Potential of tidal power plants on Tibo Beach with spektrum method

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Abstract. As time evolved, the demand for electrical energy also increased. As a result, renewable energy is needed to replace fossil fuels as fuel for electricity generation. Tidal water is one of the renewable alternative energy sources used as fuel for electricity generation. The tides will never run out and can also be predicted. One method that can predict data about waves is the Spectrum Method. Tide prediction data can be indicated by carrying out tidal height observations for 15 days at Tibo Beach, Donggala Regency, Central Sulawesi. Based on observations, the data obtained are the highest high water level (HHWL) is 2.4 meters, and the lowest low water level (LLWL) is 0.1 meters. Also, the type of tides on the Tibo coast is a type of mixed waves that tend to double daily, there are two tides with high water and two tides with low water with different water levels. Because the value of formzahl is 0.312. With a 2.4 meter high HHWL and a sea area of 35.4 km², the electricity generated is 13.08 MW.

1. Introduction
Along with the development of human civilization, the need for energy is also increasing. So far, most of the energy needs come from non-renewable energy, such as coal, which is usually used as fuel for electricity generation.

However, this energy cannot always fulfill all human needs in the long term, given that energy reserves are getting depleted and the production process, which takes millions of years. Therefore, an in-depth study of the use of renewable alternative energy is needed to answer this challenge. Apart from being renewable, alternative energy sources that are environmentally friendly and at low cost are also needed. (Saputra, 2019)

An innovation by utilizing alternative energy sources, which has not been used to overcome electricity problems, is developed through this research. One of the abundant and inexhaustible energy sources is energy in the oceans, including tidal power, which is commonly found in Indonesian waters. (Sangari, 2014)

Tibo is one of the villages in Sindue District, which has relatively large sea waves. This is used as a reference that the beach, according to the author, is feasible in the research of Tidal Power Plants (PLTPS). For the village of Tibo itself, the technology to be developed is a tidal power plant using On Shore technology. This is because On Shore technology is very suitable for building areas that do not require extensive construction. The sea waves in Tibo Village are large enough to make it possible to produce electrical energy.

The purpose of this study was to determine the type of tides at Tibo Beach based on the calculation of the Formzahl number with the Spectrum method, to obtain the design water level elevation of the HHWL and LLWL at Tibo Beach, and to determine the potential generated by the tidal power plant on the coast of Tibo Beach.
Based on the description above, the problem formulation of this research is how the type of tides that occur at Tibo Beach based on the calculation of Formzahl numbers using the Spectrum Method, what is the water level elevation of the HHWL and LLWL plans on Tibo Beach, and whether there is potential for tidal power plants at Tibo Beach.

2. Overview Of The Research Location
The research location is planned to be located in Tibo Village, Sindue District, Donggala Regency, Central Sulawesi Province, approximately 55 km from Palu City, with coordinates 00029′12.59″ S, 119049′1.97″ E

![Research location on the beach of Tibo](Google Earth, 2020)

3. Literature Review
3.1 Tidal
Tides are fluctuations in sea level due to the attraction of objects in the sky, especially the sun and the moon, to seawater masses on earth. The moon's interest, which affects the tides, is 2.2 times greater than that of the sun (Triatmodjo, 2012). This is what causes when one area is experiencing high tide; other regions will experience receding seawater.

3.2 Tidal Curve
Tidal conditions can be displayed visually in the form of tidal curves. The curve describes the sea level at a particular time. The x-axis shows the time, while the y-axis shows the sea level. Tide height is the vertical distance measured from the top of the highest water to the lowest water position. The tidal period is the time it takes from the highest (or lowest) water level to the next highest (or lowest) water level. When the sea level moves up is called the Tide period, while the sea level moves down, it is called the quiet tide period.

According to Nontji (1987), there are four types of ebb and flow based on their period and regularity. Within a month, the daily variation of the tidal range changes systematically with the lunar cycle. The tidal range also depends on the shape of the waters and the configuration of the ocean floor. Here below the tides of seawater in Indonesia are divided into four types, namely: Regular Double Daily Tides (Semi Diurnal Tide), Mixed Semi-Diurnal Tides, Mixed Semi-Diurnal Tides, Mixed Tides Leaning to a Single Daily (Mixed- Diurnal), Regular Single Daily Tides (Diurnal Tide)
Apart from looking at the tide data plotted in the form of a tidal type graph, it can also be determined based on the Formzahl (F) number, which is expressed in the form of the following equation:

\[ F = \frac{AK_1 + AO_1}{AM_2 + AS_2} \]  

Where:

- \(F\) or tidal constant
- \(AK_1\): The amplitude of the single daily mean tidal wave chicks are affected by the declination of the moon and the sun
- \(AO_1\): The amplitude of the mean single daily tidal wave children as affected by the declination of the sun
- \(AM_2\): The amplitude of the sub-daily mean double tidal wave affected by the moon
- \(AS_2\): Amplitude of the mean daily double tidal wave child affected by the sun

The tidal type classification can be seen in Table 1.

| Form Value | Type of Tide | Phenomenon |
|------------|-------------|------------|
| \(F \leq 0.25\) | Semi Diurnal Tides | 2x pairs a day with the same relative height |
| \(0.25 < F \leq 1.5\) | Mixed Mainly Semidiurnal Tides | 2x pairs a day with different heights and different intervals |
| \(1.50 < F \leq 3.0\) | Mixed Mainly Diurnal Tides | 1x or 2x pairs a day at different intervals |
| \(F > 3.0\) | Diurnal Tides | 1x pair a day, when Spring can occur 2x pairs a day |

(Source: Triatmojo, 2010)

### 3.3. Tidal Power Plant

Tidal Power Plants Seawater is a power plant that utilizes tidal energy in seawater to make energy in other forms, especially electricity, where tides can drive turbines to run a generator. Tidal power generation for seawater is renewable energy. There are two types of generator types: Tidal Dam (Barrage Tidal System) and Offshore Turbines (Onshore Turbines). The Sea Water Tidal Power
Generation System is very suitable for Indonesia, especially in Central Sulawesi, because Indonesia is known for its ocean waves.

3.4. The advantages of using PLTPS

1. Once built, tidal energy can be obtained free of charge.
2. Does not produce greenhouse gases or other waste.
3. Does not require fuel
4. Low operating costs.
5. The tides are predictable.
6. Offshore turbines have low installation costs and do not cause a large environmental impact

3.5. The lack of using PLTPS

1. Depends on the characteristics of the Tides.
2. Need a precise location.
3. The tools must be sturdy so they can withstand any weather conditions.
4. A dam that covers a river mouth is very expensive to build, and covers a very large area so that it changes the environmental ecosystem both upstream and downstream for many kilometers.
5. Can only supply energy for approximately 10 hours per day, when the waves move in or out.

3.6. Tidal Power Plant (PLTPS) Type Onshore Turbines

This tidal power plant uses an offshore turbine method, which is more like an underwater version of a wind power plant. The form of a tidal turbine is as varied as the wind turbine. This system does not require a dam but is directly installed in the open seas; the thrust is generated from the movement of the kinetic energy of ocean currents; because the density of water is higher than the wind, the onshore turbine can produce tremendous power with the same size as the wind turbine where the tides can also be utilized so that they can drive turbines and generators.

![Figure 3 Tidal Turbine in the Sea](image)

Where to calculate the amount of energy produced can be calculated using the following equation:

\[ \text{E} = \frac{1}{2} \times A \times \rho \times g \times H^2 \]  

Where:
- \( \text{E} \) = Energy (Joule)
- \( A \) = Sea area (m²)
- \( \rho \) = Sea water density (kg/m³)
- \( g \) = Gravity (m/s²)
- \( H \) = Head (m)
For the sea area (A) which is estimated to be able to push and produce energy movement in the sea area, it is assumed that the surface of the tidal energy generator is 9 km² (Theocsbury, 2020).

3.7. Tidal Harmonic Components
predict tides, the amplitudes and faces of each component of the tidal generator are needed. The main features of waves consist of the daily middle part, daily tides, and long-period tides. However, due to the interaction with the beach morphology and the superposition between the main tidal wave components, new tidal features are formed. These principal components, also called astronomical frequencies, are used to create interactive programming for the decomposition of tidal components. In the tidal analysis using the least-squares method, the amplitude and phase parts of the tidal harmonic equation are calculated based on observational data on the water level position within a certain period, using components with known frequencies. The number of tide components that can be decomposed depends on the length of the data; the longer the observation data, the more tidal details can be produced. For example, the number and pairs of components resulting from observation with a length of 1 month will differ from an observation length of 1 year. The tidal parts can be seen in Table 2 as follows

Table 2. The frequency of 9 ocean waves

| No | Type of Component | Frequency (deg/hr) | Period (hours) |
|----|------------------|------------------|----------------|
| 1  | K1               | 15.04            | 23.94          |
| 2  | O1               | 13.94            | 25.82          |
| 3  | P1               | 14.96            | 24.06          |
| 4  | M2               | 28.98            | 12.42          |
| 5  | S2               | 30               | 12             |
| 6  | K2               | 30.08            | 11.97          |
| 7  | N2               | 28.44            | 12.66          |
| 8  | M4               | 57.97            | 6.21           |
| 9  | MS4              | 58.98            | 6.1            |

Source: (Hidayati, 2017)

3.8. Least Square Method
In this study, the data processing method used the Spectral method. The Spectral Method is a transformation method which is presented as a Fourier Transform (Zakaria, 1998), as follows

\[ P(f_m) = \frac{\Delta t}{2\sqrt{n}} \sum_{n=1}^{n} \frac{2\pi}{m} P(t_n) e^{-2\pi i m n} \]

(3.3)

where:
- P(tn) = Time series
- P(fm) = frequency domain
- tn = time series that shows the amount of data up to n
- fm = Frequency domain.

3.9. Error Rate
Root Mean Square Error (RMSE) or error rate is the average value of the error; it can also express the size of the error generated by a forecast model. A low RMSE value indicates that the variation in the amount generated by a forecast model is close to its observation value variation. The closer to
zero the RMSE value, the more accurate the elevation prediction results are. RMSE is the simulation result error rate.

The error rate calculation aims to determine how much difference the simulation results from data with the measurement data. The analysis of the RMSE value is calculated using the following equation:

\[
\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{n}}
\]

Information:
- \(Y_i\) : initial data (observational data)
- \(\hat{Y}_i\) : final data (predictive data)
- \(N\) : amount of data

3.10. Water Level Elevation

The sea level elevation changes every time, it is necessary to have an elevation determined based on tidal data, which can be used as a guide in planning a port. Some of these elevations are; High Water Level, (HWL), Low Water level (LWL), Mean High Water Level (MHWL), Mean Low Water Level (MLWL), Mean Sea Level (MSL), Highest High Water Level, (HHWL), Lowest Low Water Level (LLWL), Higher high water level, and Lower low water level.

3.11. Bathymetry

A bathymetric map is a map of the sea's depth, which is expressed in several depths or depth contours measured against a vertical datum. Bathymetry (from the Greek meaning "depth" and "measure") is the study of the centers underwater and the three-dimensional analysis of the floor of an ocean or lake. A bathymetric map generally displays base or direct relief with contour lines called depth contours (isobaths) and may have additional information in the form of surface navigation information.

In general, the seabed relief is not very varied compared to land relief. This is due to weak erosion and sedimentation

4. Results And Discussion

4.1. Tidal Data Analysis

The data to be analyzed is tidal data from observations in the field that take place every hour for 15 days, from March 14, 2020, to March 28, 2020.

From the data observation process, table compilers can be made to facilitate tidal data analysis. Then from this table, we can obtain the tide observation graph as follows:

![Figure 4. Tide Observation Chart](attachment://tide_chart.png)

4.2. Results of the Least Method of Tidal Data Analysis

Based on the results of tidal data analysis at Tibo Beach with the spectrum method, the tidal constituent values of 8 harmonic constants are shown in Table 3 below.
Table 3. Result Harmonic Constants Spectrum Method

| Tidal Component | Constant (A) |
|-----------------|--------------|
| M$_2$           | 0.586        |
| S$_2$           | 0.341        |
| K$_2$           | 0.093        |
| K$_1$           | 0.172        |
| O$_1$           | 0.123        |
| P$_1$           | 0.567        |
| M$_4$           | 0.003        |
| MS$_4$          | 0.0007       |

By experimenting with 9 constituents, the results of the Formzahl number, RMSE, water level elevation are as follows:

- Formzahl (F) : 0.312
- RMSE : 0.049
- HHWL : 2.4 m
- MSL : 1.2 m
- LLWL : 0.1 m

The results of calculations using this spectrum method can be obtained by the type or type of tide based on the Formzahl number with a comparison $F = \frac{(AK_1) + (AO_1)}{(AM_2) + (AS_2)}$. Here’s how to calculate it with a comparison of the F value:

$$F = \left[ \frac{(AK_1) + (AO_1)}{(AM_2) + (AS_2)} \right]$$

$$F = \left[ \frac{(0.172) + (0.123)}{(0.586) + (0.341)} \right]$$

$$F = 0.312$$

Requirement:

- $F \leq 0.25$ : Semi Diurnal
- $0.25 < F < 1.50$ : Mixed tide prevailing semi diurnal
- $1.50 < F < 3.00$ : Mixed tide prevailing diurnal
- $F \geq 3.00$ : Diurnal tide

Based on the requirements for the Formzahl number, the F value for the spectrum method is 0.312 ($0.25 < F < 1.50$), so the type or type of tide for the Tibo Beach area, Donggala Regency, Central Sulawesi is mixed tide prevailing semi diurnal. This means that in one day there are two tides and two ebbs with different heights and intervals.

4.3. Calculating the Potential Electrical Energy Generated

To calculate the electric power that can be generated based on the tidal height of Tibo Beach, the description of the calculation of the power / energy that can be generated is as follows, by comparing the energy produced by forecasting sea water waves

Known:

- $\rho = 1025 \text{ kg/m}^3$
- $g = 9.81 \text{ m/s}^2$
- $H_{tide} = \text{HHWL - LWLL} = 2.3 \text{ m}$
- $A = 35.4 \text{ km}^2$ (fetch value)

Amount of $E_{tide} = \frac{1}{2} \times A \times \rho \times g \times h^2 = 94 \times 10^{10} \text{ J}$

From the results of the previous discussion that on Tibo Beach there were 2 tides and 2 receding times a day, then the potential energy generated when the sea water receded was 0. So that the total electrical energy that can be generated in one day can be $188 \times 10^{10} \text{ J}$

$E \text{ per day} = 188 \times 10^{10} \text{ J} / (24 \times 3600)$
It is assumed that the efficiency value of the generator is 60%. So the potential generated by the tidal effect of sea water on Tibo Beach with an estimated sea area can push and produce energy movement in the sea area covering an area of 35.4 km² and a head as high as 2.4 meters namely 13.08 MW.

4.4. Determining the Position of PLTPS

Bathymetry maps can be interpreted as a measure of the sea's depth, both regarding the seafloor elevation's size, which is a source of information and an overview of the seabed, and provides many clues about marine structure (Nurjaya, 1991).

The following is a bathymetric map of the Tibo beach which can be seen in Figure 5

![Bathymetry Map Tibo Beach](image)

The image above is the Contour Map of Tibo Beach. The tool used when measuring is a depth meter; this is a tool to measure the sea's depth, centered from above sea level to below the seabed. The purpose of bathymetry measurement is to determine the seafloor depth's condition, which will then be used as the basis for determining the position of the power plant so that it can be known and also as a reference point for determining the height of MSL, HHWL, and LLWL. In the data collection process, the depth of seawater is measured at an interval of 10 meters from the coast, then the surfer software is used to create the bathymetric map image results.

5. Conclusion

Based on the calculation of Formzahl numbers, the Type of Tides at Tibo Beach is a type of tide. Mixed tide tends to double daily (composite wave prevailing semi-diurnal), where in one day, there are two times Tide a day with different heights and different intervals. Based on the results of data processing using the Spectrum method, the HHWL value is 2.4 meters. And the LLWL value is 0.1 meter.

Tibo Beach is one of the beaches in Central Sulawesi, which can become a place for a Tidal Power Plant. Because based on the results of data processing, the power generated from the calculation of tidal power potential energy at the coast of Tibo is 13.08 MW. Also, Tibo Beach is one of the beaches in Central Sulawesi that has the potential and meets the requirements for constructing a tidal power plant.

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