Pakistan Meteorological Department

A STUDY OF WIND POWER POTENTIAL

AT

SABZAL KOT – RAJANPUR (PUNJAB)

using

SODAR

By:

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(Preliminary report based on one month data)

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EXECUTIVE SUMMARY

Pakistan Meteorological Department (PMD) conducted a survey for wind power potential at Sabzal Kot, District Rajanpur. This report is based on the analysis of wind data collected from 18th January to 16th February 2007 through **SODAR** wind profiler installed at Sabzal Kot some 50 km towards North-West from Rajanpur city. Wind data with ten minute average speed and direction was collected from 20 to 200 meters heights. This report contains the data of four heights 20m, 30m, 50m and 80m.

At 20 meter, average wind speed was 4.42 m/s during the period whereas average wind speed at 80m height was recorded as 4.57 m/s. Analysis of diurnal variation in wind speed depicts that maximum wind speed is available during late night time thought-out the whole month. The wind frequency distribution at 20m, 30m, 50m and 80m depicts that during 32%, 31%, 32% and 34% of the time, wind speed is above 5 m/s respectively.

Sometimes simply wind speed averages may not reflect the true picture of the actual wind power potential of an area. For this purpose, it is pertinent to compute Wind Power Density and assign the area to one of the seven wind classes based on "Wind Power Density" data. Monthly wind power density has been computed and added in the report. The total power density for Sabzal Kot at 50m height is **120 W/m^2.** According to international wind classification, this power density categorizes Sabzal Kot as a below marginal site for wind power generation.

1.0 INTRODUCTION

Wind energy is the fastest growing renewable energy source today. A continued interest in wind energy development worldwide has produced steady improvements in technology and performance of wind power plants. New wind power projects have proven that wind energy not only is cost competitive but also offers additional benefits to the economy and environment.

A steady supply of reasonably strong wind is necessary requirement for utilizing the power in the wind. Development of wind energy depends upon a clear understanding of wind resources. Site location, turbine performance and physical effects of turbulence and energy extraction represent a few of the issues that must be addressed by anyone interested in developing wind energy.

2.0 WIND MAPPING PROJECT OF PAKISTAN METEOROLOGICAL DEPARTMENT:

Any plan to develop wind energy must begin by understanding the wind resources like where are the best potential wind sites located? How much energy could be extracted from the wind at those sites? Will the wind turbine performance be affected by the turbulence or other wind resources characteristics?

To answer these questions and to provide wind resources database for various potential areas of the country, Pakistan Meteorological Department prepared a phased programme. Government of Pakistan, Ministry of Science and Technology provided the necessary funding for undertaking the study. First phase covered the coastal areas of Sindh and Balochistan Provinces. After the completion of Phase-I, Phase-II is started which covers the Northern parts of Pakistan. Besides these studies, PMD has the honour of conducting studies of other potential areas e.g. Sabzal Kot (Rajanpur), Hari-chand (Charsada), Chitral City and Kallar Kahar (Chakwal) using SODAR wind profiler.

2.1 STUDY AREA:

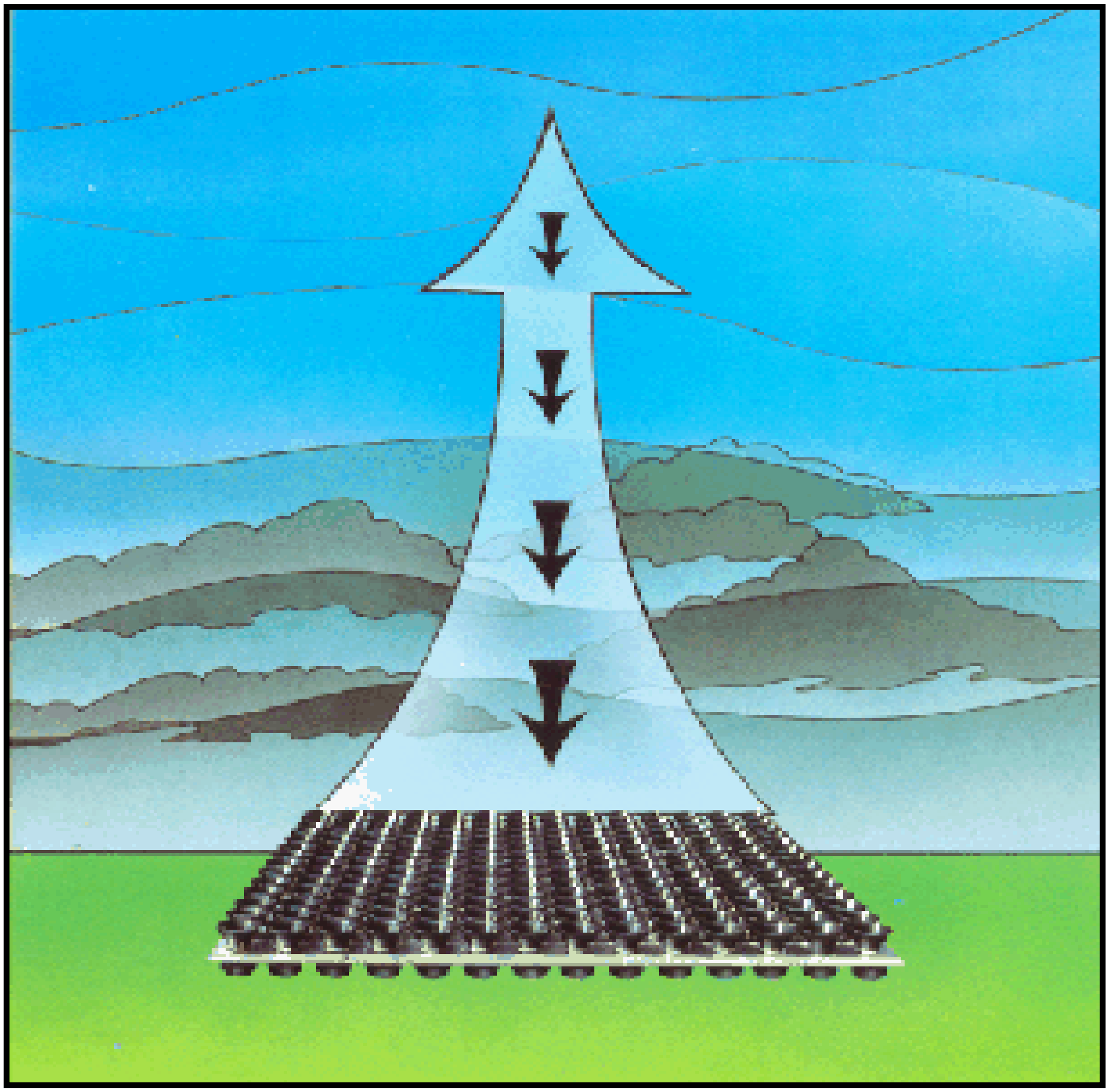
SODAR *(Sonic Detection and Ranging)* was installed at Sabzal Kot, 50 km towards north-west from Rajanpur city. Location parameters of the site are:

<u>Latitude: 29.15ºN, Longitude: 69.98ºE.</u>

2.2 **DATA SOURCE:**

To undertake this study, SODAR (PA0) system is used. This SODAR System records average wind speed from 20 to 200 meters. It consists of two main components; data receiver and antenna. The SODAR processes the echo of an acoustic pulse, which is directed into the atmosphere. The frequency shift of the echo varies according to the wind speed (the Doppler Effect) while the echo intensity varies according to thermal turbulence and structure. SODAR uses a single, multicellular antenna whose beam is steered electronically. The basic antenna is composed of 52 elements. It is capable of measuring wind data up to 200m.

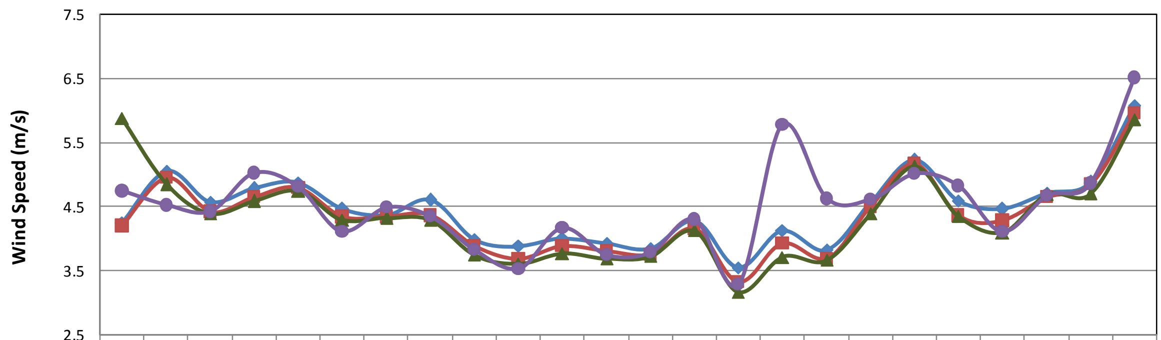
DOPLLER EFFECT OF SODAR



3.1 Diurnal Wind speed Variation:

Fig-1 shows the diurnal wind speed variations at Sabzal Kot for Jan and Feb-2007. The wind speed is generally batter during night as compare to day. At mid night it reaches maximum, wind speeds are around 6.08 m/s, 5.96 m/s, 5.85 and 6.51 m/s at 20 meter, 30 meter, 50 meter and 80 meter height respectively.

Fig-1 **Diurnal Variation Wind Speed at Kot Sabzal (Jan-Feb 2007)**



	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
WS10m	4.25	5.05	4.57	4.78	4.87	4.46	4.37	4.6	3.99	3.88	4	3.92	3.85	4.28	3.55	4.12	3.82	4.56	5.22	4.59	4.46	4.71	4.88	6.08
WS30m	4.2	4.95	4.42	4.65	4.79	4.34	4.34	4.36	3.89	3.68	3.88	3.81	3.75	4.16	3.32	3.93	3.69	4.5	5.17	4.36	4.28	4.65	4.85	5.96
WS50m	5.88	4.84	4.39	4.58	4.74	4.29	4.32	4.29	3.74	3.61	3.77	3.69	3.72	4.12	3.16	3.71	3.66	4.39	5.13	4.35	4.09	4.69	4.7	5.85
WS80m	4.74	4.52	4.42	5.02	4.81	4.11	4.49	4.35	3.83	3.53	4.17	3.75	3.79	4.3	3.28	5.77	4.62	4.61	5.01	4.82	4.11	4.67	4.86	6.51

PST (Hours)

3.2 Wind Speed Frequency Distribution:

Wind speed frequency distribution can simply be obtained by plotting the different wind speeds against their frequencies / relative frequencies. For obtaining frequency distribution the following two procedures are necessary.

3.3.1 *Binning of Data:*

The sorting of the data into narrow wind speed bands is called binning of the data. In our case a bin width of 1m/sec has been used e.g. a measured wind speed of 3.5 m/sec would be placed in 3<X<=4 m/sec bin. The central value of each bin i.e. 0.5 m/sec, 1.5 m/sec etc has been used in calculations and frequency distribution group.

3.3.2 *Relative Frequency:*

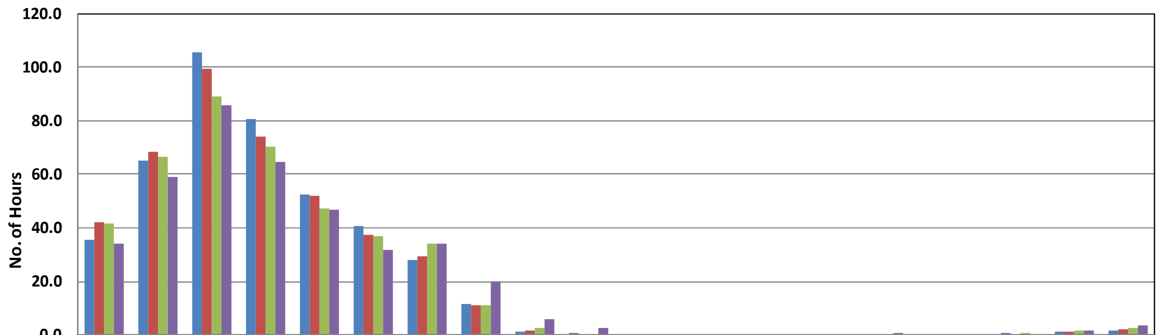
It is proportional wind speed in each bin. It can be viewed as the estimate of probability of given wind speed in the bin. Relative frequency is defined as:

R .F = probability P (Vi$_)$ = Frequency of given wind speed / Total period

3.3.4 *Wind Frequency Distribution:*

Fig-2 shows the wind frequency distribution at Sabzal Kot. It depicts that wind speed is 5 m/s or more for 52.5 hrs at 20m, 51.7 hours at 30m, 47.2 and 46.7 hours at 50m and 80m respectively.

Fig-2 **Wind Frequency Distribution at Kot Sabzal (Jan-Feb 2007)**



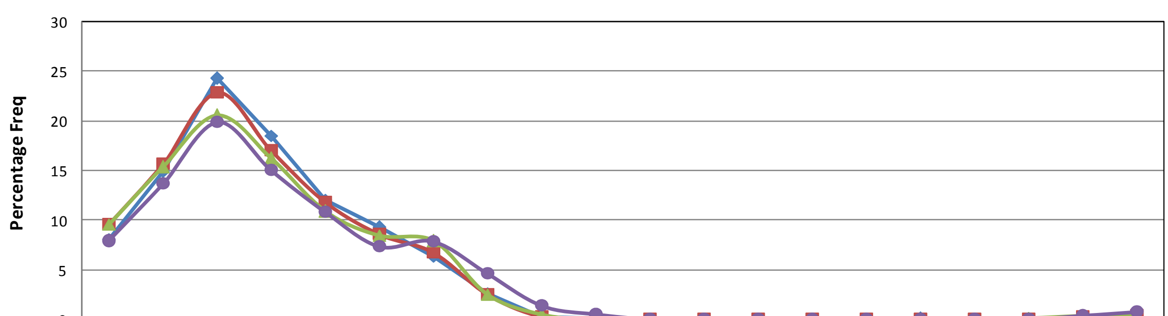
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20m	35.3	64.8	105.7	80.7	52.5	40.5	27.8	11.7	1.3	0.5	0.0	0.0	0.0	0.2	0.0	0.5	0.3	0.7	1.0	1.7
30m	41.8	68.3	99.3	74.0	51.7	37.3	29.5	11.0	1.5	0.0	0.2	0.0	0.3	0.2	0.0	0.2	0.3	0.3	1.2	1.8
50m	41.3	66.3	88.8	70.2	47.2	36.7	34.2	11.2	2.3	0.3	0.0	0.0	0.2	0.0	0.3	0.0	0.3	0.8	1.7	2.5
80m	34.0	59.0	85.5	64.5	46.7	31.7	33.8	19.8	6.0	2.5	0.2	0.2	0.2	0.0	0.2	0.0	0.2	0.2	1.7	3.5

Wind Speed (m/s)

3.3.5 *Percentage Wind Frequency Distribution:*

Fig-3 shows the percentage wind frequency distribution at Sabzal Kot. Analysis indicates that wind speed is more than 5 m/s for 10.87% of time at 80m, 10.92% of the time at 50m and 11.88% of the time at 30 meters.

Fig-3 **Percentage Wind Frequency Distribution at Kot Sabzal (Jan-Feb 2007)**



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
WS20	8.12	14.92	24.31	18.56	12.08	9.31	6.41	2.68	0.31	0.11	0	0	0	0.04	0	0.12	0.07	0.16	0.23	0.38
WS30	9.63	15.72	22.85	17.03	11.88	8.59	6.79	2.53	0.34	0	0.04	0	0.08	0.04	0	0.04	0.07	0.08	0.27	0.42
50m	9.57	15.36	20.57	16.25	10.92	8.49	7.92	2.58	0.54	0.08	0	0	0.04	0	0.07	0	0.08	0.2	0.38	0.58
80m	7.93	13.74	19.93	15.03	10.87	7.38	7.88	4.62	1.4	0.58	0.04	0.04	0.04	0	0.04	0	0.04	0.04	0.38	0.82

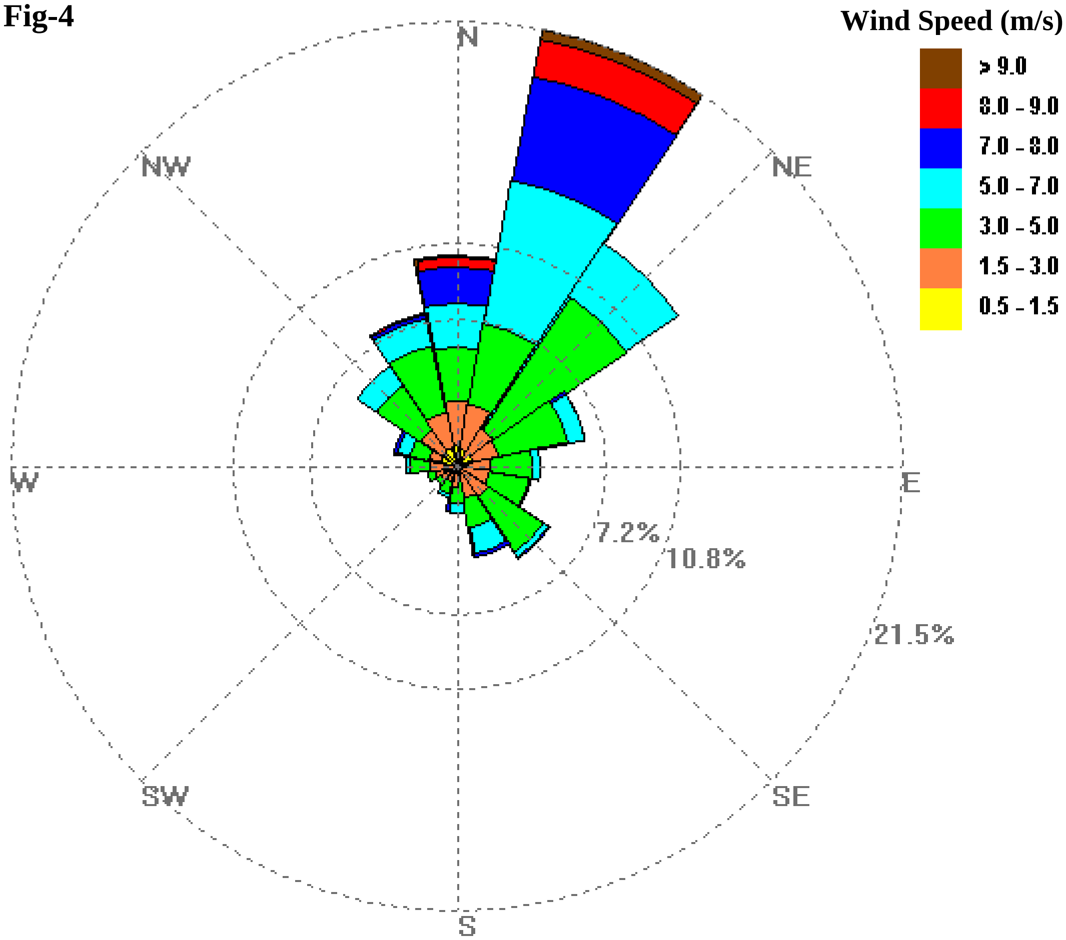
Wind Speed (m/s)

3.4 Wind Rose:

Fig-4 shows the Wind Rose based on the data of Jan-Feb 2007 collected at 50 meters height. Wind Rose depicts that the prevailing wind direction during Jan-Feb is mostly between north and north east and the average wind speed is 4.32 m/s.

<u>Wind Rose at Sabzal Kot (50m height during 01 month)</u>

Fig-4



Average Wind Speed at 50m	Average Wind Direction at 50m	Wind speed greater than 5 m/s
4.32 m/s	107°	32%

3.5 Wind Power Density:

While investigating a wind power potential of an area, the average values of wind speed does not truly represent this potential because lot of information regarding frequency distribution of wind speed is suppressed in the process of averaging wind speed. As such the most important values for estimating the wind power potential of a given site is the value of the wind power density or the available theoretical instantaneous power from the wind. This available wind power in the wind is the flux of Kinetic Energy crossing the wind energy conversion system and its cross – sectional area.

Like water flowing in the river, wind contains energy that can be converted to electricity using wind turbines. The amount of electricity that wind turbines produce depends upon the amount of energy in the wind passing through the area swept by the wind turbines blades in a unit of time. This energy flow is referred to as the wind power density.

A key aspect of wind power density is its dependence on wind speed cubed. This means that the power contained in the wind increases very rapidly with wind speed; if the speed doubles, the power increases by a factor of eight. In practice, the relationship between the power output of a wind turbine and wind speed does not follow a cubic relationship. Below a certain minimum speed, the turbine does not have enough wind to operate, whereas above a certain speed its output levels off or begins to decline. In very high winds the turbine may even be shut down to prevent damage to it.

Wind power density also depends on air density. At higher attitudes, air density decreases and, as a result, so does the available power. This effect can reduce the power output of wind turbines on high mountains by as much as 40 percent compared to the power that could be produced at the same wind speeds at sea level. Air density depends inversely on temperature: colder temperatures are favorable for higher air densities and greater wind power production.

<u>*Power density:*</u>

$$P/A = 1/2\, \varphi V^{3}$$

3.5.1 ***Wind Power Classes:***

To simplify the characterization of the wind power potential, it is common to assign areas to one of seven wind classes, each representing arrange of wind power density at the special height above the ground. The standard International wind power classifications are shown in Table 1.

Table-1: International Wind Power Classification

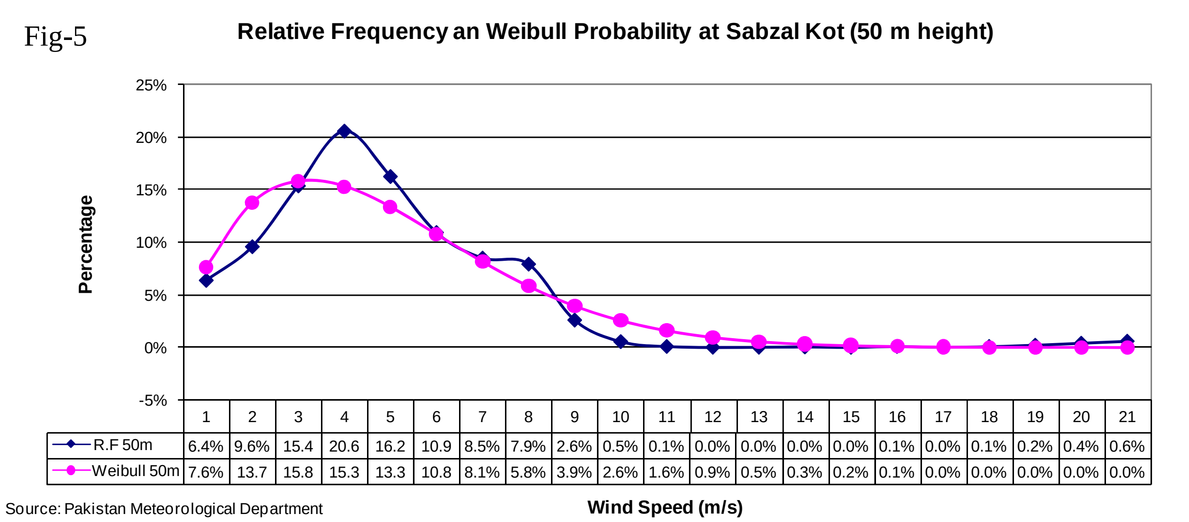
Class	Resource Potential	30m Height		50m Height	
		Wind Speed m/s	Wind Power W/m²	Wind Speed m/s	Wind Power W/m²
1	------	0 – 5.1	0 – 160	0 – 5.6	0 – 200
2	Marginal	5.1 – 5.9	160 – 240	5.6 – 6.4	200 – 300
3	Moderate/Fair	5.9 – 6.5	240 – 320	6.4 – 7.0	300 – 400
4	Good	6.5 – 7.0	320 – 400	7.0 – 7.5	400 – 500
5	Excellent	7.0 – 7.4	400 – 480	7.5 – 8.0	500 – 600
6	Outstanding	7.4 – 8.2	480 – 640	8.0 – 8.8	600 – 800
7	Superb	8.2 – 11.0	640 – 1600	8.8 – 11.9	800 – 2000

By and large, the areas being developed today using large wind turbine are ranked as class 5 and above. Class 4 areas are also being considered for further development as wind turbines are adopted to run more efficiently a lower wind speeds. Class1 and class2 areas are not being deemed suitable for large machines, although a smaller wind turbine may be economical in areas where the value of the energy produced is higher

3.5.2 ***Weibull Parameters:***

Fig-5 shows the Weibull fit to the relative frequency of wind speed.

Fig-5



The Weibull parameters for four different heights 20 meters, 30 meters, 50 meters and 80 meters are given in Table-2 along with other key results of analysis.

Table-2: Monthly Average Wind, St. Deviation and Wind Power Density at Sabzal Kot

Month: June-2009					
Heights	**AWS (m/s)**	**St Dev**	**C (m/s)**	**K**	**P/A (w/m^2)**
20m	4.40	2.38	4.97	1.95	**102.93**
30m	4.28	2.44	4.84	1.84	**101.46**
50m	4.30	2.72	4.85	1.65	**120.0**
80m	4.42	2.93	4.99	1.56	**141.43**

Table-3: Hypothetical wind generated electric energy output & Capacity Factor for a Bonus 600/44MK IV Turbine at Sabzal Kot.

PMD Calculator (using 50M at Sabzal Kot)				
Month	**Input W/m^2**	**Output W/m^2**	**C.F.**	**KWh**
Jan-Feb 2007	125	46	12%	51,792

Conclusion:

The total power density of Sabzal Kot at 50m height is 120 W/m^2. According to international wind classification, this power density categorizes Sabzal Kot as a below marginal site for wind power generation. Since the observational data is limited to only one month and significant variations exist in wind and thermal profile of the area during different seasons, it is, therefore pre-mature to decide the suitability of site for wind power generation. More efforts are required for data generation and subsequent analysis for finalizing the study.