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

Kamran Ahmed Samo[1,a], Andrew Ragai Henry Rigit[2], Azhaili Baharun[3]

[1,a]*Kamran Ahmed Samo, PhD student, Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak Malaysia*
[2]*Andrew Ragai Henry Rigit, Professor, Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia (arigit@unimas.my).*
[3]*Azhaili Baharun, Associat Professor/Director Centre of Renewable Energy, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia (bazhaili@unimas.my).*

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].

[a] corresponding author: kamransamo2@gmail.com

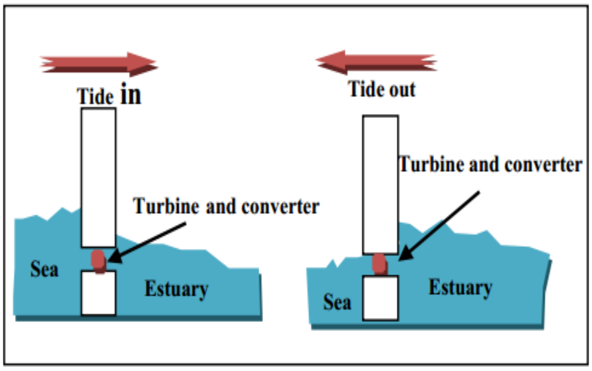

Figure 1: Basic method of operation for tidal barrage [7]

The tidal barrage is a dam, which blocks the incoming and outgoing tides and then builds a water head [18]. It makes use of potential energy due to its alteration in height between high and low tides [19]. The high tide and low tide of ocean level of water is effect by the gravitational force of the solar system. The scale of gravitational force for an object depends on its mass and distance. The moon has higher gravitational force compare to the sun, even though it is smaller than the sun. This force affected to the increment about 71% to the sea level. The greater movement of sea waters comprises largest amount of energy [7]. The tidal barrage were typically comprises turbines of either unidirectional or bi-directional [6]. The tidal barrages were planned to generate electric power by ebb or flood mood or can be both the ways [18]. In general, tidal barrage structure needs a very high investment cost [20] and thus, these schemes were not economically much appealing to the investor due to their delayed in time line of profit [21].

In contrary to the barrage technology, tidal current turbines extract kinetic energy by moving water to produce the electric power. The tidal technology is alike wind technology [6, 11]. The tidal turbines were mounted underwater at the sites in the ocean wherever great tidal stream occur and the tidal stream energy was an 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):

$$E=hMg \qquad (1)$$

Where; h = height of tidal water, M = mass of water (1025 kg/m^3), g = gravitational force (9.81 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].

$$W = \frac{(E\times(A\times H)\times 4)}{T} \qquad (2)$$

Where; E = potential energy (Joule), A = area of barrage (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 ebbs 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].

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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.

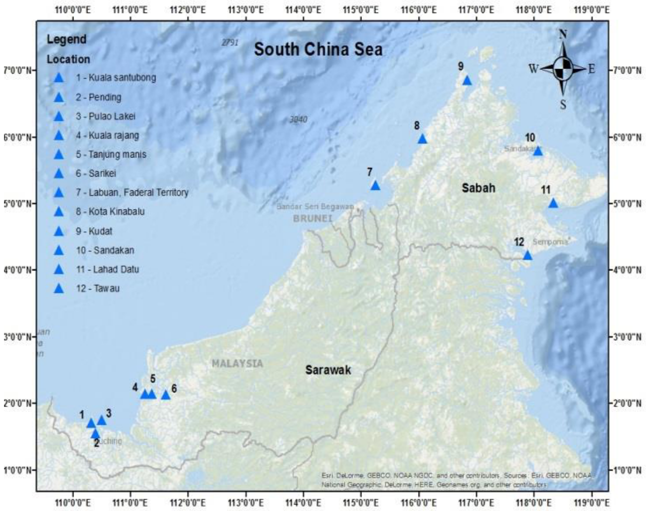

Figure 2: Map showing potential locations for tidal energy along Sabah and Sarawak coastline

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 spread sheets.

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 1: The parameters used for locating tidal energy at various potential locations

Locations	Lat N	Long M	Height (m)	E (Energy)	P_{max} (kW)	P_{min} (Kw)
Kuala Santubong	01 43	110 19	5.0	50276.2	93.1	80.1
Pending	01 33	110 23	6.2	62342.5	115.4	100.6
Palau Lakei	01 45	110 30	4.8	48265.20	89.4	76.3
Kuala Rajang	02 09	111 15	5.7	57314.9	106.1	91.2
Tanjung Manis	02 09	111 22	5.8	58320.4	108.0	95.0
Sarikei	02 08	111 37	5.5	55303.8	102.4	91.2
Labuan	05 17	115 15	2.2	22121.5	41.0	27.9
Kota Kinabalu	05 59	116 04	1.9	19104.9	35.4	24.2
Kudat	06 52	116 50	2.0	20110.5	37.2	26.1
Sandakan	05 48	118 04	2.4	24132.6	44.7	33.5
Lahad Datu	05 01	118 20	2.3	23127.0	42.8	37.2
Tawau	04 14	117 53	3.6	36198.9	67.0	57.7

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.

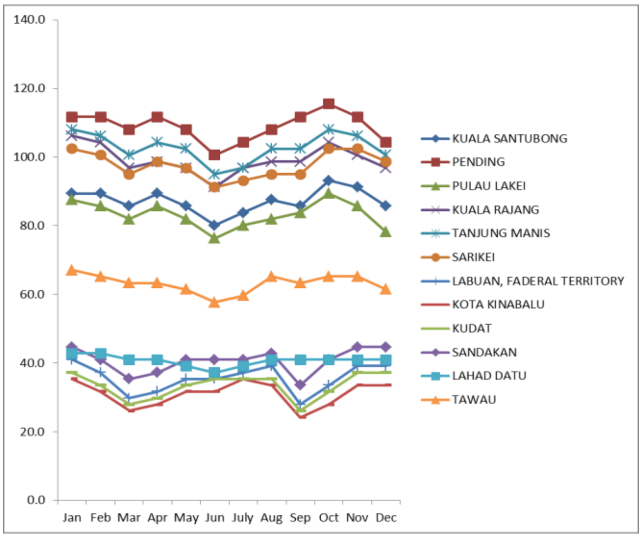

Figure 3: Graph of optimum height limit of power generated vs (month) of twelve locations at Sabah and Sarawak

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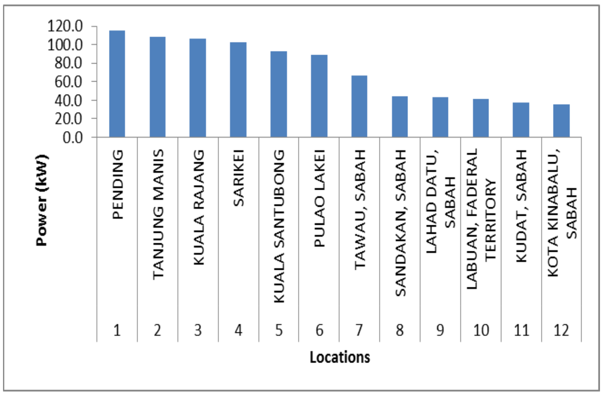

Figure 4: The tidal water energy generation

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 Sarikei 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 compare 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 of low and high tide east Malaysia.

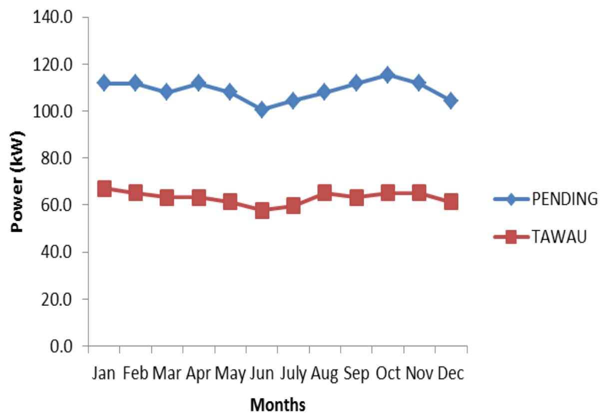

Figure 5: Shows two potential locations

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 two 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 the 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 67.0kW to generate electrify 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

1. A. S. Bahaj, Generating Electricity From the Oceans, *Renewable and Sustainable Energy Reviews*, Vol. 15, pp. 3399-3416, 2011.

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2. L. Myers and A. S. Bahaj, Simulated Electrical Power Potential Harnessed by Marine Current Turbine Arrays in The Alderney Race, *Renewable Energy,* Vol. 30, pp. 1713-1731, 2005.
3. H.B. Lu, Y.L. Li, L.L. Ma, and X.L. Pao, The Design and Optimization for The Dome Of Tidal Turbine, *Energy Procedia,* Vol. 17, part B, pp. 1710-1716, 2012.
4. A. Q. Malik, Assessment of The Potential of Renewables for Brunei Darussalam, *Renewable and Sustainable Energy Reviews,* Vol. 15, pp. 427-437, 2011.
5. P. Lenee-Bluhm, R. Paasch, and H. T. Ozkan-Haller, Characterizing The Wave Energy Resource of The U.S Pacific Northwest, *Renewable Energy,* Vol. 36, pp. 2106-2119, 2011.
6. F. O. Rourke, F. Boyle, and A. Reynolds, Renewable Energy Resources and Technologies Applicable To Ireland, *Renewable and Sustainable Energy Reviews,* Vol. 13, pp. 1975-1984, 2010.
7. K. N. A. Maulud, O.A.Karim, K.Sopian and S.N.F.A.Aziz, Determination of Tidal Energy Resource Location in East Coast of Peninsular Malaysia Using Geographical Information System, 2009.
8. P. Meisen and A. Loiseau, Ocean Energy Technologies for Renewable Energy Generation, *Global Energy Network Institute,* 2009.
9. Z. Fan, Tidal Power Energy, *Renewable Energy In Future. Retrieved,* pp. 30-11, 2011.
10. J. F. Atwater and G. A. Lawrence, Power Potential of A Split Tidal Channel, *Renewable Energy,* Vol. 35, pp. 329-332, 2010.
11. A.R.H.Rigit, A. Q. Jakhrani, S.A.Kamboh, W. H. Kong and K. A. Samo, Mapping of Tidal Stream Energy Resources in The Coastline of Sarawak, pp. 1252-1261, 2013.
12. G. I. R. Carballo, A. Castro, Numerical Model Evaluation of Tidal Stream Energy Resources in The Ria De Muros (Nw Spain) *Renewable Energy,* pp. 1517-1524, 2009.
13. T. J. Hammons, Tidal Power, pp. 419-433, 1993.
14. G. Tom, *Oceanography: An Invitation to Marine Science (6th Edition Ed.)*,2007
15. P. B. H. George, Epri North American Tidal in Stream Power Feasibility Demonstration Project., 2006.
16. K. A. Maulud, W. W. Mohtar, and O. Karim, Spatial Multi Criteria Analysis for The Determination o Areas With High Potential Wave Energy, *Jurnal Teknologi,* Vol. 65, 2013.
17. J. K. N. P. Purbaa, R. Sandrob, S. Gibranb, R. A.I. Permatab, and M. K. M. F. Maulidab, Suitable Locations of Ocean Renewable Energy (ORE) in Indonesia Region – GIS Approached, *Energy Procedia,* pp. 230 – 238, 2015.
18. J. Xia, R. A. Falconer, B. Lin, and G. Tan, Estimation of Annual Energy Output from A Tidal Barrage Using Two Different Methods, *Applied Energy,* Vol. 93, pp. 327-336, 2012.
19. Z. Defne, K. A. Haas, H. M. Fritz, L. Jiang, S. P. French, X. Shi, B.T.Smith, V.S.Neary and K.M.Strewart , National Geodatabase of Tidal Stream Power Resource in U.S.A, *Renewable and Sustainable Energy Reviews,* Vol. 16, pp. 3326-3338, 2012.
20. E. Denny, The Economics of Tidal Energy, *Energy Policy* pp. 1914–1924, 2009.
21. R. H. Charlier, Sustainable Co-Generation from The Tides: A Review, *Renewable and Sustainable Energy Reviews,* pp. 187–213, 2003.
22. J. Hardisty, Assessment of Tidal Current Resources: Case Studies of Estuarine and Coastal Sites, *Energy & Environment,* Vol. 18, pp. 233-249, 2007.
23. S. Couch and I. Bryden, Tidal Current Energy Extraction: Hydrodynamic Resource Characteristics, *Proceedings of The Institution of Mechanical Engineers, Part M: Journal of Engineering for The Maritime Environment,* Vol. 220, pp. 185-194, 2006.
24. M. Previsic and R. Bedard, Methodology for Conceptual Level Design of Tidal in Stream Energy Conversion Power Plants, *Epri North American Tidal In Stream Power Feasibility Demonstration Project,* 2005.
25. I. Bryden, S. Naik, P. Fraenkel, and C. Bullen, Matching Tidal Current Plants to Local Flow Conditions, *Energy,* Vol. 23, pp. 699-709, 1998.
26. J. B. Blanchfield, The Extractable Power from Tidal Streams, Including A Case Study for Haida Gwaii, University of Victoria, 2007.
27. M.S. Guney and K.Kaygusuz, Hydrokinetic Energy Conversion Systems: A Technology Status Review, *Renewable and Sustainable Energy Reviews,* pp. 2996-3006, 2010.
28. C. M. Johnstone, D. Pratt, J. A. Clarke, and A. D. Grant, A Techno-Economic Analysis of Tidal Energy Technology, *Renewable Energy,* Vol. 49, pp. 101-106, 2013.
29. C. Baker, J. Walbancke and P. Leache, Tidal Lagoon Power Generation Scheme in Swansea Bay, A report on behalf of the Department of Trade and Industry and the Welsh Development Agency, 2006.
30. A. Q. Jakhrani,A.R.H.Rigit and S. R. Samo, Estimation of Tidal Stream Energy Resources at Sarawak Coastline and Their Potential Impact on Environment, *Australian Journal of Basic and Applied Sciences,* vol. (6), pp. 503-514,, 2013.