The potential of tidal power plant with a double-cycle system with a single pond in Merauke

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Abstract. Tide is an important parameter in obtaining the amount of tidal energy based on the value of the highest and lowest tide levels. Nearshore of Merauke, Papua Province, are waters located in the Arafuru Sea which is suspected of having high tidal energy potential. These tides are caused by the influence of the attraction of the moon and sun. Also, local factors that influence are the shape of the beach morphology which is natural and coastal waters such as bays and narrow straits, and the depth of nearshore. The results of HHWL and LLWL calculations for tide data sourced from the Center for Geodesy and Geodynamics Control Network (Gravity and Tidal Control Network Field) for 1 year and obtained the largest letter tide ride occurred in January at 4,072 m. The simulation results with a pond area of 10,000 m2 amounting to 142,436.99 kWh for one year in 2019. So it can be concluded that the known energy use can be used as a reference in future planning development to obtain maximum tidal energy as an alternative energy source. This paper is part of a series of research on a single pond dual cycle system in empowering tidal energy that is being carried out.

1. Introduction

Energy development on a large scale is still referring to the conventional exploitation of natural resources, namely steam power, diesel, and nuclear power, although it is believed that these resources will run out at a certain time in the future. Other renewable energy sources from nature such as tidal power, solar thermal power, geothermal power, wind power, and hydrodynamic magnetic fields are not so developed because up to now the amount of energy produced by these three main sources, the contribution is still very small.

France in 1968 has succeeded in building a power plant that utilizes tidal power from seawater, the energy generated from this power plant is quite large, reaching 240 MW, this power plant is precisely located in Kuala Rance, namely between Saint Maro and Dinard, Brittany, France [1]. Indonesia has great potential for tidal power, considering that Indonesia is an archipelagic country surrounded by oceans, two large oceans that surround Indonesia, namely the Indian Ocean and the Pacific Ocean.

The need for energy that continues to increase causes a decrease in energy which is important in everyday life. So that most of Indonesia use conventional energy. Conventional energy is the energy that cannot be renewed (Unrenewable) and if it is used continuously it will run out like petroleum. The use of conventional energy not only has an impact on the energy shortage crisis but also has an impact on the environmental crisis because it is non-renewable. Tidal energy is an alternative source that can
be developed at this time. This energy can be used as an alternative energy source by utilizing the potential energy stored in each water flow [2].

The potential for tidal energy in Indonesia is greater because tidal energy is renewable and does not cause pollution (pollution-free), it is necessary to develop and utilize tidal energy to support sustainable economic development [3]. With its position at equatorial latitude, this causes tides, winds, waves, and ocean currents to be quite large. Also, the Indonesian archipelago has a coastline of approximately 80,000 km, in several locations, there are quite large differences in the height of the tides and tides, especially waters in the Papua Province area or facing the Arafuru Sea. The energy source in Merauke waters, Papua Province, has untapped potential. The tidal energy potential of Merauke waters itself is quite high. This paper is part of a series of research on a single pond dual cycle system in empowering tidal energy that is being carried out.

2. Tidal data
The tide data used is data issued by the Center for Geodesy and Geodynamics Control Network (Gravity and Tidal Control Network Field) for at least 1 year.

Identification of the potential that has a different tidal height suitable for the construction of a tidal power plant is known, then it can determine the dimensions of the pond to be built. The dimensions of the pool to be built are based on the reference for the minimum pool area that is still feasible to build and the optimum pool area that is feasible to be built to produce electrical energy. After all the required data is known, the calculation process can determine the amount of electrical energy produced for 1 year.

The results from the calculation of tidal harmonic constants obtained a high value of tidal energy potential based on the highest water level (HHWL) and the lowest low water level (LLWL) in meters. So that the potential of tidal energy is obtained by using a single pond system simulation and a double-cycle system. This single pond system is a combination of a single tide and tide cycle system.

3. Tidal energy in dual cycle system
The potential of tidal energy is obtained by using a single pond system simulation and a double-cycle system. This single pond system is a combination of a single tide and tide cycle system [4].

![Figure 1. Single pool system](image_url)

This system is a combination of a single tide and tide cycle system. This system is very advantageous because it can generate electricity at high tide and low tide. When the T1-T2 of the sea is experiencing a low tide, the water gates are opened so that the water in the pool can come out along with the receding seawater, so that it reaches its lowest point. When the sea level and the storage pool are the same, that is when T2 the floodgates are closed so that the pool remains empty. T2-T3 is the waiting time interval so that the water has a minimum height difference (Hmin) which is considered capable of moving the
turbine, after the minimum height difference is reached, at T3 the water begins to be fed into the pond through the turbine so that electricity will be generated during T3-T4. At the time of T4, the floodgates were closed because the water level was unable to turn. T4 - T5 is the waiting time interval so that the water level in the pool becomes the same as the sea which is experiencing receding, when T5 the floodgates are opened to remove water from the pool into the receding sea. Henceforth, the electricity generation in the next cycle will be the same as the previous cycle, see figure 2.

![Diagram of the double-cycle system in a single pond](image)

**Figure 2.** double-cycle system in a single pond

Electrical energy can be generated when filling the pond (during high tide) or emptying the pond (during low tide). In this method, the electrical energy generated depends on the length of time it is used for production. Estimates of calculated electrical energy can be calculated from the size of the function of the area of the pool and the difference in the height of the tide and the resulting discharge, namely the volume of the pool inflow, \( V \) (m³), as shown in equation 1.

\[
V = A \times \Delta h
\]  

(1)

Water discharge is average; \( Q \) (m³/sec) as in equation 2.

\[
Q = \frac{V}{t}
\]  

(2)

The amount of energy that can be produced, \( P \) (kWh), calculated using equation 3.

\[
P = \zeta \times \frac{hp \times y}{75}
\]  

(3)

In a year consisting of 365 days, for the double daily tidal type, there are 705 full tidal cycles then, the energy produced \( E \) per year for the double daily tidal type will be obtained as shown in equation 4.

\[
E_{(1 \text{ tahun})} = 2 \times \frac{\zeta \times hp \times y}{75} \times t \times 705 \times 0.736 \text{ kWh}
\]  

(4)

4. Result

In the method of calculating the estimated potential of electric power, 3 methods are used, in these three methods, the first assumption is that the water flow is steady (steady flow). This contradicts the reality on the ground that the flow of seawater into a pond or pond water to the sea at a certain point, the amount of pressure and velocity always changes with time (unsteady flow). The second assumption is that the calculation of energy availability analyzed is only for tidal production. The third assumption is that the
size of the pond used is 1 hectare (10,000 square meters). The calculation of the estimated electrical energy is carried out with the consideration that for tidal power potential estimates, the value obtained is only to determine the potential energy availability roughly. For deeper purposes, this energy availability data can be used as a reference for mapping the energy quantities contained for the review area. From the three methods, it can be concluded that method 1 is considered as the method that is closest to the actual situation in the field for the estimation of tidal power generation calculations because the method already takes into account the tide or ebb times and the number of tides or ebbs in one year.

The high yield of tidal energy potential obtained for 1 year in 2019 obtained an average of 3.651 meters in Merauke waters. The highest potential tidal energy was obtained in January of 4.072 meters. The high yields of tidal energy potential in 2019 in Merauke waters can be seen in table 1. The potential height of tidal energy can be seen in figure 3. The potential for tidal energy over one year can be seen in table 2. The tidal energy potential in 2019 can be seen in figure 4.

Table 1. High yields of tidal energy potential in 2019 in Merauke waters

| Month    | HHWL (m) | LLWL (m) | Different Height (m) |
|----------|----------|----------|----------------------|
| January  | 1.494    | -2.578   | 4.072                |
| February | 1.376    | -2.333   | 3.709                |
| March    | 1.281    | -1.958   | 3.239                |
| April    | 1.218    | -2.073   | 3.291                |
| May      | 1.24     | -2.215   | 3.455                |
| June     | 1.291    | -2.426   | 3.717                |
| July     | 1.377    | -2.546   | 3.923                |
| August   | 1.419    | -2.505   | 3.924                |
| September| 1.362    | -2.137   | 3.499                |
| October  | 1.343    | -2.225   | 3.568                |
| November | 1.347    | -2.377   | 3.724                |
| December | 1.273    | -2.421   | 3.694                |

Figure 3. Graph of the potential height of tidal energy
Table 2. The potential for tidal energy over one year

| Month   | pool area (m²) | Different Height (m) | V (m³) | Q (m³/sec) | E (kWh)  |
|---------|----------------|----------------------|--------|------------|----------|
| January | 10000          | 4.072                | 40720  | 11.31      | 176374.72|
| February| 10000          | 3.709                | 37090  | 10.30      | 146330.37|
| March   | 10000          | 3.239                | 32390  | 9.00       | 111594.47|
| April   | 10000          | 3.291                | 32910  | 9.14       | 115206.39|
| May     | 10000          | 3.455                | 34550  | 9.60       | 126974.61|
| June    | 10000          | 3.717                | 37170  | 10.33      | 146962.29|
| July    | 10000          | 3.923                | 39230  | 10.90      | 163703.29|
| August  | 10000          | 3.924                | 39240  | 10.90      | 163786.76|
| September| 10000        | 3.499                | 34990  | 9.72       | 130229.29|
| October | 10000          | 3.568                | 35680  | 9.91       | 135416.16|
| November| 10000          | 3.724                | 37240  | 10.34      | 147516.34|
| December| 10000          | 3.694                | 36940  | 10.26      | 145149.18|

Average 142436.99

Graph of Tidal Energy Potential in 2019

Figure 4. Graph of tidal energy potential in 2019

High The potential for tidal energy in Merauke waters is very high based on the maximum and lowest tides the energy obtained from tidal power plants is at high tide and low tide. The high potential of tidal energy based on the results obtained is due to the time of the full moon or new moon which occurs in turns every two weeks, when the position of the moon and sun are in a straight line with the earth so that the highest tide occurs for 15 days, namely on the new moon and moon full. tidal behavior varies depending on the location and time of day on the southern coast of Papua. The potential of tidal energy obtained in Merauke waters based on a simulation of making a tidal pool for one year with a pond area of 10,000 m² obtained an energy conversion for one year of 142436.99 kWh. The greater the area of the pond formed and the length of time obtained in production operations, the greater the potential for energy produced, so that the known energy utilization can be used as a reference in future planning development to obtain maximum tidal energy.

5. Conclusions
Based on the results of this study, it can be concluded that Merauke waters have the potential energy obtained based on simulations with a pond area of 10,000 m² of 142436.99 kWh for one year in 2019.
With the results of HHWL and LLWL calculations for tidal data sourced from the Center for Geodesy and Geodynamics Control Network (Gravity and Tidal Control Network Field) for 1 year and it was obtained that the largest tide of letters occurred in January at 4,072 m.

References
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