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Wind Resource Investigation of Terengganu in the West Malaysia

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ABSTRACT
The analysis of wind data collected from the Renewable Energy Research Center, University Malaysia Terengganu (RERC UMT) using NRG Symphonie data retriever in Kuala Terengganu between the years 2004 and 2007. The RERC UMT station is located at 4°13.6′ N and 103°26.1′ E. Wind data were recorded at a height of 18 m above the ground level. This paper presents wind characteristics of the study site in Terengganu. The daily, monthly and annual wind speed values have been studied together with their prevailing direction. The monthly average wind speed and yearly mean wind speed for Kuala Terengganu ranged from 2.0–5.2 m/s and 2.9 m/s respectively. Northeast monsoon season (November to March) mean wind speed was 3.9 m/s for the same period. The average Weibull shape parameter *k* and scale parameter *c* were 1.76 and 3.21 m/s respectively for this period. The wind power is lowest during southwest monsoon season and highest during the northeast monsoon season (mean value 84.60 W/m^2). The wind energy density is lowest at 11.33 W/m^2 in June 2005, highest at 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 40.52 W/m^2 and 0.51 based on Weibull distribution, respectively. The annual average turbulence intensities were 0.58 and no significant seasonal variation in turbulence intensity was observed. In conclusion, wind energy could be used to provide power during the northeast monsoon season at the study site, using small (kW range) wind machines.

Keywords: Wind speed, Wind energy density, Weibull distribution, Probability of wind, Monsoon season

1. INTRODUCTION
Renewable energy has generally been more expensive than fossil fuels and the source are often located at remote areas and it is expensive to build power lines to the cities where they are needed. The use of renewable sources is also limited by the fact that they are not always available. The production and use of renewable fuels has grown more quickly in recent years due to higher prices of fossil fuels. The use of renewable fuels is expected to continue to grow over the next 30 years, although we will still rely on non-renewable fuels to meet most of our energy needs [1].

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Wind is the fastest growing energy source in the world today. Over the past decade, annual worldwide growth in installed wind capacity is near 30% (over 94,000 MW installed currently) [2]. However, the development of new wind projects continues to be hampered by the lack of reliable and accurate wind 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 [3]. The distribution of wind speeds is important for the design of wind farms, power generators and other applications such as the irrigation.

Wind speed and 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 and locations will provide more detailed data to potential investors. A continuous record of wind data over a year cycle would be sufficient to realize its potential.

Kuala Terengganu, the capital of Terengganu state is undergoing rapid economic development. Its location, facing the South China Sea provides opportunities to tap wind energy during the monsoon season. The introduction of renewable energy options can produce significant environmental, economic, and social benefits. The use of wind energy reduces the combustion of fossil fuels and the consequent CO_2 emission which is the principal cause of the greenhouse effect and global warming [4, 5, 6, 7].

The overall energy consumed in Malaysia between 1980 and 2008 use in all sectors, has increased. Importantly, the energy use for transport and industry has almost four times increased in this 28-year period, and continues to grow, representing around 80% of the overall primary energy use in 2008. 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 [8].

Figure 1 shows the contribution of the main primary energy carriers to the total energy consumption in Malaysia in 1995 and 2008. It can be seen that the use of fossil fuels (coal, oil and gas) accounted for 95% of the total Malaysia energy supply in 2008, which is an increase of 6.3% on the year 1995[8].

The government of Malaysia is encouraging the use of renewable energy (RE) sources in her Ninth Malaysian Plan [9]. Initiatives to enhance local capabilities in the development of indigenous RE based technologies as new sources of growth will also be supported by Malaysian government.

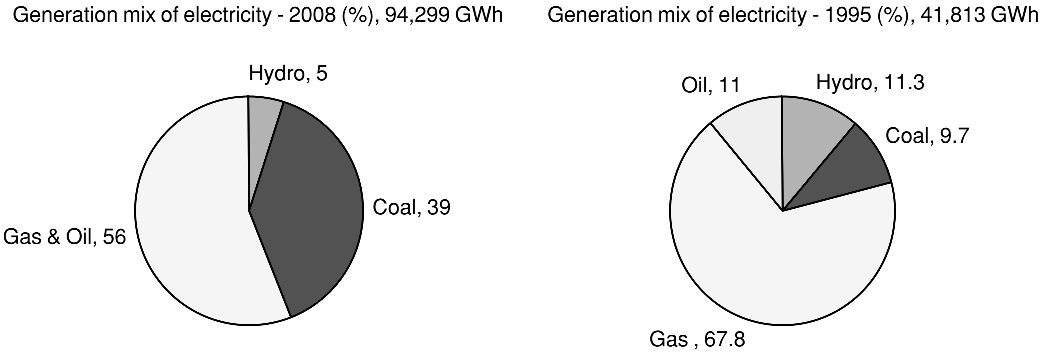

Figure 1: Malaysia Primary Energy Consumption in 1995 and 2008.

The scope of this article is to find out the wind energy potential at the selected Kuala Terengganu site. Several studies had published substantial results regarding the wind energy in Malaysia where it had identified the wind regimes in some areas with estimates of its energy potential [10, 11].

2. STUDY AREA METEOROLOGICAL PHENOMENON AND DATA COLLECTION

In this study, the wind speed, direction and temperature data from 2004 to 2007 were measured at ten minutes intervals by Renewable Energy Research Center of University Malaysia Terengganu (RERC UMT) using 'NRG Symphonic Data Retriever. It consists of a 20m tall guyed pole tower. The hourly averaged data was stored on computer. The instruments and sensors were regularly calibrated against reference sensors maintained at the station. Wind observations using the cup anemometer were recorded at a height of 23 m at mean sea level (18 m above the ground level). The RERC UMT station is located at 4°13.6′ N and 103°26.1′ E. The site is in close proximity to the sea in the north and the east directions. The topography surrounding the tower is relatively flat and hence there is no orographic forcing in this study. The terrain is covered by sea sand and lawn grass. Figure 2 shows the location of the chosen site.

The Kuala Terengganu lies in the equatorial zone and the climate is governed by the regime of the northeast and southwest monsoons which blows alternately during the course of the year. The wind distributions are classified into 3 categories: (i) Northeast monsoon season

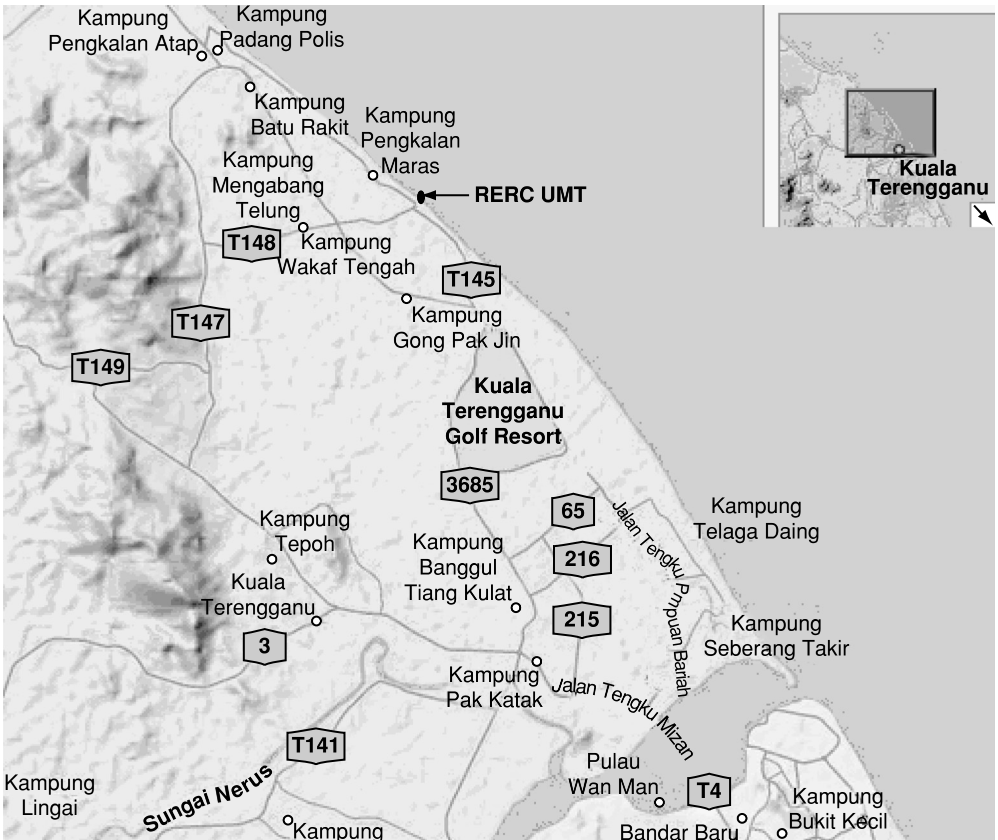

Figure 2: Location and terrain of Kuala Terengganu wind observation station.

(November–March), (ii) Inter monsoon season – Transition period (April and October) and (iii) Southwest monsoon season (May–September).

3. DATA VALIDATION AND PROCESSING

The integrated hourly time-series data from multiple months (2004–2007), excluding incomplete data were combined for validation. Data were manually validated to remove outlier events due to failure of instruments, etc. and statistically analyzed. MATLAB was used to process raw data to generate useful wind characteristics. Using simple encoding in MATLAB based on Equations (5) and (6) the energy density (E_D) and the probability of wind to exceed a velocity $P(V>V_x)$ were generated. Then graphs were plotted by using the MATLAB and EXCEL function.

4. RESULTS AND DISCUSSION

4.1. Daily Variations

The wind speed varies not only with different seasons but also times of the day. The knowledge of these variations is important to get an idea about the amount and time of availability of wind power. These variations are required for the design of energy storage and load scheduling with other generating systems. Figure 3 shows the hourly average wind speeds and temperature in a day of July and December 2004 in Kuala Terengganu, Malaysia. These variations are related to the differences in the warming of the earth's surface during the daily radiation cycle. A typical variation consists of the increase of the wind speed during the day, followed by its decrease from midnight to dawn. These diurnal variations in the wind speed are influenced by the location and altitude in relation to the sea level.

The most remarkable characteristic of wind at the station is the difference in speed throughout the 24-h period. In northeast monsoon, the wind speeds are generally higher in midnight till afternoon and lower in the evenings. On the other hand, in southwest monsoon, the trend is slightly different when wind speeds are higher in afternoon till late evening and lower in night till noon. In southwest monsoon, from 10:00 hour the wind speed increases up to reach its maximum between the 17:00 and 18:00 hours. Wind speeds start to decrease at 19:00 hour, later it decreases under the average value. The lowest value was registered after 01:00 hour. In northeast monsoon, from 23:00 hour the wind speed increases up to reach its

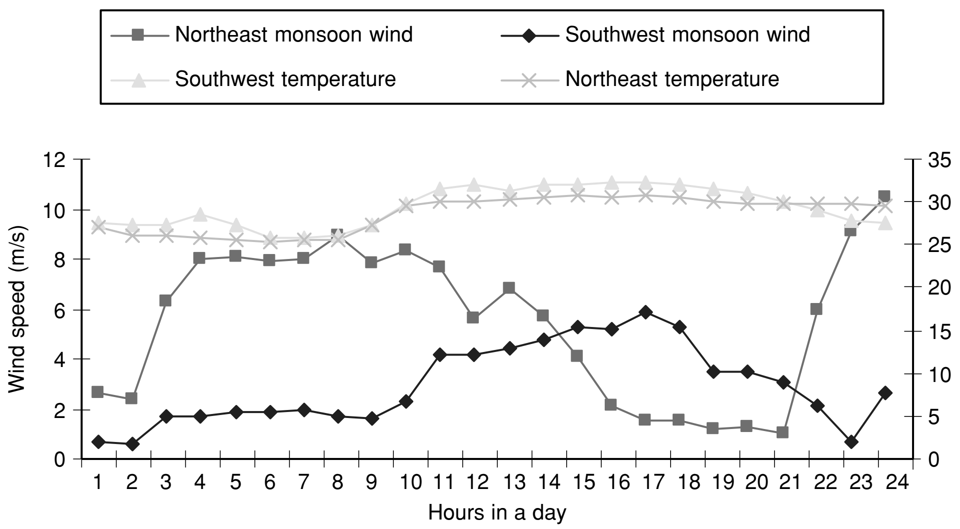

Figure 3: Hourly average wind speeds and temperature on July and December 2004 in Terengganu.

maximum between the 08:00 and 09:00 hours. It starts to decrease at 16:00 hour; and later to below the average value. The lowest value was registered after 21:00 hour. Wind speeds undergo noticeable variations between northeast monsoon and southwest seasons. The station registers a temperature without noticeable differences between day and night. On the other hand, independent of the considered season, the daily wind speed average was almost constant.

4.2. Monthly and Inter-annual Variation

Figure 4 shows the typical monthly average hourly wind speed over the four year period at Kuala Terengganu. Monthly behavior of the temporal annual series shows a similar pattern i.e. entire period of 2004 to 2007 were calm and was no much inter-annual variation of wind speed as 3.00, 2.72, 2.81 and 2.95 m/s respectively. The highest monthly mean wind speed was 5.20 m/s in January 2007 while the lowest mean wind speed was 2.00 m/s in June 2005. Annual mean wind speed for a 4 year period (representing long-term wind) was 2.90 m/s. The monthly average wind speeds was higher during the northeast monsoon months as expected compared to other months. This clearly reflects that a wind energy conversion system would produce appreciably more energy during the northeast monsoon months.

The frequency distribution/histogram of hourly average wind speed for a complete year (year 2004) is presented in Figure 5. The frequency is highly peaked in the range 1-6 m/s. This indicates that most of the wind energy at Kuala Terengganu lies in this range. This distribution of wind speed is important in determining the percentage of time during a year, the power that could be generated from a wind machine. Moreover, this information can be used to determine the amount of power which can be generated in a given speed band. Hence it indicates the wind power potential of Kuala Terengganu for wind power applications.

Data of wind speed frequency distribution is very important to evaluate the wind potential and the economic feasibility. The simplest and most practical method is to use wind distribution function. There are several density functions to describe wind speed frequency curve. The most widely used and accepted in the specialized literature [12, 13, 14, 15]; the Weibull and Rayleigh functions were used in this study. The Weibull distribution function which is a two-parameter distribution can be expressed as

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

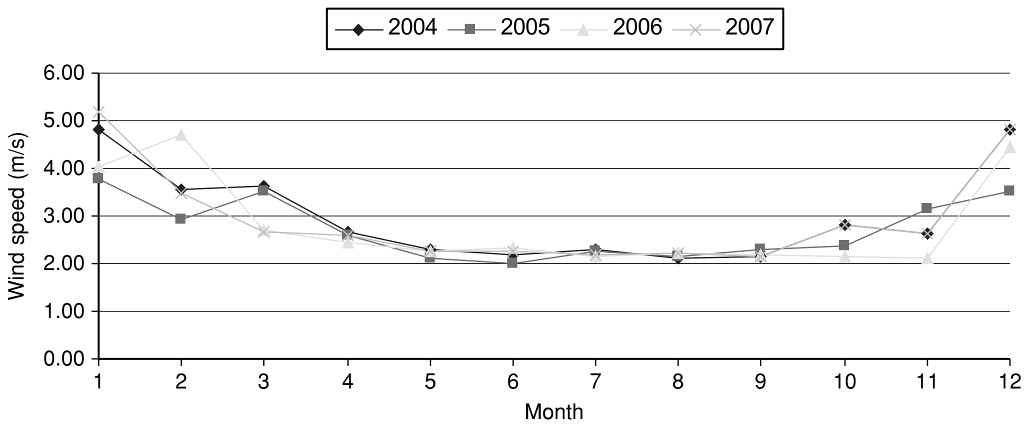

Figure 4: Monthly average wind speeds between the years 2004 and 2007 in Kuala Terengganu.

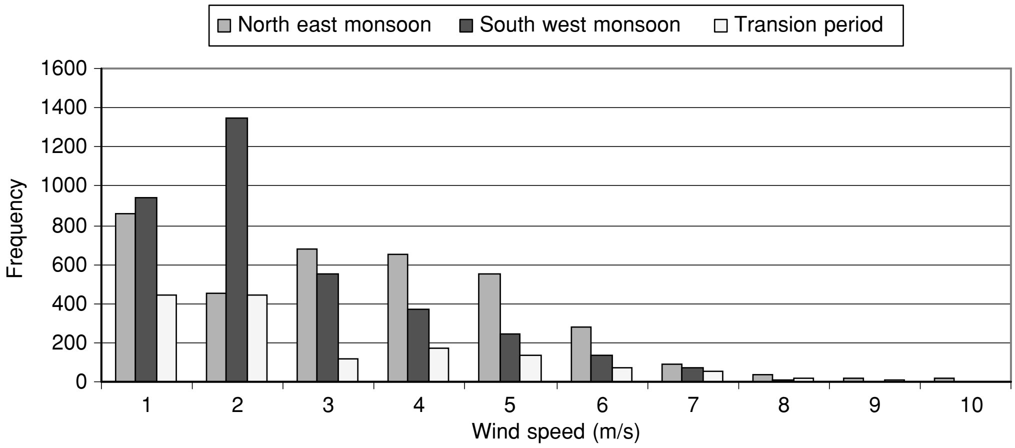

Figure 5: Frequency distribution of hourly average wind speed for year 2004.

Table 1: Monthly variations of Weibull parameters (*k* and *c*) for Kuala Terengganu, Malaysia

	Weibull Scale Parameter *c* (m/s)				Weibull Shape Parameter *k*				Monthly Average	
Month/Year	**2004**	**2005**	**2006**	**2007**	**2004**	**2005**	**2006**	**2007**	***c* (m/s)**	***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	5.31	3.93	2.16	2.01	2.12	1.94	4.14	2.06
March	4.00	3.93	3.04	2.98	1.46	1.64	1.85	1.61	3.49	1.64
April	2.99	2.90	2.77	2.93	1.68	1.61	1.74	1.72	2.90	1.69
May	2.61	2.35	2.55	2.57	1.78	1.55	1.96	1.76	2.52	1.76
June	2.47	2.25	2.64	2.52	1.78	1.67	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	2.35	2.44	2.54	–	1.57	1.80	1.86	–	2.45	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	–	1.81	1.27	1.35	–	4.68	1.48
Annual Average	3.35	3.04	3.13	3.34	1.53	1.51	1.52	1.54	3.20	1.52

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

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

The second distribution function used to model 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.

Table 1 shows monthly variation of Weibull parameters for Kuala Terengganu during the period 2004–2007. The Weibull shape parameter k varies between 1.27 and 2.68, while scale parameter c varies between 2.25 m/s and 5.83 m/s. The average values of Weibull shape parameters k and c are 1.52 and 3.22 m/s, respectively.

The monthly average value of Weibull shape parameter k was between 1.47 and 2.15, while for c it was between 2.45 m/s and 5.02 m/s. The lowest k value was in December 2005 and the highest was in January 2004. It can be seen that the highest c value was in January 2007 at 5.83 m/s. No seasonal variation is seen in the shape parameter. The annual average value of Weibull shape parameter k was between 1.51 and 1.54, while for scale parameter c was between 3.04 m/s and 3.35 m/s. The annual average values of Weibull parameters were calculated using the entire year wind data while monthly average values were obtained from the monthly values of each year.

To determine the goodness of fit, it is necessary to introduce a formal statistical that enable observed frequency distribution to be compared with the theoretical frequency distribution. The Kolmogorov-Smirnov goodness of fit test (K-S) is used to decide if a sample comes from a population with a specific distribution [16]. The K-S test is based on the empirical cumulative distribution function (ECDF). Given N ordered data points $Y_1, Y_2, \ldots, Y_N$, the ECDF is defined as $E_N = n(i)/N$; where $n(i)$ is the number of points less than Y_i and the Y_i are ordered from smallest to largest value. This is a step function that increases by $1/N$ at the value of each ordered data point.

An attractive feature of this test is that the distribution of the K-S test statistic itself does not depend on the underlying cumulative distribution function being tested. Another advantage is that it is an exact test. Despite these advantages, the K-S test only applies to continuous distributions.

The Kolmogorov-Smirnov test is defined by: H_0: The data follow a specified distribution; H_a: The data do not follow the specified distribution. The Kolmogorov-Smirnov test statistic is defined as

$$D = \max\left|F(Y_i) - E_N\right| \quad (3)$$

where F is the theoretical cumulative distribution of the distribution being tested which must be a continuous distribution and it must be fully specified.

The hypothesis regarding the distributional form is rejected at the chosen significance level (α) if the test statistic, D, is greater than the critical value obtained from a table. The fixed values of α (0.01, 0.05 etc.) are generally used to evaluate the null hypothesis (H_0) at various significance levels. A value of 0.05 is typically used for most applications. Alternately, the decision to reject the null hypothesis occurs when the significance level (α) equals or exceeds the p-value of test.

In Table 2, the K-S test results are given. The Weibull distribution model gives a good fit to the measured wind data. Because, the Weibull distribution satisfies the K-S test at 5% significant level in January, February, March, October, November and December and in other months satisfies the K-S test at 1% significant level. Further, the Weibull distribution satisfies the K-S test at 30% significant level in year 2004, 2005, 2006, 2007 and the entire period of wind data as shown in Table 2.

Comparison of probability density distributions for 2005 based on observed field data with Weibull and Rayleigh functions for RERC UMT site is illustrated in Figure 6. The peak probability value for Rayleigh probability distribution is 0.2642 at wind speed of 2 m/s, while the peak value for Weibull probability distribution is 0.2442 at wind speed of 2 m/s. And the peak value for field data probability distribution is 0.3105 at wind speed of 1 m/s. Figure 6 clearly shows that Weibull and Rayleigh distribution are almost identical shapes.

Table 2: K-S test results of Weibull distribution of wind data

Month	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Octo.	Nove.	Dece.
p-value	0.30	0.07	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.15	0.30
Year	2004	2005	2006	2007	2004/07							
p-value	0.30	0.30	0.30	0.30	0.30							

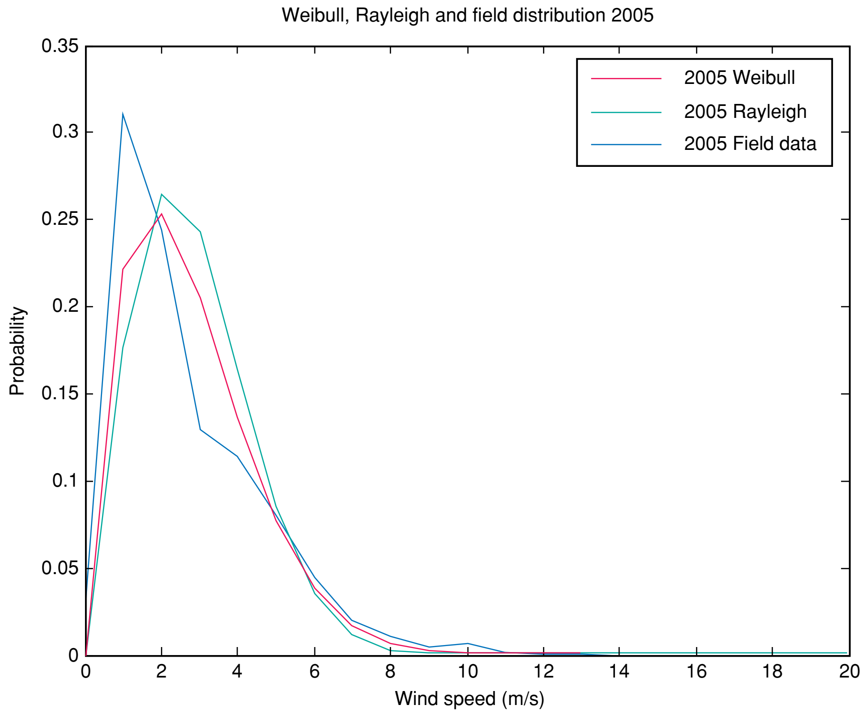

Figure 6: Comparison of probability density distributions of year 2005 according to field data with Weibull and Rayleigh functions.

The entire period value of Weibull shape parameter *k* was 1.52 and scale parameter *c* was 3.20 m/s. In Figure 7, comparison of probability density distributions for entire period based on observed field data with Weibull, Rayleigh functions and Weibull seasonal distribution for RERC UMT site is illustrated. The peak probability value for Rayleigh probability distribution is 0.2301 at wind speed of 3 m/s, while the peak value for Weibull probability distribution is 0.2282 at wind speed of 2 m/s. And the peak value for field data probability distribution is 0.2947 at wind speed of 1 m/s and the peak value for northeast monsoon seasonal Weibull probability distribution is 0.1853 at wind speed of 2 m/s.

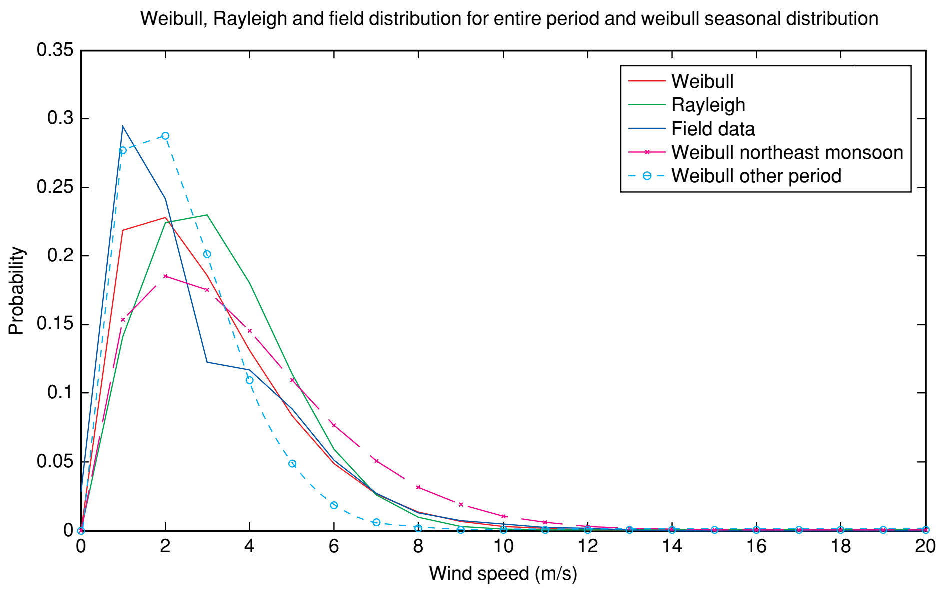

Figure 7: Comparison of probability density distributions of entire period according to field data with Weibull and Rayleigh functions and Weibull Seasonal Distribution.

4.3. Seasonal Variation

The power density, P_D of wind can be estimated by;

$$P_D = \frac{1}{2}\rho V_m^3 \quad (4)$$

where ρ is mean air density, and V_m is mean value of the wind speed. The average wind energy density, E_D of a site can be expressed based on Weibull probability density function as;

$$E_D = \frac{\rho \cdot c^3}{2}\frac{3}{k}\Gamma\left(\frac{3}{k}\right) \quad (5)$$

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

$$P(V > V_x) = e^{-\left(V_x/c\right)^k} \quad (6)$$

The seasonal wind characteristics in Kuala Terengganu are given in Table 3. The highest mean wind speed value at 3.90 m/s occurred during the northeast monsoon season while the lowest was recorded during the southwest monsoon season at 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 was during the northeast monsoon season and lowest during the southwest monsoon season. The lowest standard deviation at 1.32 m/s was calculated during the southwest monsoon season. The wind power potential is lowest during southwest monsoon season, while it is highest during the northeast monsoon season estimated at 84.55 W/m^2. The probability of wind to exceed a velocity of 2.5 m/s estimated at 0.68 and 0.37 during northeast and southwest monsoon seasons, respectively.

Figure 8 shows the seasonal wind speed cumulative probability distributions (Weibull and Rayleigh) for 2004 at RERC UMT site indicating close similarity in shape.

Table 3: Seasonal wind characteristics in Kuala Terengganu, Malaysia

Monsoon Season	c (m/s)	k	V_m (m/s)	σ	P (W/m^2)	Probability (> 2.5 m/s)
Northeast	4.37	1.69	3.90	2.37	84.55	0.68
Southwest	2.49	1.74	2.22	1.32	15.15	0.37
Transition Period	3.05	1.54	2.75	1.82	33.67	0.48

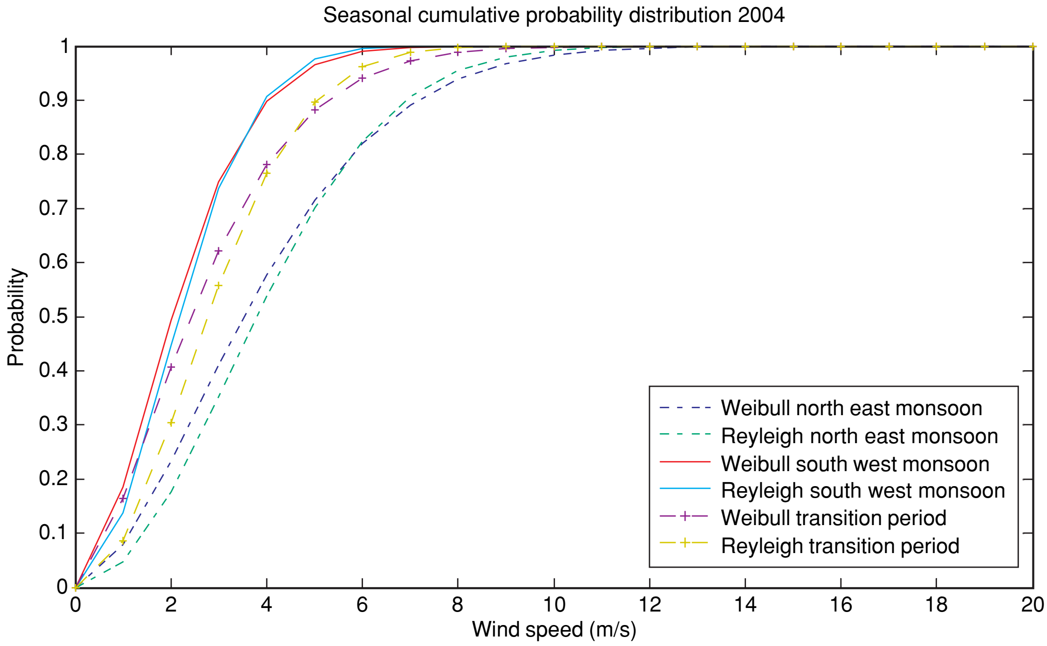

Figure 8: Seasonal wind speed cumulative probability distributions in Kuala Terengganu for 2004.

4.4. Wind Speed at Different Heights

Wind speed increases with height. A monthly wind shear coefficient, or wind gradient exponent, α, is defined by

$$\frac{V_2}{V_1} = \left(\frac{h_2}{h_1}\right)^{\alpha} \tag{7}$$

where, V_1 is reference wind speed measured at a height h_1; V_2 is the wind speed at the required or extrapolated height h_2.

The value of α varies with some parameters such as height, period time of the day, seasons, terrain characteristics, wind speed, temperature and mixture of mechanical and thermal parameters. The value of α was calculated as 0.11 based on Counihan's correlation dependent on surface roughness [3, 17].

Alternatively, the logarithmic wind profile can be used to calculate wind speed at different heights, given in equation (8).

$$\frac{V_2}{V_1} = \ln\left(\frac{h_2}{z_0}\right) \Big/ \ln\left(\frac{h_1}{z_0}\right) \tag{8}$$

where, V_1 is reference wind speed measured at a height h_1; V_2 is the wind speed at the required or extrapolated height h_2 and z_0 is the surface roughness length, which characterizes the roughness of the ground terrain. For this study the surface roughness length value of 8 mm that is related to lawn grass surfaces has been adopted [3].

In Kuala Terengganu, the wind speed values were recorded at 18 m height over the ground level. Wind speeds at other heights were extrapolated based on Equation (7). The correlation between the wind turbine height and wind velocity must be established before installing the turbine. Eighteen meter height is used as reference for wind speed. Figure 9 shows the wind velocities at 10m, 30 m, 50 m and 100 m above ground level.

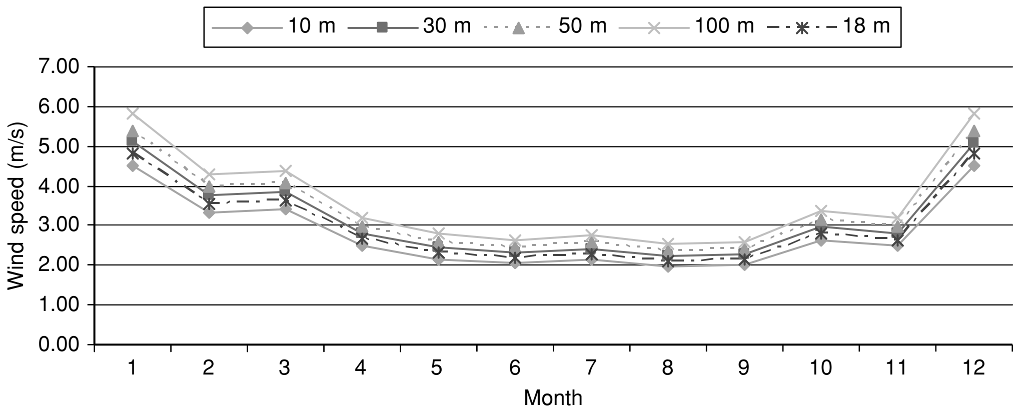

Figure 9: Monthly average wind speed at different heights of 10, 18, 30, 50 and 100 m.

Table 4: Comparison of the wind velocities at deferent height based on log law and power law

	18 m	10 m		30 m		50 m		100 m	
Month	Measured	Log Law	Power Law	Log Law	Power Law	Log Law	Power Law	Log Law	Power Law
January	4.82	4.45	4.52	5.14	5.10	5.46	5.39	5.89	5.82
February	3.55	3.28	3.33	3.78	3.76	4.02	3.97	4.34	4.29
March	3.63	3.35	3.40	3.87	3.84	4.11	4.06	4.44	4.38
April	2.66	2.46	2.49	2.84	2.81	3.01	2.98	3.25	3.21
May	2.31	2.13	2.17	2.46	2.44	2.62	2.58	2.82	2.79
June	2.19	2.02	2.05	2.33	2.32	2.48	2.45	2.68	2.64
July	2.29	2.12	2.15	2.44	2.42	2.59	2.56	2.80	2.77
August	2.10	1.94	1.97	2.24	2.22	2.38	2.35	2.57	2.54
September	2.15	1.99	2.02	2.29	2.27	2.43	2.41	2.63	2.60
October	2.80	2.59	2.62	2.99	2.96	3.17	3.13	3.42	3.38
November	2.64	2.44	2.47	2.81	2.79	2.99	2.95	3.23	3.19
December	4.81	4.44	4.51	5.13	5.09	5.45	5.38	5.88	5.81

Wind speeds at other heights were also extrapolated based on Equation (8). Table 4 shows comparison of the wind velocities based on log law and power law at 10m, 30 m, 50 m and 100 m above ground level. It was found that, the maximum deference in calculated wind velocity is 1.47 % at 10 m height with minimum is 0.79 % at 30 m height using two methods. From these results one can conclude that both models can be used to extrapolate the wind velocity at different heights.

4.5. Turbulence Intensity

The turbulence intensity is defined as;

$$TI = \frac{\sigma}{V_{avg}} \tag{9}$$

where σ is the standard deviation of the samples and V_{avg} is average wind speed in each hour [18].

Turbulence intensity, TI of wind was calculated at 18 m using the above equation (9), and the monthly values are shown in Table 5. The annual average turbulence intensity was 0.58. No significant seasonal variation in turbulence intensity was observed. The turbulence in the wind is caused by dissipation of wind's kinetic energy into thermal energy via the creation and destruction of progressively smaller eddies. The range of wind speeds is high at Kuala

Table 5: Monthly turbulence intensity at 18 m above ground level

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
TI	0.56	0.50	0.56	0.59	0.53	0.57	0.62	0.56	0.56	0.56	0.65	0.75	0.58

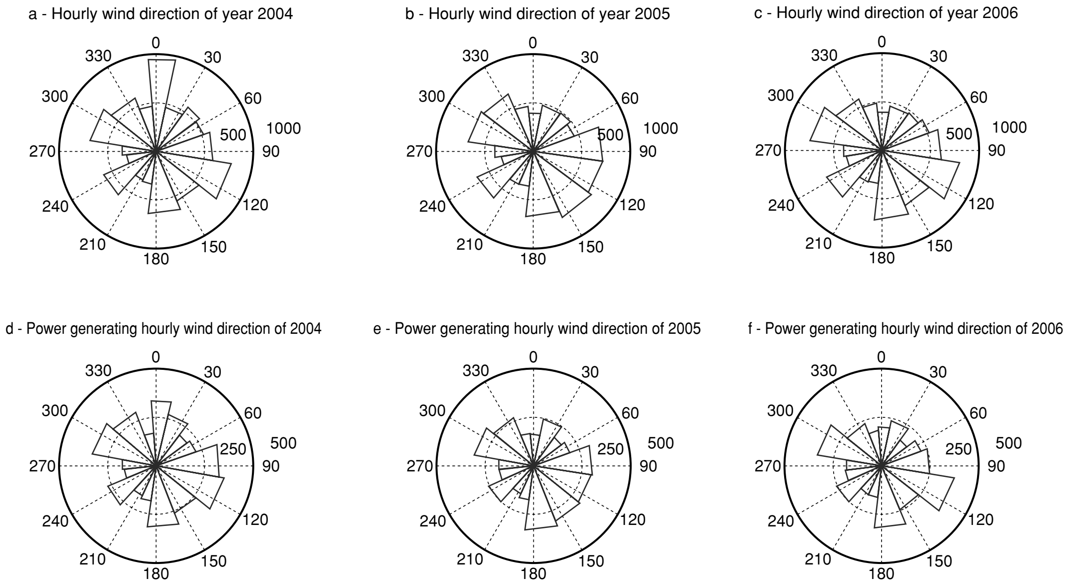

Figure 10: Wind roses showing wind direction during the period 2004–2006. (a-c) all wind direction and (d-f) wind direction with wind speed exceeding 2.5m/s.

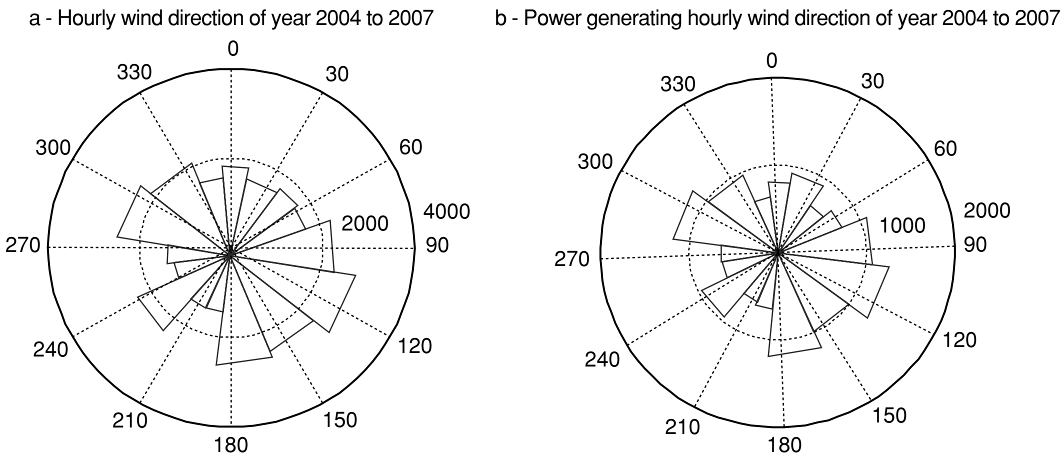

Figure 11: Wind roses showing wind direction during the entire period 2004–2007. a- all wind direction and b- wind direction with wind speed exceeding 2.5m/s.

Terengganu as a result standard deviation of the wind speed is very high, mainly due to the low average wind speeds combine with monsoons. Therefore, the turbulence intensity is at unacceptable level.

4.6. Wind Direction

The wind direction corresponds to years 2004–2006 is shown in Figure 10. Figure 10 (a-c) indicate the directions of all wind speeds and Figure 10 (d-f) indicate the direction of wind with speeds exceeding 2.5 m/s. Mean wile Figure 11 a – indicate the directions of all wind speeds for entire period of four year and Figure 11 b – indicate the direction of wind with speeds exceeding 2.5 m/s for entire period. For power producing wind, the prevalent directions are those corresponding to the S, SE, NW and E sectors. Kuala Terengganu is located in the tropical area slightly to the north of Equator is generally under the influence of the trade wind that blows from NE and SE.

The wind direction data are important to evaluate the feasibility of any wind energy project to obtain the highest power production.

5. CONCLUSION

The government of Malaysia is encouraging the use of renewable energy sources. Initiatives to enhance local capabilities in the development of indigenous renewable energy based technologies as new sources of growth will also be supported by Malaysian government. It is quite evident from the results of wind energy study based on data collected between 2004–2007 in Kuala Terengganu that the potential of renewable energy options of wind energy cannot be overlooked especially during the northeast monsoon when the average wind speed was 3.9m/s. The potential wind power generated reach 84.55 W/m^2 with probability time factor value of 0.68. Therefore, Small (kW range) wind machines could be used to provide power during northeast monsoon. Other locations which are also subjected to the same wind system would also have similar potential.

There is no significant different in estimating wind speed frequency distribution using Weibull or Rayleigh distribution functions as such either one could be used for estimation. 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.

During other months there will be limited wind energy potential with about 11.33 W/m^2 on minimum. During these months other sources of energy such as solar energy would be needed for hybrid system. Therefore further research and experimentation are still needed to determine the feasibility (economic and technical) of wind-solar hybrid system. It would also be an advantage to make additional measurements at higher heights at the locations where the best wind speeds are expected.

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