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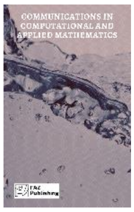

Investigation of Wind Power Potential in Equatorial Area from the Meteorological Data Measurement in Universiti Tun Hussein Onn Malaysia, Johor

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Abstract: Renewable energy has an increasing role in achieving the goals of sustainable development, energy security and environmental protection. As a tropical country, Malaysia has significant wind resources, but a very limited monitoring network. Meteorological data are available in more locations, but analyses of these data are limited. This work aims to investigate the potential renewable energy such as wind power using recent meteorological data collected in UTHM Johor, Malaysia. The analysis of wind energy potential was evaluated by means of few key variables such as temperature, humidity, wind speed, wind direction and pressure in order to estimate wind power energy. The average power, the optimum wind speed for a wind turbine as well as power output characteristics are determined subsequently. On the other hand, wind speed and wind direction statistics are computed based on the available meteorological data collected with respect to a diurnal and monthly basis. The outcome of this work should provide critical information on the potential of alternative renewable energy in tropical area of Malaysia, specifically in the Southern region.

Keywords: Renewable energy; Wind energy; Sustainable development; Southern Peninsular Malaysia

1. Introduction

Nowadays, the electricity demand rises each days. Major secondary source to generate electricity are biomass, hydropower, solar power and wind force. Conventional or primary source such as coal and fossil fuels (petroleum and natural gas) are depleting throughtout the years of usage [1]. As an alternatives, the propagation of electricity through renewable sources has gathered momentum over the final few years. Renewable energy had brought out to engineering world as alternative for the power energy sources and other ways on how to generate electricity for our future generation. Renewable energy have smaller impact on the environment compared to fossil fuels, which produces pollutant such as greenhouse gases as a by-product leading to climate change [2]. Renewable energy is the one of natural energetic processes that can be harnessed with little contamination.

Kuala Lumpur is the capital city in Malaysia, although the adminis-trative seat of government moved in 1999 to the newly designed Federal Territory of Putrajaya. The total Malaysian land mass is around 329,845 square kilometers [3]. As a tropical country situated along the equator, Malaysia has a wide range of energy sources such as wind resources. Malaysia are located at the equatorial region with has an average wind power of 400 MJ/m² – 600 MJ/m² per month so it has a promising potential of wind energy to establish large scale wind power but this energy still at the infancy stage due to one major problem that is the high cost of installation and mainte-nance [4]

Malaysia is known as the equatorial region and climate by the mon-soons, the potential for wind energy to collect the data speed in Malaysia depending on the availability of wind that the differences with a specific location. There are two types of monsoon that occur in Malaysia, which is Northeast monsoon and Southwest monsoon. The Northeast monsoon occurs when the wind blows from Asia central to South China Sea through Malaysia and change to Austral-ia between the month of November and March while the Southwest monsoon occurs when the wind from Australia blows across the Sumatra Island and move to the Strait of Malacca between May and September [5].

This study are focused on utilize wind energy to generate electricity based on wind speed and wind direction. Section 2 presents the general theory of wind energy and Weibull parameters used to de-termine the model for analyses. Section 3 deals with the specifica-tion of the instrument used to measure wind speed and details of data set. Section 4 discuss the result of this study while Section 5 draws the conclusion.

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2 General Theory of Wind Energy Assessment

Earth rotation causes air between 30˚ N and 30˚ S of the equator to move at the direction of southwest in the northern hemisphere and northwest direction in the southern hemisphere. This phenomenon called the Coriolis effect. The trade winds is the moving air in the direction of east to west. Intense solar heats up the trade winds in the Inter-Tropical Convergence Zone (between 5˚ N and 5˚ S of the equator) creating a thrusting air upwards into the upper atmos-phere. The rised air moves toward the poles and sink back toward the Earth's surface near the 30˚ N and 30˚ S latitudes [4], [6]. Ener-gy output of wind energy conversion system predicted using statictical model of wind speed frequency distribution by analyzing wind speed and direction by using Weibull parameters [7].

Wind energy resource can be classify into few category based on wind speed to estimate its wind power density as shown in Table 1.

Table 1 Classification of wind energy resource [1]

Wind resource category	Wind class	Wind speed (m/s)	Wind power density (W/m^2)
Poor	1	3.5-5.6	50-200
Marginal	2	5.6-6.4	200-300
Moderate	3	6.4-7.0	300-400
Good	4	7.0-7.5	400-500
Excellent	5	7.5-8.0	500-600
Excellent	6	8.0-8.8	600-800
Excellent	7	Above 8.8	Above 800

Wind speed means is the speed that has a certain speed at which air is making a motion relative to the earth's surface. The wind power density, P determine based on the air velocity, V and density of air, ρ given by equation [8]:

$$P = \frac{1}{2}\rho V^3 \quad (1)$$

The density of air, ρ can be calculated from:

$$\rho = \frac{p}{RT} \quad (2)$$

where p is the air pressure (kg/m^3), R is the specific gas constant (J/kg K) and T is the absolute temperature (K). The value of R is 287.05 J/kg K for dry air.

The variation of wind speed are characterized by two Weibull distribution functions which are the probability density function, $f(v)$ and the cumulative distribution function, $F(v)$ [1], [6], [9], [10]. Probability density function represent the percentage of time for the wind flows with a specific wind speed, expressed as:

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^k\right] \; (k > 0, v > 0, c > 0) \quad (3)$$

where c is the Weibull scale parameter, k is the dimensionless Weibull shape parameter and v is the wind speed. Cumulative distri-bution function also known as cumulative density function or distri-bution function where it indicates the percentage of time over the wind speed is equal or lower than the wind speed, v. The function is expressed as:

$$F(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^k\right] \quad (4)$$

where $v \geq 0$ is the wind speed (m/s), $k > 0$ is a shape parameter (dimensionless) and $c > 0$ is a scale parameter (m/s). Mean wind speed, $\bar{v}$ and standard deviation, σ is used to estimate the Weibull parameter of c and k.

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} \; (1 \leq k \leq 10) \quad (5)$$

$$c = \frac{\bar{v}}{\Gamma(1 + 1/k)} \quad (6)$$

The mean wind speed is expressed by

$$\bar{v} = c\Gamma(1 + 1/k) \quad (7)$$

or

$$\bar{v} = \frac{1}{n}\sum_{i=1}^{n} v_i \quad (8)$$

The standard deviation function is given by

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(v_i - \bar{v})^2 \quad (9)$$

3.0 Methodology

The wind speed data was collected at Universiti Tun Hussein Onn Malaysia (UTHM) with latitude and longitude approximately 1°51' N and 103°05' E from August 2015 until July 2016 (1 year). Data logging interval was set every 1 hour. Equipment that used to record the data is wind speed smart sensor model S-WSA-M003. The instrument provides average wind speed over logging interval and highest 3 second gust during the logging inter-val. The detail specification of wind sensor as shown in Table 2.

Table 2 Wind sensor specification

Range	0 to 45 m/sec (0 to 100 mph)
Accuracy	±1.1 m/sec (2.4 mph) or ±4% of reading, whichever is greater
Resolution	0.38 m/sec (0.8 mph)
Starting Threshold	≤ 1 m/sec (2.2 mph)
Housing	Three cup polycarbonate anemometer of modified Teflon bearings and hardened with beryllium shaft with ice shedding design.

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4.0 Result and Discussions

High wind speeds can be observed during 1300 hours to 1800 hours period with the maximum mean wind speed of 2.2778 m/s peaked at 1500 hours. After that, the value of mean wind speed droped below 2.0 m/s. This diurnal mean wind speed pattern is shown in Figure 1.

Diurnal wind speed variation pattern occurs due to the differential heating of the earth's surface during the daily radiation cycle [4], [9]. Typical of the diurnal pattern is wind speeds increase during the day with wind speeds, low during the hours from mid-night to sunrise.

The monthly mean wind speed reached above 2.0 m/s at February and August with velocity of 2.1406 m/s and 2.1720 m/s repectively as shown in Figure 2. February and August is the month before equinox month, March and September. Equinox is where the equator plane of the earth pass through the centre of the sun. The lowest monthly mean wind speed is at November with velocity of 1.4585 m/s. However study conducted in Mersing [5] does not show significant value of monthly wind speed rises on the month February and August.

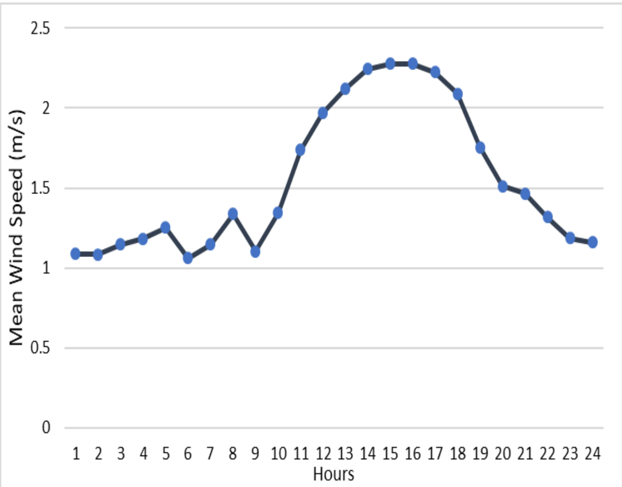

Figure 1 Diurnal variation of mean wind speed with hours

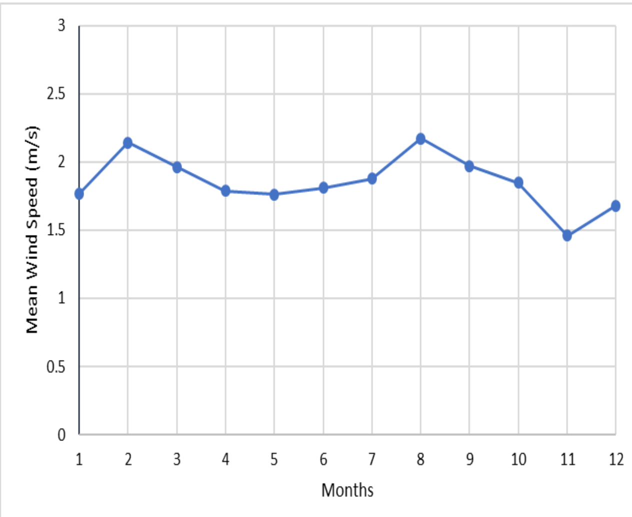

Figure 2 Monthly mean wind speed in one year at UTHM, Johor Malaysia

Highest value of mean power is in February for all of the height variation with the value of 104.9323 W/m^2, 419.7292 W/m^2 and 1165.9143 W/m^2 for the height of 3 m, 6 m and 10 m respectively. The lowest determined mean power is in the month of November with value of 36.6989 W/m^2, 146.7955 W/m^2 and 407.7652 W/m^2 for the height of 3 m, 6 m and 10 m respectively. Greater height has more wind power potential, compared as shown in Figure 3.

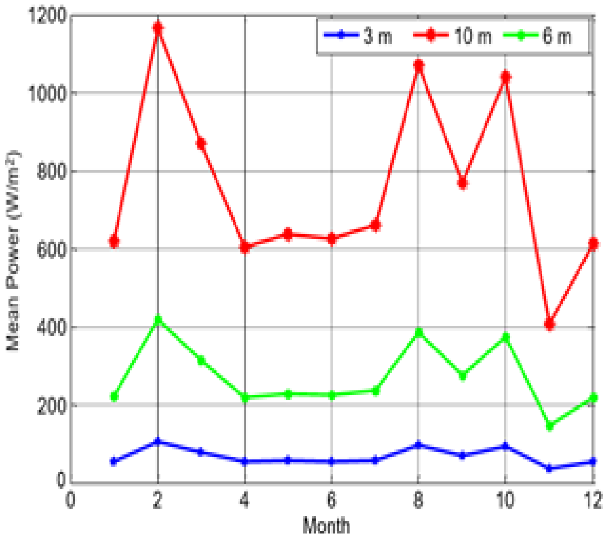

Figure 3 Mean power derived from wind speed

Using Weibull cumulative distribution function a graph of cumulative frequency wind speed for UTHM was plotted in Figure 4. Cumulative frequence of wind speed with range of wind velocity be-tween 0.0 m/s and 2.0 m/s has percentage value of 87.4315%. Above 7.0 m/s, the cumulative frequency of wind speed is 0.0011%. Point of interest, UTHM, has low overall wind velocity with value of lower than 2.0 m/s most of the time.

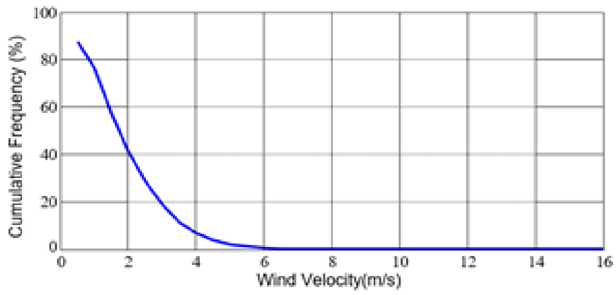

Figure 4 Cumulative frequency distribution of wind speed

The highest recorded value of wind speed at UTHM is 11.840 m/s and the lowest value of wind speed was 1.010 m/s. Weibull proba-bility distribution function for the highest wind speed is 2.2645 m/s at density of 0.35 with derived standard deviation and variance of 1.1133 and 1.2225 respectively.

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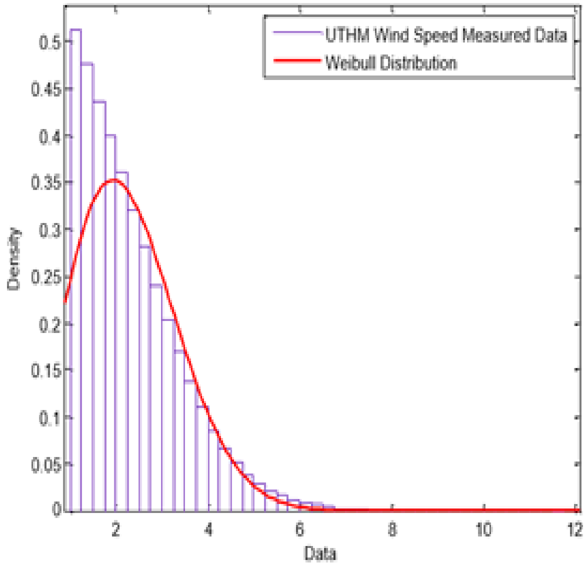

Figure 5 Probability density distribution of wind speed derived from the weather station for 1 year at UTHM, Johor Malaysia

5.0 Conclusions

Wind power potentials over Johor, Malaysia were examined in this paper. The data meteorology are taken from the Automatic Weather Station and then analyzed. The conclusion of this project is proposed work aims to investigate the potential renewable energy such as wind power using recent meteorological data collected in UTHM, Johor Malaysia. The analysis should evaluate the potential for using the key variables of temperature, humidity, wind speed, wind direction, rainfall and pressure to estimate wind generation power. In addition, Malaysia has a strong potential to build large scale wind energy due to its location. The average power, the optimum wind speed for a wind turbine as well as power output characteristics will be determined subsequently.

On the other hand, wind power energy will be predicted based on the available meteorological data with respect to a diurnal and seasonal variations as well as monthly basis. The outcome of this work should provide critical information on the potential of alternative renewable energy in tropical area of Malaysia, specifically in the Southern region.

Wind speed are peaked at the month of February and August with mean value of 2.1406 m/s and 2.1720 m/s repectively while achieve very low velocity at month of November with the mean value of 1.4585 m/s. From the results, the average of wind speed recorded ≈ 2.0 m/s. We can conclude that UTHM has a poor potential of wind energy to be extracted for electricity generation. However, wind power has higher energy density at higher elevation height as shown in Figure 3. To maximize the extraction of wind energy, wind turbine must install at higher places. Diurnal statistics of wind speed also shown that wind velocity are higher during the day compare to night due to differential heating of earth surface.

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