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INVESTIGATION OF WIND CHARACTERISTICS AND WIND ENERGY UTILIZATION OF KUALA TERENGGANU, PENINSULAR MALAYSIA

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ABSTRACT

The purpose of this paper is to study and estimate the wind characteristic and wind energy potential of Kuala Terengganu, which is located in the east cost region of Peninsular Malaysia. The wind speed data was collected during the period 2004–2007 for this study. The wind speed distribution curves of Kuala Terengganu were developed by using the Weibull and Rayleigh probability density functions. The average Weibull shape parameter k and scale parameter c were found as 1.76 and 3.21 m/s respectively for this period. The yearly mean wind speed in Kuala Terengganu was obtained as 2.9 m/s and monsoon season (November to March) mean wind speed was 3.9 m/s for the same period. The wind energy density of investigated site is lowest as 11.33 W/m^2 in June 2005 while it is highest as 154.02 W/m^2 in January 2007. The monthly average wind energy density and probability of wind to exceed of electricity generation wind speed 2.5 m/s were found as 40.12 W/m^2 and 0.30 based on Weibull distribution respectively.

Keywords: Wind speed, Wind energy density, Time factor, Weibull distribution

1.0 INTRODUCTION

Renewable energy technologies can bring social, environmental and economic benefits to our community. Our energy strategy should seek to maximize our city's own generation of renewable energy and aim to minimize the impacts on health and on local and global environment for meeting the essential energy needs of all those living and working in our city [1]. One of the renewable energy technologies and its uses are well suited to urban environments is wind power generation. As the energy yields of wind turbines have the cubic relationship with wind velocity, the wind speed increase could make wind turbines in favor of wind.

The wind represents a clean, abundant and inexhaustible energy source. Wind resources vary with the time of day, season, height above ground and type of terrain. Proper sitting in windy locations away from large obstructions enhances a wind turbine's performance. Wind energy gained importance after the rapid increase in world energy production through combustion of fossil fuels that have caused heat trapping "greenhouse gases" accumulation in the troposphere. In this regard, there is now a growing concern that our human activities are going to affect the climate of earth in the future.

Wind energy is considered one of the economic alternatives that meet the needs of modern societies by protecting the atmosphere from the adverse consequences of global warming. Malaysia, as a country, faces a high rate of population growth. The Malaysia economy has witnessed active growth in the last decades, and consequently, the demand for energy has also increased [2].

Annual average wind speeds of about 3 m/s are generally needed for grid-connected wind generating systems to be an economical resource. Annual average wind speeds of 3 to 4 m/s may be adequate for electrical or mechanical applications for water pumping, residential or small commercial loads [3]. These systems may be interconnected to the grid. They may be operated independent of the grid using battery storage to provide electric supply during times of low or no wind. The utilization of wind energy has been increasing around the world at an accelerating pace. However, the development of new wind projects continues to be hampered by the lack of reliable and accurate wind resource data in many parts of the world. Such data are needed to enable governments, private developers and others to determine the priority that should be given to wind energy utilization and to identify potential areas that might be suitable for development [4]. The distribution of wind speeds is important for the design of wind farms, power generators and other applications such as the irrigation.

To know if a specific site has a good wind resource, need to measure the wind speed and direction with an anemometer and direction gauge. Wind speed, wind direction, roughness of the terrain, seasonal cycles, air pressure or temperature and obstacles affect the amount of wind energy available at any site. Several anemometers mounted at different heights or at several locations will provide more detailed data and give any potential developer higher confidence. Recording data from the meters can be done on strip charts or computer data loggers. A good study of wind resources will include data from at least one year, but more years of data would be better.

2.0 ENERGY DEMAND

The State of Terengganu, Malaysia is situated at the South China Sea. The demand for energy and particularly for electricity is growing rapidly, because of social and economic development of the country. Figure 1 shows the final use for the overall energy consumed in Malaysia between 1980 and 2001 [5]. From this it can be seen that the energy use in all sectors has increased during this period. Importantly, the energy use for transport and industry has almost four times increased in this 20-year period, and continues to grow, representing around 80% of the overall primary energy use in 2001. Similar patterns can be seen in other industrialized and developing nations, showing energy use for transport and industry to be a significant and increasing problem. Despite this, there has been a 10% increase in the overall annual energy use in Malaysia since 1980.

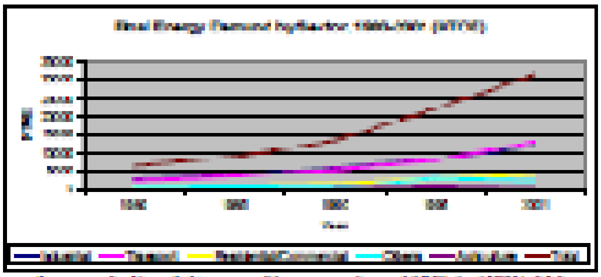

Figure 1. Final Energy Consumption 1980 to 2001 [5]

Figure 2 shows the contribution of the main primary energy carriers to the total energy consumption in Malaysia in 1995 and 2007 [6]. It can be seen that the use of fossil fuels (coal, oil and gas) accounted for 95% of the total Malaysia energy supply in 2007, which is an increase of 6.3% on the year 1995.

Figure 2. Malaysia Primary Energy Consumption in 1995 and 2007 [6]

The general increase in energy consumption and overall reliance on fossil fuels shown here are not unique to Malaysia. Global energy consumption is increasing, and this is particularly noticeable in the developing nations as they move towards industrialization. It is therefore important that, where new energy demands are created, these are met, where possible, by sustainable and non-polluting means, in order to stop the escalation of the already visible environmental effects of fossil fuel use. This alone, however, will not be enough to meet emissions targets, and reduce the environmental threat posed by the production of carbon dioxide and other pollutants. To achieve this, the current reliance on fossil fuels for all energy uses must be reduced, and, eventually, eliminated. Consequently, it will be necessary to re-evaluate the way in which energy is produced, distributed and used in Malaysia and worldwide. This, however, will not happen until less expensive, easily implemented, and equally reliable alternatives become available.

Further the government of Malaysia encouraging the use of renewable energy (RE) sources in her Ninth Malaysian Plan [7] as "The development and utilisation of RE will be further intensified in the Plan period. Towards this end, efforts will be continued to foster a more conducive environment to support the implementation of RE projects. RE sources such as standalone systems of solar hybrid will be developed while biomass based cogeneration will be expanded in the Plan period". In addition to this it mentioned further as "New sources of energy such as solar and wind will be developed with emphasis on utilising cost-effective technology as well as strengthening capacity building. In this regard, efforts will be undertaken to coordinate R&D activities of the various energy-related research centers. In addition, activities under the roadmap on solar, hydrogen and fuel cells such as technology development and knowledge sharing will be implemented while financing mechanisms will be explored. Initiatives to enhance local capabilities in the development of indigenous RE based technologies as new sources of growth will also be supported".

The purpose of this study is to investigate and evaluate the properties of the wind energy potential of Kuala Terengganu for a possible hybrid renewable energy system for electrical application located in the eastern region of peninsula Malaysia.

3.0 STUDY AREA AND MEASUREMENT

In this study, the wind speed and direction data were measured at ten minutes intervals by University Malaysia Terengganu Renewable Energy Research Center (UMT RERC) using NRG Symphonie Data Retriever in the Kuala Terengganu between the years 2004 and 2007. The UMT RERC station is located at 4°13.6′ N and 103°26.1′ E. All measurements in the wind observation station are recorded using the cup anemometer at a height of 20 m at mean sea level (18 m above the ground level). Figure 3 shows the location this chosen site.

Figure 3. Location of Kuala Terengganu wind observation station.

4.0 METHOD OF WIND ENERGY ESTIMATION

Knowledge of the wind speed frequency distribution is a very important factor to evaluate the wind potential in the windy areas. If ever the wind speed distribution in any windy site is known, the power potential and the economic feasibility belonging to the site can be easily obtained. Wind data obtained with various observation methods has the wide ranges. Therefore, in the wind energy analysis, it is necessary to have only a few key parameters that can explain the behavior of a wide range of wind speed data. The simplest and most practical method for the procedure is to use a distribution function. There are several density functions, which can be used to describe the wind speed frequency curve. The most common two are the Weibull and Rayleigh functions [8].

The Weibull distribution function which is a two parameter distribution can be expressed as

$$f(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} e^{-\left(V/c\right)^{k}} \tag{1}$$

where V is the wind speed, c is a Weibull scale parameter and k is a dimensionless Weibull shape parameter. In this study, the two parameters of Weibull are determined by using maximum likelihood method. The cumulative probability function of the Weibull distribution is given as follow.

$$F(V) = 1 - e^{-\left(V/c\right)^{k}} \tag{2}$$

Another distribution function used to the wind speed frequency is Rayleigh distribution. This distribution is a special case of the Weibull distribution in which the shape parameter k is 2.0. Probability density and cumulative function of Rayleigh distribution are given bellow,

$$f(V) = \frac{\pi}{2}\frac{V}{V_m^{2}} e^{-\left[\frac{\pi}{4}\left(V/V_m\right)^{2}\right]} \tag{3}$$

and

$$F(V) = 1 - e^{-\left[\frac{\pi}{4}\left(V/V_m\right)^{2}\right]} \tag{4}$$

where V is the wind speed and V_m is the mean wind speed.

The power of wind can be estimated by using the following equation (7):

$$P = \frac{1}{2}\rho \quad V^{3} \tag{5}$$

where ρ is mean air density, V is mean value of the wind speed and A is sweep area. The average wind energy density of a site can be expressed based on Weibull probability density function [9 and 10] as

$$E_D = \frac{\rho \quad c^{3}}{2}\frac{3}{k}\Gamma\left(\frac{3}{k}\right) \tag{6}$$

where ρ is mean air density, c is a Weibull scale parameter, k is a dimensionless Weibull shape parameter and Γ is a gamma function. The probability of wind to exceed a velocity of V_x is given by equation (7).

$$P\left(V > V_X\right) = e^{-\left(V_X/c\right)^{k}} \tag{7}$$

3.0 RESULTS AND DISCUSSION

The monthly mean wind speed variation during the period 2004–2007 at Kuala Terengganu region is given in Table 1. The highest monthly mean wind speed is determined as 5.20 m/s in January 2007 while the lowest mean wind speed 2.00 m/s is occurred in June 2005. Annual mean wind speed for a 4 year period is obtained as 2.85 m/s.

Table 1. Monthly average wind speeds between the years 2004 and 2007 in Kuala Terengganu, Peninsula Malaysia.

Month	Year				
	2004	2005	2006	2007	2004–2007
January	4.82	3.78	4.03	3.20	4.46
February	3.33	2.94	4.72	3.45	3.68
March	3.63	3.51	2.69	2.65	3.12
April	2.66	2.58	2.45	2.60	2.57
May	2.31	2.10	2.23	2.27	2.28
June	2.19	2.06	2.33	2.25	2.19
July	2.29	2.25	2.16	2.17	2.22
August	2.10	2.16	2.24	–	2.17
September	2.15	2.31	2.17	–	2.21
October	2.80	2.34	2.13		2.48
November	2.64	3.12	2.12	–	2.68
December	4.81	3.52	4.43	–	4.25
Annual Average	3.00	2.72	2.81	2.93	2.80

Table 2 shows monthly variation of Weibull parameters for Kuala Terengganu during the period 2004–2007. As seen from this table, Weibull shape parameter *k* varies between 1.27 and 2.68, while scale parameter *c* varies between 2.25 m/s and 3.83 m/s. The average values of Weibull shape parameters *k* and *c* are 1.76 and 3.22 m/s for the period 2004–2007, respectively.

The monthly average value of Weibull shape parameter *k* is between 1.47 and 2.15, while the monthly average value of *c* is between 2.45 m/s and 5.02 m/s. The lowest *k* value is in the month of December 2005 and the highest value is in the month January 2004. It can be seen that the highest *c* value is found in the month of January 2007 as 3.83 m/s.

Table 2. Monthly variations of Weibull parameters (*k* and *c*) for Kuala Terengganu, Malaysia.

Month/ Year	Weibull scale parameter *c* (m/s)				Weibull shape parameter *k*				Monthly Average	
	2004	2005	2006	2007	2004	2005	2006	2007	C	k
January	5.41	4.27	4.57	5.83	2.68	1.91	1.87	2.13	5.02	2.15
February	4.01	3.32	3.31	3.93	2.16	2.01	2.12	1.94	4.14	2.08
March	4.00	3.93	3.04	2.98	1.46	1.64	1.85	1.61	3.40	1.64
April	2.99	2.90	2.77	2.93	1.68	1.51	1.74	1.72	2.90	1.69
May	2.61	2.23	2.33	2.37	1.78	1.53	1.98	1.78	2.32	1.78
June	2.47	2.25	2.64	2.52	1.78	1.57	1.82	1.55	2.47	1.70
July	2.59	2.55	2.44	2.45	1.80	1.83	1.66	1.87	2.51	1.79
August	2.53	2.44	2.34	-	1.37	1.80	1.86	-	2.43	1.74
September	2.43	2.61	2.45	-	1.80	1.79	1.86	-	2.50	1.82
October	3.11	2.67	2.42	-	1.44	1.71	1.86	-	2.73	1.67
November	2.94	3.44	2.38	-	1.49	1.34	1.57	-	2.92	1.47
December	5.40	3.80	4.83	-	1.31	1.27	1.35	-	4.68	1.48
Annual Average	3.36	3.04	3.16	3.32	1.79	1.58	1.79	1.80	3.22	1.76

Comparison of probability density distributions of January 2004 according to observed field data with Weibull and Rayleigh functions for UMT RERC site is illustrated in Figure 4. It is seen from this figure that the peak probability value for Rayleigh probability distribution is found as 0.1540 on the wind speed of 4 m/s, while the peak value for Weibull probability distribution is determined as 0.1932 on the wind speed of 5 m/s and the peak value for field data probability distribution is determined as 0.1962 on the wind speed of 5 m/s.

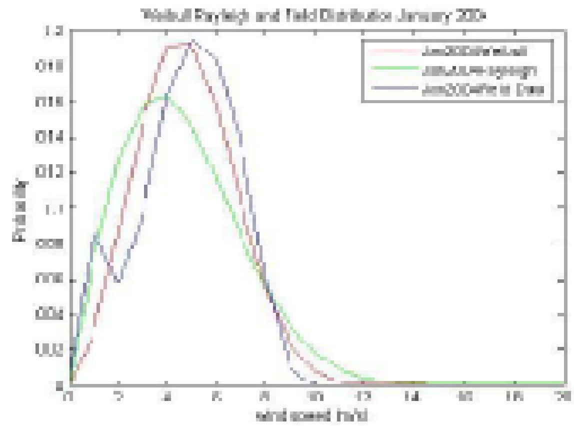

Figure 4. Comparison of probability density distributions of January 2004 according to Field data with Weibull and Rayleigh functions.

Figure 5 shows the annual variation of observed field data with Weibull and Rayleigh distribution for 2004 year in Kuala Terengganu. It clearly shows that Weibull and Rayleigh distribution are almost identical shape.

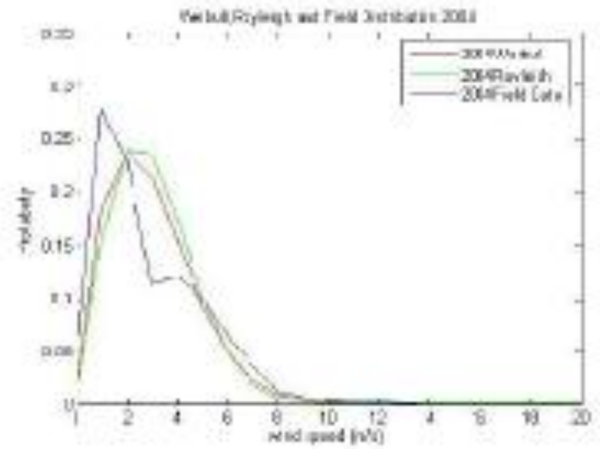

Figure 5 Comparison of observed and calculated probability density distribution for UMT RERC site at different year 2004.

A comparison of the seasonal Weibull probability density distributions in the UMT RERC site is shown in Figure 6. It is seen this figure that the highest peak probability value is obtained in the south west monsoon season as 0.30 on the wind speed of 2.0 m/s. The lowest peak probability value is found in the north east monsoon season as 0.175 on the wind speed of 3.0 m/s for the investigated site.

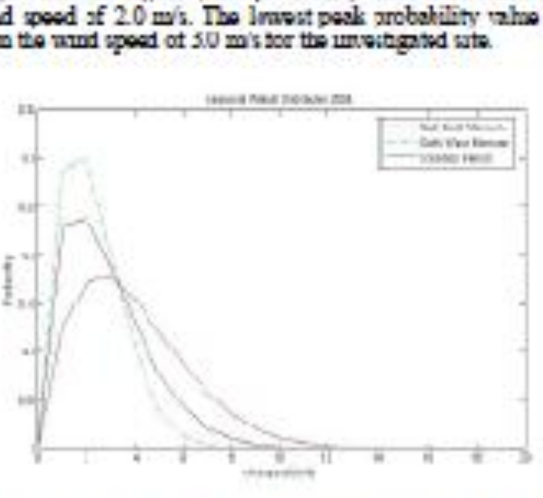

Figure 6. Comparison of seasonal wind speed frequency distributions in the investigated site.

The seasonal wind characteristics in Kuala Terengganu are given in Table 3. As seen from this table, the highest mean wind speed value with 3.90 m/s is determined in the north east monsoon season while the lowest value is in the south west monsoon season with 2.22 m/s. The Weibull shape parameter k varies between 1.54 and 1.74, while the scale parameter c varies between 2.49 and 4.37 m/s. The highest c value is found in the north east monsoon season and lowest value is in the south west monsoon season. The lowest standard deviation with 1.32 m/s is calculated in the south west monsoon season. The wind power of investigated site is lowest in south west monsoon season, while it is highest in north east monsoon season as 64.33 W/m^2. The highest time factor value with 0.68 is determined in the north east monsoon season while the lowest value is in the south west monsoon season with 0.37.

Table 3. Seasonal wind characteristics in Kuala Terengganu, Malaysia

Season	c (m/s)	k	V_m (m/s)	σ	P (W/m²)	*Time Factor*
North East Monsoon	4.37	1.69	3.90	2.37	84.35	0.68
South West Monsoon	2.49	1.74	2.22	1.32	15.15	0.37
Transition Period	3.03	1.34	2.73	1.82	35.67	0.48

The wind speed cumulative probability distributions obtained from probability density functions (Weibull and Rayleigh distribution functions) for the UMT RERC site are shown in *Figure 7*. It is seen that wind speeds on the cumulative probability distributions have a similar effect for Weibull and Rayleigh functions.

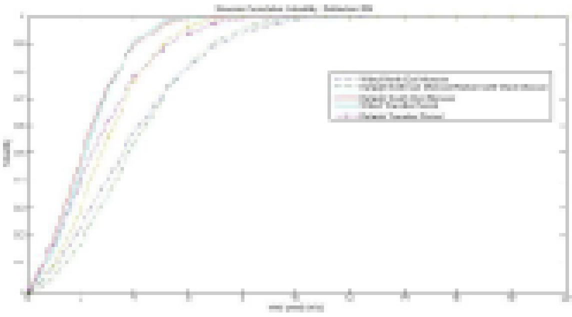

Figure 7. Wind speed cumulative probability distributions in Kuala Terengganu, Malaysia

6.0 CONCLUSION

In this study, the monthly and yearly wind speed distribution and wind power density during the period of 2009–2006 in Kuala Terengganu, Malaysia were evaluated. The wind speed frequency distribution of location was found by using Weibull and Rayleigh distribution functions. It can be concluded as follows.

1. The highest monthly mean wind speed is determined as 5.20 m/s in January 2007 while the lowest mean wind speed 2.09 m/s is occurred in June 2005. Annual mean wind speed for a 4 year period is obtained as 2.85 m/s.
2. The lowest wind energy is occurred in 11.55 W/m² in June 2005 while it is highest wind energy as 154.02 W/m² is obtained in December 2006.
3. The highest c value is found in the north east monsoon season and lowest value is in the south west monsoon season. The lowest standard deviation with 1.32 m/s is calculated in the south west monsoon season.
4. The average values of Weibull shape parameters k and c were found as 1.76 and 3.22 m/s for the period 2004–2007, respectively.
5. The highest mean wind speed value with 3.90 m/s is determined in the north east monsoon season while the lowest value is in the south west monsoon season with 2.22 m/s.
6. The wind power of investigated site is lowest in south west monsoon season, while it is highest in north east monsoon season as 84.35 W/m².
7. The highest time factor value with 0.68 is determined in the north east monsoon season while the lowest value is in the south west monsoon season with 0.37.
8. The North east monsoon having the wind energy potential. And small wind machine could be used to provide power.

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