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Performace of Wind Turbine Based on Wind Speed Data and Turbine Tower Height in Kangar, Northern Malaysia

I. Daut, M. Irwanto, Y.M. Irwan, N. Gomesh, N. S. Ahmad

Cluster of Electrical Energy and Industrial Electronic Systems Universiti Malaysia Perlis (UniMAP), Malaysia

Abstract: This paper presents an analysis of the wind speed characteristic in Kangar, Northern Malaysia. The Weibull distribution function is applied to analyze the wind speed characteristic and used to calculate the wind power generation potential. The wind power and energy as function of tower height are presented and analyzed in this paper. The result shows that during fifteen days (1st March to 15th march 2011), the average hourly wind speed is 2.252126 m/s, based on the analysis of the Weibull distribution function, the wind speed of 2.03 m/s has the highest probability density, exactly is 37.99%, it is an important information to choose a suitable wind turbine for a wind power generation. According to the wind turbine applied in this research, when the wind speed is below 2 m/s or above 16 m/s, the output power is zero and the rotor can not be loaded. At its nominal speed of 8 m/s, the power output is at the rated value of 500 W. During the observation condition, on the 11 March 2010, the average wind turbine voltage is 7.1 V during the day time and 1.3 V during the night time. On the 12 March to 15th March 2010, the wind speed gives a big energy potential to generate the wind turbine, therefore the average wind turbine voltage 31 V during the day time and 20.3 V during the night time.

Key words: Wind speed; Weibull distribution function; Wind power generation.

INTRODUCTION

Renewable energy has an increasing role in achieving the goals of sustainable development, energy security and environmental protection. Nowadays, it has been recognized as one of the most promising clean energy over the world because of its falling cost, while other renewable energy technologies are becoming more expensive (Aynur, 2010; Ahmed O, 2010).

Wind energy is one of renewable energy which produced by continuously blowing wind and can be captured using wind turbines that convert kinetic energy from wind into mechanical energy and then into electrical energy (Alam HM, 2010). Today, wind energy is widely used to produced electricity in many countries such as Denmark, Spain, Germany, United States, and India (Ahmed SA., 2010).

A lot of researchers have been studying the wind speed characteristics and its potential as a wind power generation in many countries worlwide. Six kinds of numerical methods for estimating Weibull parameters were reviewed by (Tian PC., 2010) i.e. the moment, empirical, graphical, maximum likelihood, modified maximum likelihood, and energy pattern factor method. The result showed that the maximum likelihood, modified maximum likelihood and moment methods present relatively more excellent ability throughout the simulation test. From analysis of actual data, it is found that if wind speed distribution matches well with Weibull function, the six methods are applicable, but if not, the maximum likelihood method performs best followed by the modified maximum likelihood and moment methods, based on double checks including potential energy and cumulative distribution function. Wind speed and direction at 20 m and 30 m above ground level and in the Gulf of Tunis were studied by (Dahmouni, 2010) during 2008. The obtained results can be used to perform wind park project and confirm that the Gulf of Tunis has promising wind energy potential. A new formulation for the turbine-site matching problem was presented by (Albadi MH, 2010), based on wind speed characteristics at any site, the power performance curve parameters of any pitch-regulated wind turbine, as well as turbine size and tower height. The results revealed that higher tower heights are not always desirable for optimality.

Corresponding Author: I. Daut, Cluster of Electrical Energy and Industrial Electronic Systems Universiti Malaysia Perlis (UniMAP), Malaysia.

This paper presents analysis of the wind speed characteristics in Kangar, Northern Malaysia. The Weibull distribution function is applied to analyze the wind speed characteristic and used to calculate the wind power generation potential. The wind power and energy as function of tower height are presented and analyzed in this paper. The effect of wind speed on the performance of wind turbine is observed and analyzed.

Methodology:

Research Location Description:

Kangar is Perlis's capital, Northern Malaysia. Perlis (6^0 $29^'$ N , 100^0 $16^'$ E) has about 795 square kilometers land area, 0.24% of the total land area of Malaysia, with a population about 204450 people (Daut I, 2009), as shown in Fig. 1. In this research, weather station and wind turbine are installed in Kangar, exactly in front of Electrical Energy and Industrial Electronic Systems Cluster (EEIES cluster), Universiti Malaysia Perlis (UniMAP), as shown in Fig. 1 and 2.

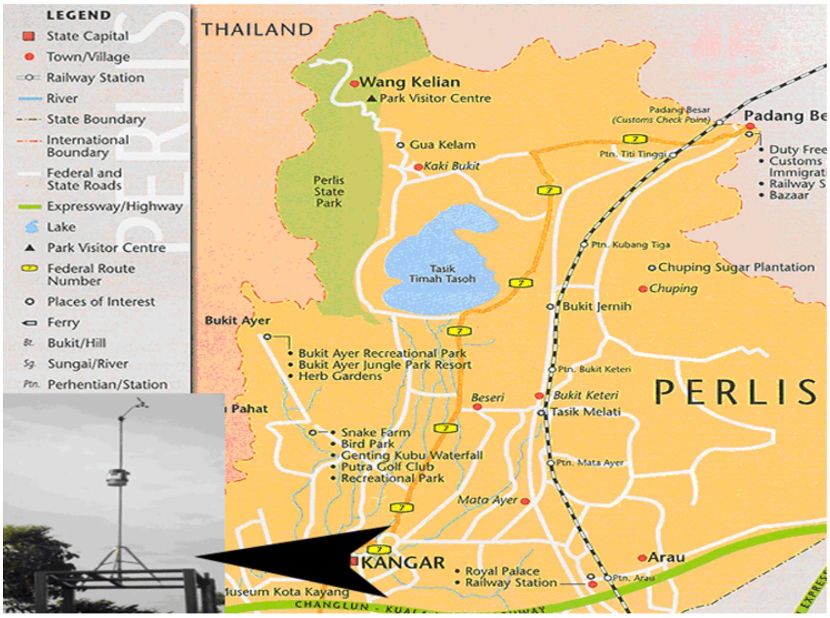

Fig. 1: Weather station is installed in Kangar, Northen Malaysia.

Fig. 2: A wind turbine is installed in front of EEIES cluster, Universiti Malaysia Perlis.

Weibull Distribution:

There are several probability density functions (pdf), which can be used to present the wind speed frequency curve. The Weibull distribution is the most commonly used statistical distribution for representing wind speed data. This function has the advantage of making it possible to quickly determine the annual wind energy production of a given wind turbine.

The probability density function *f*(v) indicates the percent of time for which the wind flows with a specific wind speed. It is expressed as (Aynur, 2010; Dahmouni, 2010).

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{1}$$

where *V* is the wind speed, *C* is a Weibull scale parameter and *K* is a dimensionless Weibull shape parameter.

The cumulative distribution function *f*(v) is also called the cumulative density function or simply the distribution function, it gives the percent of time that the wind speed is equal or lower than the wind speed *V*. It is expressed by the integral of the probability density function.

$$F(v) = \int_0^v f(v)\, dv = 1 - \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{2}$$

In order to estimate Weibull *K* and *C* parameters, numerous methods has been proposed over last few years. In this study, the two parameters of Weibull are determined using mean wind speed ($\bar{v}$) and standard deviation (σ) (Aynur, 2010; Tian, 2010; Gokcek, 2007).

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} \qquad (1 \le k \le 10) \tag{3}$$

$$c = \frac{\bar{v}}{\Gamma(1 + 1/k)} \tag{4}$$

Wind Power Density:

For a period of measurement the mean wind power density (the available power of wind per unit area) is given by the following expression (Dahmouni, 2010)

$$\bar{P} = \frac{1}{2}\rho \bar{v}^{3} \tag{5}$$

where ρ is the standard air density (ρ=1.225 Kg/m^3 dry air at 1 atm and 15 ^{0}C).
The wind energy density for a period of time can be calculated as

$$E = \bar{P}.T \tag{6}$$

where *T* is the time period. For the annual wind energy density estimation the value of 8640 h is used.

Wind Turbine Output:

The power curve of a pitch-regulated wind turbine is characterized by three speeds: the cut-in, nominal and cut-out speeds. When the wind speed is below the cut-in speed (V_c), the output power is zero and the rotor can not be loaded. At its nominal speed (V_r), the power output is at the rated value (P_{rated}). In response to the power control mechanisms, the power output remains constant as wind speed increases until the cut-out speed (*Vf*), at which point the turbine will be turned off to prevent mechanical damage, it is given by:

$$P_e(v) = P_{rated} x \begin{cases} 0 & v < V_c \ or \ v > V_f \\ P_{asc} & V_c \le v \le V_r \\ 1 & V_r \le v \le V_f \end{cases} \tag{7}$$

RESULTS AND DISCUSSION

The most important part of the measured wind speed data is its characteristics. An evaluation of the data is needed to understand its characteristics. The characteristics can be evaluated from the daily wind speed, the wind speed distribution function, the mean wind power and energy density. The data is measured at the height of 10 m above ground level and become as an original value of estimation of the mean wind power and energy density for the other height.

Hourly Wind Speed:

The wind speed data is measured and logged every minute by weather station during fifteen days (1st March to 15th march 2011). During the days, the hourly wind speed fluctuates as shown in Fig. 3. The minimum hourly wind speed is 0.007407 m/s and occurs on 7 March 2011, 1.00 AM. The maximum hourly wind speed is 5.402263 m/s and occurs on 12 March 2011, 3.00 PM. The average hourly wind speed is 2.252126 m/s. The highest hourly wind speeds occur on 9th March to 14th March 2011, their values are above 2 m/s.

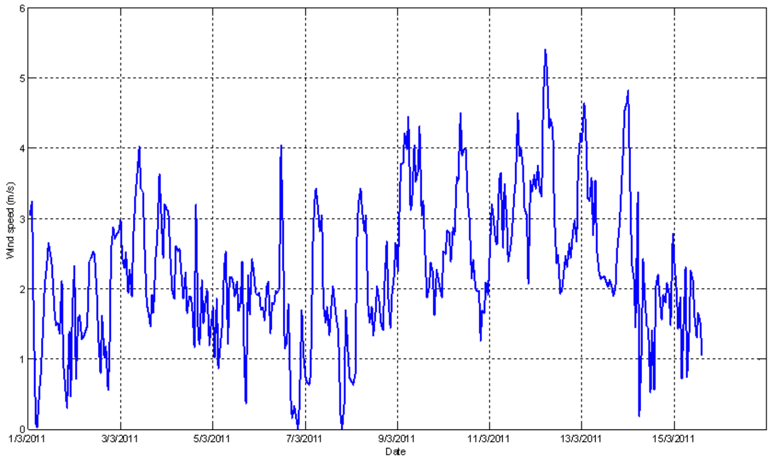

Fig. 3: Hourly wind speed.

Wind Speed Distribution Function:

Weibull distribution function is usually used to describe the wind speed distribution of a given location over a certain period of time. In this paper, the annual Weibull distribution function and its two parameters are derived from the available data and are shown in Fig. 4, and 5.

The result shows that during fifteen days is the windiest days which have the largest scale parameter, *C* of 2.541 and the highest shape parameter, *K* of 2.36, and its wind speed of 2.03 m/s has the highest probability density, exactly is 37.99%.

Wind Power and Energy Density:

The evaluation of the wind power and energy per unit area are importance information of wind power project assessment. During fifteen days, the wind speed data at 10 m above ground level is evaluated to obtain the wind power and energy density as shown in Fig. 6.

Fig. 6 shows the wind power and energy density as function of tower height. The tower height of 10 m above ground level is become as an original height and calculated the other tower height. From these tower heights, the wind power and energy density can be calculated. Fig. 6 shows that the higher tower height will produce the higher wind power and energy density.

Performance of Wind Turbine:

The wind speeds will effect on the performance of wind turbine. According to the data of wind turbine and the equation (7),when the wind speed is below 2 m/s, the output power is zero and the rotor can not be loaded. At its nominal speed of 8 m/s, the power output is at the rated value (P_{rated}) of 500 W. In response to the power control mechanisms, the power output remains constant as wind speed increases until the cut-out speed (16 m/s), at which point the turbine will be turned off to prevent mechanical damage. The performance of wind turbine is shown in Fig. 7.

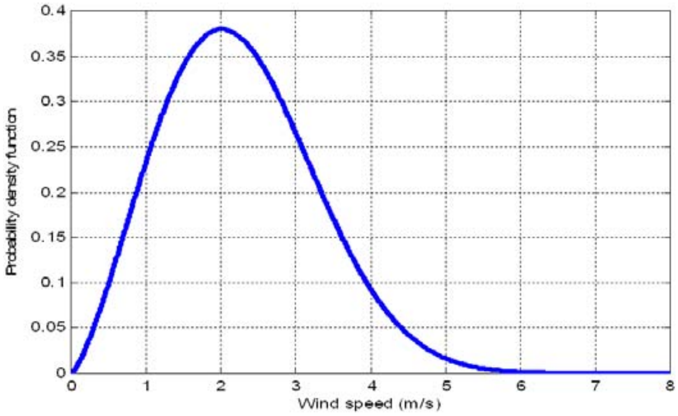

Fig. 4: Wind speed probability density.

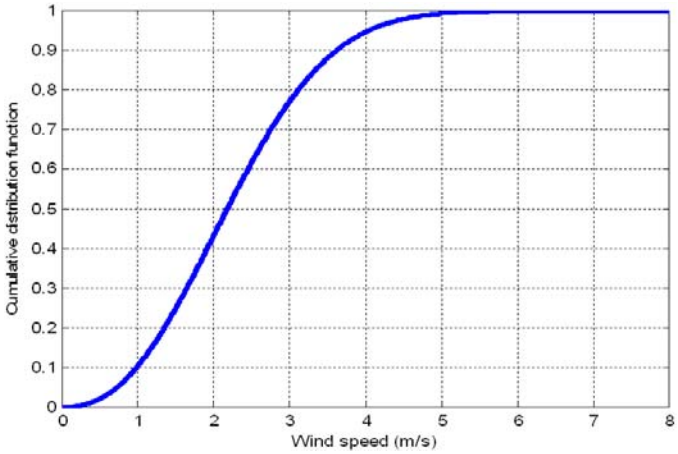

Fig. 5: Wind speed cumulative probability distribution.

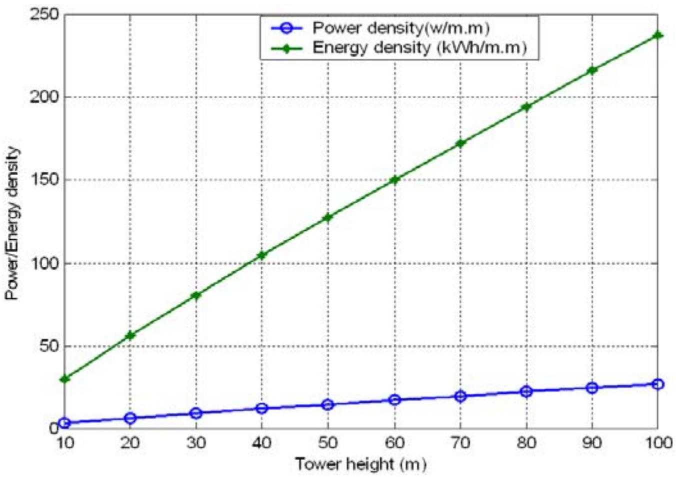

Fig. 6: wind power and energy density as function of tower height.

The effect of wind speed on the performance of wind turbine is observed during four days (11 March to 15th march 2011). The wind turbine voltage is measured and logged by electrocorder every minute as shown in Fig. 8. This observation data condition is divided by two parts, the first is during the day time and the second is during the night time. Based on Fig. 3 and Fig. 8, the wind speed and the wind turbine voltage are higher during the day time rather than during the night time. On the 11 March 2010, the average wind turbine voltage is 7.1 V during the day time and 1.3 V during the night time. On the 12 March to 15th March 2010, the wind speed gives a big energy potential to generate the wind turbine, therefore the average wind turbine voltage 31 V during the day time and 20.3 V during the night time.

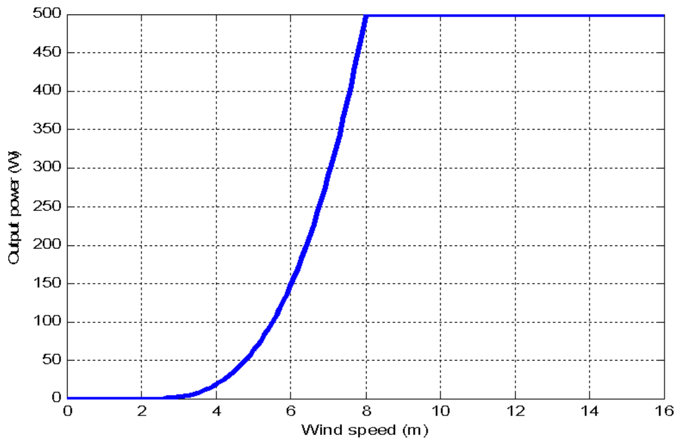

Fig. 7: Wind turbine output power.

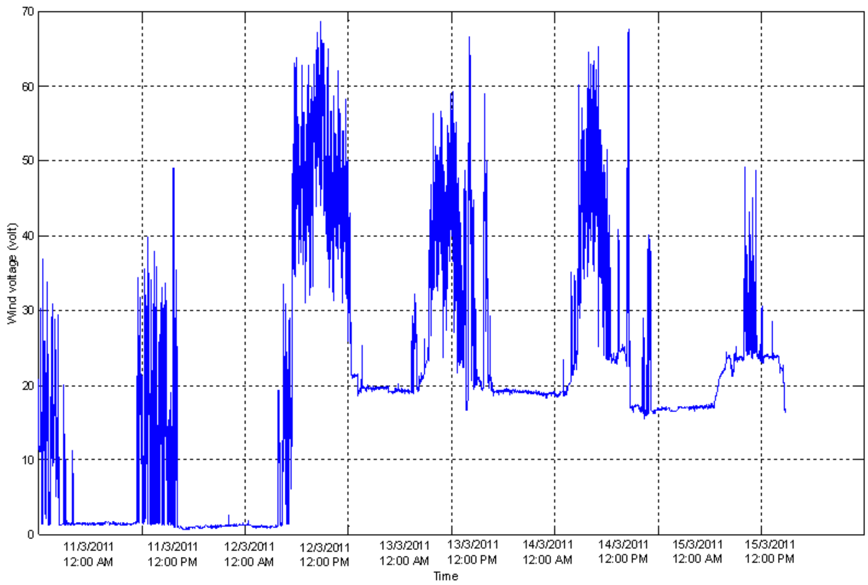

Fig. 8: Wind turbine voltage.

Conclusion:

In this study, the wind speed characteristics in Kangar, Northern Malaysia is analyzed. The following conclusions can be drawn from the result of the presented study:

The wind speed data is measured and logged every minute by weather station during fifteen days (1st March to 15th march 2011). The average hourly wind speed is 2.252126 m/s.

Based on the analysis of the Weibull distribution function, the wind speed of 2.03 m/s has the highest probability density, exactly is 37.99%, it gives an important information to choose a suitable wind turbine for a wind power generation.

The analysis result of the wind power and energy density as function of tower height show that the higher tower height will produce the higher wind power and energy density.

According to the wind turbine applied in this research, when the wind speed is below 2 m/s or above 16 m/s, the output power is zero and the rotor can not be loaded. At its nominal speed 8 m/s, the power output is at the rated value (P_{rated}) of 500 W. During the observation condition, on the 11 March 2010, the average wind turbine voltage is 7.1 V during the day time and 1.3 V during the night time. On the 12 March to 15th March 2010, the wind speed gives a big energy potential to generate the wind turbine, therefore the average wind turbine voltage 31 V during the day time and 20.3 V during the night time.

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