Analyzing the East Coast Malaysia Wind Speed Data

Siti Khadijah Najid, Azami Zaharim, Ahmad Mahir Razali, Mohd Said Zainol, Kamarulzaman Ibrahim & Kamaruzzaman Sopian

Abstract**—**Wind energy has been widely used for navigation and agriculture for the past centuries. Wind energy is given a lot of attention because of the focus on renewable energy. Wind energy growth in Asia is currently on the rise with both India and China as leading countries with their installed capacity and manufacturing facilities. Recently, wind energy conversion is also given a serious consideration in Malaysia. Since Malaysia lies in the equatorial region and its climate is governed by the monsoons, the potential for wind energy generation in Malaysia is very much depends on the availability of the wind resource that varies with specific location. In the present study, the wind energy potential of the location is statistically analyzed based on wind speed data, measured over two years period. The probability distributions are derived from the wind speed data and their distributional parameters are identified. Three types of probability distributions have been used to estimate the wind energy potential in Kuala Terengganu, east Malaysia. A comparison is made of the ability to describe the experimental mean wind power density. The application of the graphical plot along with different types of numerical analysis in terms of model validations show that of all the three distributions used, Burr distribution, whose parameters are estimated using the maximum likelihood principle, provide the best fits for the year 2005 and 2006 respectively.

Keywords**—** Goodness of fit, renewable energy, wind speed, wind speed distribution.

I. INTRODUCTION

RESEARCH on renewable energy is currently given a serious consideration. Many countries leaders has shown their interest and positive attitudes in terms of willingness to develop alternative energies, based on the fact that the fossil fuel reserves on the earth is lessened years by years. Serious attention should be paid to reduce the dependence on fossilized organic found in this earth planet. The negative effects on the environment which increased from fossil fuel combustion in addition to its limited stock also have forced many countries to explore and change to renewable energy. Changing to renewable energy sources would ensure sustainability. Since the world reserved with a very limited fossil fuel, and there are also adverse effects with their use, the alternative to conventional energy sources, especially the renewable ones becomes increasingly attractive.

Renewable energy refers to energy resources that occur naturally and repeatedly in the environmental and can be harnessed for human benefit [1]. There are many types of renewable energies discovered world widely; solar energy, wind energy, geothermal energy, biomass, and hydropower. However, the potentiality to build up or develop the renewable energy system is different to a specific region due to its own location. Certain locations are suitable to develop solar and wind energy, while other location in the part of the world are suitable for other renewable energy implementation such as hydropower, biomass or geothermal.

Asian countries including Malaysia, has the potential to develop alternative energy. Unlike the European countries, they are very new in this project types of energy that could give not only benefits in the short period of time but for the long term undoubtedly. For the past few decades, Malaysia has start implementing new technologies to discover its potential of renewable energy. In order to install and implement the technology in the country, many organizations both from the private and government industries are now competing each other in discovering a new challenge with the renewable energy.

A vast installation and research on the solar energy is done recently all around the country. Solar cell, solar bowl, solar photovoltaic, solar hydrogen and many other solar energy systems had been implemented in certain parts of the country. Besides, new discovering on other types of renewable energy is also being considered. Power plant expert M. Umakanthan says the biomass from Malaysia's oil palm plantations alone can power 5% to 10% of the country's total energy requirements [2]. Geothermal energy which contained within vapour or hot water with temperature of more than 200°C existing in the subsurface at depth about 2000 – 3000 meter. Above the ground occur in a volcanic region such as Indonesia and Sabah, Malaysia. However, it also occurs in a formation intruded by granitic body such as in Semenanjung, Malaysia. Not only that, Sarawak also was endowed with abundant

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Siti Khadijah Najid is with the Centre of Engineering Education, Faculty of Engineering and Built Environment, National University of Malaysia, 43600, Bangi, MALAYSIA (Corresponding author: +603-89216843; faks: 603-89216860; email: khadijahnajid@gmail.com)

Azami Zaharim is with the Centre of Engineering Education, Faculty of Engineering and Built Environment, National University of Malaysia, 43600, Bangi, MALAYSIA (email: azaminelli@gmail.com)

Ahmad Mahir Razali is with the School of Mathematical Sciences, Faculty of Science and Technology, National University of Malaysia, 43600, Bangi, MALAYSIA (email: mahir@pkrisc.cc.ukm.my)

Mohammad Said Zainol, Department of Quantitative Sciences, Faculty of Computer and Mathematical Sciences Universiti Teknologi MARA,40450 Shah Alam, Selangor (e-mail: saidzainol@gmail.com)

Kamarulzaman Ibrahim is with the Solar Energy Research Institute, National University of Malaysia, 43600, Bangi, MALAYSIA (email: kamarulz@pkrisc.cc.ukm.my)

Kamaruzzaman Sopian is with the Solar Energy Research Institute, National University of Malaysia, 43600, Bangi, MALAYSIA (email: ksopian@vlsi.eng.ukm.my)

hydropower potential which could produce a huge amount of electricity at a low cost to benefit the Asean member along with many hydropower installation.

Wind energy is also in the same progress. Wind energy which is actually a form of solar energy is one of a kind that researchers put efforts in addressing the challenges to greater use it nowadays. The importance of wind energy potential was increased by economic limitations after the economic crises in 1973, and today, there are wind farms in many western European countries [3]. Wind energy plans produce no air pollutant or greenhouse gasses. Wind energy is considered a green power technology as other renewable energy, it has only minor impact on the environment. Thus, this is the reason why human named them environmental friendly.

II. WIND ENERGY POTENTIAL IN MALAYSIA

Despite the bright future foreseen for solar power globally, Malaysia is way behind other countries in harnessing the renewable energy. In fact, in some parts of rural area in the coastal region like Malaysia, the electrical power can also be generated from wind energy. A number of feasibility study had been done by researchers on the potential of wind energy in Malaysia. Large number of the study comes from the government or private institute of higher learning. There are number of institutions that are trying pilot wind energy projects, both on large scales and small, home based turbine scales.

Malaysia is a net energy exporter. It either comes from the renewable energy or non-renewable energy. Both types of energy is abundant here. However, the renewable energy in Malaysia is not fully explored and implemented by all Malaysians as they are still not fully commercialized. There are a few problems which seemed to be occurred in Malaysia. Among the major problems associated to the implementation of the wind energy system are lack of local expertise, spare parts availability, transportation and inefficient energy management.

Malaysia is divided into two distinct parts: Peninsular Malaysia which shares a land border with Thailand in the north and the East Malaysian provinces of Sabah and Sarawak in North Borneo. The two regions are 650 km (403 mi) apart, separated by the South China Sea. Peninsular Malaysia shares borders with Thailand and Singapore. The term East Coast is particularly used to describe either one of the states in Peninsular Malaysia facing the South China Sea. The three states located at the East Coast are Kelantan, Pahang and Terengganu. The term West Coast refers informally to a collection of states in Peninsular Malaysia situated towards the western coast generally facing the Straits of Malacca. Unlike the East Coast, the West Coast is partitioned further into several regions. The Northern Region include Perlis, Kedah, Penang and Perak, the Central Region include Selangor and federal territories of Kuala Lumpur and Putrajaya, while the Southern Region is Negeri Sembilan, Malacca and Johor. Figure 1 shows a picture of Malaysia; Peninsular Malaysia, Sabah and Sarawak together with all types of sea surrounded by the country.

The northeast monsoon is the major rainy season in the country. Monsoon weather systems which develop in conjunction with cold air outbreaks from Siberia produce heavy rains which often cause severe floods along the east coast states of Kelantan, Terengganu, Pahang and East Johore in Peninsular Malaysia, and in the state of Sarawak in East Malaysia.

Fig. 1 Peninsular Malaysia, Sabah and Sarawak

Wind farming is feasible in Malaysia and offers high theoretical potential as a renewable source of energy. The Energy Information Bureau (EIB) of Malaysia considers it a serious option. The first wind farm in Malaysia was set up on Pulau Terumbu Layang-Layang off Sabah. A study from University Kebangsaan Malaysia (UKM) in 2005 has shown that the use of 150 kW turbines on the island has shown a good degree of success. Terumbu Layang-Layang has the largest wind energy potential compared to other places in Malaysia[4].

Offshore wind speeds are generally higher than coastal wind speeds, hence higher available energy resource. Here, in Malaysia, wind speed usually measured in the offshore or up on the certain mountain where wind speeds are found to have more potential. In a study done by a student from Science University of Malaysia (USM), 16 locations were chosen on the nearest sea grid to Malaysian coastline, all facing the South China Sea, the Straits of Malacca, Sulu Sea or Celebes Sea. Wind speed at the location in the East Peninsular Malaysia reach above 5 m/s during the northeast monsoon season and for the rest of the year, wind speed is low [5]. Moreover, there is also a study done to three so called islands in Malaysia surrounded by those sea described earlier. Kamaruzzaman Sopian et. al found that the available power of the wind in Malaysia is affected by the monsoons weather pattern with mean power recorded at the three islands; Redang, Tioman and Perhentian island are 85.1 W/m^2 , 3.4 W/m^2, and 49.8 W/m^2 respectively.

Listed below are some of many characteristics to evaluate and test wind farming as an option for implementing wind energy in Malaysia:

i. Good potential for farms based on the East Coast of Peninsular Malaysia that face the South China Sea.
ii. Good potential during the monsoon season (November - February)
iii. During the monsoon season, the average wind speed for East Coast states can reach up to 30 knots. 30 knots is equivalent to about 15.4 metres per second, which is about 55 km per hour.

Despite all the problems, Malaysia is facing the challenge in continuing the effort to put the renewable energy into action where every human being can feel the benefit. Thus, it is predicted that this beneficial situation remains only until 2010 due to the limitation of the resources like coal and gas [7].

III. WIND ENERGY ANALYSIS

Nowadays, wind analysis gives remarkable information to researches involved in renewable energy studies. Several mathematical models have been used to study wind data. Knowledge of the statistical properties of wind speed is essential for predicting the energy output of a wind energy conversion system. Because of the high variability in space and time of wind energy, it is important to verify that the analyzing method used for measuring wind data will yield the estimated energy collected that is close to the actual energy collected. Besides, the use of wind speed data is of great important in civil engineering, especially in structural and coastal engineering applications.

In recent years, many efforts have been made to construct an adequate model for the wind speed frequency distribution [8]. Usually, sets of raw data were provided by the meteorological include the climatological station. The Climatology is defined as a set of probabilistic statements on long-term weather conditions [9]. Effective utilization of wind energy entails a detailed knowledge. The distribution of wind energy at different wind speeds is commonly known as the wind power density which is calculated by multiplying the power of each wind speed with the probability of each wind speed. In the field of engineering, the wind speed distribution functions are ultimately used to be able to correctly model the wind power density, not the wind distribution itself [10]. Therefore, the most important criterion of the ability as how successful it is to predict the measured wind power density, not only the wind speed distribution.

Various distributions have been used by past researchers on the efforts of utilizing wind energy potential. There are several methods to calculate the parameters of specific wind speed distribution. The most commonly used is through graphical method. In addition, to check for the accuracy of the specific distribution, ones have to apply two or more methods to the given data. A statistical distribution commonly used for describing measured wind speed data is the Weibull distribution. A review of the methods found in statistical literature for the purpose of estimation of the parameters in Weibull distribution is given, with a special emphasis on the efficiency of the different methods. From this review, the most appropriate method for a given application can be chosen. The maximum likelihood estimators should be used due to their large sample efficiency. When wind speed data are available in time series format, the maximum likelihood method is the recommended method for estimating the Weibull distribution function for wind energy analysis [11].

IV. OBJECTIVE

Due to the location of the country which in the equatorial region, researchers in Malaysia found that the potentiality to implement the system based on the wind energy is very hard. This is because wind speed in Malaysia is usually low and always unpredictable. Malaysia experienced many types of monsoons along the whole year. Certain part of Peninsular Malaysia especially at the east part is characterized by the monsoons. There are northeast, southwest monsoons and also the intermonsoons that blow on its own specific time. Malaysia is now continuing efforts in developing wind energy technology system. Many researchers in Malaysia are trying to test the technical instrument of wind speed in Malaysia. It was found that the power availability at different locations of three specific east coast islands of peninsular Malaysia is affected by the weather pattern [12]. Kamaruzzaman et. al concluded that the mean power densities generated were 85.1 W/m^2, 49.8 W/m^2 and 3.4 W/m^2 for Redang, Perhentian and Tioman Island respectively. From there, it can be concluded that certain places like the islands have wind energy potential and the process of utilizing it is possible in Malaysia. The aim of the present work is to evaluate the potentiality of wind energy in Terengganu, east coast area of Malaysia. Terengganu is one of many other states in Malaysia which experience a great effect from the northeast monsoon. Apart from being located at the east coast area of Malaysia, almost all parts of Terengganu is covered by the sea. This current project is done through investigating the wind characteristics at the location using statistical analysis techniques and performing it using an adequate statistical distribution.

V. WIND SPEED DATA

Realizing that the wind speed is the most important parameter in the process of estimating wind energy potential, there are numbers of private and other government institutions, organizations, universities, schools, plantations, and hospitals located the Automatic Weather Stations (AWS) including wind energy conversion system (WECS). The AWS located at specific meteorological stations are operated by professionally trained observers of Malaysian Meteorological Department and primarily established for weather forecasting. The conventional instruments include the non-autographic type where hourly eye readings are made and the autographic type where hourly values are tabulated. The AWS stations not only gather the surface wind speed data but also other meteorological elements namely wind direction, rainfall, atmospheric pressure, dry and wet bulb temperatures using special electronic sensors. The present work only involved sets of wind speed data. Figure 2 shows the anemometer used to collect the wind speed data.

Fig. 2 Anemometer

Detailed knowledge of the wind at a site is needed to estimate the performance energy project. The present study used data collected from a government institution in Malaysia. Located at the east coast area of Malaysia, the data sets of this study consist of daily wind speed measured in meter per second. Measured at 18 meters height above the ground level at the university's climatological station situated at the Kuala Terengganu seaside, near the university itself, the data covered with two years wind speed data. Figure 3 shows the state in which the data is collected.

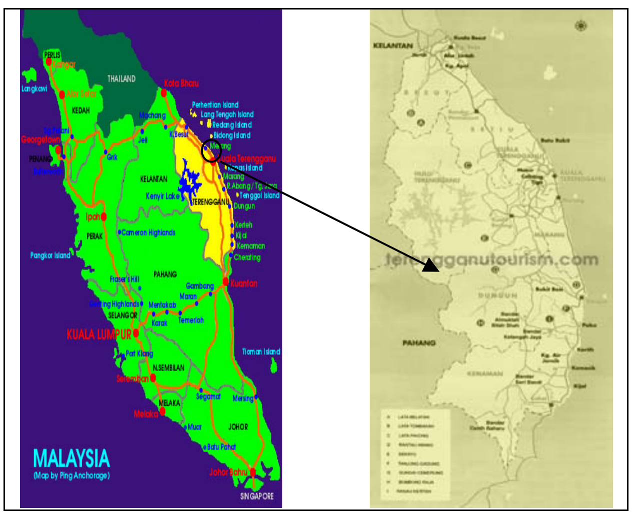

Fig. 3 Kuala Terengganu

Since the wind speed 'v' is a random variable, a long term meteorological data is desirable to describe the wind energy potential of the sites [14]. The data set used for the present work covered over two years surface wind speed data which is from January 2005 until December 2006.

TABLE I
Yearly Descriptive Statistics

	2005	2006
Mean	2.7834	2.8053
Std. Dev.	1.202	1.5692
Skewness	1.521	2.728
Kurtosis	2.114	7.887
Min. Value	0.64	0.99
Max. Value	7.29	11.47
Sample Size	351	340

The descriptive statistics for the data set is shown in Table I above. From the table, the total number of observation for the year 2005 and 2006 is 351 and 340 respectively. The mean wind speed in 2006 is higher than the earlier year with the mean of 2.8053 m/s. The mean wind speed for 2005 is 2.7834 m/s. The standard deviation which devotes a statistic that tells how tightly all the various examples are clustered around the mean in a set of data is also shown in the table above. Comparing the value of the standard deviation between those two years, the value for the year 2006 is higher than the year 2005 with a value of 1.5692 and 1.202 respectively. This means the data for the earlier year are pretty tightly bunched together and if it can be viewed in terms of normal distribution plot, the bell-shaped curve is steep. Otherwise, the data will spread apart and the bell curve is relatively flat. The kurtosis which shows that the peak is narrower than the normal distribution gives a value of 2.114 m/s for 2005 and 7.887 m/s for 2006.

VI. PROBABILITY DISTRIBUTION FUNCTION

The output of a wind machine at a particular site, required the knowledge of the distribution of the wind speed. A few distributions have predominantly been used in fitting the measured wind speed data. There are commonly used distributions such as Weibull, Rayleigh, Exponential, Lognormal, Gamma distribution and many other distributions. This current paper will discuss only on a few of the distributions. This present paper analyzed the available data sets using the Weibull distribution. According to the flexibility of this type III extreme distribution, Weibull distribution models have been used in many different applications and also for solving variety of problems from many different disciplines. Over the last two decades, many researchers have been devoted to develop an adequate statistical model to describe wind speed frequency distribution. E. Kavak Akpinar and S. Akpinar (2004) summarize that the Weibull and Rayleigh functions are commonly used for fitting the measured wind speed probability distribution. Corotis et al. (1978) found that the Rayleigh distribution is better than the Weibull distribution. However, Hennessey J. (1977) found that the energy output calculated using wind speeds derived from Rayleigh distribution was within 10% of those derived from the Weibull distribution. Justus et al. (1976) found that Weibull distribution gave the best fit to wind speed data from more than 100 stations in the United States National Climate Centre. A.S.S Dorvlo (2002) found that in using the Weibull distribution, the parameters estimated using the Chi Square method gave a better estimates for the parameters compared to other methods, as once indicated by the Kolmogrov-Smirnov statistic.

This work involved only three of the most used statistical applied to the wind speed data. The Weibull function is a two parameter function which involve a shape parameter, β and a scale parameter denote by α . This flexible probability distribution function is given by

$$f(x) = \left(\frac{\beta}{\alpha}\right)\left(\frac{x}{\alpha}\right)^{\beta-1} exp\left[\left(-\frac{x}{\alpha}\right)^{\beta}\right] \quad (1)$$

where $f(x)$ is the probability of observing wind speed is, α is the scale parameter, β is the shape parameter, and x is the wind speed. The corresponding cumulative probability function of the Weibull distribution is

$$F(x) = 1 - exp\left[\left(-\frac{x}{\alpha}\right)^{\beta}\right] \quad (2)$$

In probability theory and statistics, the gamma distribution is a two-parameter family of continuous probability distributions. It has a scale parameter θ and a shape parameter k. If k is an integer then the distribution represents the sum of k independent exponentially distributed random variables, each of which has a mean of θ (which is equivalent to a rate parameter of θ^{-1}). The probability density function of the gamma distribution can be expressed in terms of the gamma function parameterized in terms of a shape parameter k and scale parameter θ:

$$f(x) = x^{k-1}\frac{e - x/\theta}{\theta^{k}\Gamma(k)} \quad (3)$$

The cumulative distribution function is the regularized gamma function, which can be expressed in terms of the incomplete gamma function,

$$F(x) = \int_0^x f(u)\,du = \frac{\gamma(k, x/\theta)}{\Gamma(k)} \quad (4)$$

While, the Burr distribution is a continuous probability distribution for a non-negative random variable. Also known as Singh-Maddala distribution but sometimes called the generalized log-logistic distribution. It is most commonly used to model household income. The Burr's probability density and its cumulative distribution function is given as;

$$f(x) = \frac{\alpha k\left(\frac{x}{\beta}\right)^{\alpha-1}}{\beta\left(1+\left(\frac{x}{\beta}\right)^{\alpha}\right)^{k+1}} \quad (5)$$

$$F(x) = 1 - \left(1 + \left(\frac{x}{\beta}\right)^{\alpha}\right)^{-k} \quad (6)$$

VII. PARAMETER ESTIMATION

Whenever it involves modeling technique in terms of statistical distribution, there will usually be parameter estimation. There are a number of approaches to estimating the parameters of a statistical distribution from a set of data. There are many model validations used by past researchers in estimating the parameter for their own project. Several parameter estimation methods available are Maximum Likelihood estimator, Bayes estimator, method of moment estimator, Cramér-Rao bound, minimum mean squared error (MMSE) which is also known as Bayes least squared error (BLSE), maximum a posteriori (MAP), minimum variance unbiased estimator (MVUE), best linear unbiased estimator (BLUE) and many other. Maximum likelihood estimates are popular because they have good statistical properties. The parameter estimation can be made in the final step after decision has been made.

The primary drawback is that likelihood equations have to be derived for each specific distributions (other approaches, such as least squares or PPCC plots, allow a more general approach). In some cases, the maximum likelihood estimates are trivial while in other cases they are quite complex and may require specialized methods to solve.

In this present work, the only one used is Maximum Likelihood Method (MLE). The results of the parameter estimation using these statistical formulas will be displayed in the results and discussion section.

VIII. GOODNESS OF FIT

Evaluation of the goodness of fit is very important in the process of choosing the best distribution. As it is common in statistical literature, the term goodness of fit is used here might be understood in several senses: A "good fit" might be a model that your data could reasonably have come from, given the assumptions of least-squares fitting in which the model coefficients can be estimated with little uncertainty that explains a high proportion of the variability in your data, and is able to predict new observations with high certainty. Two types of goodness of fit tests were used in this paper which are Kolmogrov-Smirnov (Ks) and Anderson Darling (AD). Anderson-Darling test statistics can be written as [11]

$$A_{mw} = \left\{-n + \sum_{i=1}^{n}\frac{1-2i}{n}\left[ln\left(1 - e^{-w_i}\right) - w_{n+1-i}\right]\right\}\left\{1 + \frac{0.2}{\sqrt{n}}\right\} \quad (7)$$

According to the Kolmogorov-Smirnov test method [20], the distribution function of the parent set X is defined as F(x), while the empirical distribtution is

$$F^{*}_{n}(x) = \frac{k}{n}; \qquad k=1,2,\ldots,n-1 \quad (8)$$

where k is the cumulative frequency and n is the sample size. The statistical term, define as D_n;

$$D_n = \max_{1\le k\le n}\left|F_n^{*}(x_k) - F(x)\right| \quad (9)$$

The value of D_n need to be compared with a critical value, D_α in the Kolmogorv-Smirnov statistical table. If $D_n \leq D_\alpha$, then the model can be considered as a good fit to the data sets. Otherwise, it is unsatisfied.

IX. RESULTS AND DISCUSSION

Results were firstly done in terms of graphical and numerical analysis. However, section IX will only discuss about the graphical analysis used. The other analysis will be in Section I, the conclusion part. There are many types of graphs that can be used as graphical analysis other than the probability density function and the cumulative distribution function.

Table II shows the yearly parameter value for the data sets. It shows the statistics for all the three distributions. Using the Easyfit 5.0, the statistical computer software which uses maximum likelihood estimator to estimate the parameter, the result of the parameter estimation is like shown in the table. The monthly mean wind speed values and the standard deviations from the data obtained for the overall and individual two years are presented in Table III. As indicated for the overall two years, the mean wind speed is about only 3.70 m/s. The minimum value of wind speed for both years is recorded as 2.04 m/s which arise in the month of September, while the maximum is 6.54 m/s in February.

Figure 4 and 5 shows the probability density function (PDF) plot for the year 2005 and 2006 respectively. Both plots can be seen skewed to the right with the skewness values calculated as 1.521 m/s and 2.728 m/s respectively. It can be seen in those figures that all the three distributions are quite similar for both of the years. Both of the PDF plot represents a narrow peak for the whole distributions at about 2.0 to 2.6 m/s and 2.0 to 3.0 m/s in the year 2005 and 2006 respectively.

On the other hand, figure 6 and 7 shows the cumulative function (CDF) plot for all the three distributions for the year 2005, and 2006 respectively. From there, it can be seen that the plot for the Burr distribution is closer to the empirical distribution, plotted as the sample data in 2005 compared to the other two distributions. Similarly, the plot for the year 2006 also show that the Burr distribution is the most closest to the empirical plot. Figure 8 and 9 shows the P-P plot for both year. From here also, it is shown that the plot for Burr distribution has the closest distance to the straight line. Hence, by looking at the graphical result only, it can be concluded that the Burr distribution fit the data well.

TABLE II
Yearly parameter

	(2005)	(2006)
Weibull	α=3.46 β=2.97	α=2.98 β=3.01
Burr	k=0.14 α=25.37 β=2.04	k=0.004 α=10356.0 β=2.12
Gamma	k=9.42 θ=0.30	k=7.18 θ=0.40

TABLE III
Monthly wind speed and standard deviation, 2005-2006

Years	**(2005)**		**(2006)**		**Whole Year**	
Parameters	V_m	σ	V_m	σ	V_m	σ
January	4.44	1.11	7.74	21.24	**6.09**	**11.18**
February	3.47	1.89	9.61	20.44	**6.54**	**11.16**
March	3.16	0.90	5.13	14.05	**4.15**	**7.48**
April	2.54	0.36	4.66	12.55	**3.60**	**6.45**
May	2.24	0.28	4.30	11.76	**3.27**	**6.02**
June	2.25	0.25	4.44	11.95	**3.35**	**6.10**
July	2.18	0.38	4.13	11.31	**3.16**	**5.84**
August	2.13	0.28	4.28	11.71	**3.21**	**5.99**
September	1.91	0.55	2.17	0.40	**2.04**	**0.47**
October	2.40	0.80	2.14	0.38	**2.27**	**0.59**
November	2.38	0.79	2.12	0.79	**2.25**	**0.79**
December	4.58	1.42	4.40	2.99	**4.49**	**2.21**
Yearly	**2.81**	**0.75**	**4.59**	**9.96**	**3.70**	**5.357**

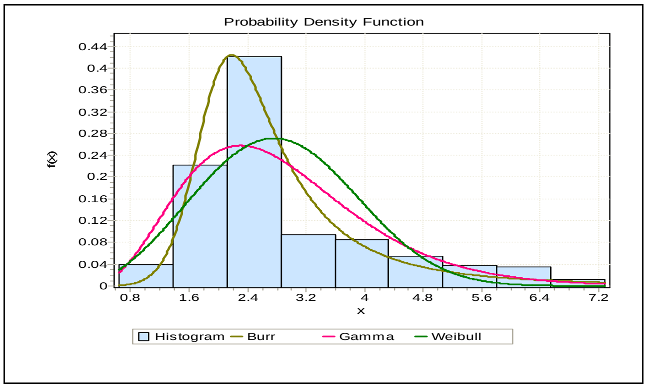

Fig. 4 PDF for the year 2005

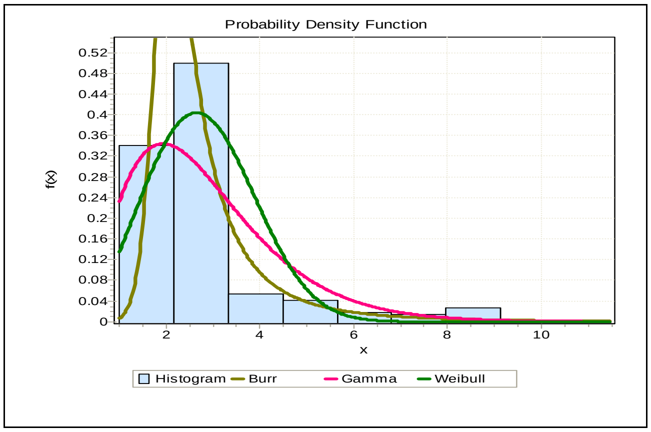

Fig. 5 PDF for the year 2006

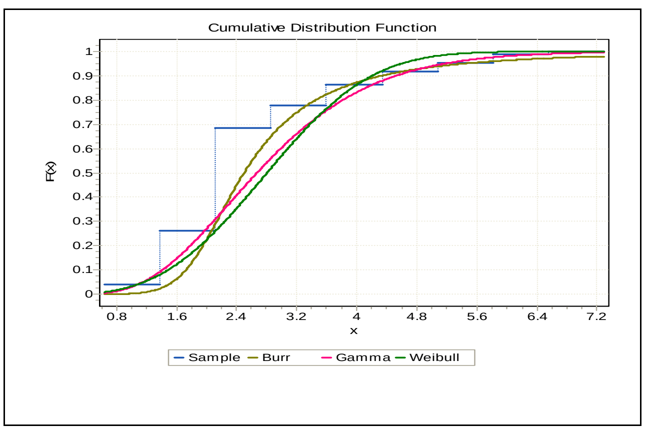

Fig. 6 CDF for the year 2005

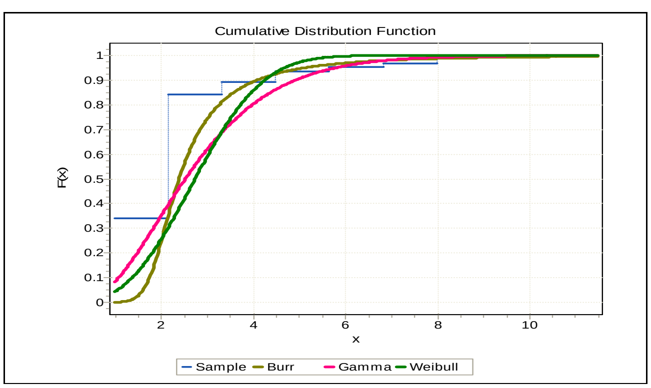

Fig. 7 CDF for the year 2006

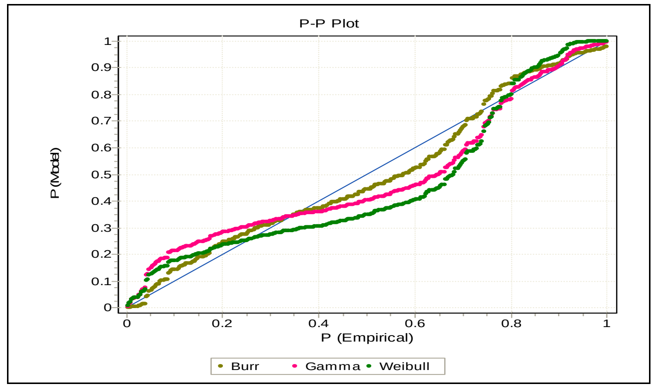

Fig. 8 P-P plot for the year 2006

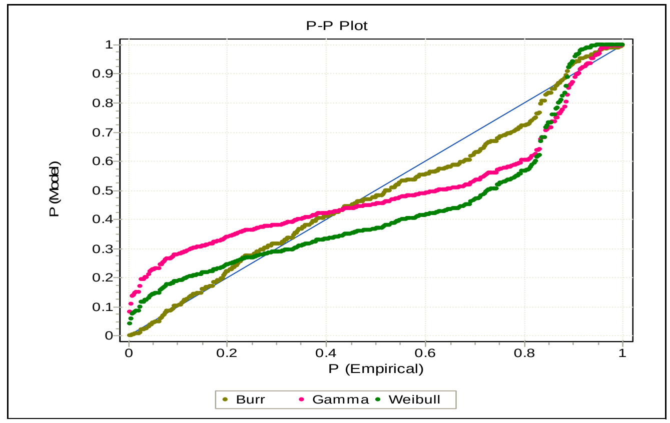

Fig. 9 P-P plot for the year 2006

I. CONCLUSION

This paper investigates a comparative assessment between three statistical distributions; Burr, Weibull and gamma distribution. Using a two years period data sets taken from the University Malaysia Terengganu, Terengganu, it was found in this paper that Burr distribution gives a close approximation of all the three distributions. As it can be seen from table IV, the chi squared value for the three distributions are null due to the unsuitable data set that comes from the year 2006 itself.

TABLE IV
Goodness of fit test

		2005	2006
Ks	**Weibull**	0.2265	0.2958
	Burr	0.1508	0.0000
	Gamma	0.2471	0.2721
AD	**Weibull**	1.0849	1.5633
	Burr	0.3278	0.0000
	Gamma	0.7802	1.3262
χ^2	**Weibull**	1.8233	0.000
	Burr	0.4996	0.000
	Gamma	2.6802	0.000

From goodness of fit table above, comparing the critical value of Kolmogorov-Smirnov (Ks), Anderson Darling (AD), and the

Chi Squared value (χ^2), Burr distribution seems to satisfy the statistical decision criteria.

REFERENCES

[1] Baharuddin Ali, Kamaruzzaman Sopian, Chan Hoy Yen, Sohif Mat & Azami Zaharim. 2008. Key success factors in implementing renewable energy programme. 4th IASME/WSEAS International Conference on Energy, Environment, Ecosystems and Sustainable Development (EEESD'08). June 11-13, 2008. Algarve, Portugal.

[2] Bernama, Hydropower to propel Sarawak to become regional power house, 17 April: 2008

[3] Sen Z, Sahin AD. Regional wind energy evaluation in some parts of Turkey. Journal of Engineering Ind. Aerodynam 1998; 74-76:345-53. Simiu E, Scanlan R.H. Wind Effect on structures. New York: John Wiley & Sons; 1986.

[4] Kamaruzzaman Sopian, Ahmad Mahir Razali and Mohd. Yusof Hj. Othman. 1995. Potensi tenaga angin di Terumbu Layang-Layang. *Journal of Industrial Technology* 5(1):19-32

[5] Chiang, E.P., Zainal, Z.A., Aswatha Narayana, P.A., and Seetharamu, (2003) *Potential Of Renewable Wave And Offshore Wind Energy Sources In Malaysia.* In: Marine Technology 2003 Seminar, 2003.

[6] Kamaruzzaman Sopian, Mohd Yusof Hj. Othman, Rosli Zulkifli and Ahmad Shazli Abdul Wahab. 1999. Wind energy potential on Malaysian islands: A case study of Tioman, Redang and Perhentian Island. *Proceedings of the World Renewable Energy Congress, Malaysia*. 493 – 497.

[7] Jaafar, Z., 2005. The Way Forward, Malaysia's Energy Plan, Malaysia Energy Center.

[8] Hafzulah Aksoy, Z. Fuad Toprak, Ali Aytek, N. Erdem Ünal. 2004. Stochastic generation of hourly mean wind speed data. *Renewable energy* (29) : 2111-2131

[9] Al Buhairi, Mahyoub H. 2006. A statistical analysis of wind speed data and an assessment of wind energy potential in taiz-yemen. *Ass. Univ. Bull. Environ. Res.* 9(2) : 21 – 33.

[10] Tina, G. , Gagliano, S., Probability Analysis of Weather Data for Energy Assessment of Hybrid Solar/ Wind Poweer System. 4th IASME/WSEAS International Conference on Energy, Environment, Ecosystems and Sustainable Development (EEESD'08). June 11-13, 2008. Algarve, Portugal

[11] Rozaimah Zainal Abidin, Ahmad Mahir Razali, Azami Zaharim and Kamaryzzaman Sopian. 2008. Modelling wind speed data via two parameter weibull. *Proceedings of Seminar on Engineering Mathematics*, 27 - 29 June 2008. Cameron Highlands, Pahang.

[12] Cellura, M., Cirrincione, G. , Marvuglia, A., Miraoui, A. (2008). Wind speed spatial estimation for energy planning in Sicily: Introduction and statistical analysis. *Renewable energy* (33) : 1237-1250

[13] Kamaruzzaman Sopian, Mohd Yusof Hj. Othman, Rosli Zulkifli and Ahmad Shazli Abdul Wahab. 1999. Wind energy potential on Malaysian islands: A case study of Tioman, Redang and Perhentian Island. *Proceedings of the World Renewable Energy Congress, Malaysia*. 493 – 497.

[14] Yap, D. 1992. Biomass as renewable energy. *The Star*, 17 January: 2009

[15] Akpinar, E. Kavak and Akpinar, S. 2004. An assessment on seasonal analysis of wind energy characteristics and wind turbine characteristics. *Energy Conversion and Management* 46; 1848 – 1867.

[16] Corotis RB, Sigi AB, Klein J. 1978. Probability models of wind velocity magnitude and persistence. *Solar energy* 20: 483 – 493.

[17] Hennessey J. Some aspects of wind power statistics. 1977. *Journal of Applied Meteorology*. 16 (2): 119 – 128.

[18] Justus, C.G., Hargraves, W.R and Yalcin (1976). Nationwide assessment of potential output from wind generators. *Journal of Applied Meteorology* 15: 673 – 678

[19] Dorvlo A.S.S.2002. Estimating wind speed distribution. *Energy Conversion and Management* 43: 2311 – 2318

[20] Seguro, J. V and Lambert, T. W. 2000. Modern estimation of the parameters of the Weibull wind speed distribution for wind energy analysis. *Journal of Wind Engineering and Industrial Aerodynamics* 85: 75 – 84.