
<td>05 01</td>
<td>118 20</td>
<td>2.3</td>
<td>23127.0</td>
<td>42.8</td>
<td>37.2</td>
</tr>
<tr>
<td>Tawau</td>
<td>04 14</td>
<td>117 53</td>
<td>3.6</td>
<td>36198.9</td>
<td>67.0</td>
<td>57.7</td>
</tr>
</tbody>
</table>

A graph of optimum height limit was generated to give a better result on focus locations, for generation of electricity. The highest energy generated at Pending in Sarawak was 115.4 kW, in the month of October, while the lowest energy of 100.6 kW was observed in June. Similarly, second highest energy of 67.0 kW was generated in the month of January at Tawau in Sabah, while the lowest energy was 57.7 kW in the month of June. A consistent energy could be generated at these areas.

The Figure 3 shows, the maximum energy generated at Pending in Sarawak among other analyzed areas. Therefore, Pending area is considered as the highest potential area of Sarawak coastline for tidal energy.

![Graph of optimum height limit of power generated vs (month) of twelve locations at Sabah and Sarawak](image)

Figure 3: Graph of optimum height limit of power generated vs (month) of twelve locations at Sabah and Sarawak
Figure 4: The tidal water energy generation

Figure 4 shows the generated energy between these twelve analyzed areas. The highest energy of 115.4 kW was generated from Pending in Sarawak. The second highest energy of 108.0 kW was generated from Tanjung Manis in the Sarawak area. The third highest energy generated was noted from Kuala Rajang in Sarawak area at 106.1 kW. An energy of 102.4 kW was reported as the fourth highest energy generated from Sarakei area. The fifth highest energy generated from Kuala Santubong area was 93.1 kW and the sixth highest energy generated from Pulau Lakei in the Sarawak area was 89.4 kW.

Further, the figure 4 shows highest energy of 67.0 kW was generated from Tawau in Sabah. Subsequently 44.7 kW, 42.8 kW, 41.0 kW, 37.2 kW and 35.4 kW were generated respectively from Sandakan, Lahad Datu, Labuan, Kudat and Kota Kinabalu in Sabah area.

The graph shows the different of generated energy for six areas of Sarawak coast line involved in this research. Notably, Pending was observed as a potential area to generate electricity. The maximum generated power of 115.4kW for throughout year 2015 was observed. While a lowest power of 89.4 kW was generated from the Pulau Lakei area as shown in figure 3.

Similarly, the graph shows the different ranges of energy generated for six areas of Sabah coast line involved in this research. From the results, Tawau area is a potential area to generate electricity. A maximum energy of 67.0 kW was generated power throughout year 2015. While lowermost energy of 35.4 kW has been generated from Kota Kinabalu area as shown in figure 3.

There are two factors that affect tidal power. The first factor is the height difference between inward measure and outward measure. For Pending, the height differential is measured as 2.9 m where the highest inward movement is 6.2 m compared to others related areas which were not more than 5.8 m. The second factor in producing energy is the barrage area; barrage area that was used in the calculation has been standardized to estimate the comparison between each area. The generated energy will increase as the barrage area increases.

Among the data observed from 12 locations for high and low tides of east Malaysia, the two main locations identified as potential locations for generating maximum power of electricity are Pending in Sarawak coastline and Tawau in Sabah coastline. Figure 5 shows two potential locations.

Figure 5: Shows two potential locations

4 Conclusions

Tidal energy is an environment friendly and potential renewable energy source. Energy potential of tidal power can be utilized to generate electricity. The cost of increment and resource decrement of petroleum and natural gas give a way to improvement of renewable energy. This research has observed the potential of tidal barrage energy extraction for twelve locations at East Malaysia. The mapping of locations was carried out by ArcGIS ver. 10.3. In an effort to evaluate the potential of harnessing tidal barrage for electricity generation in East Malaysia three locations with great potential for tidal barrage energy extraction were identified. It was found from the study that the Pending location was identified as a potential location to generate electricity with great amount of 115.4 kW among other examined locations of Sarawak coastline. The second potential location was identified at Tawau with amount of 67.0 kW to generate electricity in Sabah coastline. However, the final work of the energy generated depends on the specification and design of the barrage size and turbine.

5 Recommendation for further work

For extraction of worthy electric power for utilization, it is recommended that suitable turbine will be identified for the chosen site. The turbine can be a vibrator or a spring type. A suitable low speed turbine will be identified for generation of electricity at Sabah and Sarawak coastline.

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References


