

Determination of Potential Tidal Power Sites at East Malaysia

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Abstract—Tidal range energy is one of the most predictable and reliable sources of renewable energy. This study's main aim is to determine potential sites for tidal range power in East Malaysia, by analyzing tidal range distributions and resources and the feasibility of constructing barrages. Investigation was conducted in 34 sites, estimating their potential energy outputs and studying their areas for constructing barrages. Only 18 sites were marked as appropriate for constructing a tidal range energy extraction barrage. The highest potential power was found in Tanjung Manis, and its maximum capacity was calculated as 50.7kW. The second highest potential of tidal power extraction was found in Kuching Barrage at Pending, where an energy harvester could produce electric power up to 33.1kW.

Keywords—tidal range; renewable energy; potential site; power; East Malaysia

I. INTRODUCTION

Oceans possess a huge potential to generate electric power [1]. Generating electricity from ocean power can offer many advantages compared to other renewable energy sources [2]. Ocean power is a vast and comparatively reliable source. Thermal power can be harvested from oceans by the temperature difference of warm shallow and deeper cold waters, and kinetic power can be harvested from tides, waves, and streams. Salinity gradient power is the energy extracted by the difference in the salt concentration between sea and river water. Although Malaysia is located in the equatorial zone surrounded by sea, this ocean power has not attracted much attention by the local government [3]. The country's total coastline is 4,675km, West and East Malaysia have 2,068km and 2,607km of coastline respectively [4]. The long length of Malaysia's coastline is a huge advantage in utilizing tidal range energy as a reliable alternative energy source [5].

II. LITERATURE REVIEW

A potential site can be determined by the maximum available tidal energy. The East Coast of Malaysia, was studied in [6] where four areas with high exploitable tidal water energy were determined. Data for potential energy production at the East Coast of Peninsular Malaysia, covering Kelantan and Terengganu regions, were obtained from Malaysia Meteorology Department (MMD), Department of Mapping and Survey, and National Hydrographic Centre, while potential regions were determined through GIS. Tidal power derives from the tidal range, as the water is confined in a basin during a high tide, and it runs out through a turbine at low tide [7-9]. The energy extracted from a tidal barrage can be calculated by considering the tidal range of water, as:

$$E = h \times \rho \times g \quad (1)$$

where E is the potential energy (J), h is the tidal range (m), ρ is the water density (1025kg/m^3), and g is the gravitational force (9.81m/s^2). Generated power can be calculated, concerning the space of barrage and tidal ocean as:

$$W = \frac{(E \times (A \times h) \times 2)}{T} \quad (2)$$

where, E is the potential energy (J), A is the barrage area (m^2), h is the tidal range (m), and T is the duration in one day (s). The width of the river site was assumed to be about 200m and the area of the tidal barrage was about $200 \times 200\text{m}$ [6]. The barrage area was considered using data from the Department of Irrigation and the Department of Drainage in Malaysia [6]. A graph of the optimum upper limit of power generated per month, created at Tanjung Berhala, Terengganu, is shown in Figure 1. Data were analyzed by month, and the maximum daily power was considered.

According to Figure 1 the produced power's upper limit was between 90kW and 203kW.

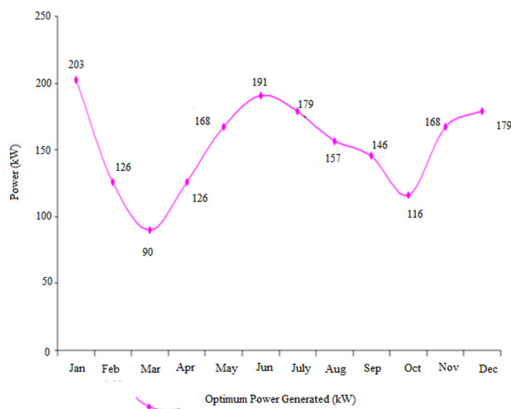


Fig. 1. Optimum upper limit of power generated per month of 2006 – © Tanjung Berhala, Terengganu [6]

The method presented in [6] was utilized with minor differences in this study, in order to calculate the power of the tidal range sites. Water mass was replaced by water density in (1), and as this research deals with one-way instead of two-way generation, 2 is used instead of 4 in (2). Potential energy based on tidal range can be calculated by (1), while the power output can be calculated by (2). This study considered four different areas in East coast of Malaysia, and the resources of tidal range power at 34 sites of Sabah and Sarawak coastline were examined, as suggested in [6, 10]. Those chosen 34 areas were measured using Google maps, in order to determine the feasibility of a barrage construction.

III. METHODOLOGY

Figure 2 shows a data flow diagram of this research method, including determination of sites, data analysis, power output calculation, and map production using Google Maps. In [6], power output was calculated for four sites using data from 2006 and 2007. This study calculated the power output of 34 sites using data from 2015. Previous researchers [6, 11] assumed the barrage area of their studied sites at 200×200m, while this research uses their actual area, except the already constructed Kuching Barrage at Pending.

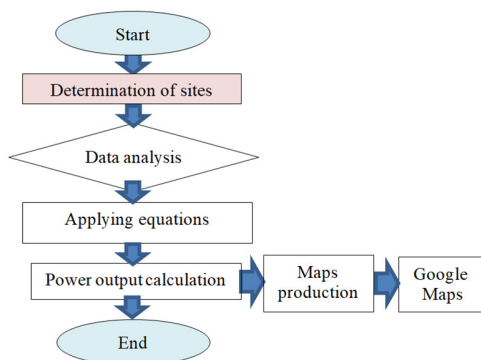


Fig. 2. Flow chart of the proposed methodology.

A. Available Resources

Tidal range data of 2015 were acquired from Sarawak Marine Department (SMD). These data included tables, namely Sarawak hourly high and low tide tables, and nautical charts. Google maps were used to measure the area and produce maps to show the position of tidal range sites. Sigma software was used for data analysis. MATLAB was used for producing graphs of tidal range potential sites. Equations (1) and (2) were used for calculating maximum power. Some preferable sites are in the sea while others are located inland.

B. Navigational Charts

Navigational charts detail the physical features of the sites, depth of sea water in meters, and nearby land information. Coordinates acquired from satellite navigation systems, such as Global Positioning System (GPS) using World Geodetic System (WGS) 1984 datum can be plotted directly on these charts [12].

C. Calculating Available Energy Resources

The determination of possible tidal range sites was performed after analyzing tidal range energy resources. Low and high tide data were acquired from [13]. The barrage areas were assumed measuring area's width on Google Maps. Equations (1) and (2) were used to calculate the power output of each site.

D. Calculation of Power Output for Tidal Range Sites

Calculations were performed after examining each site's hourly tide tables. Water's tidal range influences the potential power output from the barrage, as noted in (1) and (2). Figure 3 shows the calculation procedure flow chart.

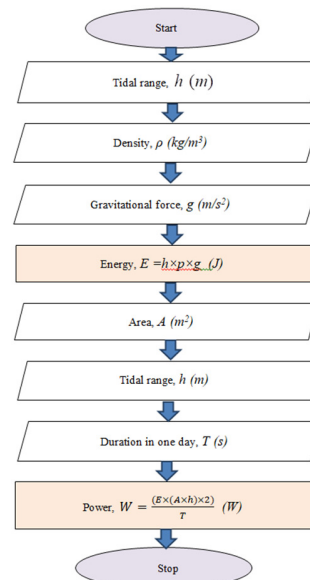


Fig. 3. Flow chart of calculated power output for 34 tidal range sites.

Power can be generated through a barrage. A barrage exists already at Pending, named Kuching Barrage. Therefore, the actual area was used for calculating the power

output of Kuching Barrage, and the estimated area using Google Maps was used for calculating the potential power output of the other 33 sites. In [6, 14], two-way power generation was utilized. However, this research deals with only one-way generation, like the Kuching Barrage, as some sites are also on a river mouth without any prominent basin. Table I depicts the 34 tidal range sites with their coordinates.

TABLE I. RESEARCH SITES

No	Sites	Latitude (N)	Longitude (E)
1	Sematan	01 47	109 47
2	PasarLundo	01 40	109 51
3	Kuala Santubong	01 43	110 19
4	Pending	01 33	110 23
5	MuaraTebas	01 38	110 28
6	PulauLakei	01 45	110 30
7	Sri Aman	01 14	111 27
8	Kuala Rajang	02 09	111 15
9	Tanjung Manis	02 09	111 22
10	Sarikei	02 08	111 37
11	Bintangor	02 10	112 38
12	Lebaan (TanjungEnsurai)	02 19	111 40
13	Sibu	02 17	111 49
14	Kanowit	02 06	112 09
15	Kuala Paloh	02 25	111 15
16	Kuala Igan	02 48	111 43
17	Kuala Mukah	02 54	112 05
18	Kuala Balingian	03 00	112 35
19	Kuala Tatau	03 04	112 48
20	Kuala Kemena	03 10	113 02
21	Bintulu Port	03 16	113 04
22	Miri	02 24	113 59
23	Kuala Baram	04 35	113 59
24	Miri Port	04 34	114 02
25	Kuala Limbang	04 51	115 01
26	Bandar Limbang	04 44	115 00
27	Kuala Lawas	04 57	115 25
28	Bandar Lawas	04 15	115 23
29	Labuan Faderal Territory	05 17	115 15
30	Kota Kinabalu	05 59	116 04
31	Kudat	06 52	116 50
32	Sandakan	05 48	118 04
33	LahadDatu	05 01	118 20
34	Tawau	04 14	117 53

E. Calculation of Areas

The areas of 33 tidal range sites and the river were measured using Google Maps. The width of barrage gates, piers and service structure was assumed by taking the fixed width of each gate of the barrage as 25m, the pier as 4m, and the barrage length as 37m, similarly to the ones already constructed on Kuching Barrage. Measurement techniques are shown in Figure 4 which shows the typical cross-section of the proposed barrage. Given the preliminary width, the number of gates was decided. The width of the ship lock was also defined as 25m. After deciding the effective width, which is the sum of all gates, piers and ship lock, the remaining space was used for service structures or abutments.

F. Potential Sites

The selection of appropriate potential sites should take into account the maximum available energy and an

Environmental Impact Assessment (EIA) study [15]. A thorough EIA study is required on these potential sites, something that is beyond the scope of this study. The potential sites should be free from security (navigational police) and should not obstruct the commercial shipping line.

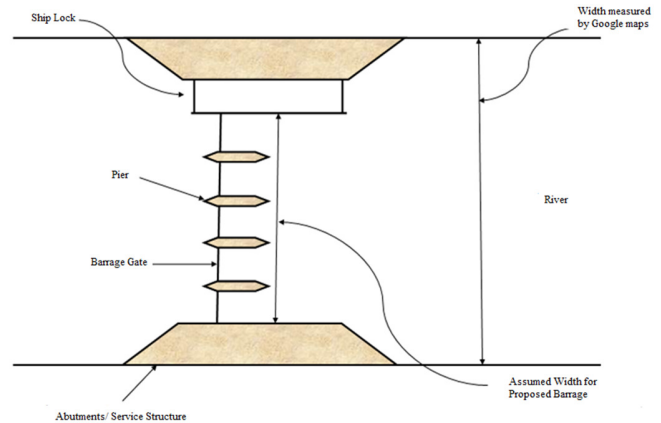


Fig. 4. Measurement techniques calculating proposed barrage's width.

IV. RESULTS AND DISCUSSION

A. Calculated Areas of Tidal Range Sites

The width of a river or stream varies across different locations. So after selecting the best possible width of gates and piers, the remaining width was considered for constructing abutment and service buildings. It was also observed that some locations are not appropriate for constructing a barrage for power generation. The proposed barrages were based on the constructed Kuching Barrage at Pending. Table II shows the calculations for the January power output of the Kuching Barrage. The first three columns show the data variables of (1), column 4 shows the potential energy, power output is shown in column 5 by using (2), and column 6 shows power in kilowatts. Power output was calculated in a daily basis for all tidal range sites. In Table II, A represents the barrage area, and h is the tidal range calculated from high and low tide data [13].

B. Extractable Energy at Tidal Range Sites

The potential extractable energy of the 34 tidal range sites in Sabah and Sarawak coastline was calculated. It was concluded that only 18 of them are appropriate for power generation. Figure 5 shows the potential power output of the 18 main potential sites. The highest potential power was noted in Tanjung Manis in the Sarawak region, measured between 50.7kW and 39.2kW. Results showed that maximum power was observed in January and October, while minimum was observed in June. The second highest power was calculated at Pending, being between 33.1kW and 25.1kW. The maximum power was observed in October, while the minimum was observed in June. The Kuala Kemena in Sarawak region was identified as the least potential site, as its potential power was calculated between 1.9kW to 0.9kW. The maximum potential energy of Kuala Kemena was calculated during July and December, while the

minimum was found in January and September. The greater power values in [6] are explained by the two-way power generation, the areas defined as 200×200m, and the variations in yearly tidal ranges.

TABLE II. CALCULATION OF POWER OUTPUT OF PENDING SITE

h	p	g	E	P	kW
3.6	1025	9.81	36198.9	11161.3275	11.2
3.9	1025	9.81	39215.475	13099.05797	13.1
4.3	1025	9.81	43237.575	15923.83839	15.9
4.7	1025	9.81	47259.675	19024.20714	19.0
4.9	1025	9.81	49270.725	20677.73714	20.7
4.9	1025	9.81	49270.725	20677.73714	20.7
4.9	1025	9.81	49270.725	20677.73714	20.7
4.7	1025	9.81	47259.675	19024.20714	19.0
4.4	1025	9.81	44243.1	16673.09417	16.7
4.1	1025	9.81	41226.525	14476.99964	14.5
3.6	1025	9.81	36198.9	11161.3275	11.2
3.2	1025	9.81	32176.8	8818.826667	8.8
2.7	1025	9.81	27149.175	6278.246719	6.3
2.6	1025	9.81	26143.65	5821.803542	5.8
2.7	1025	9.81	27149.175	6278.246719	6.3
2.6	1025	9.81	26143.65	5821.803542	5.8
3.2	1025	9.81	32176.8	8818.826667	8.8
3.9	1025	9.81	39215.475	13099.05797	13.1
4.7	1025	9.81	47259.675	19024.20714	19.0
5.3	1025	9.81	53292.825	24191.48839	24.2
5.8	1025	9.81	58320.45	28971.22354	29.0
6.0	1025	9.81	60331.5	31003.6875	31.0
6.0	1025	9.81	60331.5	31003.6875	31.0
5.9	1025	9.81	56309.4	27007.65667	27.0
5.0	1025	9.81	50276.25	21530.33854	21.5
4.2	1025	9.81	42232.05	15191.80688	15.2
3.8	1025	9.81	38209.95	12435.92354	12.4
3.4	1025	9.81	34187.85	9955.628542	10.0
3.0	1025	9.81	30165.75	7750.921875	7.8
3.2	1025	9.81	32176.8	8818.826667	8.8
3.5	1025	9.81	35193.375	10549.86589	10.5

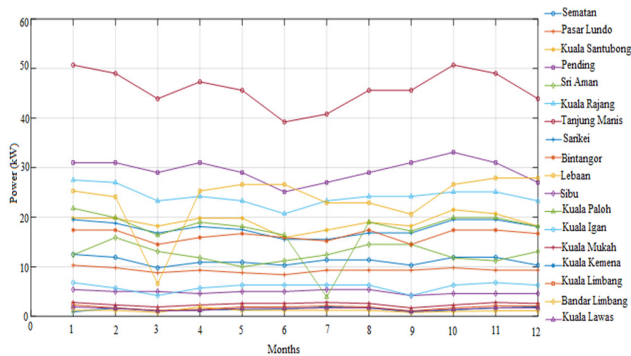


Fig. 5. Potential power of 18 main sites of Sarawak coastline Malaysia.

Figure 6 shows the location of 18 tidal range potential sites in a map generated by Google Maps. The locations of the maximum potential power sites (i.e. Tanjung Manis site and Pending site) are shown in Figure 6 as numbers 4 and 7. Figure 7 shows the maximum and minimum of potential energy for the 18 sites, while Table III shows their mean tidal range and maximum and minimum potential power.

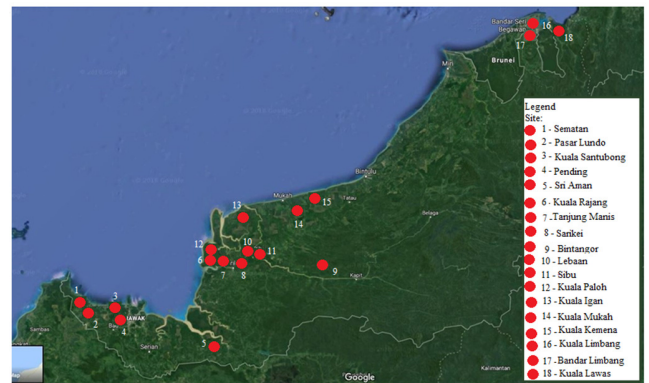


Fig. 6. Position of 18 potential sites, © Google Maps, Terrametrics .

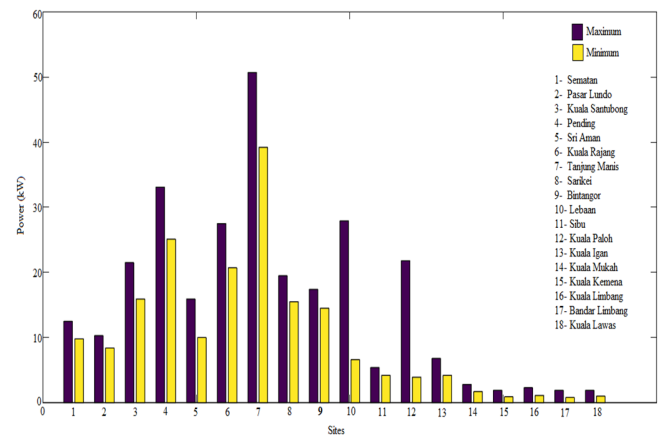


Fig. 7. Max/min potential power in convenient tidal range sites.

TABLE III. TIDAL RANGE MEAN AND MAX/MIN POWER PER SITE

No	Sites	Tidal range mean (m)	Pmax (kW)	Pmin (kW)
1	Sematan	3.0	12.5	9.8
2	PasarLundo	2.9	10.3	8.4
3	Kuala Santubong	3.3	21.5	15.9
4	Pending	4.2	33.1	25.1
5	Sri Aman	2.9	15.9	10.0
6	Kuala Rajang	3.8	27.5	20.7
7	Tanjung Manis	4.0	50.7	39.2
8	Sarikei	3.9	19.5	15.5
9	Bintangor	3.8	17.4	14.5
10	Lebaan (TanjungEnsurai)	3.0	27.9	6.6
11	Sibu	2.0	5.4	4.2
12	Kuala Paloh	3.0	21.8	3.9
13	Kuala Igan	1.6	6.8	4.2
14	Kuala Mukah	1.4	2.8	1.7
15	Kuala Kemena	1.0	1.9	0.9
16	Kuala Limbang	1.4	2.3	1.1
17	Bandar Limbang	1.3	1.9	0.8
18	Kuala Lawas	1.3	1.9	1.0

C. Selection of Suitable Site

A total of 18 tidal range sites seem to be suitable for power generation. As ranges differ in all these tidal range sites, sites with larger tides generate more power compared to sites with lower. These sites were assumed preliminary,

the final sites should be selected after a thorough feasibility study. However, as Kuching Barrage constructed at Pending has a strong potential for power generation, an energy harvester could be installed for extracting energy [16].

V. CONCLUSION

This research studied the potential energy generation in 34 sites in East Malaysia, pinpointing 18 locations as suitable for the construction of a energy generation barrage. However, these sites were assumed as preliminary, as the final sites should be selected after a thorough feasibility study. Two sites were considered as having the highest potential. The maximum calculated power sites are the Tanjung Manis and the Pending site. The highest energy potential was calculated to come from Tanjung Manis and was measured between 50.7kW and 39.2kW, while the second highest power was calculated for Pending, between 33.1kW and 25.1kW. However, there is already an existing barrage at Pending site, and this is the only site where power could be generated by just installing turbines.

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