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WIND POWER HARNESSING BASED ON SENAI METEOROLOGICAL DATA, MALAYSIA

Ahmad Sukri Ahmad, Md Affendi M.Yusuf, Md Shah Majid
Hasimah Abdul Rahman and Mohammed Yusri Hassan

Center of Electrical Energy System, Faculty of Electrical Engineering, UniversitiTeknologi Malaysia
E-mail: maxlyn20@gmail.com, afendi@fkm.utm.my, mdshah@fke.utm.my
hasimah@fke.utm.my, yusrih@fke.utm.my

ABSTRACT: The variation in wind speed with elevation influences both the assessment of wind resources and the design of wind turbines. This paper presents an analysis of determining the prospect of wind energy potential at Senai, Johor using measured data from 2007 to 2008 obtained from Malaysia Meteorological Department. Results show the level of wind intensity of the wind profile characteristics for the high and low wind speed can be identified. Besides that, the maximum, minimum and average power were estimated.The wind speed distribution for the annual and monthly mean wind speed using 3Tier wind prospecting tool shows the potential for harnessing the wind. This paper also highlights artificial intelligence applications in wind technology.

Keywords: wind profiles, wind power, Weibull distribution, 3Tier wind prospecting tool, artificial intelligence (AI).

I. INTRODUCTION

The wind power has been a topic of discussion for decades all over the world. The method of harnessing wind power has been technologically developed in the interest of improving the performance and cost effectiveness. Despite these advanced achievements, any wind power project required a detailed analysis of the interest area or local wind behaviour and activity. Logged wind data such as speed and direction could forecasta clear statistical analysis of the power projection and capacity.

Malaysia is geographically located in the equatorial region. The regional wind profile is heavily influenced by the periodic monsoon caused by the climatic changes of the northern and southern hemispheres. This monsoon also gives seasonal effect on this equatorial region. The regional wind direction traveling in low speed moves from Southwest in the middle of May to the end of September, whereas from November until the end of March, the wind is dominated by the Northeast monsoon traveling at the nominal speed of 5.4 meter per second [1].

This paper presents an analysis of the wind power generation, based on meteorological data collected from Senai Weather Station for 2007 and 2008. The data have been recorded and supplied by the Malaysia Meteorological Department (MMD) using anemometer-tracking wind at the height of 37.8 meters above sea level. The wind sensor is placed 10 meters above the ground level, geographically located at latitude 1° 38 N and longitude 103° 40 E [1]. This data is essential for estimating the amount of wind energy available for feasibility studies of the wind power harnessing project, especially for the surrounding area. This paper also highlights an application of artificial neural network and fuzzy logic to the forecast and control of wind power.

II. WIND ENERGY CONVERSION

The energy available in the wind basically is kinetic energy. It derives from the mass of air moving on the earth's surface. The kinetic energy in the wind is captured by the blades and transformed to mechanical energy and electrical energy depending on the end use. The interaction between the rotors of the wind turbine and the wind stream contributes significant effects to the efficiency of energy conversion.

The calculation of wind power is based on the drag force. The equation of the wind power shows that the parametric relationships are governed by the instantaneous wind speed and the nominal wind density. The wind power can be calculated by using the following equations. The drag force, F_D [2];

$$F_D = \frac{1}{2}\rho A v^2 \tag{1}$$

where ρ is the air density in kg/m^3

A is the swept area in m^2

v is the average wind velocity in m/s

Drag force and the wind power are related to the torque, T acting on the wind turbine. The torque is a product of the drag force, F_D and the radius, r of vertical axis wind turbine. The wind power is formulated as;

$$P = T\omega \tag{2}$$

where $\omega = \frac{v}{r}$ is the angular speed of the wind turbine and torque, T is

$$T = F_D r \tag{3}$$

The equation for the wind power is derived by substituting equation (1), (2) and (3), hence equation (4) is obtained [3].

$$P = \frac{1}{2}\rho A v^3 \tag{4}$$

The wind power equation given in (4) is not accurate in estimating the power projection and analysis. According to the Betz' Law, the conversion factor is always limited to 59.3 even for the highest performance wind turbine ever built [2-4]. Therefore, the equation (4) is multiplied with the Betz' conversion factor to give an approximation of the true capacity that can be achieved.

From the analysis of wind speed, the power per unit area can be estimated [4]. From the equation (4), the power per unit area can be calculated as follows:

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

The analysis of wind speed will help us develop the wind turbine; it also estimate the cost of generator, size of the wind turbine, the area required to place the wind turbine and others.

Based on the wind data from Senai Meteorology Station at Johor, the preliminary result of wind speed can be concluded the wind moves mostly in low speed. But, the potential of wind energy varies from one place to another.

III.DATA ANALYSIS AND DISCUSSIONS

The raw data supplied by the Meteorological Department indicates hourly wind speed and direction by degree. These hourly recorded data will be incrementally categorized according to the specific wind speed ranges. The results were shown in percentages for the evaluation and comparison purpose where all the data are accumulated to find the percentage of the highest wind speed and lowest wind speed in the respective year. Table 1 shows the monthly wind speed distribution for the year 2007. The table indicates that an average of 46.50% of wind blow is below 1.0 m/s; 39% of wind blow is between 1.1 m/s to 3.0 m/s, and above 3.0 m/s is about 13%. The percentage distributions show that the wind profile in 2007 is not really impressive as expected. However, in a certain period in January, 2007, the wind activity above 1.1 m/s is high where the percentage of wind speed above 1.1 m/s is about 70%. During the low wind speed period in the same year, the wind speed activity above 1.1 m/s is about 50%.

The wind activities for the year 2008 show the same pattern as that of 2007. It is observed that the activities above 5.0 m/s increase slightly to 7.32% in February, 2008. The average low speed of 1.0 m/s is reduced to 44.22%. This shows a slight increase in wind speed activities above 1.0 m/s up to 55% during a high wind period. Nevertheless, in July and October, 2008, the wind speed in the area is less than 5.1 m/s.

In 2007, the highest wind profile recorded was in January. This is because in January

2007, the percentage of wind blow below 1.0 m/s is only 28.09%. This indicates that the wind speed above 1.1 m/s is higher which is about 71.91%. In December 2008, the highest wind speed above 1.1 m/s is about 76.87% where the wind speed below 1.0 m/s is about 23.12%. For the lowest wind speed, in 2007, 53.89% the recorded wind speed is less than 1.0 m/s in June. This is the higher percentage in 2007. In 2008, it is about 53.36% low wind speed recorded in May.

Table 1 and Table 2 show that the wind speed below 1.0 m/s dominates the wind activity in 2007 and 2008. Both tables also show the same pattern, in which the percentage of wind speed distribution decreases as the wind speed increases. However, Table 3 and Table 4 show that the power per unit area increases as the wind speed increases.

By using 3TIER Wind Prospecting Tool, Wind Speed Distribution, Annual Mean Wind Speed, and Monthly Mean Wind Speed can be observed at three different hub heights [8]. For this comparison, the 20 meter, 50 meter and 80 meter hub heights were selected. Hub height is the distance from the turbine platform to the rotor of installed wind turbine. Figure 1, Figure 2 and Figure 3 show the annual mean wind

Table 1
Percentages of Annual Wind Speed Distribution for 2007

Month	*< 1.0 m/s [%]*	*1.1–2 m/s [%]*	*2.1–3 m/s [%]*	*3.1–4 m/s [%]*	*4.1–5 m/s [%]*	*>5 m/s [%]*
Jan	28.09	30.24	18.41	9.95	6.45	6.85
Feb	44.79	17.22	13.70	8.18	8.93	7.17
Mar	48.66	23.92	15.19	6.18	5.11	0.94
Apr	53.06	25.69	12.08	5.42	2.22	1.53
May	49.33	24.73	15.86	7.53	1.75	0.81
Jun	53.89	23.47	13.89	6.25	2.22	0.28
Jul	51.48	24.33	14.78	6.85	2.15	0.4
Aug	50.27	20.3	15.05	10.62	2.82	0.94
Sep	48.33	21.11	14.58	13.75	1.94	0.28
Oct	45.97	29.03	15.19	6.32	2.15	1.34
Nov	47.92	26.81	15.28	6.25	3.06	0.69
Dec	36.16	30.11	14.38	9.54	5.24	4.57
Average	46.50	24.66	14.87	8.07	3.67	2.23

Table 2
Percentages of Annual Wind Speed Distribution for 2008

Month	*< 1.0 m/s [%]*	*1.1–2 m/s [%]*	*2.1–3 m/s [%]*	*3.1–4 m/s [%]*	*4.1–5 m/s [%]*	*>5 m/s [%]*
Jan	29.97	22.85	20.7	13.98	9.41	3.09
Feb	32.33	27.44	12.36	8.91	11.64	7.33
Mar	43.01	27.42	15.32	8.47	3.63	2.15
Apr	50.97	30.14	12.64	3.89	1.81	0.56
May	53.36	20.3	13.31	10.75	2.02	0.13
Jun	52.5	22.78	16.81	6.53	1.11	0.28
Jul	50.54	21.64	17.34	9.54	0.81	0.13
Aug	50.67	24.19	12.37	9.01	2.96	0.81
Sep	46.53	21.39	15.97	12.78	3.06	0.28
Oct	52.38	25.67	13.58	4.3	0.94	0.13
Nov	45.28	30.56	15.83	7.08	0.69	0.56
Dec	23.12	28.09	23.12	12.63	8.33	4.7
Average	44.22	25.21	15.78	8.99	3.87	1.68

Table 3
Power per Unit Area of Wind in Senai for 2007

Month n Speed	*< 1.0 m/s*	*1-2 m/s*	*2.1-3 m/s*	*3.1-4 m/s*	*4.1-5 m/s*	*>5.1 m/s*
Jan	0.17	0.69	1.86	2.72	3.71	7.14
Feb	0.27	0.37	1.38	2.23	5.13	8.53
Mar	0.30	0.54	1.54	1.69	2.94	0.98
Apr	0.32	0.58	1.22	1.48	1.28	1.60
May	0.30	0.56	1.60	2.05	1.01	0.84
Jun	0.33	0.53	1.40	1.71	1.28	0.29
Jul	0.31	0.55	1.49	1.87	1.24	0.42
Aug	0.31	0.46	1.52	2.90	1.62	0.98
Sep	0.29	0.48	1.47	3.75	1.11	0.29
Oct	0.28	0.66	1.54	1.72	1.24	1.40
Nov	0.29	0.61	1.55	1.71	1.76	0.72
Dec	0.22	0.68	1.45	2.60	3.01	4.77
Total	3.40	6.72	18.04	26.43	25.31	27.96
% wind average	46.50	24.66	14.87	8.07	3.67	2.15
TotalPower Available [Watt]	158.26	165.79	268.29	213.28	92.87	60.11

Table 4
Power per Unit Area of Wind in Senai for 2008

Month n Speed	*< 1.0 m/s*	*1-2 m/s*	*2.1-3 m/s*	*3.1-4 m/s*	*4.1-5 m/s*	*>5.1 m/s*
Jan	0.18	0.52	2.09	3.82	5.41	3.22
Feb	0.20	0.62	1.25	2.43	6.69	7.64
Mar	0.26	0.62	1.55	2.31	2.09	2.24
Apr	0.31	0.68	1.28	1.06	1.04	0.58
May	0.33	0.46	1.35	2.93	1.16	0.14
Jun	0.32	0.52	1.70	1.78	0.64	0.29
Jul	0.31	0.49	1.75	2.60	0.47	0.14
Aug	0.31	0.55	1.25	2.46	1.70	0.84
Sep	0.28	0.49	1.62	3.49	1.76	0.29
Oct	0.32	0.58	1.37	1.17	0.54	0.14
Nov	0.28	0.69	1.60	1.93	0.40	0.58
Dec	0.14	0.64	2.34	3.45	4.79	4.90
Total	3.24	6.87	19.15	29.44	26.67	21.01
% wind average	44.22	25.21	15.78	8.99	3.87	1.68
Total Power Available [Watt]	143.14	173.21	302.22	264.65	103.20	35.30

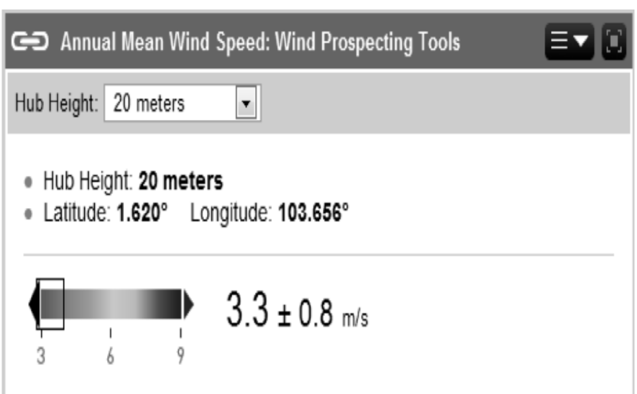

Figure 1: Senai Annual Mean Speed at 20 Meter Height

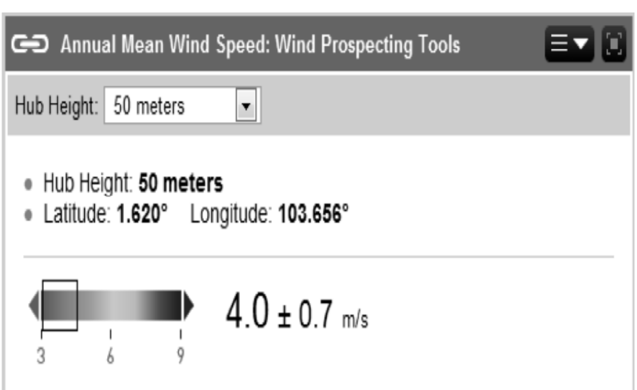

Figure 2: Senai Annual Mean Speed at 50 Meter Height

speed increases from 3.3 m/s to 4.2 m/s at different hub heights.

Monthly Mean Wind Speed shows the mean wind speed for the whole month in a year. The mean wind speed for each month changes as the hub height increases. Figure 4, Figure 5 and Figure 6 show the Monthly Mean Wind Speed for Senai. The wind speed patterns for three different heights are almost the same. Figures show that the highest wind speed is in January, and the lowest is in April.

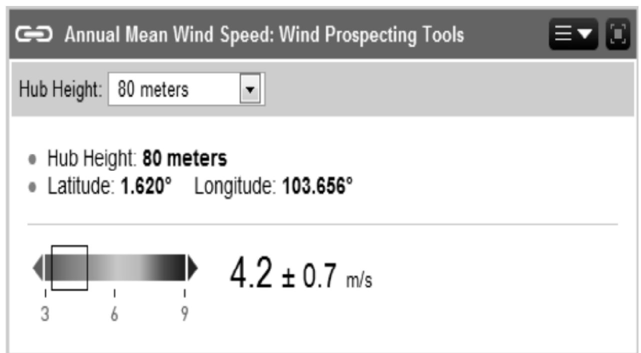

Figure 3: Senai Annual Mean Speed at 80 Meter Height

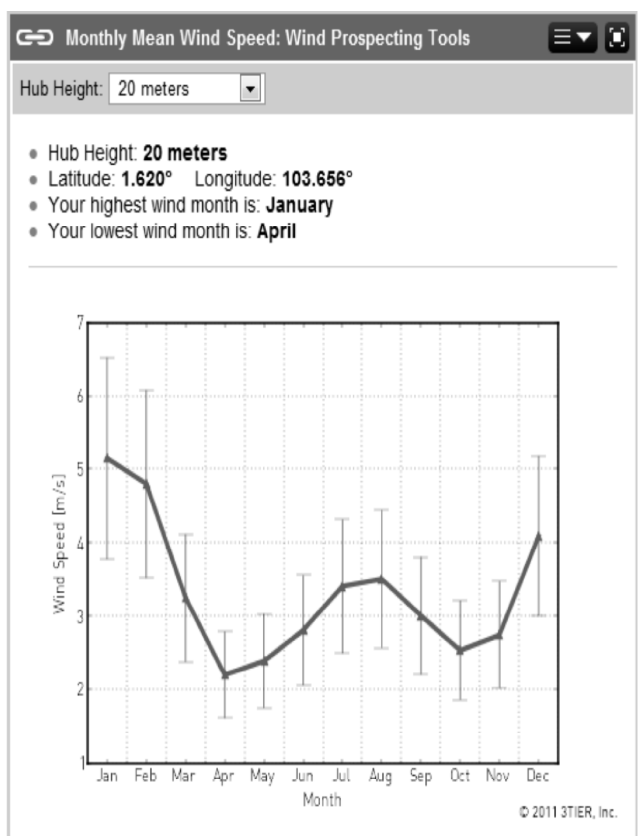

Figure 4: Senai Monthly Mean Wind Speed at 20 Meter

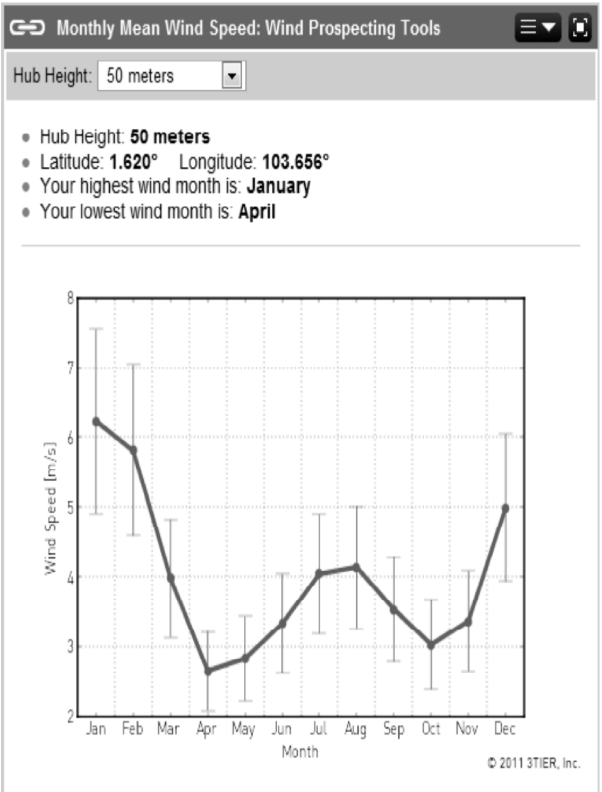

Figure 5: Senai Monthly Mean Wind Speed at 50 Meter

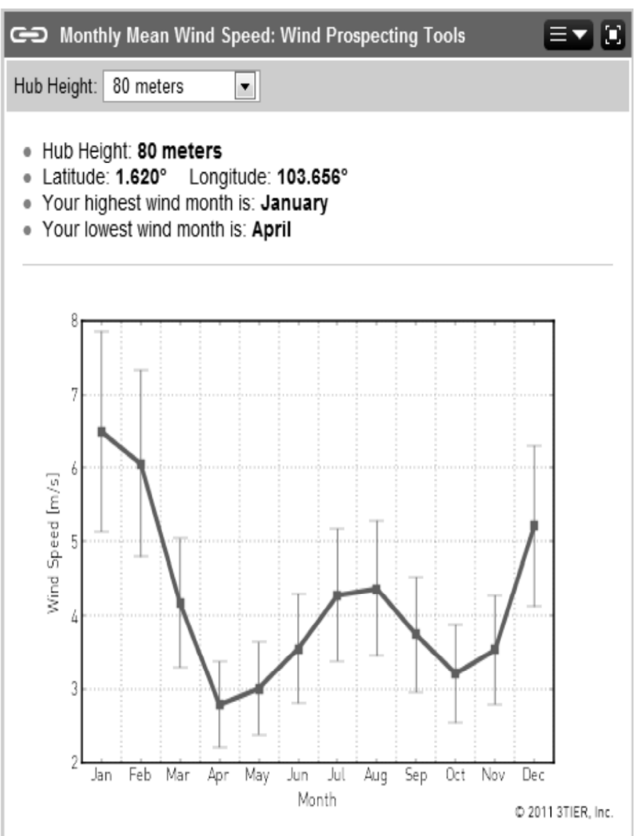

Figure 6: Senai Monthly Mean Wind Speed at 80 Meter

Wind speed distribution can be used to calculate the probability of wind speed at particular location. Weibull Distribution Analysis was used in analyzing the local wind speed distributions. The Weibull Distribution is a two parameter function commonly used to fit the wind speed frequency distribution. The wind speed probability density function (PDF) can be calculated by the following equation [9, 10, 11].

$$f(x) = \left(\frac{k}{c}\right)\left(\frac{x}{c}\right)^{k-1} \exp\left[-\left(\frac{x}{c}\right)^{k}\right] \qquad (6)$$

where k = shape parameter (dimensionless)

c = scale parameter (m/s)

x = wind speed velocity (m/s)

Wind speed distributions for Senai are shown in Figure 7, Figure 8 and Figure 9. 3TIER defined that Weibull A is shape parameter and Weibull k is the scale parameter for Weibull Distribution. A narrow distribution of wind speed indicates that the wind speed is very consistent with the particular location and

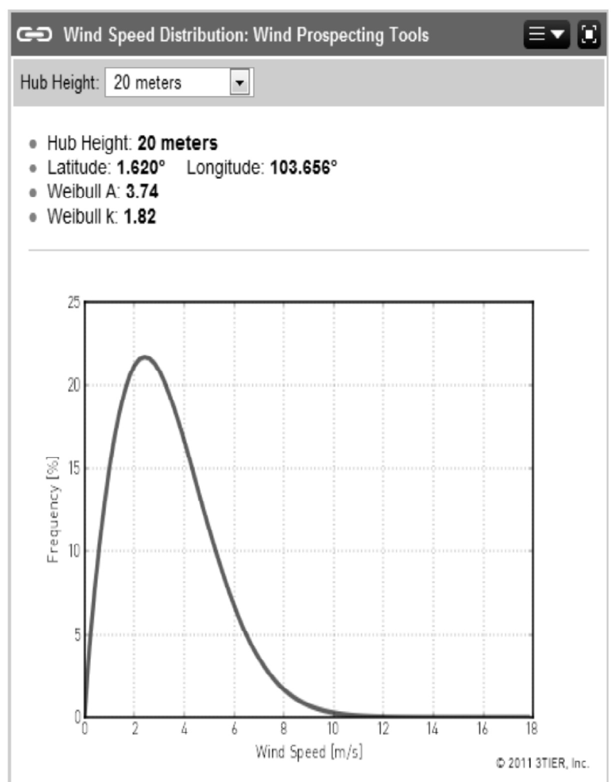

Figure 7: Senai Wind Speed Distribution at 20 Meter

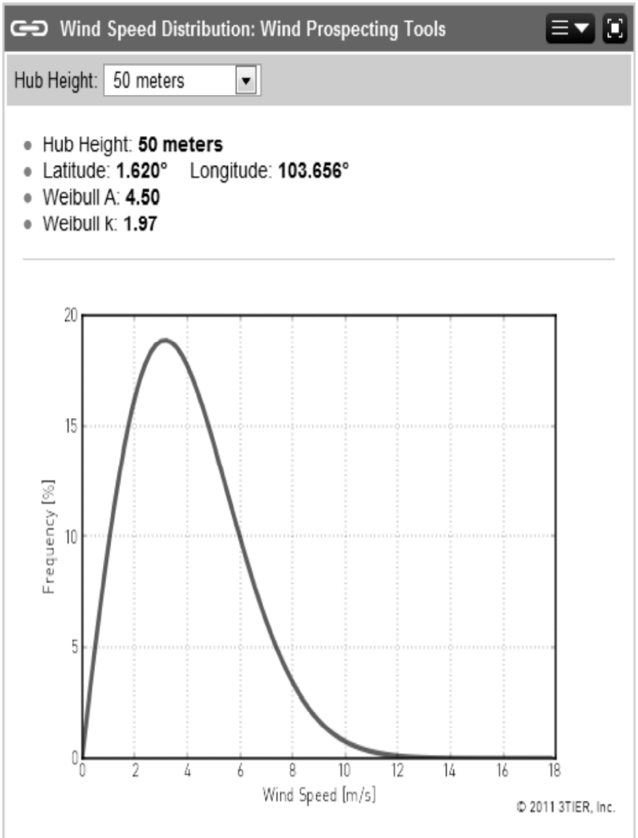

Figure 8: Senai Wind Speed Distribution at 50 Meter

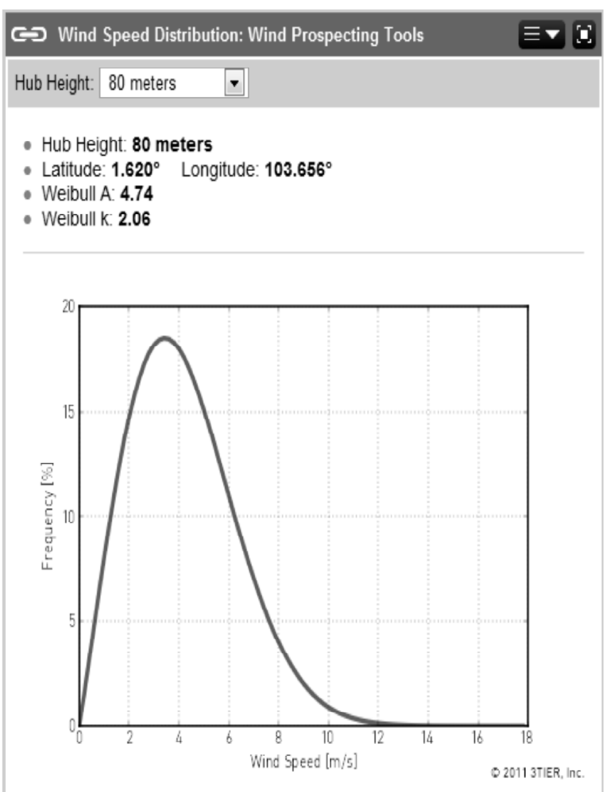

Figure 9: Senai Wind Speed Distribution at 80 Meter

a wide distribution means the wind speed varies greatly. Table 5 shows the various shape parameters and scale parameters at different heights.

Table 5
Distributional Parameter of Senai

Height (meter)	*Shape Parameter (Weibull A)*	*Scale Parameter (Weibull k)*
20	3.74	1.82
50	4.50	1.97
80	4.74	2.06

IV. AI APPLICATIONS IN WIND TECHNOLOGY

Artificial Intelligence (AI) is a term that in its broadest sense would indicate the ability of a machine to perform the same kind of functions that characterize human thought. The term AI has also been applied to computer systems and programs capable of performing tasks more complex than straight program even though it's still far from the realm of actual thought. AI is a part of computer science concerned with the design of intelligent computer systems, i.e., systems that exhibit the characteristics associated with intelligence in human behaviour [12]. AI techniques are becoming useful as alternate approaches to conventional techniques or as components of integrated systems. Branches of AI consist of fuzzy logic, artificial neural network (ANNs), expert systems, genetic algorithms, machine learning, natural language processing, and computational creativity. The use of AI is to overcome the deficiencies encountered in the conventional approaches whereby in certain cases the objective is to produce better, more efficient and effective computing systems. AI techniques have been used in several applications, such as damping power system oscillations [13, 14], load forecasting [15, 16], signal processing [17], scheduling for manufacturing [18] and photovoltaic [19, 20].

Renewable Energy (RE) resources have enormous potential and can meet to a large extent the present world's energy demand. Since the price of oil is unpredictable, RE can enhance diversity in energy supply markets, secure long term sustainable energy supplies and reduce global atmospheric emissions. One of the promising technologies is wind technology. Wind energy is one of the distributed resources which are developed to meet a substantial increasing in energy demand. Besides, it is one of the effective solutions to the global warming and fossil fuel depletion. It has become the world fastest growing renewable energy source of electricity generation. AI techniques such as fuzzy logic, and artificial neural network have been used to estimate and predict wind speed. Some methods based on ANN [21-23] and fuzzy logic [24, 25] have been developed in predicting and short term forecasting of wind speed and power output.

ANN has several key features including adaptive learning and self-organisation. Also, ANN is characterized by the rapidity of response and robustness which make them attractive to control [26].

In [20], artificial techniques using NNC and FLC have been developed for controlling hybrid PV-wind system. Simulation studies show that the overall power management is effective. The power flows between the hybrid PV-wind system and the load demand is balanced. A two-hidden layer neural network was used to predict the wind speed of two stations. The network possesses three input neurons, representing, the monthly average relative humidity, the monthly average atmospheric temperature and the monthly average atmospheric pressure, and one out layer with one neuron representing the total wind speed output. A suitable neural network for wind technology has been found and results show that ANN is an efficient tool for estimating wind speed values. [27].

AI techniques are also showing great promise in forecasting the wind speed. Reference [28] proposed a new strategy using fuzzy logic and artificial neural network in predicting the wind speed. Using the fuzzy logic, the rule has significantly reduced and also increased the wind speed accuracy estimated when compared to the traditional one. Meanwhile, applying the proposed approach to artificial neural network requires fewer neuron numbers and less learning time, but gives accurate wind speed prediction. The experimental results demonstrate that the proposed method not only provides less computational time but also a better wind speed prediction performance.

IV. CONCLUSION

A study of wind profiles using MMD Senai has been presented. The findings show the similarity between wind distribution patterns in the year 2007 and 2008. The highest wind speed occurs in June 2007 and December 2008 at the values of 8.5 m/s and 6.8 m/s respectively. On the other hand, the lowest wind speed of 2.3 happens in July 2007 and May 2008 at 2.8 m/s. The 3Tier Wind Prospecting Tool employed shows that a narrow distribution of wind speed indicates the consistency of wind speed at the particular location, and a wide distribution means that the wind speed varies greatly. In conclusion, the Malaysian wind speed can be categorized as low wind speed, which is in the range from 1.0 m/s to 3.0 m/s. Hence this shows that a vertical axis wind turbine is suitable for the application.

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