Assessment of the Malaysian Tidal Stream Energy Resources

A Rahman, I Ibrahim, and M T A Rahman

School of Mechatronic Engineering, Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.

Abstract. As a developing country, Malaysia has shown great interest and effort to commit and invest for green technology and green energy especially tidal energy resources. This research project is conducted to carry out an assessment study to analyse and compare several locations in Malaysia while using the optimal analytical approach in finding the best sites to harness tidal stream resource around Malaysia. Previous studies that only considered flow velocity at the deployment sites may not be accurate since geometry of the coastal region and the friction force exerted from the tidal flow with the seabed can also contribute to the suitability of the proposed tidal sites. Tidal Model Driver was used to extract tidal elevation data on specific harmonic constituents and tidal velocity attribute, and then compared to the data obtained from General Bathymetric Chart of the Oceans. The weighted decision matrix was used to analyse the potential of each location by considering essential criteria such as tidal velocity, depth of coastline, geometry of coastline and environmental impacts. Top locations with the highest score were chosen as potential location to invest in a tidal energy farm, which consists of Pulau Pangkor, Port Dickson, and Pulau Tioman among others. The locations that produce the highest yearly energy density are found to be Pulau Pangkor with 1.21 MWh/year followed by Pulau Pinang with 836.5 kWh/year. Notably, the inclusion of other factors besides tidal velocity such as the site characteristic and the amount of potential impact to the environment provided different outcome than published materials in this field.

1. Introduction
Tidal energy is extracted through a natural phenomenon called ocean tides, where the water in the seas and oceans rise and falls periodically [1]. Using the tidal stream approach, tidal stream turbine is planted on the oceans seabed where the current is usually strong to generate enough electricity. The purpose of this project is to carry out an assessment study on various potential locations for tidal energy farm in Malaysia’s water since different location will exert different amount of velocity. Furthermore, previous study on Malaysia’s tidal energy resources only consider the flow velocity as the main criteria in calculating the available power. Such method, however, is not comprehensive and require additional analytical assessment to determine the best sites to harness tidal energy resources. One critical factor to be considered when determining the potential locations for tidal energy farm in Malaysia is the geometry of the coastal region and the friction force exerted from the tidal flow with the seabed [2]. Planting a tidal turbine may disturb the natural conditions of the environment due to the changes of flow of water and the sediment transport [2]. Therefore, an assessment study needs to be conducted to determine suitable locations to invest in tidal energy farm without interrupting the environment. Besides, the chosen sites must also be geographically suitable to install arrays of turbine.
2. Methodology
This study follows the research and guidelines published by Claire Legrand, Black & Veatch Ltd [3]. Several other resource assessment study on tidal energy within Malaysia’s open water had been done by Yun Seng Lim et al. [4] and Saw Jun Sheng [5], which are used as the backbone of this project research.

2.1. Data collection
For the first part of this research, important parameters such as the value of harmonic constituents of the tide is obtained from the GEBCO (General Bathymetric Chart of the Oceans) database [6]. The harmonic constituents consist of M2, S2, N2, K2, K1, O1, P1 and Q1. The harmonic constituents from the TMD software are then compared with the value from GEBCO to determine the percentage in difference of both values.

2.2. Tidal Model Driver (TMD) simulation
The second part is mainly focused on the software simulation done by an ocean modelling software call TPXO or Tidal Model Driver (TMD). TMD is a database of global tides properties that uses equation such as the Laplace Tidal Equations and altimetry data to predict the properties of the oceans in the upcoming years.

2.3. Model used for simulation
In this project, the TMD’s model used is the China Seas & Indonesia 2016 that was retrieved from OTIS Regional Tidal Solutions [7]. Nonetheless, the first model that was employed in the TMD software was the Pacific Ocean 2009, and a comparison of several characteristics between the two models are highlighted in Table 1.

| Characteristics | Pacific Ocean 2009 | China Seas & Indonesian 2016 |
|-----------------|--------------------|-----------------------------|
| Bathymetry      | GEBCO 1'           | GEBCO                       |
| Resolution      | 1/12'; 1585x2065 grid | 1/30'; 1801x2161 grid       |
| OBC             | TPXO8              | TPXO7.1                     |
| Constituents    | M2, S2, N2, K2, K1, O1, P1, Q1, M4, MS4, MN4 | M2, S2, N2, K2, K1, O1, P1, Q1 |

2.4. Site selection
An assessment needs to be done to find out suitable locations in Malaysia’s open water for tidal array, in which several key factors need to be considered.[3].

2.4.1. Current velocity.
Malaysia’s ocean can be classified as shallow water, where the average current velocity is approximately 1 m/s. Table 2 shows that current velocity above 0.65 m/s are able to generate electricity, although the amount is very small. Therefore, locations that have velocities of more than 1 m/s are chosen as potential locations. The flow speed is chosen based on a simulation on the TPXO software for various locations throughout Malaysia’s coastline.

2.4.2. Site characteristics.
According Adcock [2], there are 4 examples of sites where tidal turbine can be installed, which is illustrated in Figure 1. Before deciding a potential location to invest in tidal energy farm, the effect of tidal turbine on the environment needs to be considered. According to Legrand, a minimum of 5m on
the top clearance is recommended to allow for recreational activities such as fishing activity, small boats and swimmers as well as avoiding floating garbage from hitting the turbine [3]. Likewise, a minimum of 5m is also needed for the bottom clearance as it is to allow potential damaging material to the tidal turbine to pass through along the seabed and to minimize turbulence [3].

Table 2. Mean electrical power generated per average tidal velocity [3].

| Average bin velocity (m/s) | Probability occurrence (%) | Electrical power per bin (kW) | Mean annual electrical power per bin (kW) |
|---------------------------|-----------------------------|-------------------------------|--------------------------------------|
| 0.05                      | 0.3                         | 0                             | 0                                    |
| 0.15                      | 0.9                         | 0                             | 0                                    |
| 0.25                      | 1.5                         | 0                             | 0                                    |
| 0.35                      | 2.2                         | 0                             | 0                                    |
| 0.45                      | 3.0                         | 0                             | 0                                    |
| 0.55                      | 4.0                         | 11                            | 0                                    |
| 0.65                      | 5.2                         | 19                            | 1                                    |
| 0.75                      | 6.4                         | 30                            | 2                                    |
| 0.85                      | 7.4                         | 44                            | 3                                    |

Figure 1. Different coastal geometries in which tidal turbine can be installed [2].

3. Results and Discussion

Weighted decision matrix was used to evaluate the potential locations from the selection of criteria based on ranking. The weighted factor and scoring degree will define whether the potential location meets the main criteria for the deployment of tidal energy farm. Figure 2 illustrates the objective tree for tidal energy farm’s key evaluation criteria.

Figure 2. Objective tree for criteria on potential location for tidal farm in Malaysia.
Table 3. Weighted score for top selected locations.

| Criteria                  | Weight Factor | Units | Pulau Pangkor | Port Dickson | Pulau Tioman | Pulau Redang | Pulau Langkawi |
|---------------------------|---------------|-------|---------------|--------------|--------------|--------------|---------------|
| Velocity of currents      | 0.24          | m/s   | 7             | 1.68         | 5            | 1.20         | 2             | 0.48          | 1             | 0.24         | 3             | 0.72         |
| Swept area of turbine     | 0.18          | m²    | 9             | 1.62         | 8            | 1.44         | 9             | 1.62         | 9             | 1.62         | 8             | 1.44         |
| Type of devices           | 0.18          | -     | 8             | 1.44         | 8            | 1.44         | 8             | 1.44         | 8             | 1.44         | 8             | 1.44         |
| Depth                     | 0.12          | m     | 9             | 1.08         | 7            | 0.84         | 9             | 1.08         | 9             | 1.08         | 8             | 0.96         |
| Size of turbine           | 0.12          | m²    | 9             | 1.08         | 8            | 0.96         | 9             | 1.08         | 9             | 1.08         | 8             | 0.96         |
| Geometry of coastal region| 0.08          | -     | 8             | 0.64         | 5            | 0.40         | 6             | 0.48         | 7             | 0.56         | 7             | 0.56         |
| Environmental impacts     | 0.08          | -     | 3             | 0.24         | 3            | 0.24         | 4             | 0.32         | 5             | 0.40         | 4             | 0.32         |
| Total rating              | -             |       | 7.78          | -            | 6.52         | -            | 6.5           | -            | 6.42          | -            | 6.4          |

As shown in Table 3, the top selected locations are based on the locations that scored the highest rating on the weighted decision matrix. The top ten selected locations are Pulau Pangkor, Port Dickson, Pulau Tioman, Pulau Redang, Pulau Langkawi, Batu Pahat, Pulau Pinang, Melaka, Sibu and Pulau Banggi. After obtaining the top ten locations to invest in a tidal energy farm through the weighted decision matrix, the next step is to determine the energy density of each of the location monthly. The energy density is calculated using the following equations:

\[ E_{av} = \sum_{h=1}^{8760} \left[ \frac{1}{2} C_p \rho A V^3 \right]_h \]  

where \( E_{av} \) = Yearly average energy (kWh), \( \rho \) = Water density (kg/m³), \( C_p \) = power coefficient, \( A \) = swept area of tidal turbine (m²) and \( V \) = Tidal velocity (m/s). The diameter of turbine is fixed at 5 meters and the swept area of turbine used the horizontal axis turbine swept area. The energy density of selected locations was calculated on a month to month basis as illustrated in Figure 3.

Figure 3: Energy density per month of top ten selected location.
4. Conclusion
This study has shown that there are several locations in Malaysia that are able to harness tidal energy resources from detailed analysis and comparison between the selected sites. In addition, an optimal analytical approach through the simulation of TMD software and surveying the entire locations/coastline characteristic was done to all of the selected locations. The result of this research was found to slightly differ with other past researches. The top ten locations are Pulau Pangkor, Port Dickson, Pulau Tioman, Pulau Redang, Pulau Langkawi, Batu Pahat, Pulau Pinang, Melaka, Sibu and Pulau Banggi. This assessment study brings contribution to the community of those selected locations as it have been verified that those coastal region of selected locations have the potential to harness the tidal current energy resources. Furthermore, the potential stakeholders such as the investor, government and local community will be able to benefit from this renewable tidal current energy. Lastly, this assessment study also creates an opportunity for academic scholars to further proceed on detailed site study regarding turbine design and also array system at the proposed locations.

Acknowledgement
The first author would like to acknowledge the School of Mechatronic Engineering, UniMAP for the financial support. This project would never be possible without the help of my student, Izzudin Ibrahim, who is tireless in the pursuit of knowledge.

References
[1] Khan N, Kalair A, Abas N and Haider A 2017 Review of ocean tidal, wave and thermal energy technologies Renew. Sustain. Energy Rev. 72 (May 2016) 590–604.
[2] Adcock T A A, Draper S and Nishino T 2015 Tidal power generation - A review of hydrodynamic modelling Proc. Inst. Mech. Eng. Part A J. Power Energy 229 (7) 755–771.
[3] Legrand C and B & V Ltd 2009 Assessment of Tidal Energy Resource European Marine Energy Centre Ltd (EMEC).
[4] Lim Y S and Koh S L 2010 Analytical assessments on the potential of harnessing tidal currents for electricity generation in Malaysia Renew. Energy 35 (5) 1024–1032.
[5] Sheng S J 2018 Assessment Study For The Modest Tidal Energy System in Malaysia (June, 2018).
[6] Bonar P A J, Schnabl A M, Lee W K and Adcock T A A 2018 Assessment of the Malaysian tidal stream energy resource using an upper bound approach J. Ocean Eng. Mar. Energy 4 (2) 99–109.
[7] Egbert G D and Erofeeva S Y 2010 OTIS Regional Tidal Solutions web page Oregon State University web pages [Online]. Available: http://volkov.oce.orst.edu/tides/region.html. [Accessed: 19-Apr-2019].