The Potential of Conversion of Sea Wave Energy to Electric Energy: The Performance of Central Sulawesi West Sea using Oscillating Water Column Technology

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Abstract. With seas area of 70% larger than land, Indonesia encourages the potential for marine energy as an alternative to renewable energy. One of the technologies developed to utilize ocean energy is the Oscillating Water Column (OWC). The OWC method can convert ocean wave energy by using an oscillation column directing wave energy through the OWC door opening to generate electricity. This study aims to determine the magnitude of the waves utilized in West Central Sulawesi's seas region include Alindau beach, Marana beach, and Kaliburu beach. Based on wave forecasting using wind data for five years, the maximum wave height for five years is 0.20 m. Estimated power from the calculation results obtained a rate significant with an efficiency level of 11.97%. Alindau is a potential location to develop wave energy.

1. Introduction

Along with the development of civilization humans, the level of human energy needs to more increasing. The fulfilment of this energy in part most of it comes from burning fossil fuels millions of years old and non-renewable, and only a tiny amount comes from using other more renewable energy sources. Look at the topography of the island of Sulawesi, the enormous potential of the sea ocean wave, which is very suitable to be built in Sulawesi. This ocean wave power is environmentally friendly and under construction and operation is not will damage the natural ecosystem. Many types of technology are currently developed in ocean wave power plants, including type buoy technology, overtopping devices, and oscillating water technology columns. For West Central Sulawesi's seas region, the right technology created is a power plant ocean waves with oscillating water technology column (POW-OWC). Oscillating water column (OWC) technology is very suitable for building areas with seabed topography that is sloping and has the constant height of the sea waves. It does not require an extensive construction area. The locations in West Central Sulawesi's seas region are Alindau, Kaliburu, and Marana. This location belongs to the Donggala waters, bordered by the shoreline of Alindau village, Central Sulawesi, shown in Figure 1.

That is the potential to build a power plant ocean waves with oscillating water technology. This column is in the sea in the area Donggala directly facing the open sea so that the wave height of the sea is relatively constant [1-3]. In OWC technology, air from a watertight chamber is used to move the turbine wheel, which will later drive this turbine used to generate electrical energy.
Figure 1. Research location

This waterproof room is fixed with the structure bottom open to the sea. Air pressure in the chamber and caused by the up-and-down movement from the surface of the ocean waves. Movement the waves in this room are movement compresses and decompresses movement above the room's water level. This movement results in the generation of an alternating high speed streaming from the air. Airflow is pushed through a pipe to a generator turbine which is used to generate electricity. OWC System can be placed permanently on the beach or placed in the middle of the sea. Due to winds, volcanic eruptions, ocean floor erosion, or ship traffic, ocean waves have dimensions: wave period, wavelength, wave height, and velocity [4].

2. Methods
2.1 Ocean waves
Ocean waves have potential and kinetic energy that Kim Neilsen Equation can calculate. By using the equation, it can be obtained how much power is contained in the wave. It is calculated from the wave period calculation as shown in equation 1.

\[ T = 3.55x\sqrt{h} \]  

(1)

The value of \( h \) refers to the wave height (meters). The ocean wave utilization system can use air pressure from a water-tight room to drive the turbine, which later the turbine movement is used to produce electrical energy [5]. This water-tight column is installed fixed with the bottom structure open to the sea. The wave motion is the movement of compressed and decompresses above the room's water level. This movement resulted in a high-speed airflow reserve. This airflow is pushed through a pipe to a turbine generator that is used to generate electricity. This system can be permanently placed on the beach or placed in the middle of the sea. In systems placed in the middle of the ocean, the electricity generated is conducted to the transmission on land using a sea cable [6].

The wave height and period generated are affected by the wind tension \( UA \), the length of the wind blow \( D \) and the fetch \( F \), the size of the sea surface when the wind blows. The wind tension factor influences the wind speed—the equation for calculating the wind tension factor expressed in equation (2).

\[ UA = 0.71 \times U^{1.23} \]  

(2)

with:
UA = Wind tension (m/s)
U = Wind speed (m/s)
To find out the direction and speed of the wind, mainly calculating wind tension [6]. The wave formation length that is assumed to have a relatively constant speed and wind direction to the mainland is called fetch. The fetch length is the range of the sea bounded by islands at both ends [6]. Based on wind speed, wind, and fetch blast, as discussed before, wave forecasting is found out using the Wilson Method [7].

2.2 Wave period
The period is the interval of time needed to take one wave. It can be calculated using the formulation suggested by Kim Nielsen [7] as written in equation (1). This study uses wind data plotted from the Wind Rose Plot application (WRPplot). WRPplot is software that can calculate frequency, percentage, and display diagrams classification of large amounts of wind direction and speed data [8]. The WRPplot results calculate wavelength and wave velocity using the David Ross equation according to equation (3). The wave speed is calculated by the wavelength ($\lambda$) ratio to the period (T).

\[ \lambda = 5.12 T^2 \]  

2.3 Wave energy calculation using oscillating water column (OWC)
The flow diagram in figure 2 describes the overall calculation of the potential for electrical energy generated from wave energy.

**Figure 2.** Flowchart of research

Analyzed the calculation of ocean wave energy, several things must first be known, such as the potential for ocean wave energy, wind specific gravity 1200 Kg/m$^3$, and earth's gravity acceleration 9.81 m/s$^2$. To calculate ocean wave energy with the design of ocean wave power plants oscillating water column type, use Equation (4).

\[ E = (P_2 - P_0)v_2A_2 \]  

with:
- \( E \) = OWC power (Watt)
- \( P_0 \) = Air pressure Outside the system (Pa)
- \( A_2 \) = Air speed in orifice Column (m/s)
- \( P_2 \) = Orifice air pressure (Pa) by \( P_2 = P_0 + \rho \left( \frac{A_1}{A_2} \right) \frac{d\Phi}{dt} + \rho \frac{A_2}{A_2} (v_2 - v_1) \) 
  with \( v_1 = v_1A_1 \)
\[ Q_2 = v_2 A_2 \]

\[ v_2 = \text{Column area OWC (m}^2\text{)} \times \frac{A_1 \omega}{A_2} \frac{H}{2} \sin(\omega t) \]  

(6)

To calculate the power turn out of OWC using the Bernitas formula, shown in equation (4). To find out the power of the previous generator, must be calculated the power generated by the wave using the formula in equation (7) as follows.

\[ P_w = 0,195 \rho g h^2 T \]  

(7)

which, \( P_g \) is power of generator (Watt) and \( P_w \) is the energy produced by the waves (Watt). After obtaining the wave power and output power of the OWC, the OWC Efficiency can be calculated. It results by compare the wave power entering an d leaving the column of the OWC, shown in equation (8)

\[ \eta_{OWC} = \frac{E}{P_w} \times 100\% \]  

(8)

3. Result and discussion
This study is located on the west coast of Alindau Beach, Marana Beach, and Kaliburu Beach. Wind data used is five years from 2012 – 2016. Mapped the wind data to determine the potential wind direction using WRPlot. The results of the mapping of the three locations are shown in Figure 3.

Figure 3. Mapping of wind tension UA

It was obtained from the Mutiara station, represented in the BMKG website, and processed into wind direction data. Based on data and images from Google Earth, Fetch is effectively used in wave forecasting charts to determine wave height, period, and duration.

Figure 4. Fetch length of Alindau, Marana, and Kaliburu
The fetch mapping from each location is shown in Figure 4. The UA and fetch values for each location show the potential deals obtained from Alindau beach.

![Fetch Mapping](image1)

**Figure 5.** Mapping of wave height

Referring to the UA and Fetch values from Alindau, the wave height and the resulting power proportion are calculated. Wave height affects the amount of power produced by OWC. From Figure 5, it shows that the maximum wave height occurred in 2015 in the north wind direction of 3.79 meters. Meanwhile, Figure 6 shows that the maximum wave period occurred in 2015 in the north wind direction of 6.91 seconds.

![Wave Period Mapping](image2)

**Figure 6.** Mapping of wave period

![Windrose and Histogram Data](image3)

**Figure 7.** Windrose and histogram data
As in wave height, the wave period taken is only the largest one each year, shown in Figure 7. It shows that the maximum significant wave height occurred in 2016 of 4.99 meters, and the wave period was 7.93 seconds.

Table 1. The amount of power generated by OWC for five years

| Year | UA  | dφ  | P2   | E   | Pw   | η OW C | ηWPP | Pg   |
|------|-----|-----|------|-----|------|--------|------|------|
|      | m   | rad.| m/s  | Pa  | Watt | Watt   | Watt | Watt |
| 2012 | 35.57 | -2.76 | 101038.96 | 256.34 | 777.89 | 32.95 | 23.8 | 485.86 |
| 2013 | 43.81 | -4.84 | 101011.75 | 42.50 | 1516.51 | 2.80 | 2.1 | 537.52 |
| 2013 | 40.66 | -8.93 | 101034.05 | 209.50 | 1194.52 | 17.54 | 12.8 | 511.27 |
| 2014 | 37.39 | 4.11 | 101010.15 | 26.37 | 912.86 | 2.89 | 2.1 | 490.51 |
| 2015 | 46.30 | -12.29 | 101043.33 | 300.83 | 1809.16 | 16.63 | 12.1 | 543.21 |

From the above calculations, the minor power generated in Alindau beach is 485.86 Watts in the minimum condition, while the most significant power generated is 543.21 Watts. By ignoring the power loss, the efficiency of the OWC System Prototype is 11.917%. The most undersized power that this system can generate under minimum conditions gets 57.90 Watt which gets 11.917% from 485.86 Watt. The maximum power gets 64.73 Watt that can be caused by 11.917% from 543.21 Watt.

4. Conclusion
The top wave height forecast for five per year was obtained using the Wilson Method. Based on wave forecasting using wind data for ten years, the ultimate wave height for five years is 0.20 m. Estimated power from the calculation results obtained a minimum power of 485.86 Watt and a maximum value of 543.21 Watt with an efficiency level of 11.97%. Its shows the potential that can exploit from the wave energy in Alindau Village. By applying this technology, it is estimated to cover the electricity needs of dozens of households in the Alindau village. With the development of this research, we hope that further comparisons of wave height calculation methods can be made more accurate and compare the wind data used in this study to obtain maximum results.

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