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Potential Evaluation of Wind Energy in Kuala Terengganu, Malaysia through Weibull Distribution Method

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Abstract. Malaysia faces many challenges in the development of wind energy as it is located in areas with slower wind speeds. Malaysia is located on the equator line where land and sea breezes can affect the wind regime. The wind does not blow uniformly and fluctuate by month and area. Therefore, the objective of this study is to determine the potential of the latest wind power in Kuala Terengganu. The scope of the study was not comprehensive because it focused only on Kuala Terengganu, Malaysia which is located at latitude 5° 23' N and longitude 103° 06' E. The wind data used in this study was obtained from the Malaysian Meteorological Department. The wind data that had been observed and collected was the wind direction and wind speed for year 2017 where the height of the sea level is 5.2 meters. This study uses the Weibull Distribution method as it shows a good consideration to estimate the density of wind power in Malaysia [1] The daily wind speed pattern for year 2017 can be seen that it has a corresponding pattern where it shows high wind speed at the beginning and end of the year. The wind speed frequency is also variable for the winds of the Northeast Monsoon and is almost constant during the south monsoon of the Southwest Monsoon and the Transition Monsoon. Overall, the potential of wind power in Kuala Terengganu is not too large. The annual average for 2017 is 2.01 m/s only. Wind power is high during the Northeast Wind Monsoon season.

Keywords: *Wind speed, wind data, Weibull Distribution, wind power, wind speed frequency, wind power density.*

1. Introduction

Wind power is an important renewable energy source as it is clean and existing on earth as well as cost-effective for some applications such as power generation. Wind is one of the most common sources of research and find that it has produced tremendous technology and performance worldwide [2]. It has been proved by [3]. where 150 kW of wind turbine was built in the Terumbu Layang-Layang in 2005 and has shown some good achievement.

The use of wind energy as a source of energy is growing worldwide as the use of other energy sources such as fuel, nuclear and coal contributes to environmental pollution and global warming. In addition, the use of wind power has the advantage to those living in rural areas and remote islands where it is far from the national grid electric [4]. Electricity can be produced with a free source where wind is used as a medium to move the wind turbine to produce electricity.

Wind power gained importance after a rapid increase in world energy production through the burning of fossil fuels that have led to heat trapped "greenhouse gas" accumulated in the troposphere. In this regard, there is growing concern that human activity now will affect earth climate in the future [5].

Malaysia faces many challenges in the development of wind energy as it is located in areas with slower wind speeds. Malaysia is located on the equator line where land and sea breezes can affect the wind regime. The wind does not blow uniformly and changing by month and area. Therefore, studies on the characteristics and features of wind speed have dominated wind research in Malaysia ([6].

This study find out the latest potential of wind power in Kuala Terengganu, Malaysia for the period 2013-2017. Kuala Terengganu is the largest city and is the capital of Terengganu, Malaysia. Kuala Terengganu is located in front of the South China Sea [7] at latitude 5°23'N and longitude 103°06' E. Due to the demand for energy and especially for electricity growing rapidly due to the country's social and economic development, wind turbines small-scale has been used in this state. This is because Kuala Terengganu is blessed with seasonal solar and wind power supplies. Therefore, most energy needs can be supplied from renewable energy sources.

2. Data Collection and Calculation Methodology

2.1 Data

The data used in this study were obtained from Malaysian Meteorological Department (MMD). It is data collected through observations taken daily (daily data). The raw data provided consists of wind direction and wind speed data. The period for this data is for year 2017 for area in Kuala Terengganu, Malaysia where the height from sea level is 5.2 meters. The unit of measure for wind speed is meter per second (m/s) and for wind direction is degree.

2.2. Calculation Methodology

2.2.1 Frequency distribution of wind speed

Each area has a wind speed distribution profile with different types of wind. Wind speed distribution plots the frequency for each wind speed. Typically, it is shown in the wind speed distribution curve. For example, an area may have a wind speed of 6.7 m/s, 4% and another area find out wind speed also totaled 6.7 m/s, but only 3% at that time. The distribution curve shows the percentage for a particular area at each wind speed.

2.2.2 Average wind speed

Manipulation of wind speed data observed daily has been done to obtain average wind speed for every month and year. The graph for this average wind speed is plotted for area of Kuala Terengganu. It can give an early description of the potential of wind power in the East Coast of Malaysia.

2.2.3 Weibull Distribution Parameter Estimation

This distribution is often used to adapt wind speed data. It can be explained by the Probability Density Function for Weibull Distribution which has 2 parameters, the scale parameter c (c > 1) and the form parameter k (k > 0) as shown below [8].

$$f(v) = \begin{cases} \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^k} & v \geq 0 \\ 0 & v < 0 \end{cases} \tag{1}$$

From equation 1, the cumulative distribution functions can be derived as follows:

$$F\text{ (v)} = 1- e^{-\left(\frac{v}{c}\right)^k} \tag{2}$$

Where:

k = shape parameter c = scale parameter

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The least squared method has been used in this study to estimate the value of the parameter because this method is easy to understand and the probability function is uncomplicated [9]. Since this distribution is matched to wind speed data, the probability of zero wind speed is not calculated in the Weibull distribution in estimating the parameters k and c because it is considered as:

$$f(0) = 0$$

2.2.4 Least Square Method

Wind speed data is compiled by following several specific intervals as shown in Table 1.

Table 1. The wind speed distribution interval according to the observation data.

Interval	**$f_i = f(v_i)$**	**P_i**
0.0-0.8	f_1	f_1
0.9-1.7	f_2	$f_1 + f_2$
1.8-2.6	f_3	$f_1 + f_2 + f_3$
2.7-3.5	f_4	$f_1 + f_2 + \ldots + f_4$
3.6-4.4	f_5	$f_1 + f_2 + \ldots + f_5$
4.5-5.3	f_6	$f_1 + f_2 + \ldots + f_6$
5.4-6.2	f_7	$f_1 + f_2 + \ldots + f_7$

From equation 2, F(v) is the the cumulative distribution functions, while from Table 1, P_i is the cumulative frequency value of the wind speed. Since this wind speed data is distributed with the Weibull Distribution, then:

$$P_i = F(v) \quad (3)$$

$$P_i = 1 - e^{-\left(\frac{v}{c}\right)^k} \quad (4)$$

From equation (4), equation (5) is obtained:

$$\ln(-\ln(1-P_i)) = k \ln v - k \ln c \quad (5)$$

Equation (6) is an equation of linear form:

$$y = ax + b \quad (6)$$

Where:

$y = \ln(-\ln(1-P_i))$; $x = \ln v$; $b = -k \ln c$

Weibull parameters k and c can be obtained by plotting a graph between:

$$\ln(-\ln(1-P_i)) \text{ against } \ln v$$

The values of parameters a and b can be obtained from the graph where the value a = k, where k is the gradient value of the graph. Whereas the value of c can be calculated from the value of y-intercept. Referring to equations (5) and (6), then

$$a = k \quad (7)$$

$$b = -a \ln c$$

$$c = e^{(-b/a)} \quad (8)$$

2.2.5 Estimation Average Wind Power Density

Wind power density is given by:

$$P = 1/2\,\rho\, v^3 \quad ;\ \rho = 1.16 \text{ kg / m}^3 \tag{9}$$

Where:

P = Wind power density (W/m^2) ; ρ = Air density (kg/m^3); v = Wind speed (m/s)

Therefore, the average power density can be calculated using the parameters k and c from equations (7) and (8).

$$(v^3)_m = \frac{\Gamma(1+\frac{3}{k})}{\Gamma^3(1+\frac{1}{k})}\,(v_m)^3 \tag{10}$$

Where:

v_m = Average wind speed (m/s) Γ = Gamma function

The following v is obtained for the mean wind speed,

$$v_m = c\,\Gamma(1 + 1/k) \tag{11}$$

From equations (10) and (11), the average wind power density for the Weibull function becomes [10]:

$$P_w = 1/2\,\rho\, c^3\,\Gamma\,[1+3/k] \tag{12}$$

2.2.6 Wind Direction Analysis

There are two parameters to be considered in this study which is parameters θ and r. Two equations required in the analysis of wind directions are given by equations (13) and (14).

$$\theta = \arctan\left(\frac{\sum \sin\theta_i}{\sum \cos\theta_i}\right) \tag{13}$$

$$r^2 = \left(\frac{\sum \sin\theta_i}{N}\right)^2 + \left(\frac{\sum \cos\theta_i}{N}\right)^2 \tag{14}$$

Where:

θ_i = value of wind direction observation N = Number of observations
θ = Average wind direction r = Consistency of direction

The parameter value θ is the average value of wind direction obtained within a given period. The data collected for wind speed direction is the angle value in degrees. θ_i values are the observed angle values for each day. The parameter value of r shows the consistency of wind direction. The value of r lies between the values 0 and 1 [9].If the value is equal to 1, then it indicates the direction of the wind is consistent. However, if the value is approaching zero, it shows the direction of the wind is always variable.

3. Results and Discussions

3.1 Frequency distribution of wind speed

In general, for the year 2017, the most frequently wind speed is at 0.9-1.7 m/s and 1.8 – 2.6 m/s. Both intervals contain more than 85% of the wind speed over the year that is 40.8% and 45.8% respectively while strong hurricane with wind speed of about 5.4 m/s, was very rare with less than 1 % over the year 2017.

The results of the analysis show that during wind blows Northeast Monsoon, wind speed frequency is more likely to scatter in high wind speed at 1.8-2.6 m/s especially in month November, December, January and February. Meanwhile, current wind blowing of Southwest Monsoon, wind

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speed are more likely to be wind at speed of 0.9-1.7 m/s and 1.8-2.6 m/s which are slightly slower than wind speed during the Northeast Monsoon wind as shown in Figure 1.

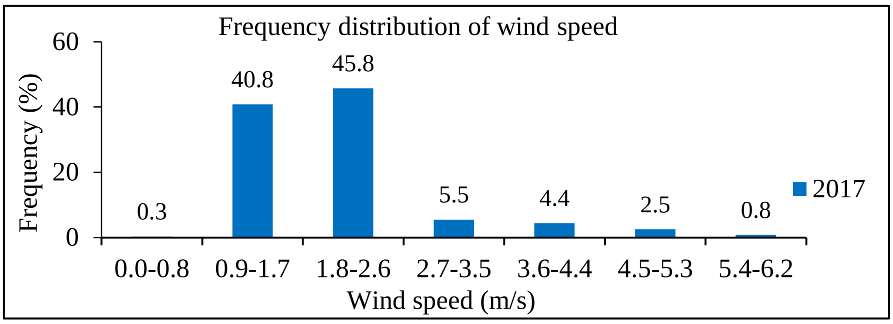

Figure 1. Average wind percentage for 2017.

3.2 Average Wind Speed

Average wind speed is an important element in this study. A high average wind speed can provide a high expectation of wind power potential. From the analysis, it was found that wind speed in Kuala Terengganu showed a high average wind speed at the beginning of the year and decreased in mid-year and increased again at the end of the year as shown in Figure 2. Highest wind speed is achieved at month October, December, January and February. The average annual wind speed does not indicate high wind speed at 2.1 m/s for 2017.

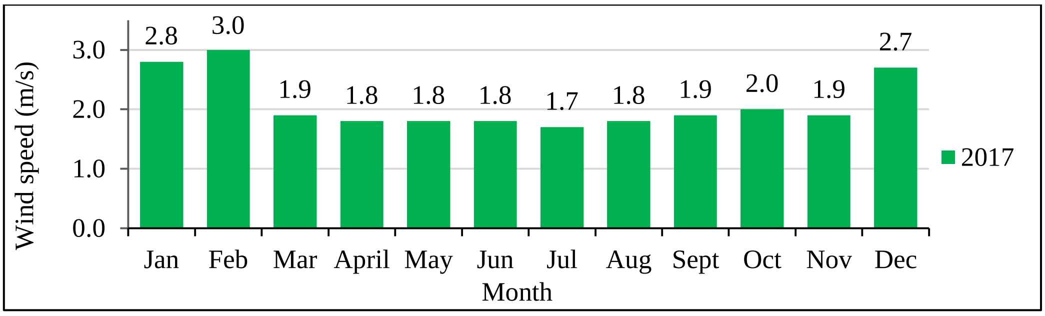

Figure 2. Average monthly wind speed graph for 2017.

3.3 Estimation Average Wind Power Density

The average annual wind power density will give an overview of wind power throughout the year with the potential to generate energy. Using the value of the shape parameters, k and scale parameters, c obtained using the estimation of the Weibull Distribution parameter, the average wind power density per month can be estimated. Figure 3 shows a monthly potential wind power graph for 2017. In general, the average wind power density is greater than 8 W/m^2. In 2017, the average approximation of wind power density is 43.42 W/m^2. This is because there are many estimates of wind power estimates that cannot be calculated. There was some countless wind power in a given month in 2017 because it had a small wind speed variation during the month and caused insufficient data to run regression analysis to obtain the value of parameter c and parameter k (month of March until November). In addition, it cannot be calculated because the value of parameter c and the parameter k obtained is so small.

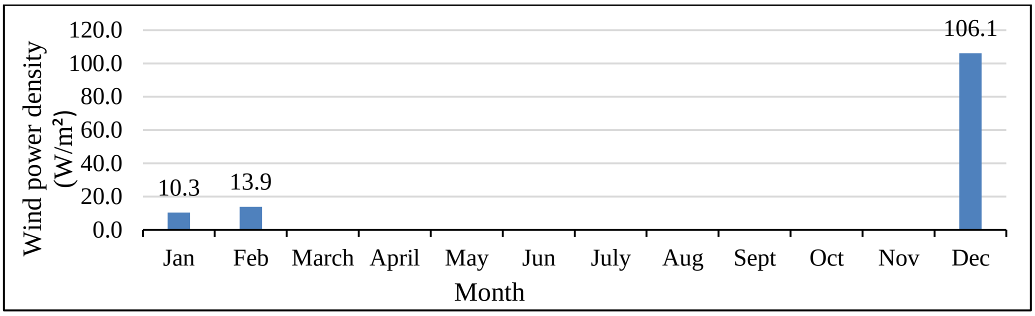

Figure 3. Graph of monthly potential wind power for 2017.

3.4 Analysis of wind directions

Average value of wind direction and direction consistency value was calculated and shown in Table 2. Based on Table 2, the annual value of the parameter r is so low for year 2017. This shows that the wind direction in Kuala Terengganu in 2017 is irregular. In 2017, it shows a relatively consistent and stable wind direction in July, August and September.

Table 2. Average wind speed direction and parameter values.

March	62	0.03226
April	87	0.03333
May	338	0.03226
Jun	341	0.03333
July	28	0.03226
August	21	0.03226
September	28	0.03333
October	319	0.03226
November	319	0.03333
December	83	0.03226
Annual	164	0.03290

4. Conclusion

The daily wind speed pattern for year 2017 can be seen that it has a corresponding pattern where it shows high wind speed at the beginning and end of the year. The wind speed frequency is also variable for the winds of the Northeast Monsoon and is almost constant during the south monsoon of the Southwest Monsoon and the Monsoon Transition. The equations obtained from the Weibull Distribution are helpful in determining the potential of wind power in Kuala Terengganu. Overall, the potential of wind power in Kuala Terengganu is not too large. The annual average for year 2017 is 2.1 m/s. There are several factors that affect wind speed such as monsoon wind, location and speed measuring device. Wind power is high during the Northeast Wind Monsoon season. Energy from the wind can be produced better for the exposed area with the Northeast monsoon wind. Meanwhile, the power of electricity maybe inadequate during the Southwest Monsoon season, but if photovoltaic panels are used for hybrid electric power generation, it is possible to obtain good economic benefits.

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References

[1] Albani, A. & Ibrahim, M.Z. 2013. A statistical analysis of wind power density based on the Weibull and Rayleigh models 9(4), 393–406.
[2] Sanusi, N., Zaharim, A. & Mat, S. 2016. Wind energy potential: A case study of Mersing, Malaysia. ARPN Journal of Engineering and Applied Sciences, 11(12), 7712–7716.
[3] Ong H.C., Mahlia T.M.I., Masjuki H.H. 2011. A review on energy scenario and sustainable energy in Malaysia Renewable and Sustainable Energy Reviews, 15, 639-647.
[4] Borhanazad, H., Mekhilef, S., Saidur, R. and Boroumandjazi, G. 2013. Potential application of renewable energy for rural electrification in Malaysia. Renewable Energy. 59, 210-219.
[5] Muzathik, A. M., Nik, W. B. W., Ibrahim, M. Z. & Samo, K. B. 2009. Wind Energy at Kuala Terengganu, Malaysia. International Annual Symposium on Sustainability Science and Management, 297–303.
[6] Islam, M.R., Saidur, R. & Rahim, N.A. 2011. Assessment of wind energy potentiality at Kudat and Labuan, Malaysia using Weibull distribution function. Energy. 36(2), 985-992.
[7] Albani, A. & Ibrahim, M. Z. 2013. Preliminary Development Of Prototype Of Savonius Wind Turbine For Application In Low Wind Speed In Kuala Terengganu, Malaysia. International Journal of Science &Technology Research, 2(3), 102–108.
[8] Razali, A. M., Sapuan, M.S., Ibrahim, K., Ismail, A.R., Zaharim, A. & Sopian, K. 2009. Fitting of Weibull Distribution to Study Wind Energy Potential in Theory and Method of Analysis. Recent Advances in Applied Mathematics, 284–287.
[9] Sopian, K., Othman, M. Y. & Wirsat, A. 1995. The wind energy potential of Malaysia. Renewable Energy, 6(8), 1005–1016.
[10] Celik, A. N. 2003. A statistical analysis of wind power density based on the Weibull and Rayleigh models at the southern region of Turkey. Renewable Energy, 29, 593–604.