Tidal Flow Renewable Energy Potential In The Capalulu Strait

C Kusuma
Sekolah Tinggi Teknologi Angkatan Laut, Surabaya, Indonesia

Abstract. The use of renewable energy that is environmentally friendly and without exhaust emissions will continue to be developed. Such as the utilization of kinetic energy from tidal currents into electrical energy with hydrokinetic turbines. The potential of the tidal current is one of the renewable energy sources given the very large majority of Eastern Indonesia is the ocean and not used optimally. The purpose of writing this paper as a reference counting tidal currents in the islands and strait Indonesia to convert electrical energy this paper calculates the potential of tidal electrical energy in the Capalulu Strait, North Maluku based on tidal stream tables. It is hoped that this paper will serve as an alternative energy source for the development of electrical energy in the province of North Maluku, especially the Sula Islands District (Sulabes, mangoli, and Taliabu) and Taliabu District.

1. Introduction
The eastern part of Indonesia has a very deep sea, but some straits have shallow depths so that it is very potential to be developed as renewable energy by utilizing tidal currents. The availability of electricity will accelerate development in an area. The availability of electricity can use fossil energy (diesel or steam turbines) or renewable energy. One area that needs to be developed is the potential for tidal currents in the Capalulu Strait. The Capalulu Strait is located between 2 districts (Taliabu and Sula Islands) and is located between 3 islands (Taliabu, Mangoli, Sulabes). The availability of electricity in the islands of Sula and Taliabu is not 100%. Even if it is flowing, it is not uncommon for rotating blackouts to occur. The Capalulu Strait is a very strong tidal strait because it is a narrow strait that connects the Pacific Ocean and the Indian Ocean. This strait has the potential to be developed as renewable electricity by utilizing tidal currents.

Currently, on Taliabu Island, only 3 districts have been electrified, namely, Taliabu Barat mines (Holbota, Kawalo, Woyo, Limbo and Lohobubaq), Taliabu Northwest, and Lede District but the conditions have not been so stable due to rotating blackouts [1] [2]. Whereas in 5 Pulau Taliabu Subdistricts namely, North Taliabu, East Taliabu, South Taliabu, Tabona Subdistricts, and South East Taliabu Districts, electricity is not evenly available. [3] [4] [5] The tidal range is the difference in water level at the time maximum tide with minimum low tide, average value ranges from 1-3 m. In several Indonesian seas such as Tanjung Priok(Jakarta), the tidal range is only 1 m, Ambon is about 2 m, Bagan Siapiapi about 4 m, while the highest tide is at the estuary of the Digul River and Muli Strait (southern Papua), which reaches 7-8 m, the strait in the islands of Nusa Tenggara, which reach 2.5 to 3 meters. The straits in East Nusa Tenggara Province are the examples where the flow speed of the marine currents between the islands typically have strong velocities in the range of 2-4 [m/s] or more[6]. The strongest tidal currents recorded in Indonesia are in the Strait Capalulu, between Taliabu Island and Mangole Island, which got the power2up to 5 m[7]. [8]
Tidal currents are currents that are formed due to tidal phenomena. Tides generate ocean currents through the resulting difference in water level, in which case the ocean currents move from a higher water level to a lower one. Based on their direction, tidal currents can be divided into two, namely tidal currents moving towards the land, which occurs during low tide towards the tide and tidal currents that move away from the land, which occurs when the tide goes towards low tide. However, in this paper, the two sides are considered to be the same because it is assumed to use a tidal turbine so that they can adjust to the current characteristics. Tidal current energy has advantages over other types of renewable energy, which is easy to predict. So that it can simplify maintenance, because it can be known with certainty how much electrical power it can generate from time to time. This is very important to know because it is used to find out how much replacement energy must be added to maintain grid stability. The amount of potential electric power generated by ocean currents is stated in 4 categories, namely theoretical, technical, practical, and accessible potential. The theoretical potential is a rough estimate of the energy sources of ocean currents in a particular location. The technical potential is an estimate that already involves the efficiency of the tools to be used. The practical potential is an estimate that already involves technical matters that will be faced, such as wave and seabed conditions at the location. The accessible potential is an estimate that already involves accessibility to the location where the ocean current power generation system will be built, such as shipping lanes, etc. in this paper will only discuss the theoretical tidal current potential.

The theoretical potential energy of tidal currents in the Capalulu Strait can be determined by calculating the velocity using the list of tidal currents in the Capalulu Strait issued by the Navy Hydrographic and Oceanographic Service of the Indonesian Navy[9].

2. Theoretical Potential Of Tidal Current
2.1. Potential Tidal in the Capalulu Strait
The Capalulu Strait can be divided into 2 areas, namely on the edge of a depth of 10-20 meters as shown in Figure 2, which has the potential for tidal flow turbines. The center of the strait has a channel depth of 50-77 as a shipping route. The width of the narrow strait connecting the Pacific Ocean and the Indian Ocean in the south makes the tidal currents in the Capalulu Strait very high and even throughout the year. The width of the Capalulu allows the construction of tidal turbines without disturbing shipping.
2.2. Marine Turbine Flow

The estimated global potential for tidal energy is around 500 GW, as shown in Figure 1h. The estimated global potential for tidal energy is around 500 GW, as shown in Figure 3.

According to Fraenkel [13], the waters in Indonesia have the potential to be developed as a
tidal flow turbine. There are several options for installing turbines in the Capalulu Strait as shown in Figure 4.

![Possible system configuration Installation of turbines on the seabed](image)

**Figure 4.** Possible system configuration Installation of turbines on the seabed[12].

In this paper, it is assumed to use a tidal turbine with 3 blades with the assumption that the blade radius is 1 m and the surface area of the blade is 1 m². The electrical system is installed in the turbine as shown in Figure 5.

![Small turbines tidal with electricity system](image)

**Figure 5.** Small turbines tidal with electricity system[14].

### 3. Methodology

Assuming the fluid velocity is a discontinuity in the vertical section of the turbine, the average mass of the turbine flow velocity can be estimated:[11]

\[ A = \rho \cdot A_r \frac{(V_1 + V_0)}{2} \]  

(1)

The results of the substance of equation (1) above for the maximum power that can be extracted from the fluid concerning the velocity of the upstream fluid only is like equation (2) [11]

\[ P = C_p \cdot 0.5 \cdot \rho \cdot A_r \cdot V^3 \text{ (Watt)} \]  

(2)

Where:

- \( P \) = power (watts)
- \( \rho \) = density of seawater (1025 kg / m³)
- \( A \) = cross-sectional area (m²)
- \( V \) = flow velocity (m / s)

\( C_p \) is the power coefficient which depends on the velocity of the fluid downstream to the upstream which has a theoretical maximum value of 16/27 or 0.59 based on the Bentz limit.
4. Result and Discussion
From the tidal stream tables obtained from the Indonesian Navy Hydrographic and Oceanographic Service of the Navy, 2015, [9] the literature shows the potential value of electric current energy in the Capalulu Strait in January 2015 in Figure 6.

Figure 6. The potential flow of Electrical tidal currents January 2015.

The potential value of electric current energy in the Capalulu Strait in February 2015 in Figure 7.

Figure 7. The potential flow of Electrical tidal currents February 2015.

The potential value of electric current energy in the Capalulu Strait in March 2015 in Figure 8.

Figure 8. Potential Data of Electrical tidal currents March 2015.
The potential value of electric current energy in the Capalulu Strait in April 2015 in Figure 9.

Figure 9. Potential Data of Electrical tidal currents April 2015.

The potential value of electric current energy in the Capalulu Strait in May 2015 in Figure 10.

Figure 10. Potential Data of Electrical tidal currents May 2015.

The potential value of electric current energy in the Capalulu Strait in June 2015 in Figure 11.

Figure 11. Potential Data of Electrical tidal currents June 2015.
The potential value of electric current energy in the Capalulu Strait in July 2015 in Figure 12.

Figure 12. Potential Data of Electrical tidal currents July 2015.

The potential value of electric current energy in the Capalulu Strait in August 2015 in Figure 13.

Figure 13. Potential Data of Electrical tidal currents August 2015.

The potential value of electric current energy in the Capalulu Strait in September 2015 in Figure 14.

Figure 14. Potential Data of Electrical tidal currents September 2015.
The potential value of electric current energy in the Capalulu Strait in Oktober 2015 in Figure 15.

![Figure 15. Potential Data of Electrical tidal currents Oktober 2015.](image1)

The potential value of electric current energy in the Capalulu Strait in November 2015 in Figure 16.

![Figure 16. Potential Data of Electrical tidal currents November 2015.](image2)

The potential value of electric current energy in the Capalulu Strait in December 2015 in Figure 17.

![Figure 17. Potential Data of Electrical tidal currents December 2015.](image3)
Based on the literature studies that have been obtained, some of the potential of ocean current energy in the Strait of Capalulu can be displayed in the form of a table of average current velocity per month and electricity potential in 2015, between January to December in Table 1 and figure 18.

### Table 1. Potential Data of Electrical tidal currents 2015.

| Month    | Mean Velocity Tidal Power |
|----------|---------------------------|
|          | (Knot)                    | (Watt)                   |
| January  | 3.283                     | 5534.8                   |
| February | 3.361                     | 6563.3                   |
| March    | 3.241                     | 5323.4                   |
| April    | 3.278                     | 5506.8                   |
| May      | 3.298                     | 5611.9                   |
| June     | 3.343                     | 5840.9                   |
| July     | 3.338                     | 5813.9                   |
| August   | 3.386                     | 6067.6                   |
| September| 3.352                     | 5889.1                   |
| October  | 3.336                     | 5804.1                   |
| November | 3.299                     | 5611.8                   |
| December | 3.341                     | 5829.4                   |
| Mean     | 3.321                     | 5783.1                   |

**Figure 18. Potential Data of Electrical tidal currents 2015.**

Based on the table and graphic images above, the average electrical tidal current velocity in the Capalulu Strait is 3.3 knot or 6.1 m / s with an average potential of 5783 Watt / Hour. The maximum current occurs in February with an average current speed of 3.36 Knot and an electric potential of 6563 Watt / Hour, while the weakest current is in March with an average speed of 3.24 miles/hour and an electric potential of 5323 Watt/hour. From the data and calculations also obtained the potential for evenly distributed flow throughout the year so it is very potential to be developed.
5. Conclusion

Based on the results of the analysis of the discussion above it can be Conclusion:

a. By using 1 tidal turbine with 3 blades, assuming the blades' radius is 1 m and the surface area of all blades is 1m², an average electric current will be 5783 Watt / Hour. The maximum electric current is obtained in February with an electric potential of 6563 watts, while the weakest electricity potential is in March with an electric potential of 5323 watts.

b. From the data and calculations also obtained the potential for evenly distributed flow throughout the year so it is very potential to be developed.

6. References

1. http://beritamalut.co/2020/08/02/pengusaha-ayam-potong-di-bobong-merugi-karena-listrik-sering-padam/
2. Lentera malut, minggu oktober 18, 2020, https://www.malut.lentera.co.id/2020/09/16/krisis-listrik- pemuda-desa-bobong-minta-pln-maluku-malut-datangkan-mesin-baru-ke-taliabu/
3. Fokus Malut, Minggu, 04 Oktober 2020, https://metro7.co.id/5-kecamatan-di-taliabu-belum-merdeka-listik/.
4. Koran metro, 07 October 2020, 10.55 WIB https://metro7.co.id/5-kecamatan-di-taliabu-belum-merdeka-listik/
5. https://www.skrinews1.com/2020/10/skrinews1-5-kecamatan-di-taliabu-belum.html
6. Erwandi, 2011, “The Development Of Indonesian Vertical Axis Marine Current Turbine For The Tidal Power Generation”, Indonesia Marine
7. ITB Indonesian Journal of Geospatial Vol. 05, No. 1, 2016, 27-39, Mapping of Sea Current Power Potential in The Strait of Capalulu, The Sula Archipelago, North Maluku
8. Rokhmin Dahuri, 2004 “Pengelolaan Sumber Daya Wilayah Pesisir dan Lautan Secara Terpadu”, Pradnya Paramitha, Jakarta
9. Indonesian Navy Hydrographic and Oceanographic Service of the Navy, 2015, List of Tidal Stream Tidal Streams in 2015, Jakarta
10. Indonesian Navy Hydrographic and Oceanographic Service of the Navy, 1993, Map of Indonesia no 10 1993, Jakarta
11. Sandor Bernhard, et.al, (2008), "Flow Investigating in Archard Turbine". The Publishing House of Romanian Academy. Proceeding of Romanian Academy Series A, Volume 9, Number 2/2008, pp 000-000
12. Faisal Wani, Jianning Dong, and Henk Polin, "Tidal Turbine Generators" Submitted: April 23rd 2019Reviewed: November 10th 2019Published: April 1st, 2020, DOI: 10.5772/intechopen.90433
13. P L Fraenkel Marine Current Turbines Limited, 2 Amherst Avenue, Ealing, London W13 8nq, Uk
14. Gregory S. Payne, Tim Stallard b, Rodrigo Martinez, www.elsevier.com/locate/renene, renewable energy 107(2017)312-326 “Design and manufacture of a bed supported tidal turbine model for blade and shaft load measurement in turbulent flow and waves”
Acknowledgments

Authors who want to thank the help or encouragement of colleagues, especially the Sekolah Tinggi Teknologi Angkatan Laut (STTAL). Acknowledgments that are not numbered immediately after the last numbered section of this paper.