The Study on Potential of Electrical Power and Energy Resulted Wave Generated By Wind

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Keywords: Wave Generation, Sverdrup-Munk-Bretschneider, Wilson, JONSWAP, Coastal Engineering Manual, Oscillating Water Column

SUMMARY

The need for energy in Indonesia is increasing in line with economic and population growth. The increasing demand for electrical power will not generate a big problem if the installed electric capacity is sufficient to accommodate all the needs of society. Ironically, conventional energy sources such as fossil fuels which are the main energy sources in Indonesia have limited reserves. One policy of the Ministry of Energy and Mineral Resources in addressing national issues is the diversification of energy supply and utilisation of new energy sources, one of which is marine energy sources. Ocean energy sources that can efficiently be converted into electrical energy is the sea wave. This study aims to determine the potential energy and electricity that can be generated from wind generated wave in Tangerang, Cilacap, Semarang, Surabaya, Banyuwangi, Kalianget, and Denpasar.

This study took the wind data from Weather Underground during the year of 2013. Data at the interpolated interval of 1 hour were used to calculate the ocean waves components, which are wave height (H) and wave period (T). Wave generation method used in this research are SMB (Sverdrup-Munk-Bretschneider), Wilson, JONSWAP (Joint North Sea Wave Project), and CEM (Coastal Engineering Manual). Around 33% of total wave generated using the above methods were found to be significant in this research. A comparative analysis between and among the generation method was done using MAE and Scatter Index value. Potential energy and electric power are calculated at each dominant wind direction based on the wind rose diagram by using Oscillating Water Column model that has a chamber size of 10 m x 18 m.

SMB method is a most accurate method to be used in the calculation of wave generation than the other methods. Based on the analysis using MAE values and Scatter Index, the result shows that most of the SMB method has a lower value than the other three methods. Each study site has different potential energy and power. The larger wave height, the greater potential energy will be generated. On the other hand, the amount of power is inversely proportional to the wave period. Results presentation and distribution of wind energy potential and power calculations are used as a determinant of the direction of the power plant, which is the dominant wind direction that produces the largest potential for energy and power.

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1. INTRODUCTION

The need for energy in Indonesia is increasing in line with economic and population growth. The increasing demand for electrical energy will not generate a big problem if the installed electric capacity is sufficient to accommodate all the needs of society. Conventional energy sources such as fossil fuels which are the main energy sources in Indonesia have limited reserves. One policy of the Ministry of Energy and Mineral Resources in addressing national issues is the diversification of energy supply, and utilisation of new energy sources, one of them is marine energy sources.

Ocean waves can be divided into several types depending on the energy sources. Among the several waveforms that can be used for generating electrical energy is wind waves. The energy that is given causes the water to move and cause small ripples on the water surface and form a wave (Triatmodjo, 1999).

Studies on the energy and power that can be generated by ocean waves are necessary to know some energy needs support the long-term national needs. Total electricity requirement Java, Madura, and Bali (Jamali) is much higher than the electricity needs in other areas in Indonesia, which is about 80% of total national electricity demand. It is very reasonable considering Jamali is the centre of all activities, but the electricity consumption is still relatively less efficient (Muchlis and Permana, 2006).

This study used wind observation data throughout the year 2014 at meteorological stations in Tangerang, Cilacap, Semarang, Surabaya, Banyuwangi, Kalianget, and Denpasar. The wind data can be accessed from http://www.wunderground.com/.

2. WIND DATA

Wind observation data used in this study had a different interval. Tangerang, Semarang, Surabaya, and Denpasar had interval around 0.5-1 hours. Meanwhile, the others had a 2-3 hours interval. Outliers data determined based on the visual presentation using the graph and retain the observational data with high values and not in extreme condition. Table 2.1 shows recapitulation data handling wind observations at the study site.

Table 2.1 Recapitulation data handling and site information

No	**Site**	**Coordinate**		**Height (m)**	**Data**	**Interval (hours)**	**Outliers**
		Latitude (N)	**Longitude (E)**				
1	Tangerang	6^o 7’ 48’’	106^o 39’ 36’’	8	20.089	0,5 – 1	24
2	Cilacap	7^o 43’ 48’’	109^o 1’ 12’’	6	2.770	2 – 3	9
3	Semarang	6^o 58’ 12’’	110^o 22’ 48’’	3	10.554	0,5 – 1	7
4	Surabaya	7^o 22’ 48’’	112^o 47’ 24’’	3	14.505	0,5 – 1	484

5	Banyuwangi	8º 13' 12''	114º 22' 48''	5	2.831	2 – 3	3
6	Kalianget	7º 3' 0''	113º 58' 12''	3	2.834	2 – 3	3
7	Denpasar	8º 45' 0''	115º 10' 12''	4	15.855	0,5 – 1	3

Surabaya was the study site with the biggest outliers data, which took from 13th October 17.00 GMT until 31st October 2013 16.00 GMT. Data on that time was left empty because the linear interpolation deemed incapable of representing observational data patterns. As for the other study sites, linear interpolation generated data at intervals of 1-hour observation.

3. THE WINDROSE AND TOPOGRAPHY ANALYSIS

Windrose was used to determine the distribution of wind direction and speed that can be obtained frequencies greatest speed and dominant wind direction. Windrose in this study created using WR Plot View version 7.0.0 by input data with the *.txt format. Radial lines on the wind rose shows the distribution of wind directions which divided in eight directions. Each colour on the wind rose indicating each interval in units m/s wind speed based on the results of equivalence by the IMO according to Beaufort scale. The width of the radius of each colour indicates the percentage of the wind in the period of observation.

3.1 Windrose in Tangerang

Most of the wind speed in Tangerang occurred at of 0.5-2.1 m/s with the number of 4988 events. Wind distribution shows that dominant wind direction place from the north with a frequency 19.57%, consist of 1,240 data at 0.5–2.1 m/s, 430 data at 2.1–3.6 m/3, and 4 data at 3.6–5.7 m/s. Figure 3.1 shows wind rose in Tangerang.

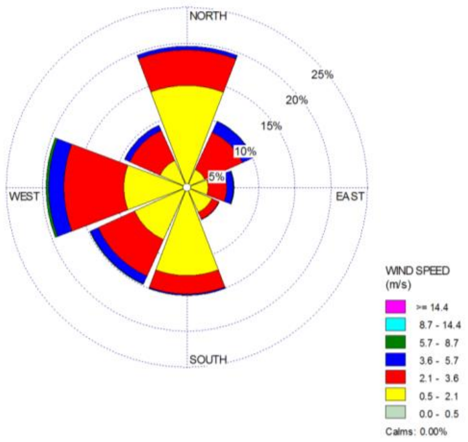

Figure 3.1 Windrose in Tangerang

3.2 Windrose in Cilacap

Mainly, the wind in Cilacap with the number of 4,541 events occurred at 2.1 – 3.6 m/s. Dominant wind directions come from the south-east with a frequency 29.05% and from West with 19.06%. Figure 3.2 shows wind rose in degrees and m/s in wind station in Cilacap.

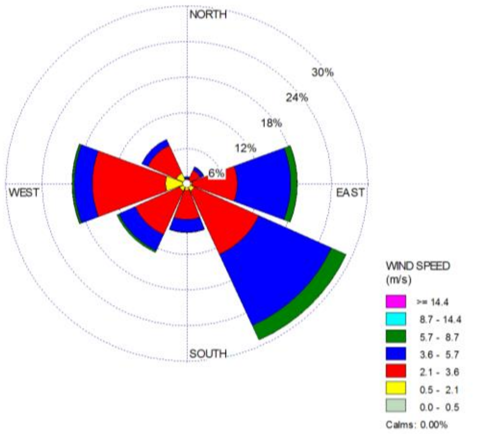

Figure 3.2 Windrose in Cilacap

Figure 3.3 Windrose plotting in Cilacap

Windrose visualisation at Google Earth in Figure 3.3 showed that wind direction from the west could not be included in wave generation because the wind comes from the land. So that wind wave generation calculated by using the third dominant wind from the east with 18.21%.

3.3 Windrose in Semarang

Most wind speeds occurred at of 0.5-2.1 m/s with the number of 3,067 events. Dominant wind directions flow from the south-east, north, and north-west with percentage 19.28%, 17.89%, and 16.36% respectively. Figure 3.4 shows wind rose in Semarang.

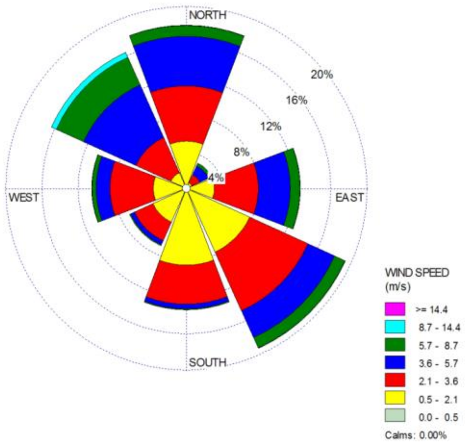

Figure 3.4 Windrose in Semarang

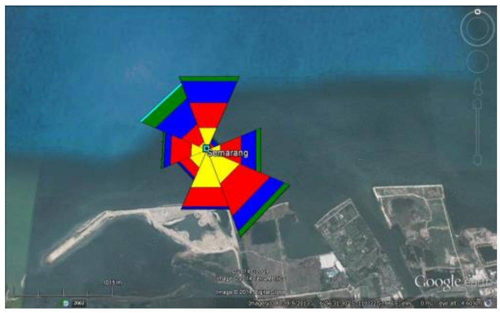

Figure 3.5 Windrose plotting

Wind directions flow from south-east cannot be included in wind wave generation because the wind comes from the land, based on the wind rose visualisation in Figure 3.5.

3.4 Windrose in Surabaya

In Surabaya, most of the wind speed occurred at 8.7 - 14.4 m/s with 2618 events. Figure 3.6 shows wind rose with dominant wind directions flow from the west with 27.15%. The next dominant directions were east and south-west with 25.54% and 12.02% respectively.

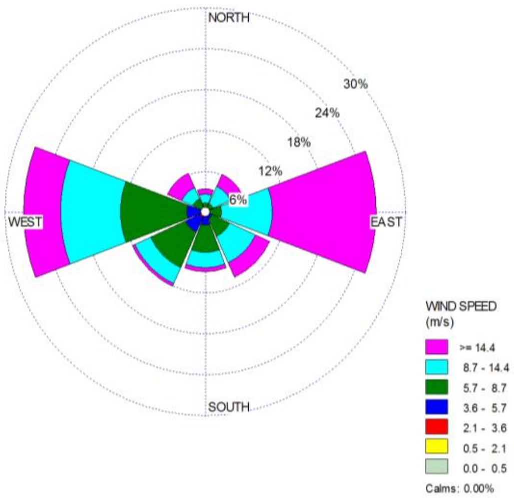

Figure 3.6 Windrose in Surabaya

Figure 3.7 Windrose plotting

Windrose visualisation at Google Earth (Figure 3.7) shows that the wind from west and south-west cannot be included in wave generation because the wind comes from the land.

3.5 Windrose in Banyuwangi

Mostly, wind speed in Banyuwangi occurred at of 2.1 – 3.6 m/s with the number of 5,675 events. Dominant wind directions came from the south with a frequency of 2,535 data or 26.65% and from the south-east with 1,669 data or 19.36%. Figure 3.8 shows wind rose in degrees and m/s in wind station in Banyuwangi.

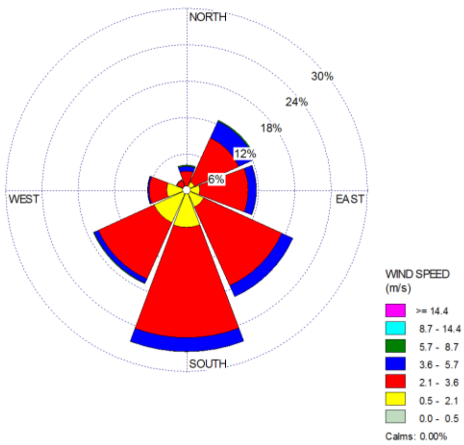

Figure 3.8 Windrose in Banyuwangi

3.6 Windrose in Kalianget

As many as 4,066 events of wind speed occurred in Kalianget at 2.1–3.6 m/s. Wind distributions show that dominant wind directions come from the south-east with a frequency of 2,583 data or 29.49% and from the east with 19.69%. Figure 3.9 shows wind rose in degrees and m/s in wind station in Kalianget.

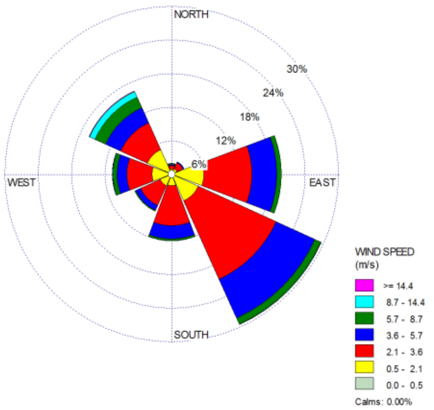

Figure 3.9 Windrose in Kalianget

3.7 Windrose in Denpasar

The biggest frequency of wind speed in Denpasar occurred at 2.1–3.6 m/s, with 4,541 events. Dominant wind directions flew from south-east and east with frequency 25.4% and 24.06% respectively. Figure 3.10 shows wind rose in Denpasar.

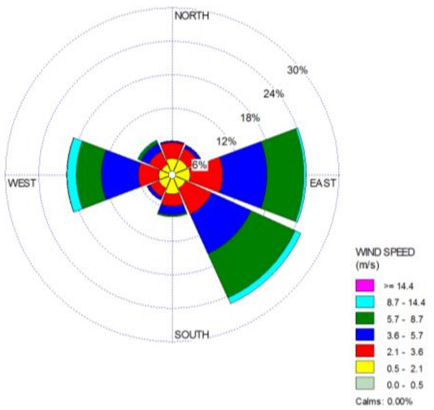

Figure 3.10 Windrose in Denpasar

4. WIND WAVE GENERATION

The wind that flows over the surface of the water could transfer energy into the water. Wind speed raises the tension at sea surface, so the calm surface of the water initially can be disrupted and formed small ripples on the water surface. If the wind speed increases, the ripple becomes increasingly large, and if the wind continues to be formed waves eventually. The longer and stronger the wind flows, the bigger the waves that formed (Triadmodjo, 1999).

According to Sorensen (1938), the height and wave period affected by the wind speed U, the wind duration td, wind direction, and fetch F. Wind direction considered to be constant if the amendments are not more than 15^o. Furthermore, the wind speed deemed to be constant if the changes are not more than 5 knots (2.5 m/s) to the average speed.

An area with unlimited fetch produced waves with certain periods and height. Wave height in these conditions could not continue to grow and reached a maximum at the time of the energy gained from wind balanced by the energy lost due to the outbreak of turbulence and waves. This condition is called fully developed sea (Yuwono, 1982).

Wave forecasting is done for various purposes in activities such as coastal engineering study of the harbour, coastal structures, coastal erosion and sediment transport, environmental studies, and estimation of wave energy (Akpinar et al., 2014). To meet these objectives, it has developed a variety of methods such as empirical, numerical methods and computational methods. Forecasting waves with the empirical method assume that the wave generation has the main factors namely wind speed (U), the long fetch (F), and wind duration (td). Empirical methods such as SMB, Wilson, JONSWAP, and CEM is an example of a simple method for predicting a wave under certain conditions.

According to the U.S. Army (1984), five factors must be considered in the conversion of wind data for the generation of waves, namely: elevation, wind duration, stability correction, location effect, and wind stress factor.

4.1 SMB Method

Sverdrup and Munk originally proposed SMB method in 1974 and later developed by Bretschneider in 1952 and 1958 based on research conducted in Lake Ontario (Bishop, 1983 in Etemad-Shahidi et al., 2009). According to Bretschneider (1964), wind speed (U_A) which flows along the fetch (F) produces wave component to the equation 4.1 and 4.2.

$$\frac{gH}{{U_A}^2} = 0{,}283\ tanh\left[0{,}0125\left(\frac{gF}{{U_A}^2}\right)^{0{,}42}\right] \quad \text{4.1}$$

$$\frac{gT}{U_A} = 2{,}4\pi\ tanh\left[0{,}077\left(\frac{gF}{{U_A}^2}\right)^{0{,}25}\right] \quad \text{4.2}$$

Where:

H : wave height (m)
T : wave periods (s)
F : *fetch* (m)
g : Earth gravitation (m/s^2)

Fetch (F) are used depending on wave conditions. Wave conditions are limited duration if the value of $tt_{min} \leq t$. In this condition fetch value used is the minimum value of the equation 4.3 and 4.4.

$$t_{min} = 56505{,}6\ \frac{U_A}{g} \quad \text{4.3}$$

$$\frac{gt_{min}}{U_A} = 68{,}8\ \left(\frac{gF_{min}}{{U_A}^2}\right)^{0{,}67} \quad \text{4.4}$$

Where:

t_{min} : minimum duration (dt)
F_{min} : minimum *fetch* (m)

4.2 Wilson Method

Wilson (1965) suggested the form of wave generation equation using the value U_{10}. Wave component can be solved by equation 4.5, 4.6, and 4.7.

$$H = 0{,}30 \frac{U_{10}{}^2}{g}\left[1-\left[1+0{,}004\left(\frac{gF}{U_{10}{}^2}\right)^{0{,}5}\right]^{-2}\right] \quad \text{4.5}$$

$$T = 8{,}61 \frac{U_{10}}{g}\left[1-\left[1+0{,}008\left(\frac{gF}{U_{10}{}^2}\right)^{0{,}33}\right]^{-5}\right] \quad \text{4.6}$$

$$t_{min} = 1{,}0\, F^{0{,}73} U_{10}{}^{-0{,}46} \quad \text{4.7}$$

4.3 JONSWAP Method

JONSWAP is the cooperative activities carried out by researchers in the UK, Netherlands, USA, and Germany to acquire waveform data. They developed the wave function empirically based on the results of the study at 13 sites located along the 160 km of Sylt Island in Germany toward North Sea (Hasselmann et al., 1973). Wave components generated by the wind calculated with the equation 4.8, 4.9, and 4.10.

$$H = 0{,}0163\, F^{0{,}5} U_{10} \quad \text{4.8}$$

$$T = 0{,}439\, F^{0{,}3} U_{10}{}^{0{,}4} \quad \text{4.9}$$

$$t_{min} = 1{,}167 \frac{F^{0{,}7}}{U_{10}{}^{0{,}4}} \quad \text{4.10}$$

4.4 CEM Method

CEM was prepared to provide relevant guidance of shore engineering activities through the combination development of JONSWAP and assumption that the local wave field propagates at speeds approaching the speed 0.85 times the peak spectral wave (U.S. Army, 2006). Wave components generated by the wind fetch and limited duration condition calculated with the equation 4.11, 4.12, and 4.13. While, for fully developed sea condition done by equation 4.14, 4.15, and 4.16.

$$\frac{gH}{U_*{}^2} = 4{,}13 \times 10^{-2}\left(\frac{gF}{U_*{}^2}\right)^{0{,}5} \quad \text{4.11}$$

$$\frac{gT}{U_*} = 0{,}651\left(\frac{gF}{U_*{}^2}\right)^{0{,}33} \quad \text{4.12}$$

$$t_{min} = 77{,}23 \frac{F^{0{,}67}}{U_{10}{}^{0{,}34} g^{0{,}33}} \quad \text{4.13}$$

$$\frac{gH}{U_*{}^2} = 2{,}115 \times 10^2 \quad \text{4.14}$$

$$\frac{gT}{U_*} = 2{,}398 \times 10^2 \quad \text{4.15}$$

$$\frac{gF}{U_*{}^2} = \frac{F^{0{,}67}}{U_{10}{}^{0{,}34} g^{0{,}33}} \quad \text{4.16}$$

4.5 Wave Generation

Ocean wave generation by the wind in each study site performed on data derived from the dominant wind direction. Significant wave is one of the wave types that most widely used. In this study, the results of wave generation components (H and T) calculated a mean value of 33 percent or one-third highest waves. Equation 4.17 and 4.18 are used to derive the value of the significant wave in each direction of the dominant wind. Table 4.1 shows the calculation result of wave generation by wind.

$$H_S = H_{33\%} = \frac{\sum H_i f_i}{\sum f_i} \quad \text{......} \quad 4.17$$

$$T_S = T_{33\%} = \frac{\sum T_i f_i}{\sum f_i} \quad \text{......} \quad 4.18$$

Where:

$H_{33\%}$, $T_{33\%}$: 33% average wave height and period

f : event frequency

Table 4.1 Wave generation calculation in Tangerang

Methods	**Significant wave**			**Waves average**	
	Direction	**Hs (m)**	**Ts (dt)**	**H (m)**	**T (dt)**
Location: Tangerang					
SMB	West	0.83	1.25	0.24	0.58
	North	0.38	0.82		
Wilson	West	0.72	1.23	0.38	0.99
	North	0.52	1.11		
JONSWAP	West	0.60	1.09	0.32	0.88
	North	0.44	0.99		
CEM	West	1.40	1.94	0.73	1.57
	North	1.05	1.79		
Location: Cilacap					
SMB	Southeast	0.17	1.5	0.1	1.13
	East	0.16	1.46		
Wilson	Southeast	0.32	3.30	0.22	2.59
	East	0.31	3.23		
JONSWAP	Southeast	0.82	3.26	0.61	2.92
	East	0.8	3.23		
CEM	Southeast	1.75	1.82	1.63	1.91
	East	1.74	1.83		
Location: Semarang					
SMB	North	0.19	1.57	0.13	1.19
	Northwest	0.30	1.98		
Wilson	North	0.35	3.42	0.24	2.67
	Northwest	0.49	4.09		
JONSWAP	North	0.85	3.33	0.66	2.99
	Northwest	1.08	3.61		
CEM	North	1.89	1.90	1.74	1.99
Location: Surabaya					
SMB	East	2.66	5.90	1.24	3.78
	Southeast	1.27	2.66		
Wilson	East	1.55	7.25	1.08	5.85
	Southeast	1.16	5.04		

JONSWAP	East	2.84	5.06	1.98	4.40
	Southeast	2.17	4.02		
CEM	East	2.68	1.63	2.25	1.68
	Southeast	2.27	1.7		
Location: Banyuwangi					
SMB	South	0.08	1.03	0.05	0.8
	Southeast	0.08	1.05		
Wilson	South	0.19	2.41	0.13	1.94
	Southeast	0.19	2.46		
JONSWAP	South	0.56	2.86	0.45	2.64
	Southeast	0.57	2.87		
CEM	South	1.65	1.95	1.55	2.01
	Southeast	1.66	1.95		
Location: Kalianget					
SMB	East	0.15	1.41	0.09	1.01
	Southeast	0.16	1.43		
Wilson	East	0.30	3.14	0.19	2.33
	Southeast	0.31	3.18		
JONSWAP	East	0.77	3.21	0.56	2.85
	Southeast	0.78	3.22		
CEM	East	1.85	1.94	1.69	2.04
	Southeast	1.86	1.93		
Location: Denpasar					
SMB	East	0.29	1.94	0.17	1.41
	Southeast	0.39	0.64		
Wilson	East	0.30	3.14	0.19	2.33
	Southeast	0.31	3.18		
JONSWAP	East	1.47	7.09	0.98	5.70
	Southeast	1.10	4.91		
CEM	East	2.55	1.60	2.12	1.64
	Southeast	2.17	1.64		

5. COMPARISON OF WAVE GENERATION METHODS

According to Akpinar (2014), a comparison between wind wave generation methods can be made using the MAE. While Etemad-Shahidi et al. (2009) using a scatter index value analysis to compare the quality/accuracy of the method. MAE is the absolute average of forecast data error, regardless of the positive or negative sign which is calculated based on the equation 5.1. MAE measures how much the prediction results of value is considered correct.

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|y_i - x| \quad \text{..........} 5.1$$

Where:

N : amount of data
y_i : prediction result
x : true value (average value)

In statistics, scatter an index is a number that indicates how well the data match with the method or statistical models. Also, it provides a measure of how well a predictable outcome is replicated by related variables, as a proportion of the total variation in results is explained by the model (Etemad-Shahidi et al., 2009). Scatter index value obtained from the equation 5.2

$$SI = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - x)^2}}{\frac{1}{N}\sum_{i=1}^{N} x} \qquad 5.2$$

Where:
SI : scatter index

Based on wind wave generation using SMB, Wilson, JONSWAP, and CEM then makes a comparison to see which method is better for wave generation. This value was calculated from the predicted wave height. Table 5.1 presents the results of the calculation of the value of MAE at each location.

Table 5.1. MAE Value

MAE	Tangerang	Cilacap	Semarang	Surabaya	Banyuwangi	Kalianget	Denpasar
SMB	0.168	0.003	0.083	0.762	0.051	0.050	0.100
Wilson	0.045	0.074	0.128	0.316	0.041	0.086	0.137
JONSWAP	0.0317	0.133	0.229	0.522	0.0809	0.161	0.243
CEM	0.137	0.088	0.163	0.249	0.082	0.139	0.152

The smaller MAE value showed, the better accuracy. Figure 5.1 presents the MAE value in the graphical form. Results presentation in graphical form shows the most value MAE on SMB method shows a lower value than the other three methods except locations in Tangerang and Surabaya. In Surabaya and Tangerang MAE value on SMB method is the highest value. Analysis using MAE provide results that SMB method is the most accurate method

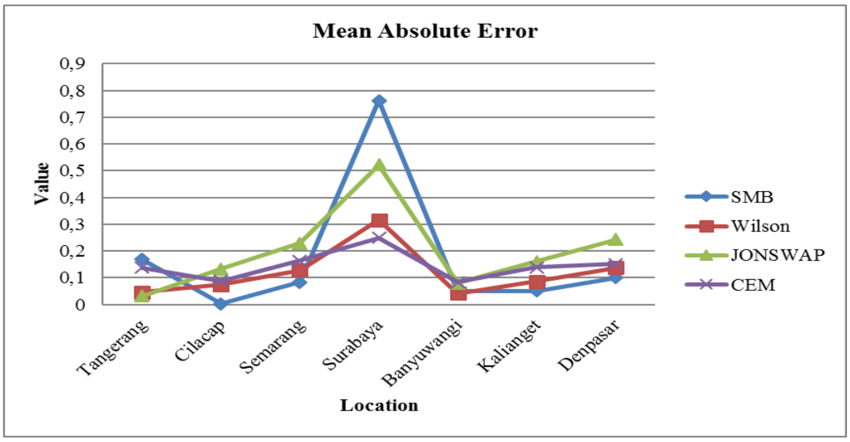

Figure 5.1 MAE value graphic

Comparative statistical analysis using scatter index value showed that the smaller value gives the better accuracy. Table 5.2 presents the calculation results scatter index values at each study site.

Table 5.2 Scatter index value

Scatter Index	Tangerang	Cilacap	Semarang	Surabaya	Banyuwangi	Kalianget	Denpasar
SMB	0.429	0.429	0.141	0.189	0.930	0.191	0.282
Wilson	0.478	0.569	0.357	0.599	0.581	0.398	0.430
JONSWAP	0.483	0.726	0.577	0.657	0.767	0.633	0.597
CEM	0.541	0.931	0.884	0.847	0.928	0.893	0.876

The smaller scatter index values indicated the better accuracy. Figure 5.2 presents the scatter index values in graphical form. The chart showed almost all scatter indexes on SMB method has a lower value than the other three methods except the location in Surabaya. Values in Surabaya scatter index showed the highest value. Analysis using scatter index values provided results that SMB method is the method most able to replicate the variables related to the method used.

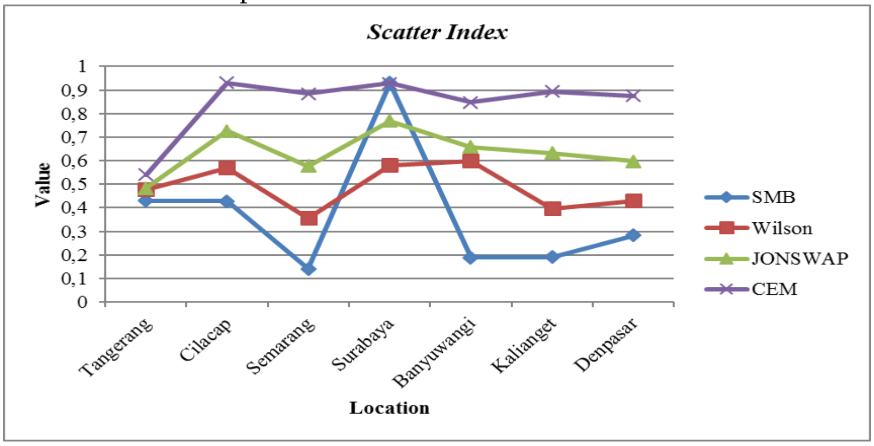

Figure 5.2 Scatter Index graphic

Analysis using MAE and scatter index values indicated that the SMB method is a better method used in the calculation of wave generation by wind compared with the three other methods. In studies in Surabaya, SMB method provided the highest MAE and scatter index value. That is because in Surabaya there were many clear data. Therefore the data predicted results do not have good proximity to the correct value (mean value).

Wilson method and JONSWAP overall showed results in MAE and Scatter Index value higher than SMB method. That was because the wave components of the generation of the condition were not defined and limited duration using fetch equivalent value. While the calculation of wave components in Jamali showed almost all the waves in conditions of limited duration. In addition to the calculation method of Wilson and JONSWAP used conversion data at an elevation of 10 m wind only and is not equipped with other wind corrections. CEM methods and SMB defined the wave component in the calculation of limited duration conditions. The calculations showed that the value of MAE and scatter index is higher than the CEM methods SMB method. That was because of the CEM method used conversion data correction of wind stability and elevation, and it was not equipped with a correction duration, location, and wind stress factor.

6. CALCULATION OF ENERGY AND POWER

The total energy of a wavelength is the sum of kinetic energy and potential energy (Triatmodjo, 1999). Thus the total energy in a wavelength as in equation 6.1.

$$E_t = E_k + E_p = \frac{\rho g H^2 L}{8} \quad \text{.......} \quad 6.1$$

Where:

E_t : total energy (joule)
E_k : kinetic energy (joule)
E_p : potential energy (joule)
ρ : rho = water density (kg/m^3)
g : Earth gravitation (m/s^2)
H : wave height (m)
L : wavelength (m)

Wave power by Hulls (1981) in Kadir (1995), the power contained in the wave can be calculated by the equation 6.2.

$$P = \rho g T \pi \frac{H^2}{64} \quad \text{.......} \quad 6.2$$

Where:

P : power (W)
T : wave period (s)
π : phi (3.14)

Wave for electric energy generation, the capacity and its efficiency depends on the technology used. Energy per unit area (energy density) is calculated using the equation 6.3

$$E_D = \frac{E_t}{\lambda w} = \frac{0{,}195 w \rho g H^2 T^2}{1{,}56 T^2 w} = \frac{1}{8} \rho g H^2 \quad \text{.......} \quad 6.3$$

Where, E_D : energy density (J/m^2)

Power per unit area (power density) is calculated using equation 6.4.

$$P_D = \frac{P}{\lambda w} = \frac{0{,}195 w \rho g H^2 T}{1{,}56 T^2 w} = \frac{1}{8T} \rho g H^2 \quad \text{.......} \quad 6.4$$

Where, P_D : power density (W/m^2)

Calculation of energy and wave power was obtained by using the results of significant wave. The power generated by each of the significant wave calculated using the equation 6.4. Energy and power captured by the chamber were calculated using the assumption that the size of the chamber was 10 x 18 m. Table 6.1 presents the results of calculation of energy and power for a significant wave at each location.

Table 6.1 Energy and power calculation

Direction	**Wave Generation Method**			
	SMB	**Wilson**	**JONSWAP**	**CEM**
Location: Tangerang				
North				
P_D (W/m$_2$)	38,952.31	54,665.04	43,224.49	138,141.6
E_D (J/m$_2$)	32,070.51	60.723.66	42.812.9	246.841.6
West				
P_D (W/m$_2$)	124,299.2	95,001.85	74,849.38	228,840
E_D (J/m$_2$)	154,828.7	116,665.4	81,815.49	443,165.3

Location: Cilacap				
Southeast				
P_D (W/m$_2$)	4,401.283	7,215.931	46,523.18	378,206.3
E_D (J/m$_2$)	6,622.083	23,790.43	151,882	688,612.3
East				
P_D (W/m$_2$)	4,057.8	22,000.58	44,460.13	372,941.5
E_D (J/m$_2$)	5,983.183	6,821.306	143,788.7	682,130.6
Location: Semarang				
North				
P_D (W/m$_2$)	5,101.163	8,091.397	49,312.31	426,062.9
E_D (J/m$_2$)	8,009.441	27,642.74	164,038	810,997
Northwest				
P_D (W/m$_2$)	10,291.14	13,135.03	73,243.11	477,797.5
E_D (J/m$_2$)	20,406.24	53,773.4	264,608.1	871,328.7
Location: Surabaya				
East				
P_D (W/m$_2$)	270,773	69,340.08	333,964.6	919,924.4
E_D (J/m$_2$)	1,596,679	491,326.4	1,655,000	1,470,234
Southeast				
P_D (W/m$_2$)	137,239.5	55,567.55	245,766.8	651,434.7
E_D (J/m$_2$)	364,955.3	272,728.2	968,455	1,068,138
Location: Banyuwangi				
South				
P_D (W/m$_2$)	1.439,033	3,244.737	86,532.62	315,668.2
E_D (J/m$_2$)	1.483,462	7,830.037	247,270.4	616,675.8
Southeast				
P_D (W/m$_2$)	1,525.475	3,395.618	89,409.05	320,305.8
E_D (J/m$_2$)	1,608.448	88353.867	257,371.1	623,975.5
Location: Kalianget				
East				
P_D (W/m$_2$)	3,773.184	6,526.539	41,654.38	401,516.3
E_D (J/m$_2$)	5,326,146	20,466.52	133,607.4	777.655.6
Southeast				
P_D (W/m$_2$)	3,939.346	6,740.136	42,659.03	405,137.1
E_D (J/m$_2$)	5,645.709	21,401.97	137,557.3	782,751
Location: Denpasar				
East				
P_D (W/m$_2$)	9,470.318	11,660.92	65,807.97	437,493.1
E_D (J/m$_2$)	18,411.73	46,006.19	231,039.1	774,805.5
Southeast				

P_D (W/m_2)	53,035.47	5,461.281	31,208.79	273,625.6
E_D (J/m_2)	33,972.39	13,229.49	87,761.41	536,267.8

The potential calculation of the energy and power at each location was performed on two of the most dominant direction. The results of these calculations were used to determine the direction of the power plant. Based on these calculations, the power plant direction to be built in Tangerang was at West that produces energy and power greater than the north. At study sites in Cilacap, the best direction was to the south-east. As for the research site in Semarang and Surabaya, the best directions were north-west and east respectively. Meanwhile, in Banyuwangi and Kalianget, the best power plant direction to be built was in the south-east. Moreover, in Denpasar, the appropriate direction to be built is at East.

7. CALCULATION OF SEABED SLOPE

Analysis of the seabed carried out to determine the magnitude of the seabed slope. Seabed profile that was used in each study area is profiled at dominant wind direction, drawn from the coast to approximately 50 m depth. According Zuidam (1983) in Arifianti (2011), the profile of the seabed that category is flat if it has a slope with 0^o - $2{,}2^o$. Table 7.1 presents the calculation results seabed slope of the beach profile to a depth of about 50 m**.**

Table 7.1 Seabed Slope Calculation

Location	**Direction**	***Slope*** **(^{o})**
Tangerang	North	0.06
	West	0.04
Cilacap	Southeast	0.17
	East	0.06
Semarang	North	0.03
	Northwest	0.01
Surabaya	East	0.06
	Southeast	0.07
Banyuwangi	South	0.05
	Southeast	0.1
Kalianget	East	0.12
	Southeast	0.17
Denpasar	East	0.6
	Southeast	0.65

Slope obtained from the comparison of tangent value between the ocean depths to the distance from the coast. Slope calculation results indicated that the overall study area was a flat area, with the slope value was less than 2.2^o.

8. CONCLUSION

1. The faster wind speed, the longer wind duration and the longer will provide high-value components and a larger wave period.

2. SMB method is a more accurate method to be used in the calculation of wave generation method than Wilson, JONSWAP, and CEM. Based on an analysis using the value MAE showed most SMB method shows a lower value than the other three methods except locations in Tangerang and Surabaya. Meanwhile almost all scatter index value on SMB method shows a lower value than the other three methods except the site in Surabaya.
3. The power plant direction to be built in Tangerang was at West that produces energy and power greater than the north. At study sites in Cilacap, the best direction was to the south-east. As for the research site in Semarang and Surabaya, the best directions were north-west and east respectively. Meanwhile, in Banyuwangi and Kalianget, the best power plant direction to be built was in the south-east. Moreover, in Denpasar, the appropriate direction to be built was at East that produces energy and power that is greater than the south-east.
4. Slope seabed profile in the study area was flat where the slope value is less than $2,2^{o}$. The area with the largest slope was in Denpasar, with a gradient value 0.6 and 0.65.

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BIOGRAPHICAL NOTES

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