Identification of Ocean Currents Potential Energy in Lombok Strait Based on Electric Turbine Scenarios

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Abstract: Lombok Strait is traversed by the Indonesian Through-Flow (ITF). ITF is a huge volume of seawater mass originated from the Pacific Ocean flowing into the Indian Ocean. An oceanographic mooring is deployed during 2004-2007 to study the ITF. One of the outcome, ocean current data is used for an advance experiment to derive a renewable energy potential. A Matlab Toolbox, called T-Tide, is employed to filtering harmonic and non-harmonic ocean currents. It reveals that Lombok Strait has an optimum velocity of 2.0335 m/s at 45 m depth for hydropower. Energy conversion using Frangenk's formula, of its current velocity that using turbine Gorlov's scenario (35% efficiency) can produce a biggest energy (1589,666 kWh). By using scenario of Darrieus turbine (23.5% efficiency) can produce 3,741.99 kWh. Another turbine scenario of In-plane Axis (20% efficiency) can produce 3,184.672 kWh.

Keyword: ocean currents, potential energy, Lombok strait, electric turbine scenarios, t-tide.

1. Introduction

Electrical Energy is one of the main necessary and it’s play an important part in the human life. Until 2006, electrification ratio in Indonesia recently reached 56%, it means that more than 100 million people in Indonesia still not gained and relished the electricity [1]. Geographical conditions of the Indonesian are consist of a thousands islands. Uneven of the deployment electricity center, electricity demand in some areas, costs marginal system development energy supply electricity, and the limited financial capabilities, are the factor problems in providing energy at national scale. One of the solution to solve the problem by using the renewable energy, such as: solar, wind, water, biomass, etc [2].

Indonesia seas can be used as an alternative energy sources for the electrical energy replacement. Electrical energy Development was derived from the potential elevation tides, the difference temperatures, ocean current, waves, and wind at the coastal. Indonesian seas have strong ocean currents that potential to be fully utilized to generate electric energy. Indonesia’s ocean currents and waves are very potential to be developed. This potential spread in various regions [3]. Indonesia Throughflow (ITF) became one characteristic of the current system in Indonesia. ITF is a system of ocean circulation in Indonesia that brings water masses from the Pacific Ocean to the Indian Ocean. Pacific water mass consists of water masses of the North Pacific and the South Pacific. The ITF mainly due to the difference in sea level between the Pacific Ocean and the Indian Ocean, namely the inner surface of the tropical Pacific Ocean West is higher than in the Indian Ocean at the east, resulting in a pressure gradient resulting flow of current from the Pacific Ocean to the Indian Ocean [4]. Study area was chosen based on one of the mooring deployment in ITF pathways. The aim of this study was to calculate the amount of electricity generated potential energy of ocean currents in one stream turbine using Cross Flow Turbine (Gorlov and Darrieus) and Axial Flow (In-plane Axis).

INSTANT Expedition data (2004-2006) has been used too by Ihsan et.al. (2015) [5] to calculate the amount of electrical energy from ITF current. This study used data from the same project (INSTANT) but only focus on the Lombok Strait East mooring. The potential energy for electrical energy is calculated more detail and using the available turbine on market. Three turbines has been used in this study each have an area (A) and efficiency (η) different will be produce varies energy.

2. Material and Method

2.1 Data

The data that used in this study was from INSTANT Expedition (International Nusantara Stratification and Transport) in 2004-2007, from the Marine and Coastal Data Laboratory, Research & Development Center for Marine & Coastal Resources (P3SDL). INSTANT Expedition is an international cooperation program between five countries: United States of America, Australia, Netherlands, France, and Indonesia. International Program is studying ocean current, temperature, and salinity ITF (Indonesia Throughflow) by deploy the oceanography instruments (mooring) in the location of ITF outflow and inflow at Lombok Strait, Ombai Strait, Timor Passage, Makasar Strait, and Lifamatola Passage. This program was started in 2003 and has two times sailing scientific (Scientific Cruise) the Deployment Cruise (2003-2004) and Rotation Cruise (2005) [6].
Table 1: Ocean current data on INSTANT expedition in Lombok Strait

| No. | Data                  | Type         | Year       | Source               |
|-----|-----------------------|--------------|------------|----------------------|
| 1.  | INSTANT Expedition   | Current data |            | Marine and Coastal   |
|     |海洋研究人员            |              |            | Data Laboratory      |
| 2.  | Deployment 1          | Mat.         | 2004-2005  |                      |
| 3.  | Deployment 2          | Mat.         | 2005-2007  |                      |

LOMBOK EAST MOORING SITE LOCATION

Figure 1: Site Map of East Mooring, Lombok Strait

Turbine data obtained from a research of BalaiBesarPengembanganTeknologiTepatGuna – Indonesian Institute of Science. That will be conducting design water turbine type L C500, to develop water flow turbine, using streams and rivers or irrigation canals. Water turbine serves to change the water flow energy into mechanical energy into shaft rotation. Mechanical energy is then converted into electrical energy using a generator. Flat flow water turbine design refers to the helical turbine that has been developed utilizing the Gorlov turbine tidal currents as an energy source driving the turbine runner. Turbine Gorlov that has been developed using the profile blade in the form of a hydrofoil symmetrical NACA 0015 that works based on the style of the elevator, the turbine proficiency level consists of the main components namely the blade profile NACA 0020, with a chord length of 500 mm, height 1250 mm, and the diameter of 1000mm with the angle of twist of 63 ° and is made of fiberglass blade 3 pieces [7].

2.2 Turbine Efficiency

One of the aims of this research is to analyze catch massive energy in turbine that is any guide, namely on turbine in the plane axis, Darrieus turbine, Gorlov Helical. From these three kinds of turbine has a massive energy efficiency catch, different and that affects nor energy produced by in each use turbine. A massive turbine efficiency was influenced by model prefabricated turbine itself. The efficiency turbine shown in Table 2.

Table 2: The efficiency turbine

| No. | Turbine            | Efficiency | Types of turbine |
|-----|--------------------|------------|------------------|
| 1.  | Gorlov Helical Strands | 35%        | CFWT             |
| 2.  | Darrieus           | 23.5%      |                  |
| 3.  | In the plane axis  | 20%        | AFWT             |

Source: Alexander N. Gorban et al, 2001[8]

The efficiency value are shown in Table 2 generally lower than that used by Ihsan et.al (2015), but values as shown above is more real and is the result or physical models are available in the market.

Axial Flow Water turbine (AFWT) is a turbine that spins in parallel to the ocean current and need control or a profitable to rotor to follow the ocean current, in an effort to improve it’s power conversion was arrested by turbine. Conversely if AFWT will turn perpendicular to have the ocean current, but in different with Cross Flow Water turbine (CFWT). CFWT is turbine that spin with movements from various directions, so that it does not require a profitable higher compared with AFWT. This type of turbine has several benefits, but more complicated in design and the prediction of the movement hydrodinamics. A massive catches ocean current in Darrieus turbine of 0.88125 m² of overall cross section of 3.75 m², with the efficiency of 23.5 %, Gorlov turbine of 1.3125 m² of overall cross section of 3.75 m², with the efficiency of 35 %, and turbine In -plane axis (axis) of horizontal 0.75 m², from broad cross section as a whole was 3.75 m², with the efficiency of more than 20 percent.

Figure 2. is illustration of models and the massive energy efficiency catches in each turbine, is AFWT and CFWT.

2.3 Conversion of Ocean Current to Electricity

Development of technology extraction energy ocean currents are usually adopting from the principle technology wind energy that has been developing countries, namely kinetic energy to change the ocean currents to energy rotation and electrical energy. The power that was produced by the ocean currents turbine is bigger than wind turbine, because the density of sea water is more dense than air masses. Capacity that can be counted on approach produced a mathematical formulate a passing through a surface or widespread, then the formula general is formulation Fraenkel [9] are:

\[
P = 0.5 \rho A \eta V^3
\]

\[P = \text{power (Kwatt)};
\]

\[\rho = \text{water mass (1025 kg/m}^3\);
\]

\[A = \text{area (m}^2\); Vary depending on the turbine that is used.
\]

\[\eta = \text{turbine efficiency (}) \text{Vary depending on the turbine that is used.}
\]

\[V = \text{current speed (m/s)}.
\]

Formulation above occurring in kinetic energy to the process of conversion electricity power generating systems at sea water.
3. Results and Discussion

3.1 Ocean Current Characteristics in Lombok Strait

INSTANT Data in Lombok Strait consists of 2 deployment mooring (see Table 1). Each deployment depth produces a different ocean current measurements. There are three measurements of ocean current velocity, which are the maximum, minimum, and it's range value.

The ocean current velocity in mooring deployment 1 is between 0 m/s to 1.6495 m/s, for the specific value in each depth can seen in Table 3.

| Depth (m) | Max (m/s) | Min (m/s) | Range (m/s) |
|----------|-----------|-----------|-------------|
| 100      | 1.068     | 0.0000624 | 1.067376    |
| 260      | 1.6495    | 0.003     | 1.6465      |
| 272      | 1.6085    | 0.002828  | 1.605672    |
| 284      | 1.7142    | 0.001414  | 1.712786    |
| 296      | 1.6303    | 0.003     | 1.6273      |
| 308      | 1.5391    | 0.001     | 1.5381      |
| 320      | 1.4173    | 0.002     | 1.4153      |
| 332      | 1.1185    | 0.001     | 1.1175      |
| 344      | 0.95754   | 0.00283   | 0.95471     |
| 350      | 0.4609    | 0        | 0.4609      |
| 356      | 0.9142    | 0.002     | 0.9122      |
| 368      | 0.8403    | 0.001     | 0.8393      |
| 380      | 0.796     | 0.002236  | 0.793764    |
| 392      | 0.7707    | 0.002829  | 0.767872    |
| 404      | 0.7558    | 0.001     | 0.7548      |
| 416      | 0.6932    | 0.002     | 0.6912      |
| 428      | 1.3142    | 0.002     | 1.3122      |
| 440      | 0.9293    | 0.001414  | 0.927886    |
| 450      | 0.5021    | 0.011     | 0.4911      |
| 452      | 0.6571    | 0.001     | 0.6561      |
| 464      | 0.5869    | 0.001     | 0.5859      |
| 476      | 0.6597    | 0.002236  | 0.637464    |
| 488      | 0.6236    | 0        | 0.6236      |

Table 4 shows that ocean current velocity in mooring deployment 2 has a vary values in each depth. It is has a same result with the mooring deployment 1 (Table 3), that the current velocity mostly decrease within the increasing of the depth. The maximum current velocity in depth of 45 m was 2.0235 m/s and in 433 m was 0.5405 m/s.

In a study that carried out by Ihsan et.al (2015) only data on deployment 2, and at this point measurement tools depth that makes data in publication was less than office although presented as a whole mooring station in the expedition INSTANT. This matter was influential in the speed findings suggest that, in comparison to speed ocean current maximum on or before around 0.162 m/s to 0.618 m/s, by using methods that period but with a data that is different from that in this research displaying data that more of it, which is in the depth of 45m with a high speed between 0.005 m/s to 2.0285 m/s. The difference is quite significant.

3.2 Estimation of Electrical Energy

Energy Conversion of the movement of ocean current to power that was produced by turbine. For converting the energy was used by the Fraenkel formation that had an objective as an approach from development of technology in changinthe kinetic energy ocean currents into thepower plant [9]. Turbine that is used as a model in this research on turbine Gorlo v, turbine Darrieus turbine, and in-plane axis. The result of energy conversion from theocean current measurements shown in Table 5, with the unit kilowatt hour.

Based on the result conversion energy ocean current thatusedFraenkel formula, using several scenarios that turbine turbine Gorlo v, turbine Darrieus, and in-plane axis turbine as a reference for the result as shown above turbine power that could get in. With the acquisition is greatest power in the depth of 45 m with great power of 1589.666 kWh.

With great power that was obtained from the result of the research plan target compared to General National Energy that is taken from the sea of 6,000 MW, then the ratio between these research results to the target energy that, at the end of 2050 to 0.00014 percent.
4. Conclusions

A massive catches ocean current in Darrieus turbine of 0.88125 m\(^2\) of overall cross section of 3.75 m\(^2\) blades, with the efficiency of 23.5\%, Gorlov turbine of 1.3125 m\(^2\) of overall cross section of 3.75 m\(^2\) blades, with the efficiency of 35\%, turbine In the plane axis of 0.75 m\(^2\), from broad cross section as a whole was 3.75 m\(^2\) blades, with the efficiency of more than 20\%.

Energy conversion of ocean currents in Lombok Strait that using scenario turbine Gorlov's has a biggest energy in the depth of 45 meters with the energy 1589,666 kWh. While for scenario Darrieus turbine produce energy of 3,741.99. And the energy that produced by turbine in the plane axis of 3,184.672 kWh in the same depth of 45 m. It is more effective and typical efficiency than the previous scenario, which is in the depth of 104m.

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