The Study of Tidal Currents as Renewable Energy in Kelabat Bay, Bangka Belitung

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Abstract. The rapid economic and population growth triggers a high demand for energy in Indonesia. This condition urges us to innovate in renewable energy which sustainable and environmentally friendly. One promising renewable energy is the tidal current energy which very potential in the island regions, such as Bangka Belitung Province. Kelabat Bay, which located in northern part of Bangka Island is a semi-closed waters and has a shallow and narrow gap in its center which separate Teluk Kelabat Luar (TKL) and Teluk Kelabat Dalam (TKD) region, which become the focus region in this research. This geographical condition allows potential energy amplification when the tides occur. Thus, this research aims to assess the potential energy of tidal currents as renewable energy in Kelabat Bay, especially at its narrow gap. The method used in this study was the numerical modelling using MIKE21 software and direct measurement to obtain tides and currents both in toward high tide and low tide condition. The current profile in Kelabat Bay is very influenced by the tidal which flow from TKL to TKD when toward high tide and vice versa toward low tide. The highest speed is measured at 15 meter depth on point 1 with speed up to 1.43 m/s. By this speed, it could be estimated 1494 watt of tidal current energy will be generated. This huge energy potential of tidal current at Kelabat Bay could be exploited to produce electricity in future works.

1. Introduction
The rapid economic and population growth triggers a high demand for energy in Indonesia. The electricity demand continues to rise by 6.4% in 2001, 12.8% in 2002 and is predicted to increase by 9% each year in the next 10 years [1]. Ironically, the main energy source in Indonesia still relies on fossil energy which has lots of negative impacts to the environments. This issue about renewable energy which environmentally friendly has implications for the emergence of studies that lead to optimization of non-conventional energy especially from the sea [2]. The increasing of electricity usage and the limitations of fossil energy which not environmentally friendly make the exploration of renewable energy developing significantly.

In Indonesia itself, the target has set of 23% optimizing of renewable energy [3] through the Presidential Decree No 79. The development of fossil energy power plants will not answer the problem that occurs in Indonesia because it will be exhausted later on [4]. Non-conventional energy from the sea become the optimistic option for renewable energy in Indonesia with almost 8 million square kilometres
of ocean. The studies on renewable energy in Indonesia develop rapidly including Ocean Thermal Energy Conversion (OTEC), wave energy, and ocean current energy [5]. The ocean current itself is a high potential renewable energy source especially in the islands region, such as the Bangka Belitung Islands Province. Bangka Belitung Province is an archipelago with 80% sea region which has lots of potential in the maritime field, such as fisheries, tourism, and also renewable energy from the sea. One of the regions which have high potential of non-conventional energy is in Kelabat Bay.

Kelabat Bay is located on the north coast of Bangka Island and faces directly into the Natuna Sea [6],[7]. Geographically, the Kelabat Bay has two regions which are Teluk Kelabat Dalam (TKD) and Teluk Kelabat Luar (TKL) and separated by narrow and shallow gaps [8]. The current velocity in this narrow gap reaches more than 1.3 m/s dominated by the tidal effects [9]. The huge current speed at this region has the potential as a renewable energy source. Besides being environmentally friendly, the energy of ocean currents is more stable and predictable among other renewable energy resources because it forced by tides. The optimization of renewable energy development in Kelabat Bay is supported by its narrow and shallow strait morphology which creates opportunities for the emergence of ocean currents to be used as energy generation. Thus, this study assess how much potential electrical energy generated by tidal currents in Kelabat Bay.

2. Research Methods
The location of the study was conducted in the waters of the Kelabat Bay, Bangka Regency, Bangka Belitung Islands Province. The focus area for estimate the energy potential of tidal currents is at narrow and shallow gap between TKD and TKL (Figure 1). This research stage is divided into preliminary data collection, field surveys, and analysis data. The field survey was conducted in July 2019 which took some data for research including tides and the current speed. These data are used to assess the potential of tidal currents energy in Kelabat Bay.

Furthermore, this research also use the numerical model to figure the current pattern in Kelabat Bay using MIKE21 developed by DHI which using the Arakawa C grid system and sigma coordinates [10]. The secondary data collection was also carried out as the input data for the numerical modelling which included bathymetry data from General Bathymetric Chart of the Ocean (GEBCO) 30°, tidal data from the Bangka-belitung Ocean Observation Science and Technologies (BOOST) Center and climatology data from the European Center for Medium-Range Weather Forecasts (ECMWF). In modelling, verification is needed to test the level of trust and deviation of the simulation results. Therefore, tidal data on the model will be compared with field survey data.
For understand the potential energy of tidal current in Kelabat Bay, this research measure the speed of the currents at area between TKL dan TKD region which has the highest velocity in Kelabat Bay [8]. 4 layer depth at three sampling point (figure 1) was choose to measure the flow in this area, both on toward high-tide condition and towards low-tide condition. With this method, it will be known which point and depth is the most potential in obtaining tidal current energy in this shallow and narrow gap at Kelabat Bay. For analysis, the current speed then converted to the electrical power through the equation below [11]:

\[ P = \frac{1}{2} \rho AV^3 \]  

where P is the tidal current power, A is the cross section of turbine blade which in this study assume for 1 meter square, \( \rho \) is seawater density (1025 kg / m3), V is the current speed in units of m/s. The results of P will consider as the estimation of tidal current energy potential in this region.

3. Results and Discussions

3.1. Tides

This study using hydrodynamic data from the model which generated by several forcing such as atmospheric forcing and tidal. Tides plays an important role in generating currents, especially in semi-closed waters such as Kelabat Bay [7]. Therefore, tidal measurements are carried out in Kelabat Bay to test the model’s accuracy. A comparison between tidal data from the survey and the model result is presented in Figure 2. Regarding the comparison, the correlation between the two data is 0.9435 with Root Mean Squared Error (RMSE) is 0.1611. The correlation value shows that the field and model data have the same tidal phase while the RMSE value proves the data in the model is good enough to be used in this study. Bangka waters including the Kelabat Bay have diurnal tidal types [6] which has 1 high-tide and 1 low tide in each day (figure 3) and strengthened by its Formzahl 7.223 [9]. The elevation value will be fluctuative due to full/half/none moon condition with tidal range reaches 2.3 meter (Mesomareal type).

![Figure 2. Comparison tides data from measurement and model](image)

3.2. Current

To describe briefly the current pattern at Kelabat Bay, numerical modelling was used especially around the focus region between TKL and TKD. The current profile in Kelabat Bay, which categorizes as semi-closed waters [9] are strongly influenced by its geographical and tidal conditions rather than the monsoon factor. As stated above, Kelabat Bay has diurnal types which generate the currents in and out Kelabat Bay consecutively for each day. Kelabat Bay itself constitutes of two regions known as TKL and TKD separated by narrow and shallow waters (Figure 1) which theoretically this gaps will amplify the currents speed.
If we focus on current profile in the narrow and shallow area between TKL and TKD (Figure 3), the current speeds at this region could reach 1.43 m/s and become the fastest current speed in Kelabat Bay. The current direction will move back and forth from TKL and TKD following the tidal phase. The currents will flow from TKL into TKD toward high tide condition and vice versa towards low tide condition. This pattern is similar to the current profile which occurs in Benoa Bay and Ambon Bay which has similar geographic condition. The current speed tends to be stronger when towards the high tide then towards the low tide both at model’s results and measurement results. The huge current speed at the narrow and shallow area between TKL and TKD is potential for renewable energy source.

![Figure 3. Current profile at Kelabat Bay on toward low tide (top) and toward high tide (bottom) ](image-url)

3.3. *The Estimation of Tidal Current Energy*

The tidal current energy is similar to wind energy which depends on the kinetic energy from the water flow to spin the turbines and generate electricity. The electricity from current turbines will produce greater energy than wind turbines at the same speed [11] due to the high density of water [12]. Therefore, the ocean energy especially tidal current energy could become so promising to the development of renewable energy.

The current speed data from measurement has been converted into the potential power as estimation of tidal current energy using eq (1). The measurement shows that Kelabat Bay has the highest current speed at the 15m depth on point 1 (Table 1) which could reach 1.43 m/s toward the high tide conditions. The bottle-neck geomorphology of Kelabat Bay triggers the amplification of the stream especially near the coastal. Toward high tide condition, the current speed reach 1.43 m/s at 15 meters depth on point 1. By the equation 1, this current speed could be use to estimate tidal current energy by calculate its power density [11]. The 1.43 m/s current speed will generate energy around 1494 watt. The current speed and power estimation tend to be higher toward the high tide than toward the low tide. Furthermore, the tidal current energy will fluctuate depends on the tide conditions and tends to be higher on spring tide [2].
This potential of ocean current energy is expected to be exploited by using marine turbines to produce electricity for the future research.

Table 1. The current energy calculation based on speed, intesify, and the power of the current profile

| Point | Tidal Phase       | Depth (m) | Speed (m/s) | Power (watt) |
|-------|-------------------|-----------|-------------|--------------|
|       | Toward Low Tide   | surface   | 0.37        | 26           |
|       |                   | 5         | 0.42        | 37           |
|       |                   | 10        | 0.56        | 91           |
|       |                   | 15        | 0.88        | 352          |
|       |                   | surface   | 0.77        | 233          |
| 1     | Toward High Tide  | 5         | 1.11        | 703          |
|       |                   | 10        | 1.11        | 703          |
|       |                   | 15        | 1.43        | 1494         |
|       | Toward Low Tide   | surface   | 0.32        | 17           |
|       |                   | 5         | 0.29        | 12           |
|       |                   | 10        | 0.24        | 7            |
|       |                   | 15        | 0.31        | 16           |
|       |                   | surface   | 1.00        | 513          |
| 2     | Toward High Tide  | 5         | 1.11        | 703          |
|       |                   | 10        | 1.00        | 513          |
|       |                   | 15        | 0.91        | 385          |
|       | Toward High Tide  | surface   | 0.40        | 33           |
| 3     |                   | 5         | 0.91        | 385          |
|       |                   | 10        | 1.10        | 687          |
|       |                   | 15        | 1.16        | 792          |

4. Conclusion
This research found that the model which used correlates 0.9435 with 0.1611 Root Mean Squared Error (RMSE) with tidal data measurement. Toward high-tide condition, the current will predominantly flow from TKL to TKD and vice versa toward low-tide condition with the maximum speed around 1.43 m/s. The highest current speed located at 15m depth on point 1 toward high-tide condition. By this speed, it could be estimated around 1494 watt tidal current energy will be generated. Based on the results, Kelabat Bay could become one of the focus region to develop the renewable energy from sea, especially the tidal current energy. The future research is needed to explore more about the monthly potential energy and also generate the electricity by using the prototype of sea turbines which environmental friendly.

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