VOL. 12, NO. 17, SEPTEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

IDENTIFICATION OF WAVE ENERGY POTENTIAL IN SUNGAI SUCI BEACH BENGKULU INDONESIA

Denny Nugroho Sugianto[1, 2], Purwanto[1], Gentur Handoyo[1], Indra Budi Prasetyawan[1], Hariyadi[1] and Inovasita Alifdini[1, 2]
[1]Department of Oceanography, Faculty of Fisheries and Marine Sciences, Diponegoro University, Indonesia
[2]Coastal Disaster Mitigation and Rehabilitation Studies (CoRem), Diponegoro University, Center of Excellence Science and Technology (PUI), Indonesia
E-Mail:dennysugianto@yahoo.com

ABSTRACT

The dependency of the forefront islands towards non-renewable energy resulting in difficulty to use this energy in the future. Sungai Suci Beach is the beach that has steep topography and high waves because it is directly facing with Indian Ocean. Based on an initial analysis, Oscillating Water Column (OWC) fixed on-shore tool is suitable to be implemented in this location. This research was conducted through collecting wind, tides, bathymetry and beach slope data. The wind data was used for wave hindcasting using SMB method. Tide data was processed by using Admiralty method. Based on hindcasting wave using 17 years wind data, the average of significant wave height were 2.3 meter and periods 8.5 second with energy availability 67 %. The capacity of power that could be generated was 1.0073 MW and categorized as small hydro. In a review of coastal bathymetry and slope, depths ranging from 0 to 25 meters, and the cliff slope average was 74 degrees. Based on the tidal analysis, OWC's top side must be built taller than 1.71 meters and the lowest side should be lower than 0.21 meters from MSL. Through this analysis, OWC quite potential to be implemented in the Sungai Suci Beach Bengkulu.

Keywords: wave energy, renewable energy, oscillating water column, Bengkulu, Indonesia.

1. INTRODUCTION

Indonesia is an archipelago with 13,466 islands, 1,922,570 km^{2}land area and 3,257,483 km^2 water area [1]. Indonesia was ranked 18th in terms of oil production and 21st in terms of petroleum reserves in the world. However, fossil energy reserves will continue to decline due to high exploitation to meet the very high energy need along with the economic growth of Indonesia. Indonesian oil energy, natural gas, and coal reserves is predicted to only last for 12 years, 32 years and 77 years respectively. Therefore, alternative energy is necessary to replace fossil energy [2]. The number of households that use electrical energy in Bengkulu Province is around 381,459 homes which were connected per group of customers amounted to 319.94 MVA, so the average power that used per house was 1200 MVA [3]. The number of electricity users in the region continue to increase which then causes the burden of the local PLTD to increase. Actually, the fact that this location directly faces the Indian Ocean which has high wave that could be developed into electrical energy can be a solution [4].

Marine energy is considered to be abundant energy and does not pollute [5]. One of the energy in the ocean that can be utilized is wave energy [6]. Wave energy can be considered as a concentrated form of solar energy. The wind is generated by the earth heating. When it passes through the open bodies of water, heat transfer some of its energy to form wave [7]. Waves can build on the distance of the ocean with an average energy density more than 100 kW / m [8]. The total of wave energy in the world beach is estimated to be 106 MW and if only 2% of this energy is extracted, it can supply the world's total energy needs [9].
OWC is a wave energy conversion device that can be located near the coast or offshore. By using the rise and fall of water in a chamber, the air in the chamber is compressed to run the turbines. The air is pushed and produces electricity [10]. OWC is a device that converts mechanical energy from waves into electricity [11]. The main part of the OWC is the capture space, consisting of a fixed structure which has an open bottom [12]. Wave entered the room, compress and decompresses the air around SWL cause the oscillation of air flow. This air flow is passed through the power take-off (PTO) system that consists of a turbine and induction generator that converts this motion into electricity [13]. Major conversion of wave energy is obtained by oscillating system. This device is the most successfully used utilizing wave energy oscillating water column (OWC) systems. The bottom of OWC chamber submerged in sea water. An air flow created by the free surface of the water in the room [14].

Sungai Suci beach is a beach located in the Pondok Kelapa district. Sungai Suci beach is the tourism place in the Bengkulu Province, Indonesia. Pondok Kelapa district, Central Bengkulu Regency is located in the western part of Sumatra Island, facing the Indian Ocean [15]. This location causes the beach in Pondok Kelapa district to receive wave's runoff. This beach has a steep topography and a large wave height. Ocean wave conversion technology using OWC system was selected because besides it can be done with low cost; this technology was also suitable in areas with steep coastal topography [16].

The significant wave height in Sungai Suci beach ranging from 1.25 to 2.5 meters as well as the period ranging from 10 to 15 seconds [17]. The 2 meter or more significant wave height has high potential to generate wave power as the power source [18]. Therefore, due to this good potential, a further research is conducted to

VOL. 12, NO. 17, SEPTEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

determine how big the potential of wave energy in Sungai Suci Beach Bengkulu.

2. METHODOLOGY

2.1 Wave hindcasting

Wind speed and direction data were taken from the Meteorology, Climatology, and Geophysics through Ogimet.com website. The data was used for wave hindcasting using the SMB method. Wind data that was processed were 17 years data (2000-2016). Wave height and period data that were obtained are in the form of significant wave height and period of the deep sea [19]. Wave height and period data obtained statistical analysis to determine the distribution and availability of wave energy.

2.2 Wave energy calculation

Waves energy total in the ocean is the sum of kinetic and potential energy. The kinetic energy is part of the total energy of the particle velocity of water along with the movement of the waves. The potential energy is a part of the energy generated from the theory of fluid mass above the troughs. Based on the Airy wave theory, if the potential energy is determined relative to SWL (Still Water Level), and all the waves grow in the same direction, a component of kinetic energy and potential alike, so that the total energy of the wave in one wavelength per width of the wave is given in equation 1 [19].

$$E = E_k + E_p = \frac{\rho g H^2 L}{16} + \frac{\rho g H^2 L}{16} = \frac{\rho g H^2 L}{8} \quad (1)$$

Subscript k and p is the kinetic and potential energy of the waves. Wave energy total average per unit area in the form of a specific energy or energy density, namely:

$$\bar{E} = \frac{E}{L} = \frac{\rho g H^2}{8} \quad (2)$$

Where:
E = the total energy per unit area
Ē = the total energy per unit width
Ep = potential energy
Ek = kinetic energy
ρ = mass density
G = gravity acceleration
H = waves height
L = wavelength

2.3 Electrical energy calculation

One of the Oscillating Water Column type is a on-shore fixed type. The type of turbine that has been used was a Kaplan turbine with a coefficient of 85%. The formulations of the type were presented in the equation (3)-(12) [20].

- Potential Energy

$$E_P = w\rho g \frac{A^2}{4} \quad (3)$$

- Kinetic Energy

$$E_k = \frac{1}{4} w\rho g A^2 \quad (4)$$

- Total Energy

$$Ew = \frac{1}{2} w \rho A^2 g \quad (5)$$

- Energy Density

$$E_w D = \frac{Ew}{\lambda w} = \frac{1}{2\lambda} w\rho g A^2 \quad (6)$$

- Working Power

$$P_w = \frac{1}{2T} w\rho g A^2 \lambda \quad (7)$$

- Power Density

$$P_w D = \frac{Pw}{\lambda w} = \frac{1}{2T} \rho g A^2 \lambda \quad (8)$$

- Wind Power

$$P_a = \frac{1}{2} \rho A V^3 \quad (9)$$

- Power Turbine

$$P_m = P_a . C_p \quad (10)$$

- Bernitsas Formula

$$P_u = (P_m + \frac{1}{2} \rho V^2) V A \quad (11)$$

- OWC Efficiency

$$ef = \frac{P_a}{P_w} \quad (12)$$

Where:
T = wave period (s)
H = wave height (m)
ρ = water density (kg /m^3)
w = wave width that was assumed equal to the area of OWC's chamber (m)
g = gravity acceleration (m/s^2)
A = wave amplitude (m)
K = $\frac{2\pi}{\lambda}$ = wave number
λ = wavelength (m)
ω = $\frac{2\pi}{T}$ = waves frequency (rad/s)
C_p = turbine power coefficient (Kaplan Turbine 85 %)

2.4 Analysis of bathymetry and coastal slope

Bathymetric data taken from Hydrography and Oceanographic Agency (Dishidros) with 1: 500,000 scale. Coast slope was measured using a geological compass and a camera. Beach slope measurement was done by making a transects (segments) [21].

2.5 Tidal analysis

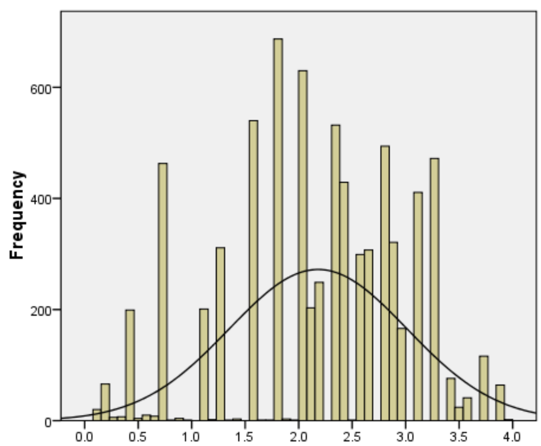
The tidal data used were Bengkulu tidal forecasting data in September 2016 obtained from Geospatial Information Agency (BIG) Indonesia. The data were processed using an Admiralty method [22] to obtain the value of Mean High Water Level (MHWL), Mean Low Water Level (MLWL), Mean Sea Level (MSL), High

Highest Water Level (HHWL), Low Lowest Water Level (LLWL), High Water Level (HWL), and Low Water Level (LWL). The admiralty method used tidal constant values to determine the value of tidal datum. Tidal data was used to give a recommendation of the Oscillating Water Column (OWC) height.

3. RESULTS AND DISCUSSIONS

3.1 Wave hindcasting

Wave hindcasting based on wind data processing for 17 years (2000-2016) using SMB (Sverdrup-Munk-Bretschneider) method [23]. Wave hindcasting was done per season. Wave hindcasting for 17 years was conducted to determine the availability and continuity of wave renewable energy development. Results of wave hindcasting data using SMB method were the significant wave height and period equivalent to the deep sea.



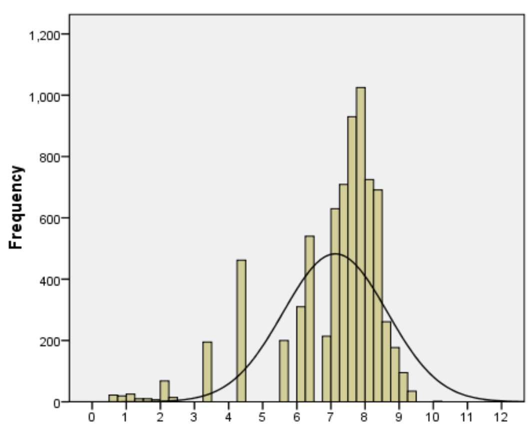


Figure-1. Significant wave height and period hindcasting results.

Wave hindcasting results above were presented in a significant wave height and period histogram curves in Figure-1. In addition, conducted an analysis of the frequency distribution and the percentage of the waves to determine the continuity and availability of the waves for 17 years [24].

Table-1. Description of significant wave height statistics based on forecasting results.

The amount of data 7377	**Hs** (m)
Average	2,24
Minimum	0,10
Maximum	4,14
Range	4
Skewness	-0,42

Table-2. Description of significant wave period statistics based on forecasting results.

The amount of data 7377	**Ts** (det)
Average	7,13
Minimum	0,63
Maximum	11,79
Range (range)	11
Skewness	-1,74

Based on Table-2, it could be seen that the average of significant wave height in 2000 - 2016 was 2.24 meters. The significant wave height ranging from 0.1 to 4.13 meters. Skewness value amounted to - 0.42 [25], which means that the wave height data were distributed greater than 2 meters. The dominant wave height was ranging from 2.1 to 3 meters by 49% (Table-3).

Table-3. Frequency distribution of significant wave height (Hs) hindcasting.

Hs (m)	**Frequency**	**Percentage** (%)
0 – 1	737	10
>1 – 2	1696	23
>2 – 3	3614	49
>3 – 4	1330	18
>4	1	0,01

Based on Table-3, it could be seen that the average significant wave period from 2000 to 2016 was 7,13 seconds. Significant wave period ranging from 0.63 to 11.79 second. Skewness value amounted to -1.74, which means that the data were distributed to a value greater than 6 seconds [25]. The dominant significant wave period were ranging from 7.1 to 8 seconds, by 44% (Table-4).

ARPN Journal of Engineering and Applied Sciences

Table-4. Frequency distribution of significant wave period (Ts).

Ts (det)	**Frequency**	**Percentage** (%)
0 – 1	44	0,6
>1 – 2	51	0,7
>2 – 3	73	1
>3 – 4	147	2
>4 – 5	442	6
>5 – 6	147	2
>6 – 7	1032	14
>7 – 8	3245	44
>8 – 9	1844	25
>9 – 10	73	1
> 10	221	3

In the analysis of the energy continuity, it can be seen that the number of waves that could potentially be used as an energy generator was the wave height above 2 meters [18]. Based on the results of hindcasting using the wind data for 17 years (2000-2016), the value of wave height above 2 meters as much as 67%. The dominant wave height ranging from 2.1 to 3 meters, while the dominant wave period ranging from 7.1 to 8 seconds. The percentage of wave height was above 50%, showing that the characteristics of the wave in the Sungai Suci Beach were quite potential for the development of electrical energy generation.

3.2 Wave energy calculation

Based on Table-5, it could be seen that the average of wave energy that could be generated from ocean wave hindcasting by wind data from 2000 to 2016 were 5.71 kJ. Wave energy that could be obtained ranging from 0.03 to 19 kJ. Skewness value was 0.381, which means that the data were distributed enough to a smaller value than 8 kJ [25] (Figure-2).

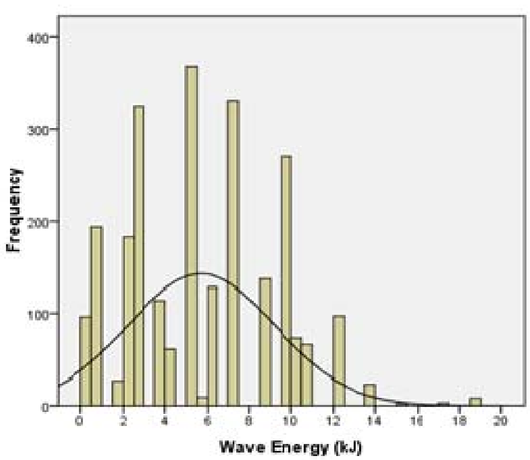


Figure-2. Wave energy (2000 - 2016).

Table-5. Statistics description of Figure-2.

Amount of data 2510	**Wave energy** (kJ)
Average	5,71
Minimum	0,03
Maximum	19
Range	19
Skewness	0,381

3.3 Electrical energy calculation

Significant wave data had been used for calculating the amount of electricity that could be generated when using a formulation of Oscillating Water Column fixed on-shore type. The electricity calculation results were displayed in a histogram curve in Figures 3-8.

Based on Figure-3, analysis of frequency distribution was done. According to Table 35 and 36, it was known that the average of electrical energy that could be generated was 1237.94 kJ. The electrical energy produced ranging from 0.311 to 6183.59 kJ. Skewness value [25] was 0.18, which means the data were distributed over a smaller value than 2000 kJ.

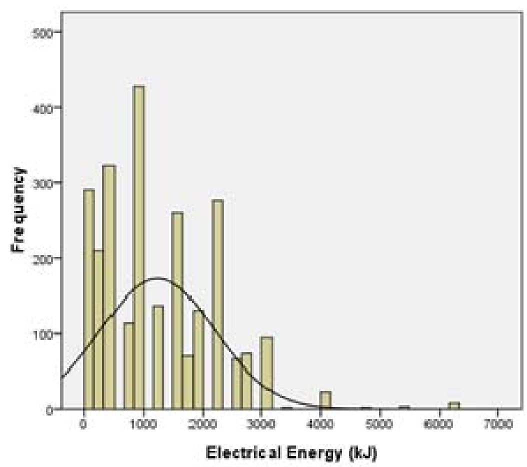


Figure-3. Total energy generated.

Table-6. Statistics description of Figure-3.

Amount of data 2510	**Energy** (kJ)
Average	1237,94
Minimum	0,311
Maximum	6183,59
Range	6183
Skewness	0,18

In this study, we also calculated the amount of electrical energy density. The electrical energy density was the electrical energy which worked per unit area chamber. The area of the chamber in this study, adopted

VOL. 12, NO. 17, SEPTEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

2.4 meters BPPT OWC chamber in Yogyakarta Indonesia (BPPD - BPPT 2005 in Mardiansyah, 2014).

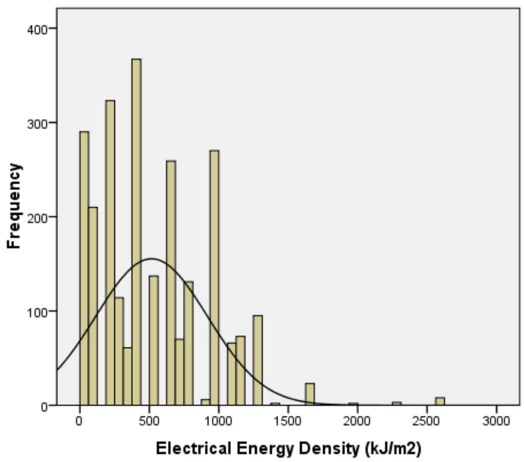


Figure-4. Electrical energy density generated.

Table-7. Statistics description of Figure-4.

Amount of data 2510	**Energy density** (kJ/m^2)
Average	515,81
Minimum	0,22
Maximum	2576,53
Range	2576
Skewness	1,01

Based on Table-7, the average of electrical energy density that could be generated was 515.81 kJ / m^2. The density of the electrical energy generated ranging from 0.22 to 2576.53 kJ / m^2. Skewness value [25] was 1.01, which means the data were distributed over a value smaller than 1000 kJ / m^2.

Based on Table-8, the average of electrical power which could be generated amounted to 161.99 kW. The electrical power that was produced ranging from 0.25 to 661.81 kW. Skewness value [25] was 0.67, which means the data were distributed over a value smaller than 300 kW.

Electrical power density was also calculated in this study. The electrical power density generated electrical power per unit area of the chamber. Based on Table-11, it could be seen that the average of electrical power density was 67.5 kW / m^2. Electrical power density generated ranging from 0.10 to 275.75 kW / m^2. Skewness value [25] of electrical power density was 0.67, which means the data were distributed over a value smaller than 150 kW / m^2.

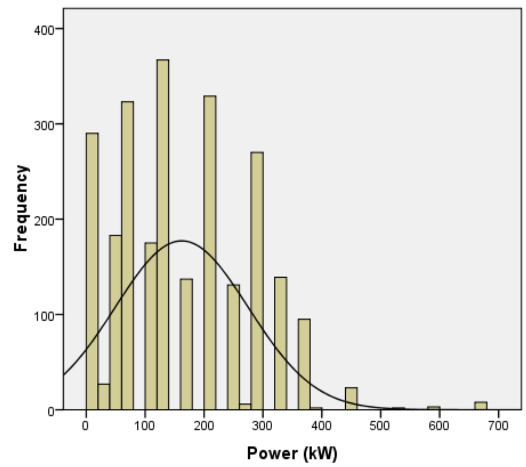


Figure-5. Power electrical generated.

Table-8. Statistics description of Figure-5.

Amount of data 2510	**Power** (kW)
Average	161,99
Minimum	0,25
Maximum	661,81
Range	662
Skewness	0,67

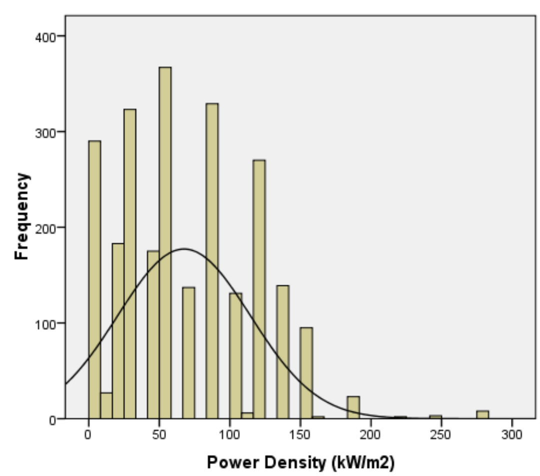


Figure-6. Power density generated.

Table-9. Statistics description of Figure-6.

Amount of data 2510	**Power density** (kW/m^2)
Average	67,5
Minimum	0,10
Maximum	275,75
Range	276
Skewness	0,67

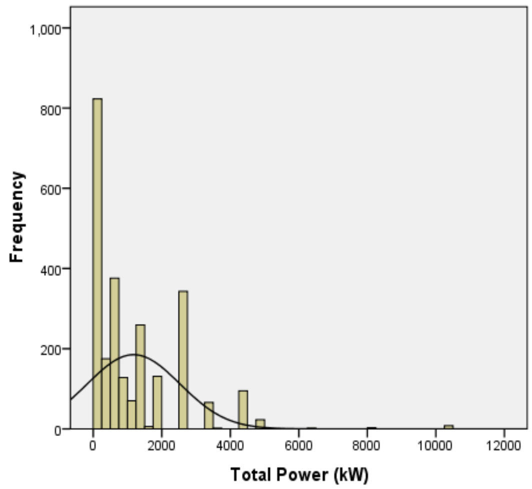


Figure-7. Total power generated.

Table-10. Statistics description of Figure-7.

Amount of data 2510	**Total power** (kW)
Average	1178,41
Minimum	0,064
Maximum	10353,53
Range	10353
Skewness	2,04

Calculation of total power above already calculated the mechanical power turbine. The turbine used in this study was Kaplan turbine (wind turbine) with a coefficient of 0.85. A value of 0.85 was an assumption in which the turbine produces electricity by 85%, and 15% energy loss. Assumption was made for each turbine because each turbine has its own performance, as well as when the turbine was implemented on the ground; there was also a difference between the values of efficiency among one area to others.

Based on Table-10, the total average of electrical power that could be generated was 1178.41 kW. The type of power plant was Small Hydro because its power less than 10 MW [26]. Total of electrical power that produced ranging from 0.064 to 10353.53 kW. Skewness value [25] was 2.04, which means the data were distributed over a value smaller than 3000 kW.

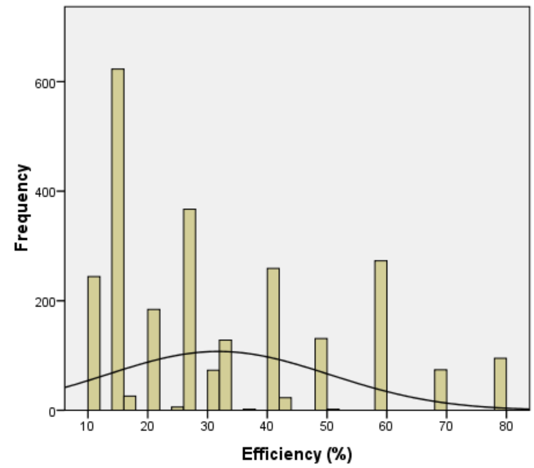


Figure-8. Efficiency generated

Table-11. Statistics description of Figure-8.

Amount of data 2510	**Efficiency** (%)
Average	31,79
Minimum	11,69
Maximum	79,55
Range	68
Skewness	0,91

Based on some of wave heights data that occurred, we were calculated the efficiency of OWC that worked when the wave came. Based on Figure-8, the analysis of frequency distribution was done. Based on Table-11, the average of efficiency which could be generated was 31.79%. The efficiency ranging from 11.69 to 79.55%. Skewness value [25] of the efficiency was 0.91, which means the data were distributed over a value smaller than 40%.

3.4 Analysis of bathymetry and coastal slope

In the analysis of bathimetry in this study, we used bathymetric map from Hydrography and Oceanography Agency Indonesia (scale of 1: 500,000). We processed it into three-dimensional shapes. The result was presented in Figure-9.

Based on the bathymetric analysis, it could be seen that the depth of Sungai Suci Beach (the beach part ranging from 0 to 25 meters). Then, getting into the sea, the depth value changed dramatically until 700 meters. It indicates that there was a trough off the coast, causing waves height in the near shore greater. For the installation of Osccillating Water Column with depths ranging from 0 to 25 meters was ideal enough. For example, the installation of this tool that has been developed by The Queen's University of Belfast Ireland [27] was installed at a 10 meters depth.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

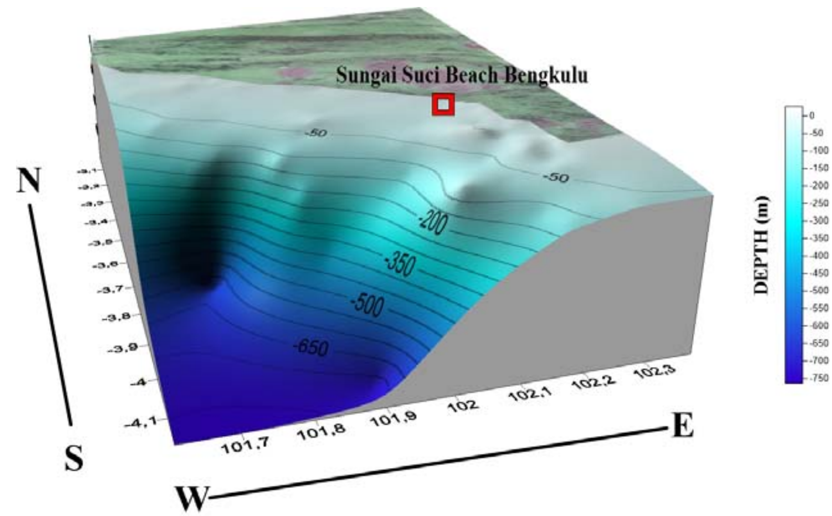


Figure-9. 3D model bathymetry of Sungai Suci Beach Bengkulu.

In addition to the bathymetry conditions, coastal slope measurement also conducted both slopes of cliffs and slopes above the cliffs. The slopes were shown in Table-12. The beach slope types in this study were divided into two, namely, the slopes of coastal cliffs and inland slopes over the cliff. Based on the table, it could be seen that the Sungai Suci beach cliff (elevation) ranging from 7 to 39 meters from the sea level. The average value of slope at the top of cliff ranging from 1 to 13.33 degrees. Those values were included in the category of flat, gently sloop, sloping, moderately steep, and steep [21]. Meanwhile, the cliff measurable ranging from 45 to 90 degrees. The whole value were included in the category of extremely steep [21].

Measurements have been conducted at the 11 point, an average value of the cliff was 74 degrees (extremely steep) and the average value of the above cliff slope was 6.3 degrees (sloping). If this slope location condition, compared with the slope in the beach where Limpet of The Queen's University of Belfast [27] were implemented, the slope value which used was 60 degrees. If the value of the Sungai Suci Beach cliff compared with the value of the Islay site slope, it is not so different.

3.5 Tidal analysis

Based on the tidal data processed with the Admiralty method, the values of the tidal components were shown in Table-13. Based on the value of these components, it could be seen the Formzahl values is used to determine the type of tidal that occur. Based on the calculations, Formzahl number was 0.27, which means that the type of tidal in the Sungai Suci Beach Bengkulu was mixed prevailing semidiurnal tides [22] where in one day occurred 2 times of high and low tides with different periods. The current cycle of the tides was lower than others. However, at the certain times the tidal type was diurnal with a high and low tides.

Other than Formzahl number, based on tidal component, we can get the value of tidal chart datum which includes the value of HHWL (High Highest Water Level), HWL (High Water Level), MHWL (Mean High Water Level), MSL (Mean Sea Level), MLWL (Mean Low Water Level), LWL (Low Water Level), and LLWL (Low Lowest Water Level). Chart datum value obtained were shown in Table-14.

According to Table-13, the highest amplitude of the tidal component was 30 cm which was the amplitude of the tidal constituents M2. M2was a semidiurnal tidal daily constituent due to Earth's rotation on its axis and got the effect of lunar gravity in orbit around the Earth. Components that dominated after M2 were the value of the S2 component with a value of 29 cm which was the main constituent of the semidiurnal daily which shows the Earth's rotation on its axis toward the earth. The lowest tides component was P1 of 0.8 which was a component of the sun that causes daily diurnal tides. Meanwhile, the largest phase delay was MS4 component which was a component of the sun and the moon a daily quarter. Meanwhile the smallest phase delay was P1 which was a component of diurnal sun. The friction factor may reduce the tidal range and causes a phase delay (phase lag) [28]. The more shallow waters, the greater the influence of friction.

VOL. 12, NO. 17, SEPTEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-12. Sungai Suci Beach slopes.

No.	Coordinates	Elevation	Beach slope	Category	Cliff slope	Category
1	S 03°43,574' E 102° 14,294'	29 m	19°	Steep	85°	Extremly Steep
2	S 03°43,495' E 102° 14,420'	39 m	-	-	90°	Extremly Steep
3	S 03°43,249' E 102° 14,191'	18 m	4,67°	Sloping	90°	Extremly Steep
4	S 03°43,241' E 102° 14,178'	17 m	7°	Sloping	75°	Extremly Steep
5	S 03°43,172' E 102° 14,127'	11 m	13,33°	Moderately Steep	85°	Extremly Steep
6	S 03°43,160' E 102° 14,114'	12 m	1°	Flat	60°	Extremly Steep
7	S 03°43,136' E 102° 14,129'	11 m	4°	Gently Slope	45°	Extremly Steep
8	S 03°43,111' E 102° 14,112'	10 m	4,33°	Sloping	70°	Extremly Steep
9	S 03°43,100' E 102° 14,100'	24 m	5°	Sloping	45°	Extremly Steep
10	S 03°43,092' E 102° 14,092'	7 m	7,5°	Sloping	80°	Extremly Steep
11	S 03°43,232' E 102° 14,174'	15 m	4,33°	Sloping	90°	Extremly Steep

Table-13. The amplitude (A) and phase delay (g°) of tidal data September 2016 in The Sungai Suci Beach Bengkulu.

	S0	M2	S2	N2	K1	O1	M4	MS4	K2	P1
A (cm)	93	30	29	4	6	10	4	4	8	0,8
g°		12	18	64	67	301	28	358	18	0,5

Table-14. Sungai Suci Beach Bengkulu tidal chart datum.

No.	Chart datum	Value (cm)
1	HHWL	171
2	HWL	152
3	MHWL	139,8
4	MSL	93
5	MLWL	46,2
6	LWL	34
7	LLWL	21

Based on Table-14 the tidal chart datum of Sungai Suci Beach Bengkulu were HHWL of 171 cm, HWL of 152 cm, MHWL of 139.8 cm, MSL of 93 cm, MLWL of 46.2 cm, LWL of 34 cm, and LLWL of 21 cm. Tidal range (the difference between the highest and lowest water level) obtained from the 30 days data was 150 cm. If the Oscillating Water Column will be implemented in the Sungai Suci Beach Bengkulu, the maximum height should be more than the value of HHWL, and the lowest side should be lower than the value of LLWL. This condition was done so that when the high tide, sea water was not overtopping to the top side of OWC. When the lowest tide, the bottom sides of OWC still stayin the submerged of the sea water, so that, no air is coming to the bottom side of OWC.

ARPN Journal of Engineering and Applied Sciences

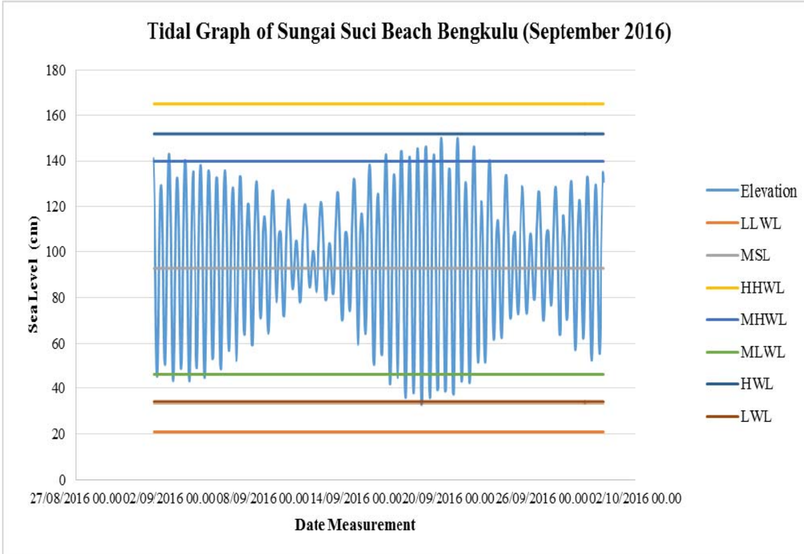


Figure-10. Tidal graph Sungai Suci Beach Bengkulu

When seawater overtop to the upper side of OWC, it will interfere with the function of generator and other components, as well as when air entered through the bottom side of OWC, the OWC cannot work (because the working principle of the OWC by oscillations of the sea water to produce air pressure above the water). If the air enter to the OWC, there was no air pressure to drive a turbine [29].

4. CONCLUSIONS

Ocean waves in the Sungai Suci Beach Bengkulu was the type of swell and wind waves with significant wave heights average2.3 meters and period 8.5 seconds. The type of wave based on wave period were the ultra - gravity and gravity waves while based on the relative depth, it was included the ttransition waters waves types.

The percentage of the wave that has the potential to be converted into electrical energy was 67% (through a review of waves hindcasting for 17 years). The capacity of power that could be generated was 1.0073 MW and categorized as small hydro. In a review of coastal bathymetry and slope, depths ranging from 0 to 25 meters, and the cliff slope was 74 degrees. Through this analysis, OWC quite potentialto be implemented in the Sungai Suci Beach Bengkulu.

ACKNOWLEDGEMENTS

We would like to thank Oceanography Department Diponegoro University and Coastal Disaster Mitigation and Rehabilitation Studies (CoRem) Diponegoro University, Center of Excellence Science and Technology (PUI) Indonesia for funding our research.

REFERENCES

[1] BIG. 2013. BIG Serahkan Peta NKRI Kepada Kemenkokesra. Available online: http://www.bakosurtanal.go.id/berita-surta/show/big-serahkan-peta-nkri-kepada-kemenkokesra (accessed on 1 February 2017).

[2] Zed F.,Suharyani Y.D.,Rasyid A.,Hayati D.,Rosdiana D.,Mohi E.,Santhani F.,Pambudi S.H., Malik C.,Santosa J.; Nurohim A. 2014. Eds. References. In Outlook Energi Indonesia; Rahman, F., Abdurahman; Dewan Energi Nasional RI: Jakarta, Indonesia. 1: 1-145.

[3] [PLN] Perusahaan Listrik Negara. Statistik PLN 2014; PLN: Jakarta, Indonesia, 2015.

[4] Alifdini I.,Andrawina Y.O.,Sugianto D.N., Widodo A.B.,Darari A. 2016. Technology Application of Oscillating Water Column on The Sungai Suci Beach as Solutions for Make A Renewable Energy in Coastal Bengkulu, Indonesia. In: Proceedings of 3rd Asian Wave and Tidal Energy Conference (AWTEC), Singapore, 24-28 Oktober 2016; Narasimalu, S., Abundo, M.L.S., Quirapas, M.A.J., Eds.; Research Publishing: Singapore. pp. 502-507.

[5] Elghali S.E.B.,Balme R.,Saux K.L.,Benbouzid M.E.H,Charpentier J.F.,Hauville F. 2007. A Simulation Model for the Evaluation of the Electrical Power Potential Harnessed by a Marine Current Turbine. IEEE Journal of Oceanic Engineering. 32: 786-797.

[6] Irhas,Suryaningsih R. 2014. Study of Wave Energy into Electricity in the South Coast of Yogyakarta Indonesia. El-Sevier Energy Procedia. 47: 149-155.

[7] Broke J. 2003. Wave Energy Conversion System; El -Sevier Ocean Engineering: Oxford, UK. pp. 27-35.

[8] Cruz J. 2008. Ocean Wave Energy. Springer Series in Green Energy and Technology, United Kingdom.

[9] Falnes J. 2007. A Review of Wave-Energy Extraction. Journal of Marine Structures. 20: 185-201.

[10] Khaligh A.,Onar O.C. 2010. Energy Harvesting: Solar, Wind, and Ocean Energy Conversion Systems; Taylor & Francais Group: New York, US. Chapter 4, pp. 223-303.

[11] Garrido A. J., Otaola E.,Garrido I.,Lekube J.,Maseda F.J.,Liria P.,Mader J. 2015. Mathematical Modeling of Oscillating Water Columns Wave-Structure Interaction in Ocean Energy Plants. Hindawi Publishing Corporation Mathematical Problems in Engineering. 727982: 1-11.

[12] Li Z.,Zuo L.,Kuang J.,Luhrs G. 2013. Energy-Harvesting Shock Absorber with a Mechanical Motion Rectifier. Smart Mater Struct. 22: 1-10.

[13] 2009. Ocean Power Technologies Inc. Making Waves in Power. Ocean Power Technology: New Jersey., USA. pp. 1-51.

[14] Takao M.,Setoguchi T. 2012. Air Turbines for Wave Energy Conversion. International Journal of Rotating Machinery. 2012: 1-10.

[15] Fadilah.2013.AnalisisKerusakanPantaiKecamatanPondokKelapaKabupaten Bengkulu Tengah danPenentuanKonsepPenanganannya; Diponegoro University: Semarang, Indonesia.

[16] Wijaya I.W.A. 2010.PembangkitListrik Tenaga Gelombang Laut Menggunakan Teknologi Oscilating Water Column di Perairan Bali. Jurnal Teknik Elektro. 168: 20-33.

[17] BMKG. Perkiraan Tinggi Gelombang. Available online: http://maritim.bmkg.go.id/ (accessed on 24 September 2016).

[18] Twidell J., Weir T. 2006. Renewable Energy Resources, 2nd Ed.; Taylor & Francais Group: New York, USA. Chapter 12, pp. 401-428.

[19] 1984. CERC. Shore and Protection Manual; US Army Coastal Engineering Research Center: Washington DC, USA.

[20] McCormick M.E., Johnson D., Hebron R., Hoyt J. 1981. Wave Energy Conversion; John illey& Sons Inc.: Boston, USA.

[21] Triandanu N.,Alfan I., Muslim D. 2016. Surface Geology Characteristic and Its Influence to Landslide Potential in Cisokan Drainage Pattern West Bandung Indonesia. International Journal of Structural and Civil Engineering Research. 5: 147-150.

[22] Ongkosongo O.S.R.Suyarso. 1989. Asean-Australia Cooperative Program on Marine Science Project I: Tides ad Tidal Phenomena: PasangSurut. Lembaga Ilmu Pengetahuan Indonesia Pusat Penelitiandan Pengembangan Oseanologi: Jakarta, Indonesia.

[23] Bretschneider C.L. 1964. Generation of Waves by Wind State of The Art. Presented at International Summer Course, Lunteren, Netherlands. September 1-18.

[24] Hyndman R. J.,Kostenko A.V. 2007. Minimum Sample Size Requirements for Seasonal Forecasting Models. J Foresight. 6: 12-15.

[25] Uyanto S. 2009.Stainislaus. PedomanAnalysis Data. GrahaIlmu: Yogyakarta, Indonesia.

[26] Sopian K.,Razak J.A. 2016. Pico Hydro Clean Power from Small Streams. In: Proceedings of the 3rd WSEAS International Conference on Renewable Energy Sources, Mallorca, Spain. pp. 414-419.

[27] 2002. The Queen's University of Belfast. Islay LIMPET Wave Power Plant (Published Report). The Queen's University of Belfast: Ireland, UK. pp. 1-62.

[28] MacMillan C.D.H. 1966. Tides. American El -Sevier Publishing Company: New York, USA.

[29] Mozahedy A.B.M.K. 2010. Composite Sea Wall for Wave Energy Conversion. Delft University of Technology (TU Delft): Delft, Netherlands.