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QUANTITATIVE ANALYSIS OF INDONESIAN OCEAN WAVE ENERGY POTENTIAL USING OSCILLATING WATER COLUMN ENERGY CONVERTER

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Abstract

Indonesia as a maritime country which is located at 6^0 N - 11^0 S latitude and 95^0– 141^0E longitude has an ocean area reach out 5,000,000 km^2. This biggest archipelago country in the world has great ocean energy potential. In the other hand, Indonesian electricity energy demand always increase. Data from Central Bureau of Statistics of Indonesia (Badan Pusat Statistik) record that in the year 2013, Indonesian electricity consumption achieved 185.9 GWh and itwas

234.9 % of Indonesian electricity consumption in 2000. It is indicated by this condition that Indonesia need another alternative energy sources to supply the electricity needs. The ocean energy potential makes Ocean Wave Energy (OWE) precise to be developed in Indonesia. In this paper, study of OWE with Oscillating Water Column (OWC) converter is discussed. Numerical method is used to analyze the quantitative approach of OWE potential in Indonesia. For the calculation, it is assumed that chamber width is 2.5 m and ocean water density is 1030 kg/m^3. To calculate the energy, data of ocean significant height from Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) is used. Power efficiency is assumed to reach 70% and from the numerical calculation, the Indonesian OWE potential distribution can be represented. The greatest power that can be produced is located in Aru Islands and Arafuru Sea, which is reach out 313 kW and has minimum value 55 kW. The median value of ocean power is located in the south coast of Middle Java, Timor Sea, and Banda Sea which have maximum value 198 kW and minimum value 20 kW. This ocean wave energy can be increased by the converter amount and chamber width modification. From the calculation it can be concluded that OWE can be potential alternative energy source in Indonesia.

Keywords

Ocean Wave Energy, Oscillationg Water Column, Indonesia, Quantitative Analysis, Numerical Method.

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1. Introduction

Final energy consumption in Indonesia for the period 2003-2013 increased by an average of 4.1% per year. Energy consumption increased parallel with the increasment of the growth rate and society lifestyle. Total of the final energy consumption increased from 117 millions Ton Oil Equivalent (TOE) on the 2003 and reached out 174 millions TOE on the 2013 (DEN, 2014). Accordingly, a renewable energy potential that more environmentally friendly and sustainable is needed. Renewable energy including hydro energy, solar energy, geothermal energy, wind energy, biomass energy, and ocean energy are potential in Indonesia (ESDM,2014).

As a maritime country which has large ocean area, Indonesia has large maritime potential. Maritime sector is related to the energy isues since the ocean area save big renewable energy potential (Luhur, 2013). One of the ocean energy potential is the OWE. The OWE is thekinetic energy which is generated by ocean wave movement toward the land and vice versa, added with the potential energy which is produced by the low high of the wave. Indonesia OWE potential is relatively high and located on the east coast of Sumatera, the south coast of Java, Bali, Nusa Tenggara Timur, and Nusa Tenggara Barat. Datafrom *Asosiasi EnergiLaut Indonesia* (ASELI) 2011 explained that ocean wave energy had the theoretical potency 510 GW, the technical potency 2 GW, and the practical potency 1,2 GW (BPPT, 2014).

Therefore, in this paper the Indonesian OWE potential will be discussed. In addition, the distribution of OWE potential in Indonesia on the several locations will be discovered. We hope that this paper can be good consideration for the development of OWE in Indonesia.

1.2 Method of Analysis

The method used in this paper was numerical method. Numerical method is a complete and unambiguous set of procedures that is used to evaluate data and apply it to the system. The aim of the method does not represent the implementation details of any statistical analysis procedures, nor to discuss how the result of statistical software could be interpreted. The purpose is to highlight a few types of research questions that can be answered on the basis of qualitative information, to discuss the types of data format that will lend themselves readily to appropriate data analysis procedures and to emphasize how the data analysis can be benefited by recognizing the data structure and paying attention to relevant sources of variations.

This paper concentrated on some quantitative analysis approaches to determine the values of the ocean wave potential energy. It also used the data of Indonesian electricity consumption, a number system dimension, and ocean wave potency in Indonesia. By used this analysis, we generated a system using OWC energy converter to meet the Indonesian electricity consumption. From these studied the effectively of the system can be found, so it can be applied in Indonesia.

Based on the reason that the data about ocean wave periods and wave lengths in Indonesia was not available, the data is approached by Kim Nielsen's formula. This formula is used to calculate the ocean wave periods using height analysis approach. After get the value of ocean wave period, it is required to find the value of wave lengths by using David Ross's formula. Both values are used to calculate the power of OWE in Indonesia. The required formulas as follows:

- Ocean Wave Period

Kim Nielsen's Formula (Nielsen, 1986) is used to measure average wave periods. The Kim Nielsen's Formula is shown as follows:

$$T = 3.55\sqrt{\square}$$

T = period (s)
H=height(m)

- Wave length

David Ross's formula (Ross, 1980) is known enough for wave length approach in the scientific writing. This formula can be the good support for the calculation of wave energy.

$$\lambda = 5.12\ T^2$$

λ = wavelength (m)

- Ocean wave velocity

v = velocity (m/s)

- Calculation of ocean wave energy

$v = \lambda/T$

$$E_w = \frac{1}{4} . w. \rho. g. a^2 . \lambda$$

E_w=energy (Joule)

w = widht(m)

ρ = density (Kg/m3)

g = gravity acceleration (M/s2)

a = half of height (m)

- Generated Power

$$P_w = E_w/T$$

$$P_w = \left(\frac{1}{4} . w.\rho.g.a^2 . \lambda\right) / T$$

1.3 Result and Discussion

Based on energy conversion principles wave energy converter is classified into 3 converters namely Oscillating Water Column (OWC), Overtopping Device, and Hinged Count our Device (Tietje, 2009). On this paper, selected wave energy converter is OWC. OWC concept on a practical level has many attractions other than the other converter kind. On the OWC installation, there are very few moving parts, no moving parts in the water, it is reliable concept, easy to maintain, and uses sea space efficiently. OWC also adaptable and can be used on a range of collector forms situated on the coastline, in the near shore region, or floating offshore (Holmukhe, 2009). The concept of OWE can be shown clearly by the following figure:

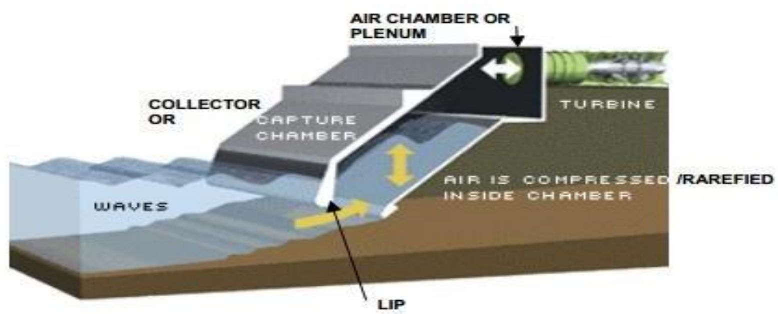

Figure 1: *The diagram of OWC (House, 2013)*

For more clearly concept, the detail and systematic explanation will be discussed on the following sections.

A. The Oscillating Water Column Converter

The Oscillating Water Column (OWC) wave energy converter is used to extract useful energy from ocean wave that is environmentally friendly and relatively simple to construct (Dorrell, 2004). It converts the hydraulic energy of the waves into an oscillating air flow. The device consists of a large wave capture chamber, a platform for an air turbine, generator, air chamber or plenum, and electricity grid. Every component has its own function as follow:

- Capture chamber, it is the major component of an OWC which is a fixed structure with its bottom open to the sea. Its mechanism of action is when the waves enter into the capture chamber, compresses and decompresses the air above the water level inside the chamber; the air will drive the turbine and generator (Marjani, 2008).

- Turbine is a component that is used to convert the pneumatic force into mechanical force. The turbine move caused by the flow of air from the chamber (Jayashankar, 2008).
- Generator is used to convert mechanical force into electrical force. The mechanical force is generated from the movement of the turbine air chamber or plenum, it is used to turn the turbine as the result of incoming and outgoing wave water inside the chamber (Jayashankar, 2008).
- Electricity grid, it is used to distribute the electricity from the generator.

B. *The Indonesian Ocean Wave Potential*

Ocean wave energy is renewable energy source in Indonesia which has not been developed optimally now. But actually, the wave energy potency in Indonesia can be more useful. Data from Indonesian Agency for Meteorology, Climatology and Geophysics 2015 showed the average significant wave height, average minimum and maximum wave height in all area of Indonesian oceans and coasts. Indonesian ocean wave condition can be represented on the Table 1 (BMKG, 2015). The Table 1 includes weekly average wave height, which valid from June 7th until June 14th2015. Even though it just be valid in those day, but it can be the representation of wave height in Indonesian coast area. In the table, the wave energy and wave power is shown after the calculation using formulas in the explanation on the previous method.

Table 1: *the* Indonesian *Ocean Waves Height, Period, & Wave Length*

No	Location	Average Significant Height (meter)		Period (Second)		Wave Length (meter)		No	Location	Average Significant Height (meter)		Period (Second)		Wave Length (meter)	
		Min	Max	Min	Max	Min	Max			Min	Max	Min	Max	Min	Max
1	North Coast of Aceh	0.3	1	1.94	3.55	19.4	64.525	16	Coast of Seribu Islands	0.75	1.3	3.07	3.97	48.39	80.66

2	West Coast of Aceh upto North Sumatera	0.4	1.25	2.25	3.97	25.8	80.656	17	Flores Sea	1	2	3.55	5.02	64.52	129
3	Coast of West Sumatera	0.5	1.3	2.51	4.05	32.3	83.882	18	South Side of Strain of Makassar	0.75	2	3.07	5.02	48.39	129
4	Coast of Bengkulu up to West	0.4	2	2.25	5.02	25.8	129.05	19	South Coast of Sulawesi	1.25	2.3	3.97	5.33	80.66	145.2
	Coast of Lampung														
5	Strain of Sunda	0.4	2	2.25	5.02	25.8	129.05	20	Maluku Sea	0.75	1.5	3.07	4.35	48.39	96.79
6	South Coast of Banten up to West Java	0.6	2.25	2.75	5.33	38.7	145.18	21	Buru Sea up to Seram Sea	0.75	2	3.07	5.02	48.39	129
7	South Coast of Middle of Java	1	2.5	3.55	5.61	64.5	161.31	22	Sulawesi Sea	0.5	1.3	2.51	3.97	32.26	80.66
8	South Coast of East Java	1	2.25	3.55	5.33	64.5	145.18	23	Arafuru Sea	1.5	3	4.35	6.15	96.79	193.6
9	South Coast of Bali up to Nusa Tenggara Barat	0.4	2.25	2.25	5.33	25.8	145.18	24	Jawa Sea	0.75	2	3.07	5.02	48.39	129
10	Sawu Sea	1	2.25	3.55	5.33	64.5	145.18	25	Bali Sea	0.75	1.5	3.07	4.35	48.39	96.79
11	Timor Sea	1	2.5	3.55	5.61	64.5	161.31	26	Coast of Sangihe Talaud Islands	0.75	1.3	3.07	3.97	48.39	80.66

12	Strain of Malaka	0.3	0.6	1.78	2.75	16.1	38.715	27	Halmahera Sea	0.75	1.3	3.07	3.97	48.39	80.66
13	Natuna Sea	0.3	0.75	1.78	3.07	16.1	48.394	28	North Coast of Papua	0.75	1.3	3.07	3.97	48.39	80.66
14	Strain of Karimata	0.5	1.25	2.51	3.97	32.3	80.656	29	Banda Sea	1.75	2.5	4.7	5.61	112.9	161.3
15	South Coast of Kalimantan	1	2	3.55	5.02	64.5	129.05	30	Coast of Aru Islands	1.5	3	4.35	6.15	96.79	193.6

For the OWE calculation, the average significant height is used to compute the wave period, wave length, wave velocity, energy, and power. To recognize the power that can be produced, the generator efficiency is assumed reach out 70% and oscillating water column width chamber is designed along the 2.5 m. The power that can be generated from Indonesia ocean wave can be seen in the figure 2.

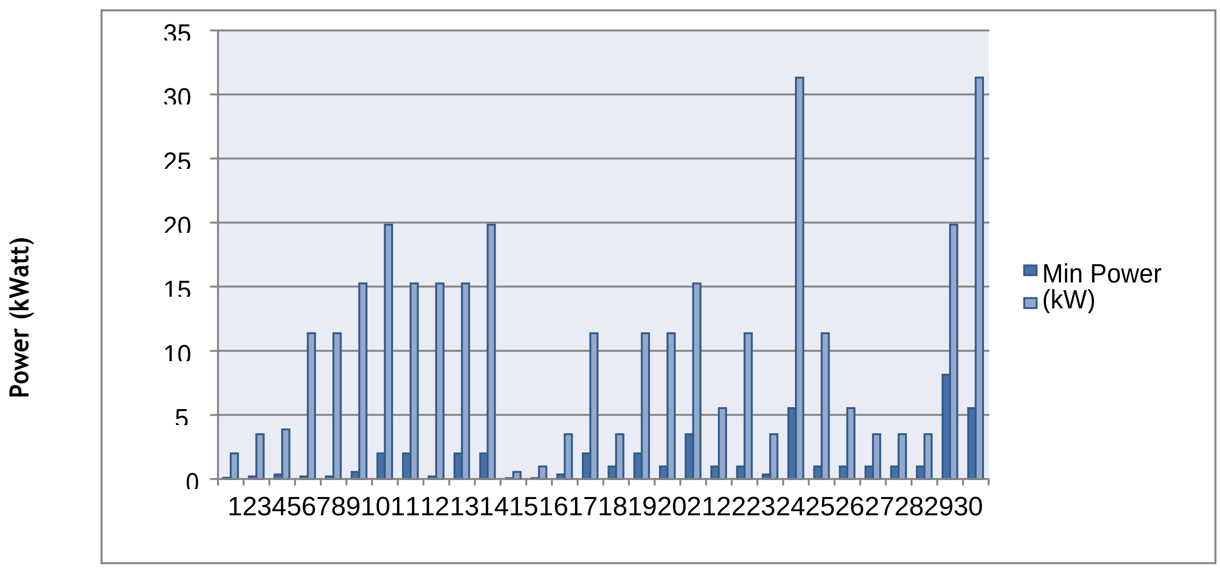

Figure 2: *The Indonesian Wave Power*

From the figure 2 it can be observed that the wave power is fluctuative inevery Indonesian coast areas. The biggest power that can be generated is located in Arafuru Sea and the coast area of Aru Islands which can reach out 313.1308 kW and have minimum value 55.35 kW.

Arafuru Sea is located at coordinates 9.5^0 South and 135^0 East. Aru Islands is located at 6.1667^0 South and 134.5^0 East. The smallest power that can be generated is located in Strait of Malaka that just have maximum value 5.6015 kW. The median power value that can be produced are located in coast of Bengkulu up to west coast of Lampung, Strait of Sunda, south coast of Kalimantan, Flores Sea, south side of Strait of Makassar and Buru Sea up to Seram Sea that have maximum value until 113.6312kW.

The potential energy, can be very advantageous for development of remotearea's electricity. The ocean wave potential in Aru Islands become the good occasion for increase the electricity ratio at this region. OWE can be more environmentally solution for electricity distribution to remote area like Aru Islands. Developing OWE in Aru Islands also can bethe appropriate pioneer for other Indonesian regions which still have low electricity ratio.

c. The Challenges for Indonesia on the OWC Development

Indonesia as a developing country faces many challenges on the renewable energy infrastructure development. In addition, OWC is a renewable energy source which needs high investment. The obstacles to develop OWC for Indonesia including many sectors, like economy, social, and politic.

The economic sector, OWC devices are expensive. Accordingly, Indonesia need to cooperate with other investors. Small project will make disproportional costs, high equipment costs, and make the program less sustainable. For the maximum result, the project will be better done on the large scale.

The social sector, Indonesian citizen consist of many different levels of educations and cultures. Not all of Indonesian citizens are ready for modern technology, especially for the citizens which live in the isolated region. Consequently, the building of OWC needs to begin with socialization about the benefits of OWE development.

The political sector, every engineering projects are dependent on the government policy. Accordingly, for the OWC development, support from the government policy and regulation are required absolutely.

D. The Future Opportunities

The potential of Indonesian OWE can be implemented with good analysis of the sustainability and the social cultural factors. In terms of the sustainability, there are many things that must be considered. Environmental conservations, economical benefits, and the risks of the OWE development should be evaluated carefully. Now on the main objectives of renewable energy device, included OWC, are to make them economically viable to complete with fossil fuels. For that, the development strategies must cover the research plan, development plan, and regulatory plan. It involve the participation from government, industry representatives, communities of interest, and all the stakeholders.

- ✓ **Research Plan:** Indonesia must completely support the researchers to disciplinary study and developing the knowledge of OWC technology. In addition, understanding environmental aspects and enhance public trust are very important.
- ✓ **Development Plan**: Project developers, government, industrial representatives, communities of interest, and all the stakeholders must cooperate to develop OWC technology in financial, science, technical, environmental, and social aspect. For the success on OWC technology, the market of electricity must be carefully planned. Electricity market must be commercially viable over time, so that research and development are very important to be concerned. For the economic sustainability, the challenges of the industry and government are to reach the point where the project size and investment are predicted have short break even point. Because of the high costs of OWC project, this project also must be trulycommercial.
- ✓ **Regulatory Plan**: All technology development need the regulatory support from the government. The legislative framework and regulatory system are required to ensure that the OWC project can be carried out with appropriate licensing, environmental protection, community benefits, and provincial revenue

2. Conclusions

The Indonesian OWE potencyial different for every coast region. For the result of Indonesia wave power calculation, the map of OWE potential in Indonesia is presented on the figure 3. From the figure 3, wave energy potential in each Indonesian region can be observed easily. Based on Indonesian OWE map for the result of OWE calculation. In general, the high potential of Indonesian OWE is located on the south and east side of Indonesia. It also represented that the highest Indonesian OWE potential is located on the east region, located on Armature Sea and Are Islands which is reach maximum value 313.1308 kW and minimum value

55.35 kW. This potential can be used to increase the electrification ratio in Indonesia, especially on the isolated region near the sea or strain. For handle the challenge of future development of OWC, Indonesia must do the strategies in many sector, covering research plan, development plan, and regulatory plan. With good attitude and the cooperation of all parties in this country, the better energy source can be implemented for better Indonesian environment.

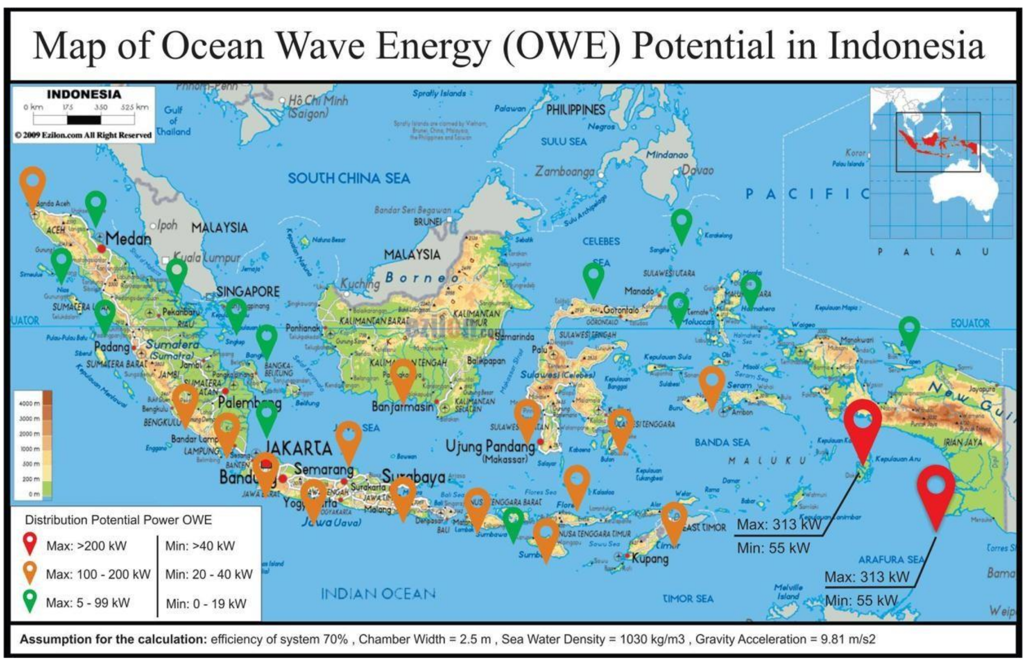

Figure 3: *Map of Ocean Wave Energy (OWE) Potential in Indonesia*

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