ANALYSIS OF WIND CHARACTERISTICS IN COASTAL AREAS OF BANGLADESH

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Abstract: *The present demand of energy is increasing day by day due to various reasons such as increasing population, the aspiration for improved living standards and general economic and industrial growth. In the wake of the increasing world energy crisis, which mostly affected the least developed countries, the interest in alternative energy resources has been increased considerably. In this regard, wind as a source of energy can hold good prospect for a underdeveloped country like Bangladesh. Besides, utilization of wind energy has been growing rapidly in the whole world due to environmental pollution, consumption of the limited fossil fuels and global warming. Bangladesh has fairly wind energy potential, exploitation of the wind energy is still in the crawling level. In the current study, wind characteristics and wind energy potential of Teknaf, Kutubdia, Sandwip, Kuakata, and Mongla in the Coastal Areas are investigated. The measured wind data were processed as hourly and monthly basis. Weibull probability density functions of the locations are calculated in the light of observed data and Weibull shape parameter and scale parameter are also calculated. The main objective is to find out wind energy potential for the utilization.*

Keywords: *Wind energy, Weibull distribution, Wind power, Coastal area.*

INTRODUCTION

Utilization of energy indicates the social development and economic growth for a country. A major portion of world's electricity energy requirement has been supplied by thermal and hydro power plants. The present non-renewable energy sources have been causing negative effects (global warming, ozone layer depletion, acid rain etc.) on the atmosphere. Renewable energy sources are inexhaustible, clean and free. These sources offer many environmental and economical benefits in contrast to conventional energy sources. Thus, recently the sources of renewable energy such as wind, solar, geothermal etc. has been growing leaps and bound within other resources as their generating cost decreases. Although mankind has been using the wind energy since ancient time, its use to produce electricity effectively by means of modern wind turbines is over two decades old (Rosa[1]).

Wind energy continued its dynamic growth worldwide in the year 2006. According to figures released recently by the World Wind Energy Association about 14 900 MW were added in the past year making a global installed capacity of 73 904 MW by the end of December 2006. The added capacity equals a growth rate of 25 percent, after 24 percent in 2005. The currently installed wind power capacity generates more than one percent of the global electricity consumption. Based on the accelerated development, WWEA expects 160 000 MW to be installed by the end of 2010. Wind power installed capacity is 59322MW for the whole world at the end of 2005[2].

Five countries added more than 1000 MW; the United States of America (2454 MW), Germany (2194 MW), India (1840 MW) and Spain (1587 MW) were able to secure their leading market positions and China (1.45 MW) joined the group of the top five and is now number five in terms of added capacity, showing a market growth of 91 percent. Five countries added more than 500 MW and showed excellent growth rates; France (810 MW, 107 percent growth), Canada (768 MW, 112 percent), Portugal (628 MW, 61 percent) and the UK (610 MW, 45 percent). The most dynamic market in 2006, Brazil, faced its long expected take off and added 208 MW, which equals a sevenfold increase of installed capacity within one year.

At present the USA is the 1st, Germany is the 2nd and India is the 3rd in the world in case of the installed capacity of Wind parks (Mukut[3]).

WIND PROSPECT IN BANGLADESH

Bangladesh is situated in the latitude between 20°34' - 26°38'N and longitude between 88°01-92°4E. The country has a 724 km long coastal line along the Bay of Bengal. There are many islands in the Bay, which belongs to Bangladesh. The strong south /south-westerly monsoon wind coming from the Indian Ocean, after traveling a long distance over the water surface, enter into Asia over the coastal area of Bangladesh. This wind blows over Bangladesh from March to September with a monthly average speed 3 m/s to 6 m/s (Ahmed[4]). The wind speed is enhanced when it enters the V- shaped coastal region of the country. According to preliminary studies, (from meteorological department, BCAS, LGED, and BUET) winds are available in Bangladesh mainly during the monsoon and around one to two months before and after the monsoon (7 months, March to September). During the months starring from late October to February wind speed remains either calm or too low. The peak wind speed occurs during the months of June and July (Ahmed[4]). Park of wind turbines in coastal areas, can be incorporated in electricity grid on a substantial basis and could add reliability and consistency to the electricity generated by the Kaptai Hydro-electric power Station from March to September, during which load shedding becomes critical than winter season. So the deficit power could be compensated with the help of wind power plants along the coastal zone. They're many islands along the Bay of Bengal where the wind speed is quite high. For example, Kuakata, Sandwip and St. Martin islands are very prospective areas for this type of wind turbines. Most of the people of these islands are fishermen and there are many shrimp-farms in these areas. They can never avail the opportunities to have the electricity from the National Grid line. Therefore, these areas have a great prospect to utilize the wind. Besides these, there are a lot of hilly and remote areas with a great open space island where the wind speed remains 2 m/s to 5 m/s in Bangladesh. The recent development of wind rotor aerodynamics makes it feasible to extract energy from wind speed as low as 2.5 m/s. Bangladesh is an agricultural land. The agriculture needs supply of water at right time for better yielding. Bangladesh Government has already undertaken many irrigation and canal digging projects to supply water. Many power pumps and hand pumps have been distributed to the farmers. A study of Bangladesh Agriculture Development Corporation (BADC) shows that low lift pumps (LLP) of about 40 feet head and two-cusec discharge were in operation. It is claimed that there is surface water potential for 54,700 LLP of two-cusec capacity. Recently man powered (TARA PUMP) water pumps have become very popular for irrigation, and every year its supply is increasing. Considering the terrain of the country about 50% of the pumps require to be operated at a total head of 20 feet or less (Ahmed[4]). Most of these power pumps along with a number of deep and .shallow tube wells are being run in most cases by diesel engines and in other cases by electric motors. The non- availability of electricity and irregular supply of diesel fuel in rural areas the existing schemes of irrigation have been adversely affected. The installation of windmills will be very much convenient for operating the pumps. The application of wind power for operating man powered water pumps will also be very convenient, and it will save energy.

WIND DATA

In the present study, wind data of some coastal areas in Bangladesh such as Kutubdia, Kuakata, Mongla, Sandwip and Teknaf from March to September, 2003 have been considered[5]. The wind data measured in ten minutes interval and then further processed to hourly time series.

CALCULATION METHODOLOGY

Knowledge of the wind speed distribution is a very important factor to evaluate the wind potential in the windy areas. In addition to speed distribution, meteorological data and topographical information for considered site have same importance. If ever the wind speed distribution in any windy site is known, the power potential and the economic feasibility belonging to the site can be easily obtained. Wind data obtained with various observation methods has the wide ranges. Therefore, in the wind energy analysis, it is necessary to have only a few key parameters that can explain the behavior of a wide range of wind speed data. The simplest and most practical method for the procedure is to use a distribution function. There are several density functions, which can be used to describe the wind speed frequency curve. The most common is the Weibull functions. The studies using this function can be found in the following section.

The Weibull distribution is characterized by two parameters: the shape parameter k (dimensionless) and the scale parameter c (m/s.) The cumulative distribution function (Weibull function, Lysen[6]) is given by

$$F(v) = 1 - e^{-\left(\frac{v}{c}\right)^k} \tag{1}$$

and the Weibull density (probability density) function by Lysen[6],

$$f(v) = \frac{dF(v)}{dv} = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \times e^{-(\frac{v}{c})^k} \tag{2}$$

There are several methods to calculate the Weibull parameter k and c such as, Weibull paper method, Standard deviation method, Energy pattern factor method etc.

WEIBULL PAPER METHOD

At first percentage of cumulative distribution is calculated and plotted for corresponding wind speed as shown in Figure 1. Then a straight line is drawn so that it covers most points and from this line an intersection with c estimation line (dotted) gives the corresponding value of c for the location. A normal from "+" of the graph is drawn upon the previous straight line, the point of intersection with the "k" axis line (top) gives the value of k.

STANDARD-DEVIATION ANALYSIS METHOD

By determining the mean wind speed V_{mean} and standard deviation σ of wind data k and c can be obtained (Lysen[6]) by solving the following equations

$$\bar{v} = c \times \Gamma\left(1 + \frac{1}{k}\right) \tag{3}$$

The standard deviation of the distribution (Lysen[6]) is calculated with the equation,

$$\sigma^2 = \frac{\sum (V_n)^2 - \frac{\left(\sum V_n\right)^2}{N}}{N-1} \tag{4}$$

Then corresponding k value (Lysen[6]) can be found from the following Figure 2.

ENERGY PATTERN FACTOR ANALYSIS

The energy pattern factor K_E is defined as,

$$K_E = \frac{\text{Total amount of power available in the wind}}{\text{Power calculated by cubing the mean wind speed}}$$

The energy pattern factor (Golding[6]) of a given set of N hourly data V_n can be determined with

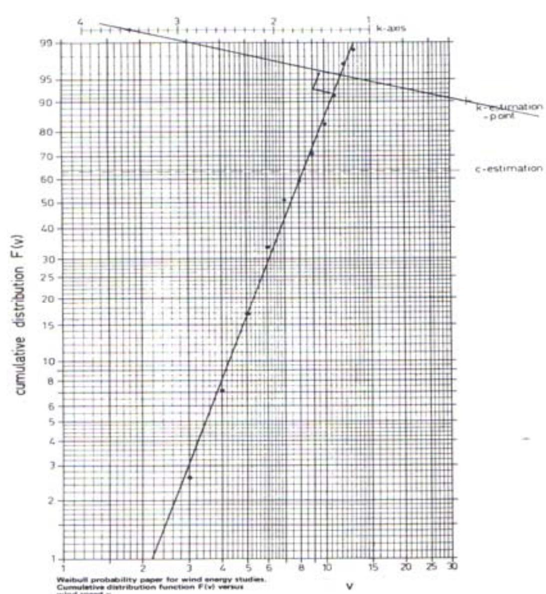

Figure 1: Cumulative Distribution versus Wind Speed Graph (Lysen[6]).
Source: Wind Energy Group, Dept. of Physics. University of Tech., Edinburgh, The Netherlands.

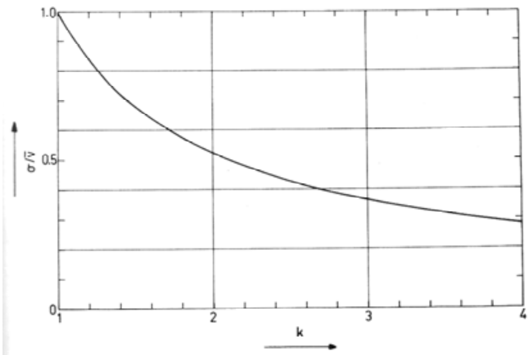

Figure 2: The Relative Standard Deviation of a Weibull Distribution as a Function of Weibull Shape Factor, k.

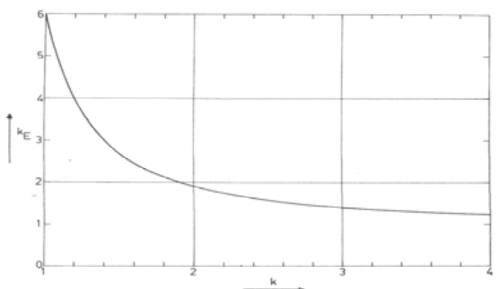

Figure 3: The Energy Pattern Factor of a Weibull Wind Speed Distribution as a Function of the Weibull Shape Factor, k (Lysen[6]).

$$K_E = \frac{\frac{1}{N}\sum_{n=1}^{N}(V_n)^3}{\left(\frac{1}{N}\sum_{n=1}^{N}V_n\right)^3} \tag{5}$$

Using the above expression the Weibull shape parameter k is easily found by the following figure.

The wind power per unit area of approach is proportional to the cube of wind speed (Beurskens[7]) and it can be expressed as $P/A = 0.6\ V^3$ where P/A is in W/m^2 and V is in m/s. This wind power represents the strength of wind, and theoretically maximum 59% of this power can be extracted.

RESULTS AND DISCUSSION

Mean Wind Speed

Figure 1 shows the mean wind speed for each Coastal region. As can be seen in Figure 4, the mean wind speed varies from 2.6 m/s to 12 m/s. Here identification is that the maximum wind speed is obtained from the month of May to August. Again, in some region like Kutubdia, Sandwip, Kuakata, another peak wind speed is found from March to May, which is the hottest month of Bangladesh. During this period, windmills may be used for pumping water for irrigation if it had been previously stored in a reservoir during the monsoon. During the operating seasons, subsoil water from shallow wells can also be pumped up by low lift pumps run by windmills.

Wind power can also be incorporated in electricity grid on a substantial basis and could add reliability and

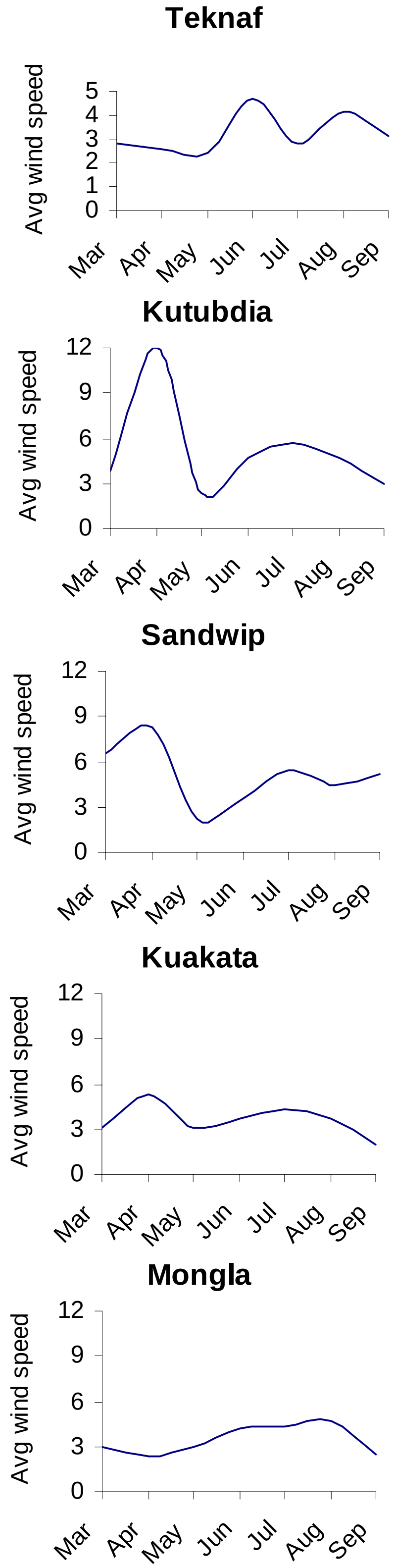

Figure 4: Monthly average velocity (m/s) for different locations.

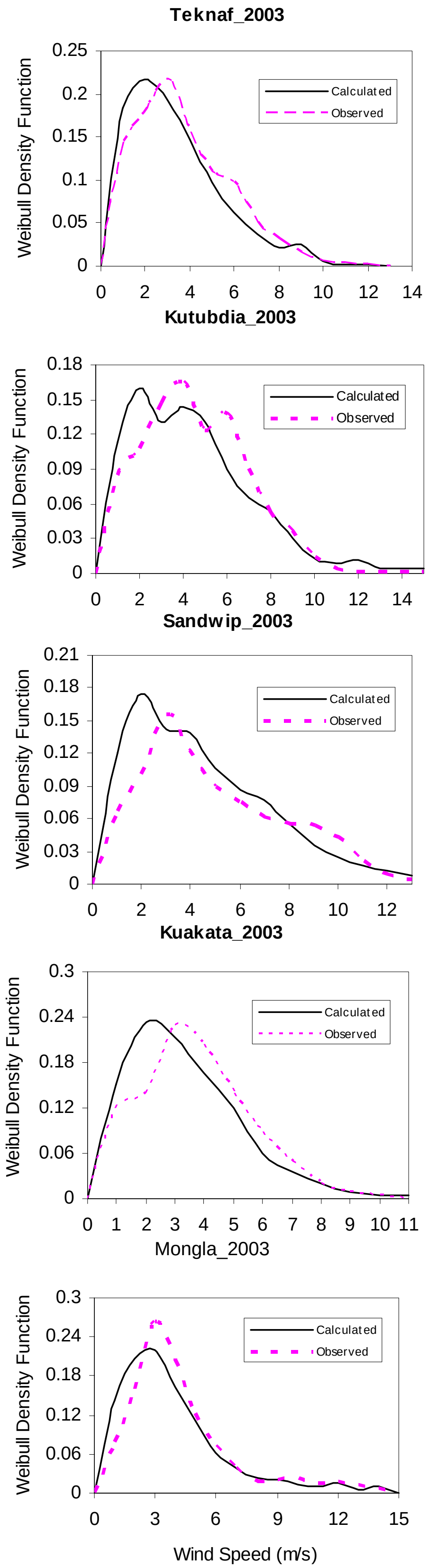

Figure 5: Weibull density function for each location.

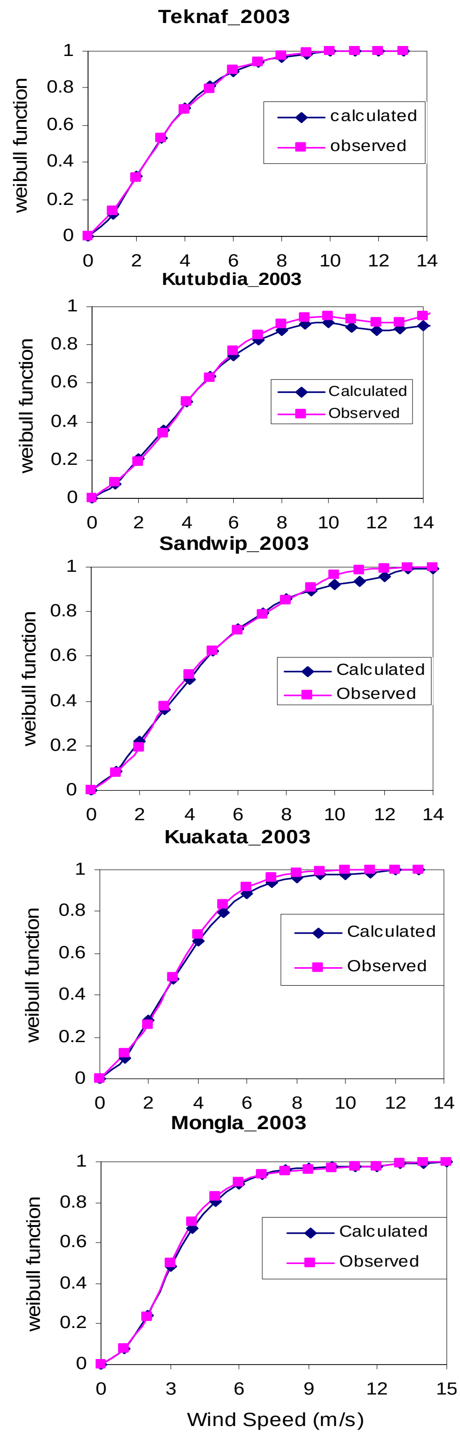

Figure 6: Weibull Function for Each Location

consistency to the electricity generated by the Kaptai hydroelectric Power Station during the dry season. This is due to fact that, during the dry season, required water head becomes rather low for total utilization of all the generators. Thus, power generation has to be curtailed during this period. So this power could be compensated with the help of wind power plant. Table 1 shows the average wind speed in the study period and it is found that among the entire region, Kutubdia has the maximum mean wind speed which is 5.17 m/s and that of Sandwip is 5.12 m/s.

Table 1: Mean speed for each location.

Location	Mean Speed (m/s)
Teknaf	3.22
Kutubdia	5.17
Sandwip	5.12
Kuakata	3.58
Mongla	3.44

Table 2: Value of Weibull shape parameter (c) and scale parameter (k).

Location		March	April	May	June	July	August	September	Mean
Teknaf	k	1.45	1.65	1.45	1.98	1.5	1.88	1.87	1.68
	c	3.14	2.86	2.63	5.3	3.13	4.68	3.48	3.60
Kutubdia	k	2.18	1.14	1.4	1.97	3.2	1.98	1.48	1.91
	c	4.19	12.06	2.6	5.31	6.4	5.4	3.2	5.59
Sandwip	k	1.2	1.15	1.38	2.1	2.1	1.39	2.17	1.64
	c	3.5	8.76	2.50	4.15	6.14	4.87	5.85	5.11
Kuakata	k	1.8	1.1	2.2	2.17	2.7	1.8	1.3	1.87
	c	3.4	5.45	3.49	4.17	4.81	3.78	2.19	3.90
Mongla	k	2.4	1.7	2.4	1.7	2.7	1.5	1.75	2.02
	c	3.3	2.7	3.3	4.74	4.88	5.25	2.78	3.85

Although the wind speed is maximum in Kutubdia but that of Sandwip is more stable, because the wind speed varies roughly in Kuakata. So, Sandwip is more effective for wind power extraction in point view of wind turbine overall performance.

WEIBULL DENSITY FUNCTIONS

Weibull/Probability density functions are usually used to determine the wind speed distribution of a windy site in a period of time. It means the relative frequency of wind speeds for the site. Therefore, the shape of wind speeds distribution can be guessed when it is plotted. The comparison between calculated and observed Weibull density function for each location is presented in Figure 5.

WEIBULL FUNCTIONS

Weibull Function is the integration of Weibull Density Function. It is the cumulative of relative frequency of each velocity interval. The comparison between calculated and observed Weibull function for each location is presented in Figure 6. The Weibull Shape parameter (c) and Scale parameter (k) were calculated using the method mentioned in earlier section. Table 2 shows the corresponding value of k and c for each location for each month.

From Table 2, it is found that in Teknaf k varies from 1.45 to 1.98 and that of c ranges from 2.63 to 4.68, for Kutubdia k varies from 1.14 to 3.2 and that of c ranges from 2.6 to 12.06, for Sandwip k varies from 1.15 to 2.17 and that of c ranges from 2.5 to 8.76, for Kuakata k varies from 1.1 to 2.7 and that of c ranges from 2.19 to 5.45, and for Mongla k varies from 1.5 to 2.4 and that of c ranges from 2.7 to 4.88.

Wind Power

This wind power represents the strength of wind of a region. The wind power, P/A is plotted in Figure 7 (see the last page) to show the strength of wind in different location. It is found that maximum wind power is obtained from 8 am to 8pm for each location and highest peak is obtained from 12pm to 4.30pm.

CONCLUSION

In this study, assessments of wind characteristic for Coastal region of Bangladesh were made. The following conclusion can be drawn from the present analysis:

(a) The shape factor (k) and scale factor (c) are determined for each month. It is found that the value of k remains between 1.1 to 3.5 and that of c remains between 2.5 to 5.5.The most of the Weibull functions follow very close to the Raleigh function (k=2) for the selected sites.

(b) The mean wind speed (vmean) for each location remains 2.5 to 5.17 m/s and highest two mean wind speed are found in Kutubdia (5.17m/s) and that of Sandwip 5.12 m/s respectively.

(c) The maximum wind power is obtained from Kutubdia which is 138 W/m2.

(d) Although in the current study the wind speed is maximum in Kutubdia but the wind speed is not so stable throughout the study period. In comparison with it, Sandwip has relatively stable wind speed. So, considering these, Sandwip can be considered as more potential energy site.

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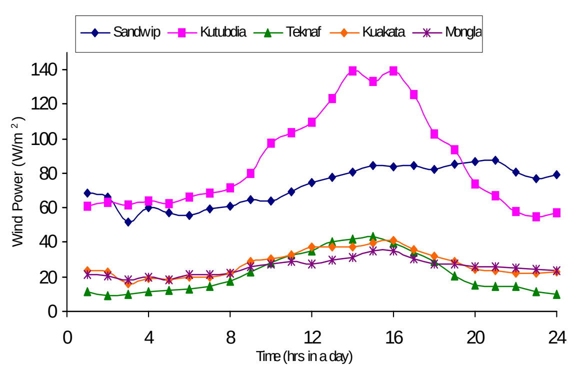

Figure 7: Wind Power in Different Coastal Region in Bangladesh