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Full Length Research Paper

Wind data analysis of Silchar (Assam, India) by Rayleigh's and Weibull methods

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In this study, wind energy potential of Silchar, the Southern part of Assam, India was analyzed for the period of five years from 2003 - 2007. The wind velocity was recorded diurnally, which was averaged over 24 h in a day. The sampling was done after every 3 h. Diurnal wind speed variation shows the actual picture of wind regime of a place. The average wind velocity in Silchar is about 3.11 kmph, which is considerably low. The wind power density of the place was determined on monthly basis of the period from 2003 - 2007 and it showed that the average power density is found highest during the month of March to April, when it becomes around 40 watt/sq.m. The probabilities of observing various wind velocities were determined using Weibull and also Rayleigh's distribution functions. The results between these two distributions were compared.

Key words: Weibull distribution, Rayleigh's distribution, wind velocity, power density.

INTRODUCTION

The use of wind energy can significantly reduce the combustion of fossil fuel and the consequent emission of carbon-dioxide, which is the main source of green house effect in the world. The increasing demand for wind energy based power systems is highlighted in the growth of installed capacity of wind power generation all over the world, year after year. Wind energy is the order of the day to be the most prolific alternative source of energy for power generation. The rise in the demand for wind energy is reflected in the increasing growth of wind based energy systems all over the world. Global Wind Energy Council (GWEC) body has revealed that in the year 2007, the total installed capacity of wind energy based systems has increased to a record high of 94,000 MW, an increase of 27% compared to the previous year (GEWC, 2008). Further, the GWEC has predicted that the global wind market will be growing by over 155% from its current size to reach 240 GW of total installed capacity by the year 2012. At present in the world, the top four countries producing wind power are: Germany (22,247 MW), U.S (16,818 MW), Spain (15,145 MW) and India

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Abbreviation: Kmph; Kilometers per hour (8000 MW) (Source: GWEC Report 2007).

Nomenclature: K; Weibull shape parameter, **C;** Weibull scale parameter **Σ;** standard deviation, **σ^2;** variance, **$\sigma 1^2$;** variance (Rayleigh), **P/A;** power density; mean wind velocity, **vi;** wind velocity recorded in a day, n; period of wind data collected over a month, **f(v);** probability of observing a wind velocity, **F(v);** average probability of observing a wind velocity, **M;** median.

WIND REGIME OF SILCHAR

In this study, the wind regime of Silchar, the southern part of Assam, North-East, India is analyzed. For this, historical wind data for the period from 2003 - 2007, as supplied by the Regional Meteorological centre, Guwahati, Assam, are used to determine the potential of wind energy in this part of the world. Silchar is situated at 92.51° east longitude and 24.5° north latitude and at a height of 114.68 m above the sea level. Two distinct seasons are observed in this region: the dry season and the rainy season. The weather remains predominantly dry from October to March, while the rainy season starts near about the end of March or the beginning of April and that lasts up to the end of September. The winter in this place spans predominantly from November to the end of February and the summer is prevalent during the course of the rainy season. The temperature during winter is

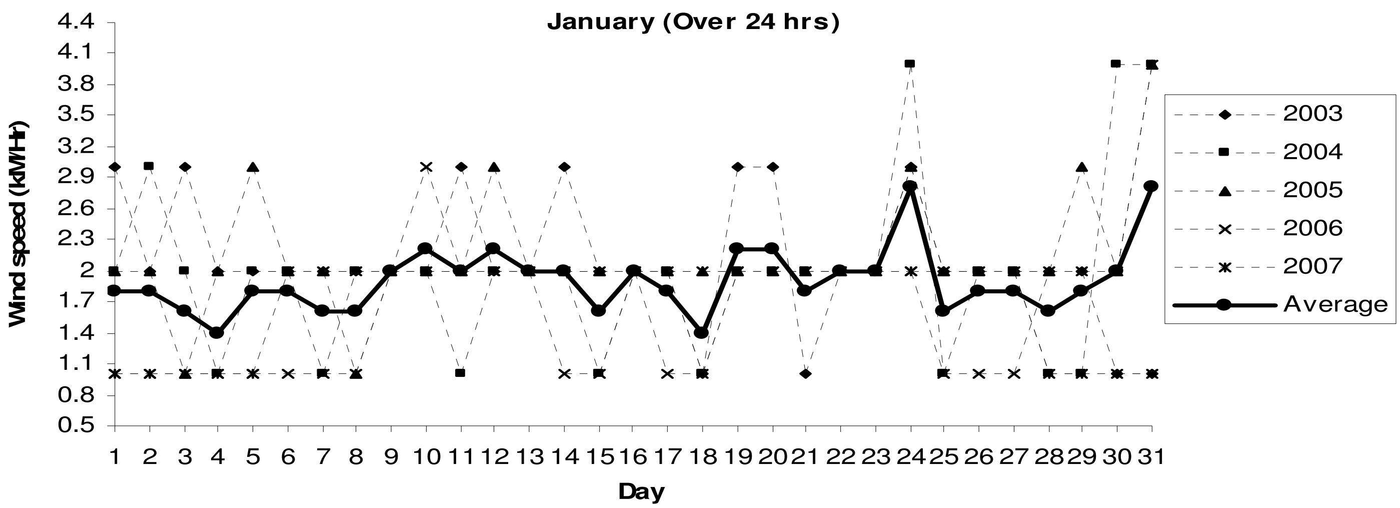

Figure 1. Variation of diurnal wind velocity over 24 h in January for the period 2003 - 2007.

expected in the range of 10 - 21°, while that during summer is in the range of 21 - 36°. The rainfall here is associated with the onset of South-West Monsoon that migrate from the southern part of India and also with the sub Himalayan weather activities such as easterly waves, tropical depression etc. During the rainy season here, variable and also sometimes severe wind patterns are also observed due to the differential heating between the landmasses and the Bay of Bengal. The annual average rainfall in this place is about 110 - 130 mm.

The wind data are collected on monthly basis of the period from 2003 - 2007, where wind velocities and directions are recorded diurnally over 24 h. Wind data of five years period from 2003 - 2007, was collected from the Regional Meteorological center, Guwahati, Assam, where wind speed was recorded using a three-cup anemometer 120° apart placed at a height of 14.37 feet, that is, almost 4.4 m from the ground level. For getting a perfect impression about the wind regime of a place, diurnal wind velocity recording is essential since wind velocity on a particular day of a month may vary from year to year. And that is more so, in the present world, when the global weather trends are fast changing due to the degradation of the biosphere. Figures 1 - 12 show the variations of diurnal wind velocity from January to December of the period 2003 - 2007. Figure 13 shows the plot of monthly variation of wind velocity of the five years period 2003 - 07. It shows that wind velocity during January to September is higher than during October - December. Being a tropical zone, the winter lasts for a short period here in Silchar. From Figure 13, it is seen that high average wind velocity in the dry season occurs late into the winter, in February, when the velocity is about 2.51 KMPH. However, the peak wind velocity occurs in the month of March, just at the onset of Monsoon in the region, when the wind velocity increases to about 3.11 kmph. Moreover over a year on average, better wind regime can be seen in the period from February to August when the wind speed is about 2.4 kmph.

Figure 14 shows the plot of monthly variation of power density for the period 2003 - 2007. The average wind power density, P/A is the average available wind power per unit area, which is given by:

$$\frac{P}{A} = \frac{1}{2}\rho \frac{1}{n}\sum_{i=1}^{n} v_i^{\,3} \qquad [1]$$

Where; n is the total period of wind data collection over a month and v_i is the record of diurnal wind velocity in a day.

It is seen from Figure 14 that the average power density is found highest during the month of March to April, when it becomes around 40 watt/sq.m. But very high value of power density could be seen in April of 2004, which is mainly due to severe wind gusts that normally prevail during April in Silchar. However, average power density of wind is higher than 20 watt/m^2 during the period from March to August. The annual wind rose for the five years period from 2003 - 2007 is shown in Figure 15. The Figure 15 shows that the prevalent winds are from the East, North-East and South-East directions.

WIND ENERGY EVALUATION IN SILCHAR

It is essential to assess wind energy potential of a site before any wind energy based system could be set up. Study of wind velocity regime over a period of time in a locality can really help to optimize the design of the wind energy conversion system by ensuring less energy generating costs (Wind power, 2002; Ulgen et al., 2002). Wind velocity is generally recorded in a time-series format,

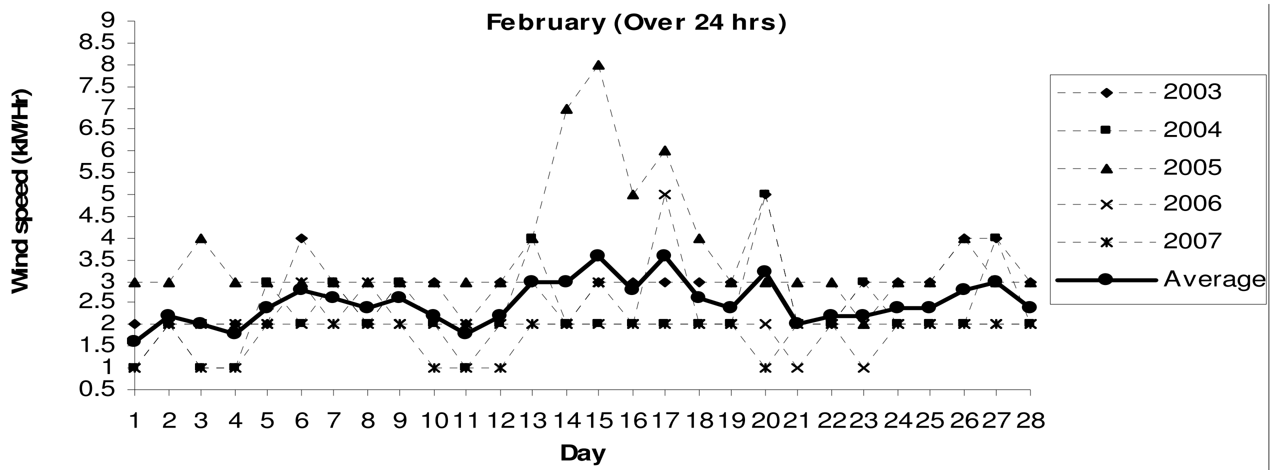

Figure 2. Variation of diurnal wind velocity over 24 h in February for the period 2003 - 2007.

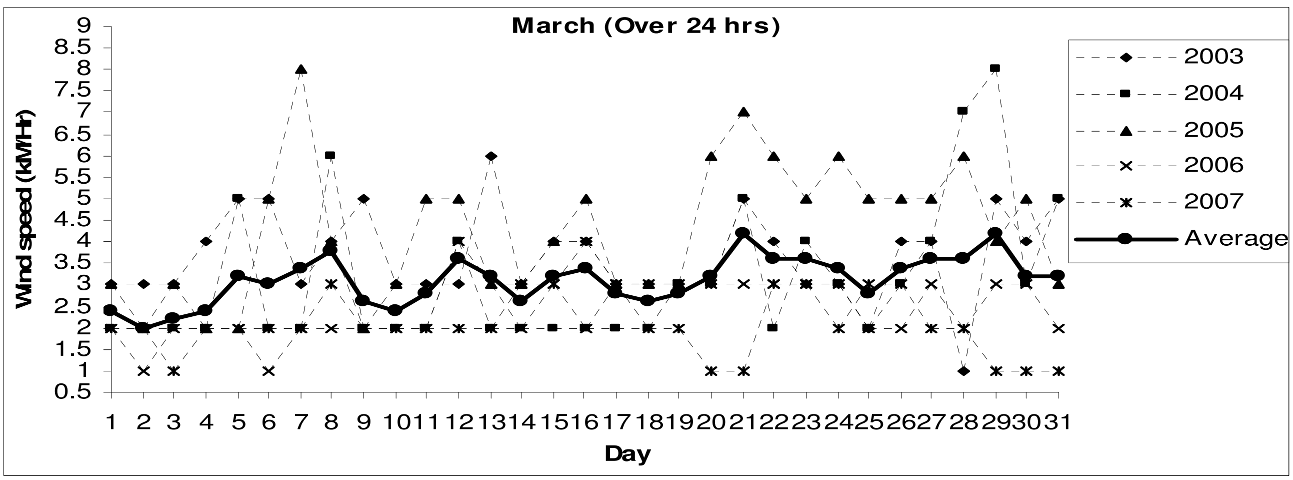

Figure 3. Variation of diurnal wind velocity over 24 h in March for the period 2003 - 2007.

which means wind velocity recorded over hourly basis in a day or over 24 h in a day. Average wind velocity over 24 h basis has been used in the present study.

Weibull distribution function

To date, Weibull density function method is widely accepted for evaluating local wind load probabilities and is considered as a standard approach (Lu et al., 2002; Seguro et al., 2000; Persaud et al., 1999; Musgrove, 1988). This method has a great flexibility and simplicity. However, the main limitation of the Weibull density function is its inability to accurately calculate the probabilities of observing zero or very low wind velocities (Weisser, 2001). Also Weibull two-parameter density function does not address the differences of wind velocity variation during the course of a day. Nevertheless, this statistical method is found to fit a wide collection of recorded wind data (Lun et al., 2000; Dorvlo, 2002). The Weibull wind velocity probability density function can be represented as:

$$f(v) = \frac{k}{c}\left(\frac{v_i}{c}\right)^{k-1} \exp\left(-\left(\frac{v_i}{c}\right)^k\right) \quad [2]$$

Where; $f(v)$ is the probability of observing wind velocity v_i , c is the Weibull scale parameter and k is the dimensionless Weibull shape parameter. Basically, the scale parameter, c, indicates how 'windy' a wind site under consideration is, whereas the shape parameter, k, indicates how peaked the wind distribution is (that is, if

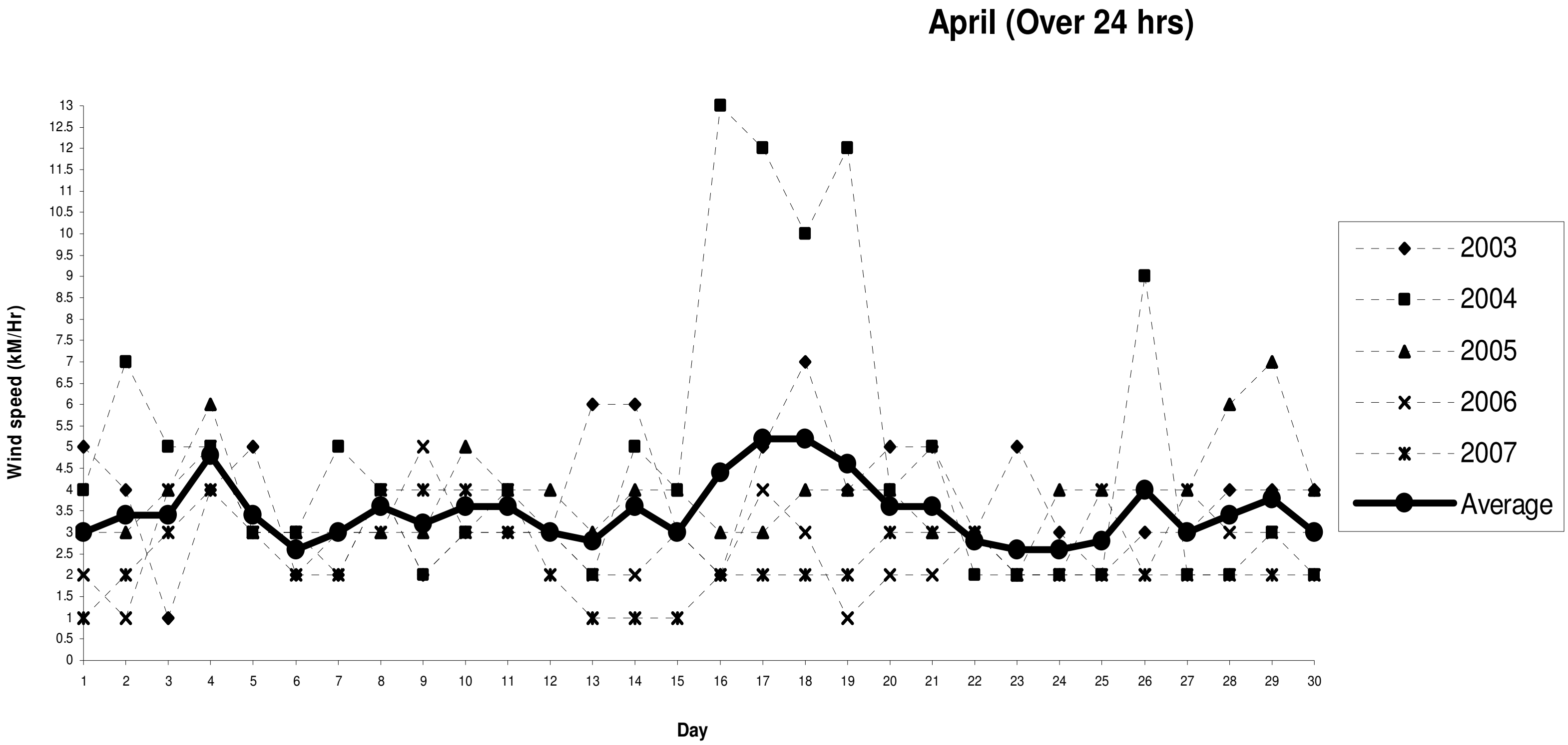

Figure 4. Variation of diurnal wind velocity over 24 h in April for the period 2003 - 2007.

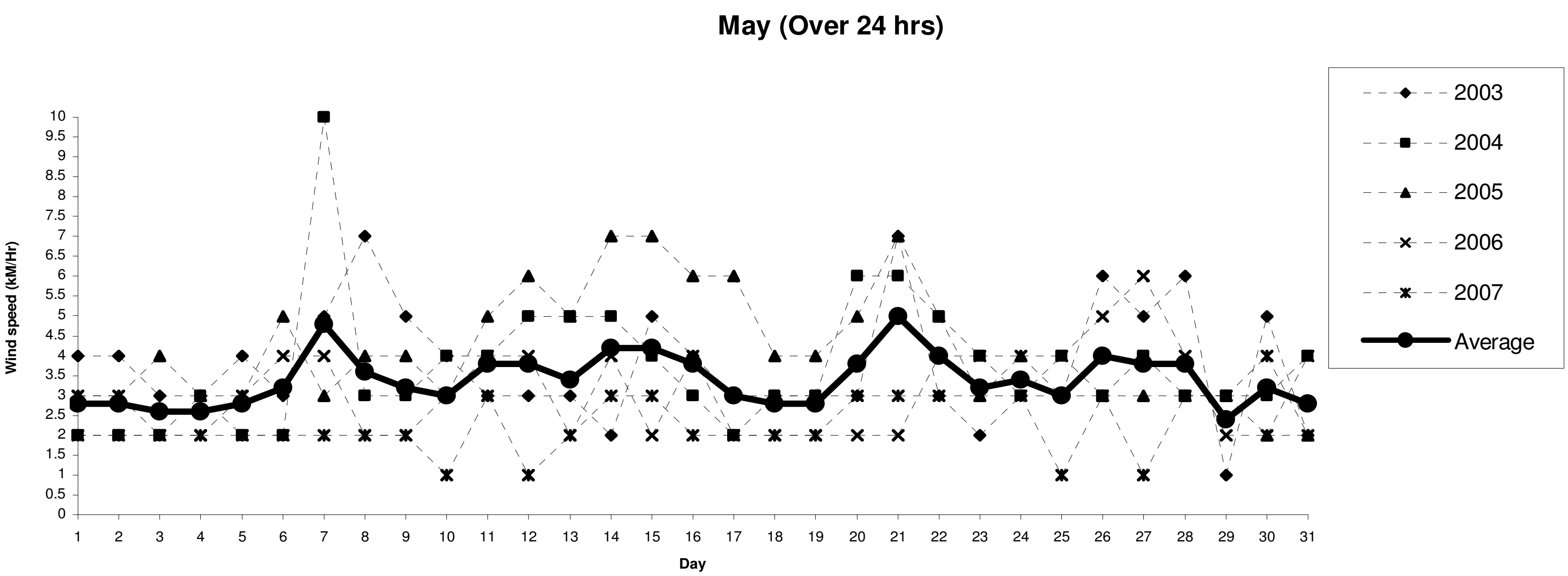

Figure 5. Variation of diurnal wind velocity over 24 h in May for the period 2003 – 2007.

the wind speeds tend to be very close to a certain value, the distribution will have a high *k* value and be very peaked). The average wind speed ($\bar{v}$) and variance of wind velocity (σ^2) are represented as;

$$\bar{v} = \frac{1}{n}\sum_{i=1}^{n} v_i, \quad [3]$$

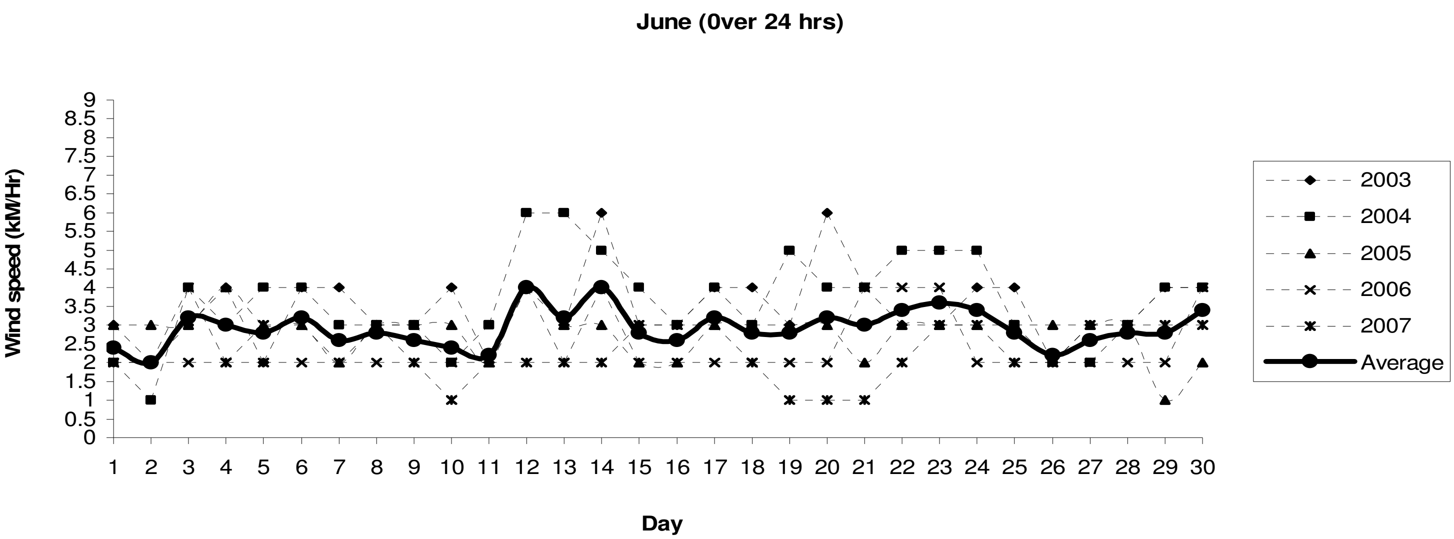

Figure 6. Variation of diurnal wind velocity over 24 h in June for the period 2003 - 2007.

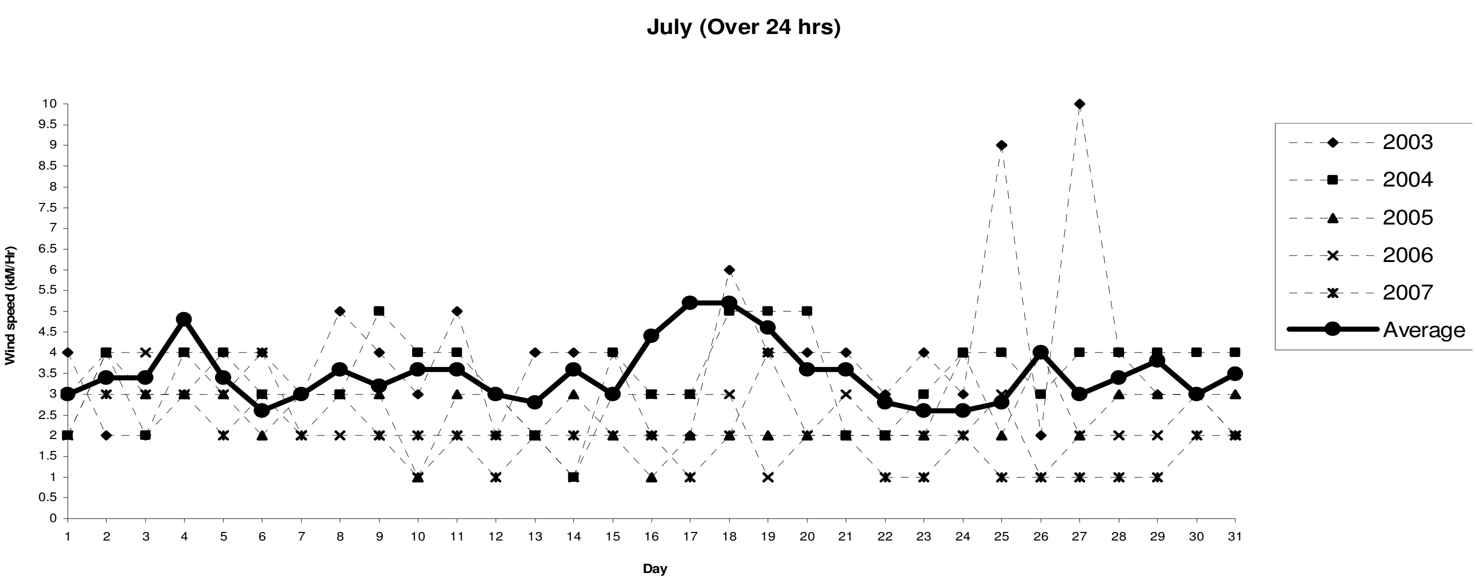

Figure 7. Variation of diurnal wind velocity over 24 h in July for the period 2003 - 2007.

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(v_i-\bar{v})^2 \qquad [4]$$

Bases on the values of mean, $\bar{v}$ and variance, σ^2, the following equations can be used to calculate the Weibull parameters *c* and *k*:

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} \qquad (1 \leq k \leq 10), \qquad [5]$$

$$c = \frac{\bar{v}}{\Gamma(1 + 1/k)} \qquad [6]$$

The results for c and k are obtained using statistical software. The values of k and c on monthly basis for evaluating Weibull probability distribution of the period 2003 - 2007 are given in Table1.

The gamma function of (*x*) (standard formula) can be calculated as:

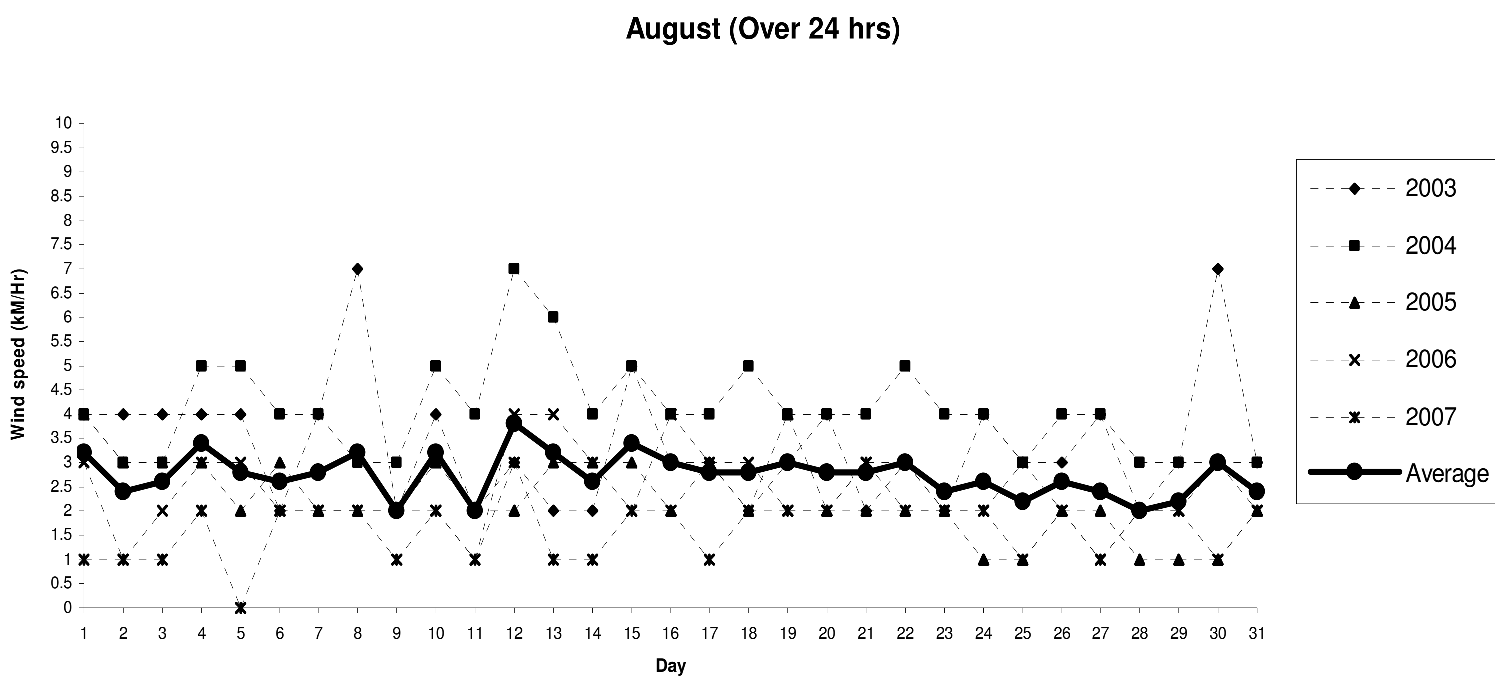

Figure 8. Variation of diurnal wind velocity over 24 h in August for the period 2003 - 2007.

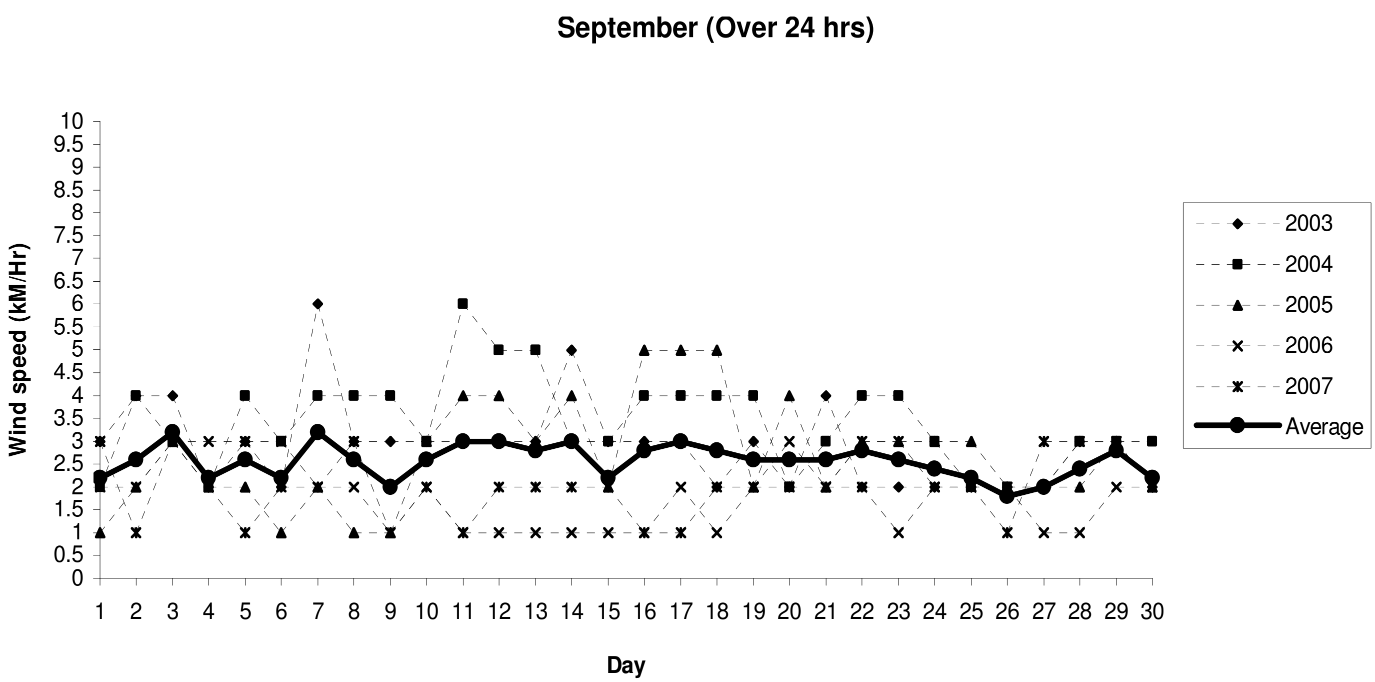

Figure 9. Variation of diurnal wind velocity over 24 h in September for the period 2003 - 2007.

$$\Gamma(x) = \int_0^\infty e^{-u} u^{x-1} \, du \quad [7]$$

The median of the probability distribution is represented as:

$$M = c \ln(2)^{1/k} \quad [8]$$

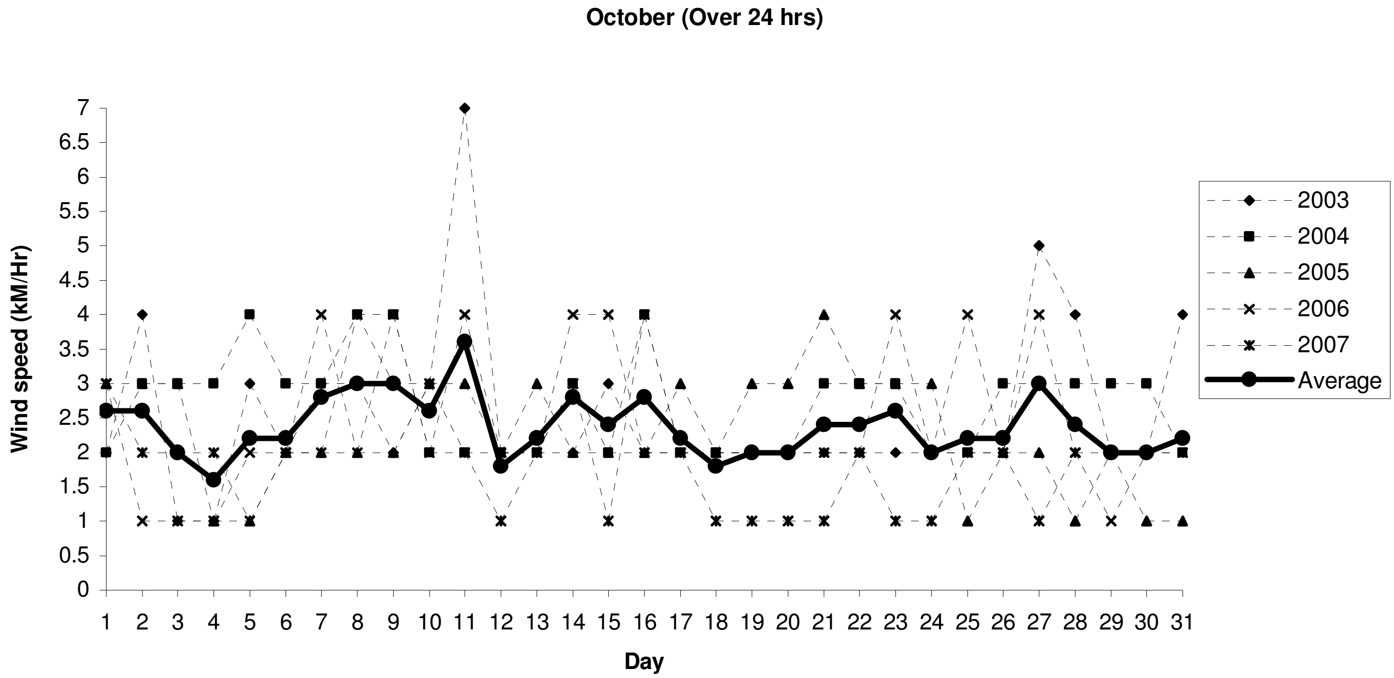

Figure 10. Variation of diurnal wind velocity over 24 h in October for the period 2003 - 2007.

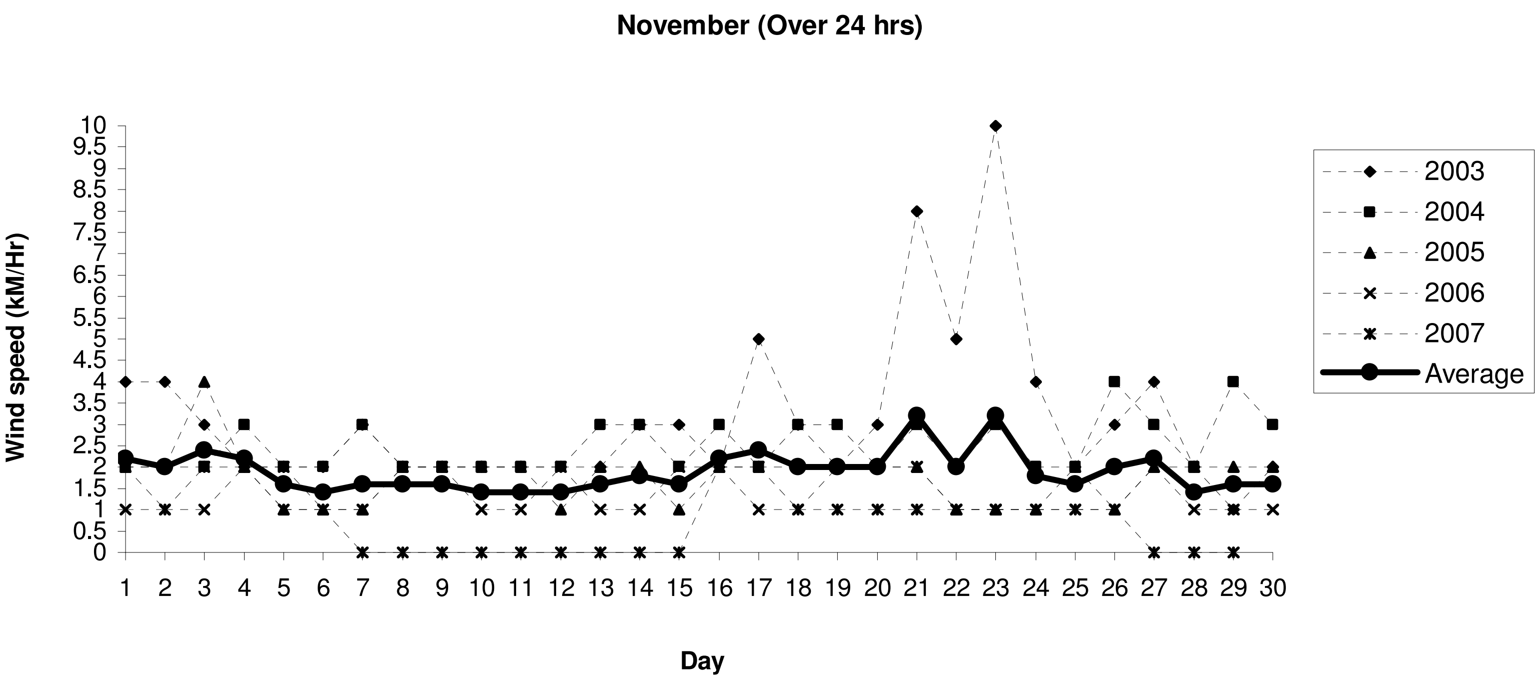

Figure 11. Variation of diurnal wind velocity over 24 h in November for the period 2003 - 2007.

And the mode of the distribution is represented as:

$$\text{Mode} = c\,(k - \frac{1}{k})^{1/k} \qquad [9]$$

For the average wind speed recorded over 24 h, the monthly values of mean ($\overline{v}$), mode, median (M) and variance (σ^2) of the period from 2003 - 2007 is represented in Table 2.

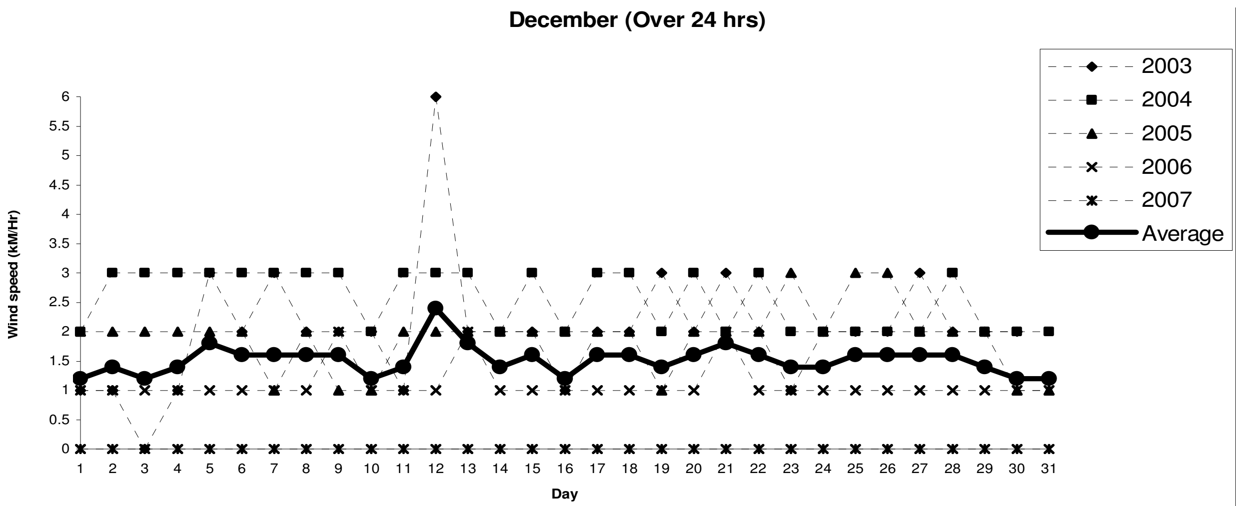

Figure 12. Variation of diurnal wind velocity over 24 h in December for the period 2003 - 2007.

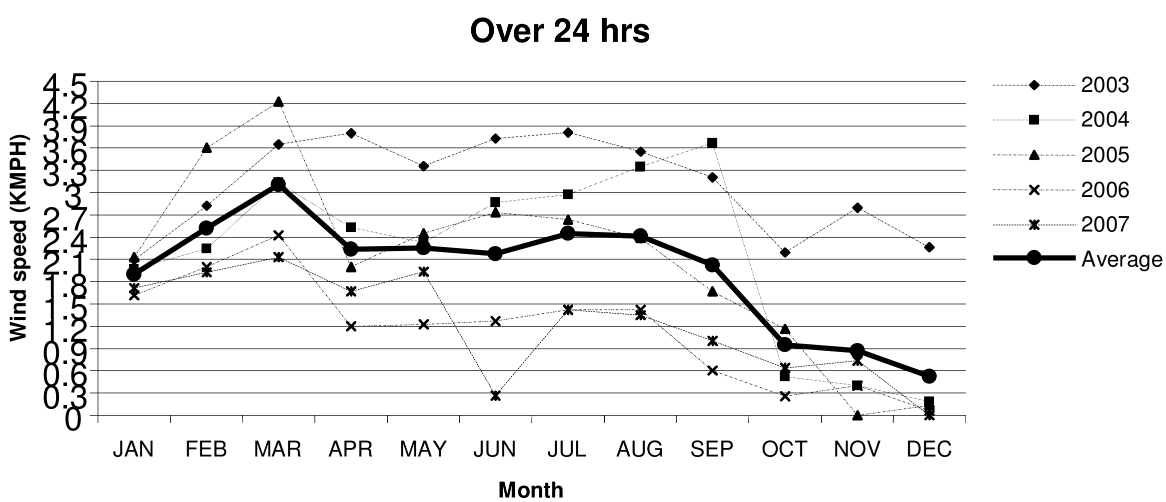

Figure 13. Plot of monthly variation of wind velocity for the period 2003 - 2007.

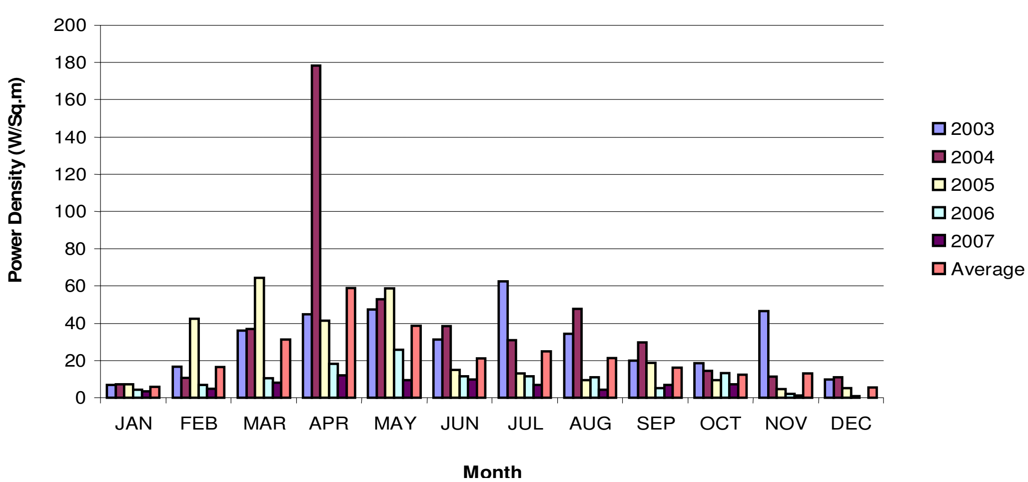

Figure 14. Plot of monthly variation of power density for the period 2003 - 2007.

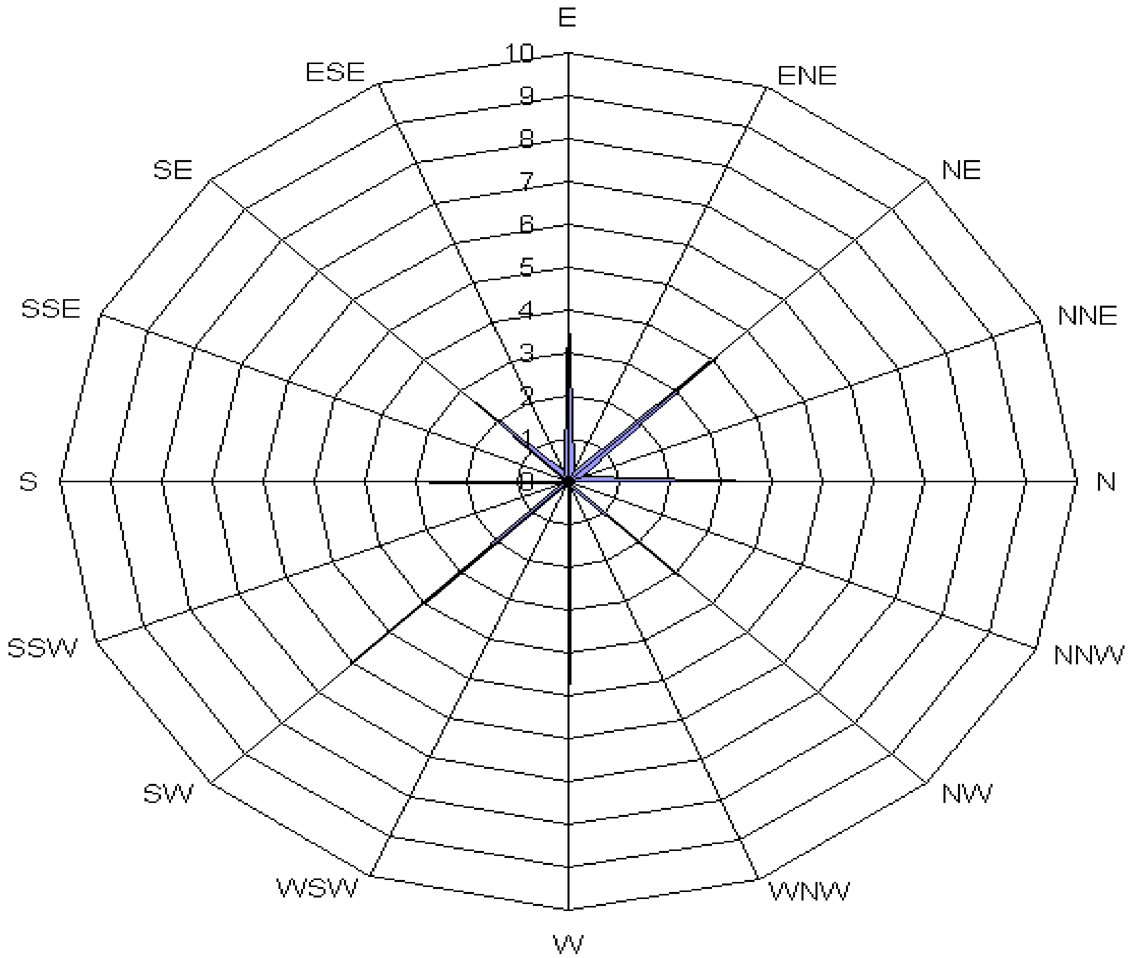

Figure 15. Annual wind rose based on time for the period 2003 - 2007.

Table 1. Values of k and c taken for Weibull distribution evaluation.

Year	Jan.		Feb.		Mar.		Apr.		May.		Jun.	
	k	c	k	c	k	c	k	c	k	c	k	c
2003	3.91	20.3	4.08	33.3	3.86	33.61	2.87	14.6	2.82	14.3	3.97	36.1
2004	2.53	6.49	2.61	7.69	2.00	9.34	1.48	17.3	2.43	10.8	3.28	19.2
2005	4.24	30.4	2.92	14.6	2.94	17.3	3.98	40.1	3.10	17.7	5.23	150.1
2006	2.41	5.1	3.30	10.9	4.01	26.51	3.07	12.6	3.06	13.4	3.23	12.2
2007	4.14	21.7	3.47	11.6	3.04	9.38	2.79	8.98	3.41	13.6	3.39	13.5

Table 1. Contd.

Year	Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	k	c	k	c	k	c	k	c	k	c	k	c
2003	2.21	11.5	2.78	12.5	3.32	15.9	2.25	7.73	1.73	9.94	2.12	6.07
2004	3.72	27.6	4.77	113.8	3.76	28.2	4.39	46.7	4.46	47.1	5.78	7.02
2005	3.74	21.1	3.02	9.8	2.46	8.6	3.02	9.80	3.08	8.01	3.93	19.1
2006	2.94	9.83	3.06	10.5	2.72	6.5	2.54	8.00	3.04	5.84	4.08	12.8
2007	2.67	6.91	2.66	6.0	3.09	9.3	2.43	6.15	0.99	5.80	--	--

Table 2. Distribution of mean, mode, median and variance of wind velocity of the period 2003 - 2007 using Weibull approach.

Year	Jan.				Feb.				Mar.			
	$\bar{v}$	Mode	Med	σ_1^2	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2
2003	2.10	18.9	18.5	0.15	2.81	0.77	0.91	0.33	3.64	1.05	1.24	0.45
2004	1.97	5.32	5.61	0.30	2.25	0.93	1.09	0.40	3.13	1.65	1.98	0.71
2005	2.13	28.5	27.9	0.13	3.61	1.34	1.58	0.58	4.22	1.56	1.84	0.67
2006	1.61	4.09	4.38	0.22	2.00	0.67	0.78	0.29	2.42	0.67	0.79	0.29
2007	1.71	20.3	19.9	0.09	1.86	0.59	0.69	0.25	2.13	0.76	0.90	0.33

Table 2. Contd.

Year	Apr.				May				Jun.			
	$\bar{v}$	Mode	Med	σ^2	$\bar{v}$	Mode	Med	σ^2	$\bar{v}$	Mode	Med	σ^2
2003	3.73	20.1	7.69	1.99	3.77	19.7	7.41	2.11	3.47	50.2	24.9	0.95
2004	4.70	14.9	3.39	10.7	3.71	14.4	4.79	2.68	3.63	26.8	11.4	1.48
2005	3.80	55.8	27.7	1.13	4.13	24.6	10.0	2.12	2.80	204.4	124.2	0.37
2006	2.80	17.5	7.07	0.99	3.13	18.6	7.49	1.25	2.40	17.0	7.15	0.66
2007	2.40	12.3	4.61	0.87	2.29	18.9	8.34	0.55	2.33	18.8	8.24	0.57

Table 2. Contd.

Year	Jul.				Aug.				Sept.			
	$\bar{v}$	Mode	Med	σ^2	$\bar{v}$	Mode	Med	σ^2	$\bar{v}$	Mode	Med	σ^2
2003	3.81	14.8	4.56	3.36	3.35	17.2	6.39	1.70	2.90	22.2	9.54	0.92
2004	3.45	38.5	18.1	1.05	4.06	156.4	88.9	0.93	3.40	39.3	18.7	1.01
2005	2.58	29.4	13.9	0.58	2.26	13.6	5.41	0.66	2.70	11.5	3.87	1.39
2006	2.39	13.6	5.30	0.78	2.35	14.6	5.87	0.70	1.80	8.90	3.25	0.51
2007	1.97	9.43	3.39	0.63	1.71	8.18	2.93	0.48	2.03	12.9	5.24	0.52

Table 2. Contd.

Year	Oct				Nov.				Dec.			
	$\bar{v}$	Mode	Med	σ^2	$\bar{v}$	Mode	Med	σ^2	$\bar{v}$	Mode	Med	σ^2
2003	2.55	10.05	6.57	1.45	3.13	8.04	10.8	3.57	2.03	5.11	7.68	1.03
2004	2.71	64.62	42.9	0.48	2.5	43.4	65.1	0.40	2.55	6.56	9.46	0.25
2005	2.26	13.60	8.68	0.66	1.77	7.11	11.1	0.39	1.90	17.4	26.6	0.29
2006	2.42	10.81	6.92	1.05	1.33	5.18	8.11	0.23	1.09	11.8	17.8	0.09
2007	1.93	8.21	5.29	0.73	0.77	4.01	0.11	0.60	0.00	0.00	0.00	0.00

Figure 16 shows the probability distribution of wind velocity for the dry season in Silchar (October - March) of the period from 2003 - 2007 using Weibull probability density function as expressed in equation 2. Only the highest probability of observing a wind speed (that is, 1, 2 or 3 KMPH etc) of the six months from October - March is considered.

Figure 17 shows the probability distribution of wind

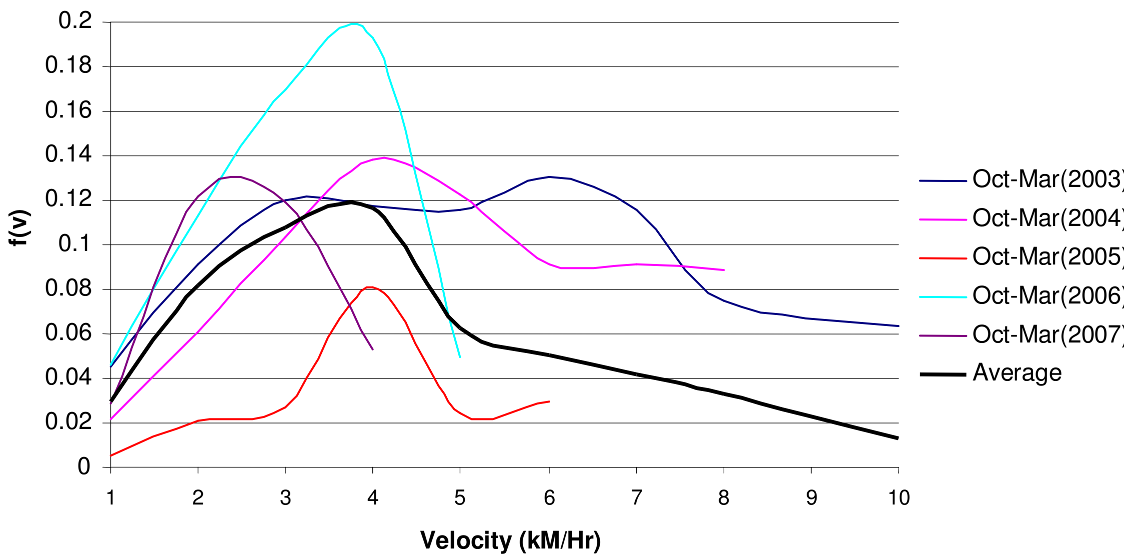

Figure 16. Seasonal Weibull distribution for the dry season in Silchar.

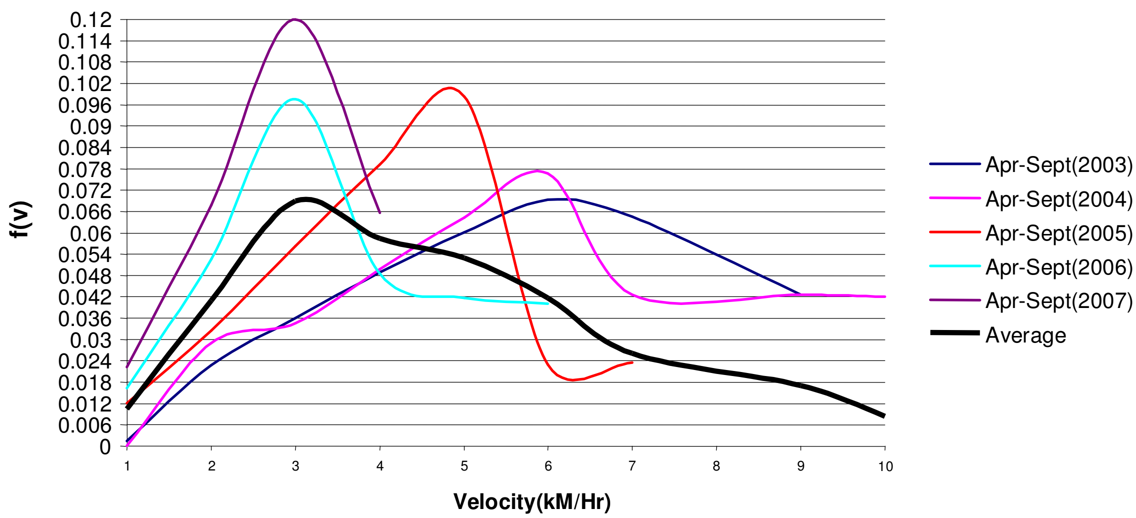

Figure 17. Seasonal Weibull distribution for the rainy season in Silchar.

wind velocity for the rainy season in Silchar (April – September) of the same period using the same equation**.** The highest probability of observing a wind speed on six monthly basis from April - September is considered here as well. The variations of average probability distributions for the two seasons have also been incorporated in the respective figures. Figure 16 shows that the probability of observing wind velocity of 4 KMPH in the dry season is the highest of the period 2003 - 2007. The average probability of 4 KMPH is 0.116. Figure 17 shows that the probability of observing wind velocity of 3 KMPH in the rainy season is the highest of the same period. The average probability of occurrence of 3 KMPH in this case is 0.069.

Rayleigh's distribution function

In circumstances when Weibull shape parameter, *k* is equal to 2; the Weibull distribution is referred to as Rayleigh's distribution. In probability theory and statistics, the Rayleigh's distribution is a continuous probability distribution. This distribution arises when wind velocity has elements that are normally distributed and are uncorrelated. The Rayleigh's wind velocity probability density function can be represented as

$$f(v) = \frac{\pi v_i}{2\bar{v}^2} \exp\left[-\frac{\pi}{4}\left(\frac{v_i}{\bar{v}}\right)^2\right] \quad [10]$$

Table 3. Distribution of mean, mode, median and variance of wind velocity of the period 2003-2007 using Rayleigh's approach.

Year	Jan.				Feb.				Mar.			
	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2
2003	2.10	0.60	0.70	0.15	2.81	0.77	0.91	0.33	3.64	1.05	1.24	0.45
2004	1.97	0.84	0.98	0.30	2.25	0.93	1.09	0.40	3.13	1.65	1.98	0.71
2005	2.13	0.56	0.66	0.13	3.61	1.34	1.58	0.58	4.22	1.56	1.84	0.67
2006	1.61	0.71	0.84	0.22	2.00	0.67	0.78	0.29	2.42	0.67	0.79	0.29
2007	1.71	0.46	0.54	0.09	1.86	0.59	0.69	0.25	2.13	0.76	0.90	0.33

Table 3. Contd.

Year	Apr.				May				Jun.			
	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2
2003	3.73	1.41	2.34	0.85	3.77	1.45	2.47	0.90	3.47	0.97	1.11	0.40
2004	4.70	3.27	12.6	4.60	3.71	1.64	3.16	1.16	3.63	1.22	1.75	0.64
2005	3.80	1.06	1.32	0.48	4.13	1.45	2.47	0.90	2.80	0.61	0.44	0.16
2006	2.80	0.99	1.15	0.42	3.13	1.12	1.48	0.54	2.40	0.81	0.77	0.28
2007	2.40	0.93	1.02	0.37	2.29	0.74	0.64	0.23	2.33	0.76	0.68	0.25

Table 3. Contd.

Year	Jul.				Aug.				Sept.			
	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2
2003	3.81	1.83	3.94	1.44	3.35	1.30	1.98	0.73	2.90	0.96	1.08	0.40
2004	3.45	1.03	1.25	0.46	4.06	0.96	1.08	0.40	3.40	1.00	1.18	0.43
2005	2.58	0.76	0.68	0.25	2.26	0.81	0.77	0.28	2.70	1.18	1.64	0.60
2006	2.39	0.88	0.91	0.33	2.35	0.84	0.83	0.30	1.80	0.71	0.59	0.22
2007	1.97	0.79	0.73	0.27	1.71	0.69	0.56	0.20	2.03	0.72	0.61	0.22

The variance of wind velocity recorded over 24 h as per Reyleigh's method can be represented as:

$$\sigma_1^{\,2} = \frac{4-\pi}{2}\frac{1}{n-1}\sum_{i=1}^{n}\left(v_i - \bar{v}\right)^2 = \frac{4-\pi}{2}\sigma^2 \quad [11]$$

Where, the average mean wind velocity $\bar{v}$ is:

$$\bar{v} = \frac{1}{n}\sum_{i=1}^{n} v_i, \quad [12]$$

The median of the monthly distribution is represented as:

$$M = \sigma^2 \sqrt{\ln(4)} \quad [13]$$

The mode of the monthly distribution according to Rayleigh's approach is represented as:

$$\text{Mode} = \sigma \quad [14]$$

The monthly values of mean ($\bar{v}$), mode (σ), median (M) and variance ($\sigma_1^{\,2}$) of the period 2003 - 2007 is represented in Table 3.

Figure 18 shows the probability distribution of wind velocity for the dry season in Silchar (October-March) of the five years period 2003 - 2007 using Rayleigh's probability density function, as given in equation 10. The results for c and k are obtained using statistical software. Figure 19 shows the probability distribution of wind velocity for the rainy season in Silchar (April - September) of the same period using the same Rayleigh's equation. The variations of average probability distributions have

Table 3. Contd.

Year	Oct.				Nov.				Dec.			
	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2	$\bar{v}$	σ	M	σ_1^2
2003	2.55	2.15	2.53	0.62	3.13	1.94	2.28	1.53	2.03	1.98	2.33	0.44
2004	2.71	1.26	1.48	0.2	2.5	1.10	1.23	0.17	2.55	0.79	0.93	0.11
2005	2.26	2.11	2.29	0.28	1.77	0.00	0.00	0.17	1.90	0.72	0.84	0.12
2006	2.42	0.85	1.01	0.45	1.33	0.81	0.96	0.10	1.09	0.36	0.42	0.04
2007	1.93	0.95	1.12	0.31	0.77	1.78	2.09	0.26	0.00	0.00	0.00	0

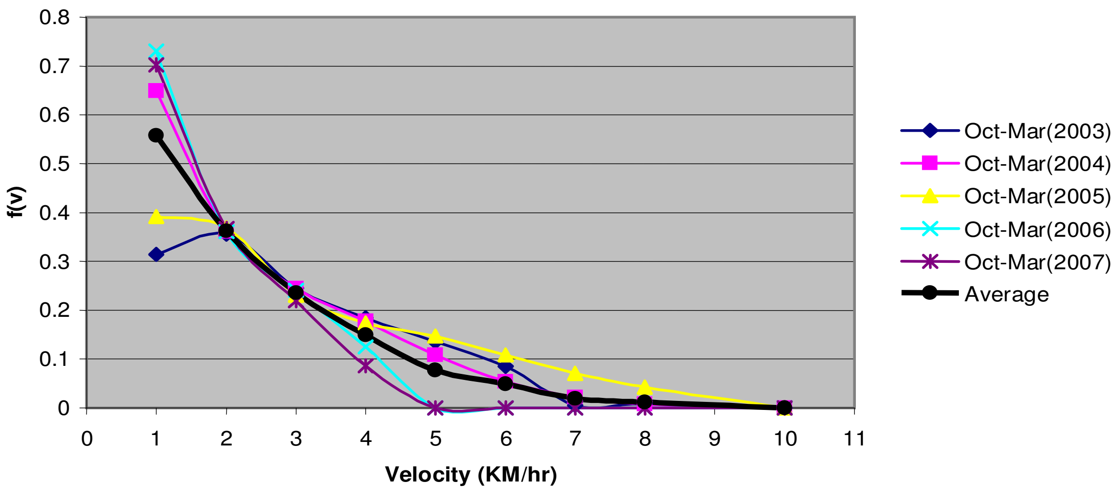

Figure 18. Seasonal Rayleigh's distribution for the dry season in Silchar.

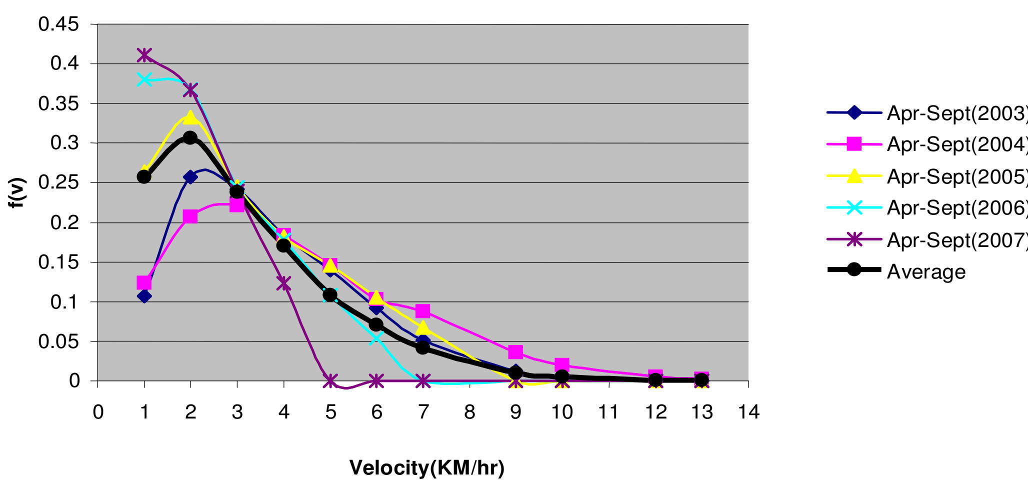

Figure 19. Seasonal Rayleigh's distribution for the rainy season in Silchar.

also been incorporated in the Figures 18 and 19. Figure 18 shows that the average probability of observing wind velocity of 1 KMPH in the dry season is the highest of the five years period. The average probability of occurrence of 1 KMPH from October to March is 0.56. The probability of observing 2 KMPH is 0.36. However, probabilities of observing higher wind velocities in this season are less, even the probability is almost zero for wind velocity as much as 8 KMPH. Similarly, Figure 19 shows that the average probability of observing wind velocity of 2 KMPH

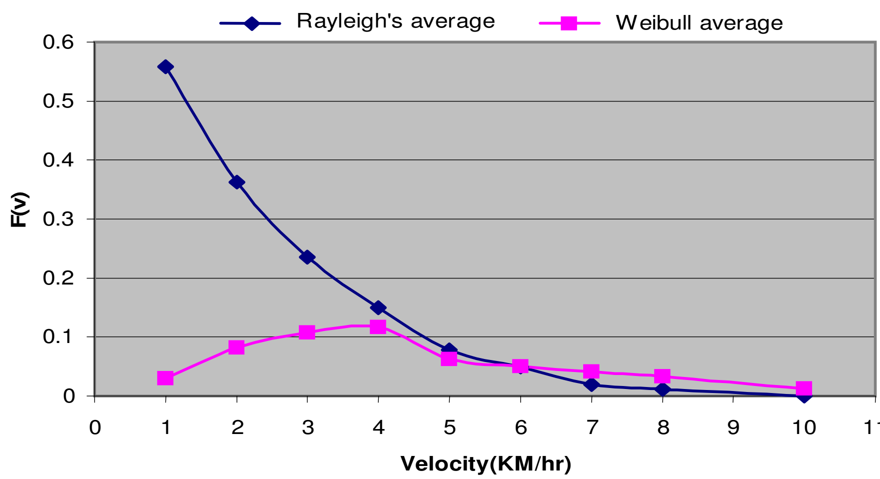

Figure 20. Comparison between Rayleigh's and Weibull average probability distribution for wind velocity in the dry season

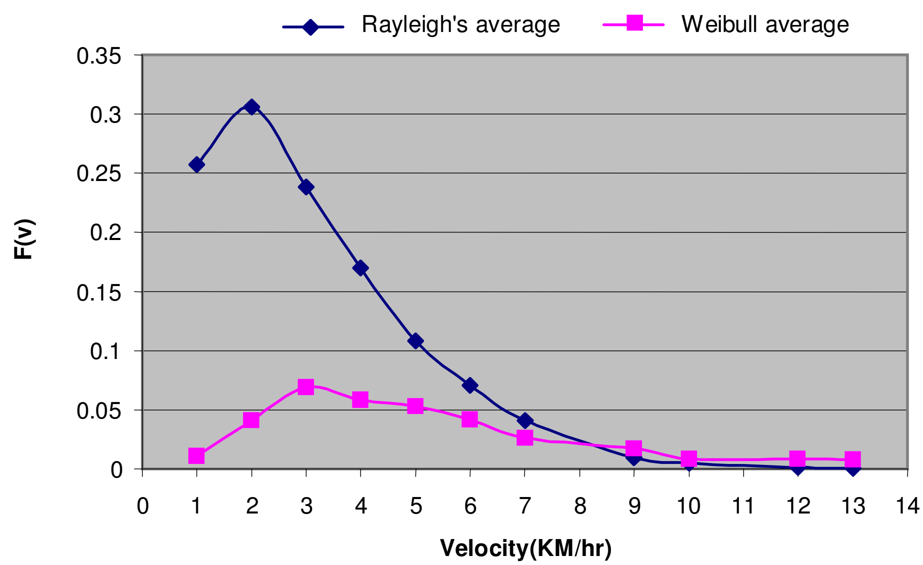

Figure 21. Comparison between Rayleigh's and Weibull average probability distribution for wind velocity in the rainy season.

in the rainy season is the highest of the same period. The average probability of observing 2 KMPH is 0.31. Now, Figures 20 and 21 show the comparison between the Rayleigh's and Weibull average probability distributions for various wind velocities in the dry and the rainy seasons respectively. Figure 20 shows that Rayleigh's probability distribution gives higher probabilities compared to the Weibull's distribution up to 5 KMPH, after which Weibull's distribution predicts marginally higher probabi-lities than the former till the end. Figure 21 shows that Rayleigh's probability distribution gives higher proba-bilities compared to the Weibull's distribution; up to 7 KMPH in the rainy season, after which both probability distributions are matching each other till the end. Figure 20 also shows that Rayleigh's probability of observing wind velocity of 1 KMPH is the highest in the dry season whereas in case of Weibull distribution, probability of observing wind velocity of 4 KMPH is the highest. Now, Figure 21 shows that probability of observing wind velocity of 2 KMPH is the highest in the rainy season as per the Rayleigh's distribution and that probability of observing wind velocity of 3 KMPH is the highest in the rainy season as per the Weibull distribution. Thus, from the above, it is clear that Rayleigh's distribution predicts higher probabilities of observing low wind velocities like 1 or 2 KMPH. However, Weibull distribution results show that the probability of observing high wind velocity like, 3 - 4 KMPH is the highest of the five years period.

Conclusion

Based on the study, the following conclusions have been drawn:

1. The wind velocity of Silchar is considerably low, with the highest of 3.11 KMPH occurring near the end of dry season (in the month of March), just at the onset of rainy season. However, over a year, on average, better wind regime can be seen in the period from February to August when the wind speed is about 2.4 KMPH.
2. The average power density is found highest during the month of March to April, when it becomes around 40 watt/sq.m.
3. Rayleigh's distribution predicts the highest probability of observing low wind velocity of 1 or 2 KMPH, but Weibull distribution predicts lower probabilities than the former. However, Weibull distribution results show that the probability of observing high wind velocity like, 3 or 4 KMPH is the highest of the five years period.

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