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ANALYSIS OF WEIBULL PARAMETERS FOR THE THREE MOST PROSPECTIVE WIND SIDES 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 (KKK) Kuakata, Kutubdia, and Khagrachari in the Coastal Areas are investigated. First of all the wind data of the coastal areas in Bangladesh from January to December, 2006 is to be collected and sorted in sequence in appropriate frequency. The data are further analyzed and converted into several useful parameters, like daily mean wind speed, monthly mean wind speed, and mean annual wind speed. After that, the velocity frequency bar graph, energy bar graph, velocity duration curve, etc. have been plotted and analyzed. The wind speed data of a location has been fitted to Weibull function to find different parameters for that site. The value of Weibull shape factor (k) and Weibull scale factor (c) have been calculated by different methods and compared and plotted them by employing different methods. Then a Wind Turbine has been designed for an effective location for electricity generation in Bangladesh.

Keywords: Wind Energy, Weibull Distribution, Wind Power, Energy Pattern Method, Standard Deviation Method.

1. INTRODUCTION
Wind energy is now being used in almost every country of the world as an important and pollution free renewable source of energy. In Bangladesh, research in the field of wind energy began only a few years ago, which has shown that some southern districts of Bangladesh have a very good potential of wind energy [1]. This wind energy can be used in many production areas [2]. In view of exhausting conventional energy sources and the green house effect due to their conversion, many scientist and engineers have been doing research extensively for pollution free renewable energy sources. As a result of technological advancement, the wind energy generation cost has come down from 25 cents (TK. 17.51) to 8 cents (TK. 5.60) per Kwh during the last 15 years in USA (according to 25th May,2009 money market). It is expected that by the year of 2015, the price will be reduced to 4cents (TK.2.80) [3]. Wind energy conversion system (WECS) are now extensively used in Germany, Denmark, UK, Netherlands, Russia and Australia. Asian countries like China, India, Indonesia, Japan etc are also used these technology [4]. The wind resource assessment has completed in Srilanka and Malaysia. Now they are going to install wind farms in wind prospective areas in their respective countries [4]. Compared to other developing countries, Bangladesh is in its initial stage for utilizing WECS [5]. Some organizations like BCSIR, LGED and BUET already started measuring wind speeds at some typical location of Bangladesh [1,5&10]. Now, "RENEWABLE ENERGY POLICY OF BANGLADESH" is a new policy given by Power Division, Ministry of Power, Energy and Mineral Resources, government of the People's republican of Bangladesh [Published on 6th November,2008]. There are many objectives of this policy such as Scale up contributions of renewable energy to Electricity production, Harness the renewable energy resources and dissemination of renewable energy

technologies in rural, pre-urban and urban areas, Create enabling environmental [6,7]and legal support to encourage the use of renewable energy etc. The policy sets targets for developing renewable energy resources to meet 5% of the total power demand by 2015 and 10% by 2020. So, it is obvious that Bangladesh is encouraged to use renewable energy. Since we are in the initial stage of utility of wind energy, we should follow the steps as implemented by other country in this region. Some of the information may be available from [9,10]. These include mainly two types of uses. First one is pumping water [8,9,10] and second is electricity generation [7&10].

2. WIND DATA

In the present study, the objective is to statistically analyze of wind characteristics in some coastal region of Bangladesh and make a comparison between various methods to determine Weibull parameter. Wind data of some coastal areas in Bangladesh such as Kuakata, Munshigonj, Khagrachari, Kishorgonj, Naogaon, Pakshey, Panchagarh, Rauzan, Sitakundu, Kutubdia (Cox's Bazar) and Teknaf (Cox's Bazar) from January to December, 2006 have been considered [4]. The wind data measured in ten minutes interval and then further processed to hourly time series. All data are supplied by LGED, Renewable energy department. For Weibull parameters analysis the 3 most important wind sides are Kuakata, Kutubdia and Khagrachari with comparison to others.

3. OUTLINE OF METHODOLOGY

In the current study, wind characteristics and wind energy potential of (KKK) Kuakata, Kutubdia, and Khagrachari are the most important windy areas Coastal Areas are investigated. First of all the wind data of the coastal areas in Bangladesh from January to December, 2006 is to be collected and sorted in sequence in appropriate frequency. The data are further analyzed and converted into several useful parameters, like daily mean wind speed, monthly mean wind speed, and mean annual wind speed. After that, the velocity frequency bar graph, energy bar graph, velocity duration curve, etc. have been plotted and analyzed. The wind speed data of a location has been fitted to Weibull function to find different parameters for that site. The value of Weibull shape factor (k) and Weibull scale factor (c) have been calculated by different methods and compared and plotted them by employing different methods. 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. Then a Wind Turbine has been designed for an effective location for electricity generation in Bangladesh.

4. PREDICTING OF WIND DATA

The potential benefits of having wind speed predictability are obvious in wind power generation (knowing wind speed ahead of time is useful in automatic power dispatch, load scheduling and wind turbine control). A new approach for wind speed forecasting is presented. This method makes use of memorized wind speed to predict the next step wind speed. It is shown that as long as the wind speed variation is not extremely brisk, the proposed predicting algorithm is able to predict wind speed
with a fairly good precision. The proposed predicting scheme does not assume the precise knowledge of the wind model. The result is verified via computer stimulation. The proposed prediction algorithm as described previous chapter for seven orders. Based on daily wind speed variation, we simulate the algorithm for each time instance (the sampling period 10 min).

5. ESTIMATION OF THE WEIBULL PARAMETERS FROM THE PROCESSED DATA

The Weibull distribution shows its usefulness when the wind data of reference station are being used to predict the wind regime in the surrounding of that station. The idea is that only annual or monthly average wind speeds are sufficient to predict the complete frequency distribution of the year or the month. This section deals with methods to extract the Weibull parameter k and c from a given set of data. There are several methods by which k and c can be determined. Three different methods are described below.

1. Weibull paper/ Regression analysis
2. Standard - deviation analysis
3. Energy pattern factor analysis.

6. WEIBULL PAPER METHOD

In this method at first percentage of cumulative distribution have been calculated then these are plotted for corresponding wind speed as shown in Fig. 1.

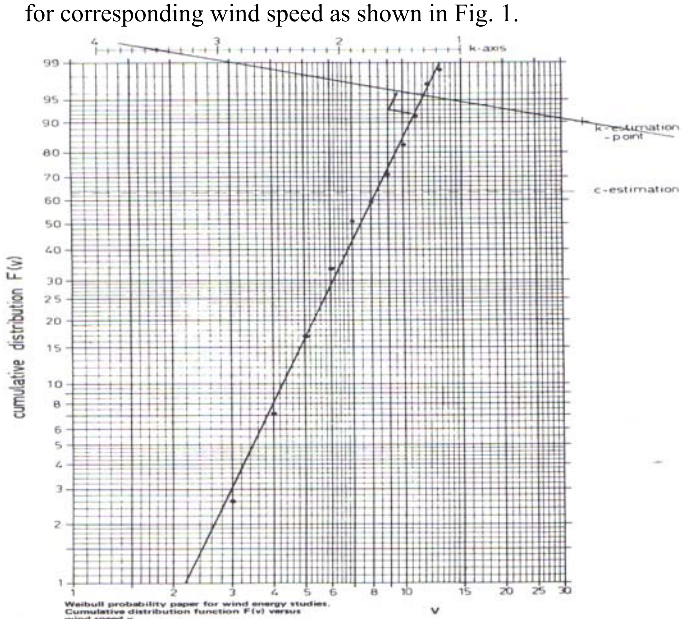


Fig 1. Cumulative distribution Vs wind speed graph

Then a straight line have been drawn in such a way that it can cover maximum point and from this line an intersection with c estimation line (dotted mark) gives the corresponding value of c for the location. A normal from "+" of the graph have been drawn upon the previous straight line, the point of intersection with the “k” axis line (top) gives the value of k.

7. 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 from equation mentioned below,

$$\sigma = \sqrt{[\int_0^{\alpha} (v - \bar{v}) \oint (v) dv} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

And the expression for f (v),

$$f(v) = \frac{dF(v)}{dv} = (\frac{k}{c})(\frac{v}{c})^{k-1} \times e^{-(\frac{v}{c})^k} \quad \ldots.(2)$$

One can find next expression for σ,

$$\sigma = c\sqrt{\left[\Gamma\left(1+\frac{2}{k}\right) - \Gamma^2\left(1+\frac{1}{k}\right)\right]} \quad \ldots.(3)$$

Or with $\bar{v} = c \times \Gamma\left(1+\frac{1}{k}\right)$ …………………………(4)

$$\frac{\sigma}{v} = \frac{\sqrt{\left[\Gamma\left(1+\frac{2}{k}\right) - \Gamma^2\left(1+\frac{1}{k}\right)\right]}}{\Gamma\left(1+\frac{1}{k}\right)} \quad \ldots\ldots\ldots\ldots\ldots..(5)$$

The standard deviation of the distribution is calculated with

$$\sigma^2 = \frac{\sum (V_n)^2 - \frac{\left(\sum V_n\right)^2}{N}}{N-1} \quad \ldots\ldots\ldots\ldots..\ldots.(6)$$

Then corresponding k value can be found from Fig 2

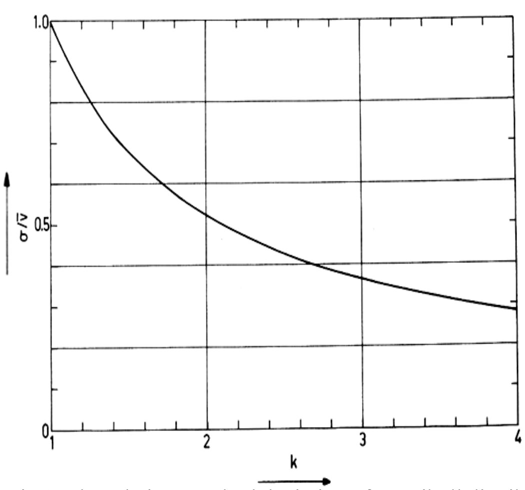


Fig 2. The relative standard deviation of a Weibull distribution as a function of Weibull sape factor (K).

Value of k and c from Standard Deviation method for each station for each month is given in result & discussion section.

8. ENERGY PATTERN FACTOR ANALYSIS

The energy pattern factor K_E is defined by Golding [5] as,

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

Realizing that the power density of the wind is given by-

$$\frac{P(v)}{A} = \frac{1}{3}\rho V^3 \quad [\text{W/m}^2] \ldots\ldots\ldots\ldots..\ldots. (7)$$

Then the total amount of energy available in the wind in a period T [26] is equal to

$$\frac{E}{A} = T\int_0^{\alpha} \frac{1}{2}\rho v^3 f(v) dv \quad [\text{J/m}^2] \ldots\ldots\ldots\ldots..\ldots\ldots,,,,(8)$$

Whereas the energy [26] is calculated by cubing the mean wind speed is equal to $\frac{E}{A} = \frac{1}{2}\rho V^3 T$ ………..…….(9)

Using Weibull provability density function f(v) in (7) results,

$$K_E = \frac{\frac{1}{N}\sum_{n=1}^{N}(V_n)^3}{\left(\frac{1}{N}\sum_{n=1}^{N}V_n\right)^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(10)$$

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

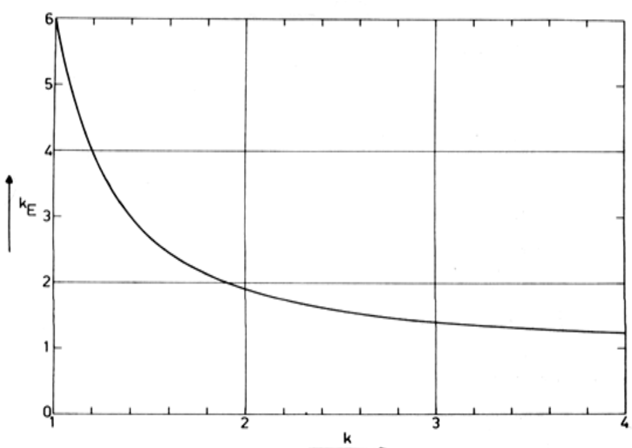


Fig 3. The energy pattern factor of a Weibull wind speed distribution as a function of the Weibull shape factor, k .

9. ESTIMATION OF WIND POWER DENSITY

The available power in the wind flowing at mean speed v_m through a wind rotor blade with sweep area A at any given site can be estimated as follows [3]:

$$P(v) = \frac{1}{2}\rho A v_m^{\ 3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(11)$$

And the wind power density (wind power per unit area) based on the Weibull probability density function can be calculated as [3]:

$$p(v) = \frac{P(v)}{A} = \frac{1}{2}\rho c^3\left(1+\frac{3}{k}\right)$$
………………..(12)

Where is *P(v)* the wind power (W), *p(v)* is the wind power density (W/m^2), ρ is the air density at the site = 1.21(kg/m^3), *A* is the swept area of the rotor blades (m^2), v_m is the wind speed at that location (m/s).

10. PREDICTION PERFORMANCE OF THE WEIBULL DISTRIBUTION MODEL

The prediction accuracy of the model in the estimation of the wind speeds with respect to the actual values were evaluated based on the correlation coefficient or determination coefficient, R^2, root mean square error (RMSE), and coefficient of efficiency (COE). In this paper, for wind speed data, the root mean square error (RMSE), determination coefficient (R^2) are used in statistically evaluating the performance of the Weibull probability density functions. These parameters were calculated based on the following K_E equation in section 7 by programming language C, which is not shown in this paper.

11. RESULT AND DISCUSSION

Value of k and c by Various Methods
(k is a dimensionless number and c in m/s)

Weibull paper Method

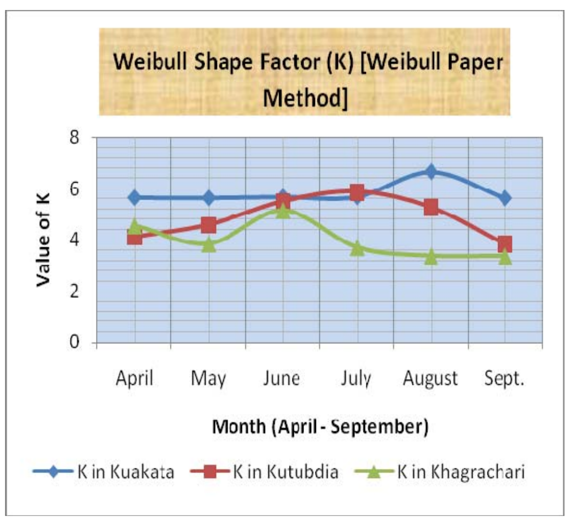
Location	Month	K	C
Kuakata	April	2.9	5.4
	May	2.6	5.2
	June	2.4	5.8
	July	2.2	6.2
	August	2.0	6.9
	September	2.6	5.6
Kutubdia	April	1.90	3.70
	May	2.30	4.60
	June	2.50	5.20
	July	2.80	6.00
	August	2.60	5.80
	September	1.50	3.40
Khagrachari	April	3.30	4.60
	May	2.40	3.80
	June	2.00	5.00
	July	2.70	3.80
	August	2.70	3.20
	September	3.00	4.00

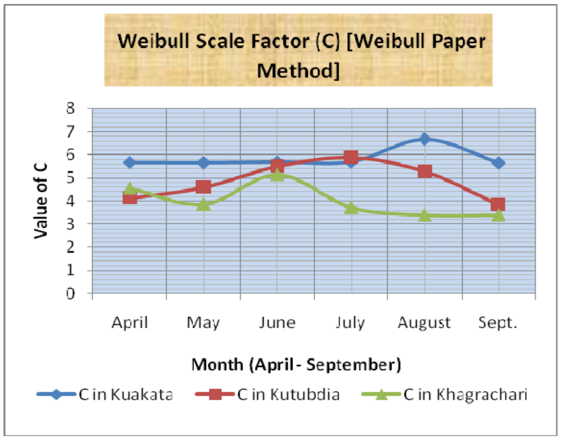
Standard Deviation Method

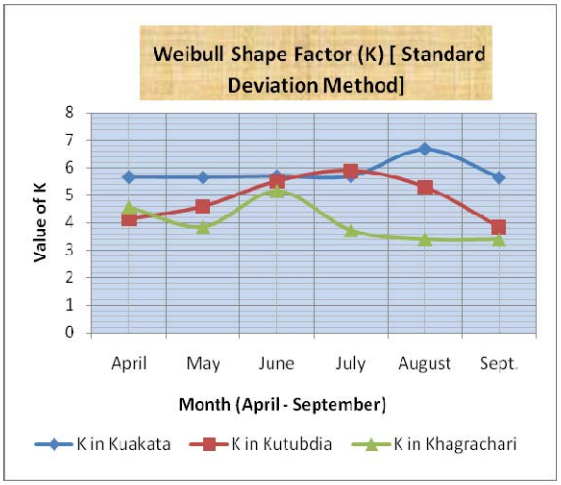
Location	Month	K	C
Kuakata	April	3.65	6.09
	May	3.16	5.49
	June	3.50	5.71
	July	3.92	6.46
	August	3.00	6.66
	September	2.41	5.64
Kutubdia	April	3.38	4.12
	May	3.2	4.60
	June	3.29	5.48
	July	4.00	5.89
	August	3.50	5.28
	September	2.1	3.96
Khagrachari	April	4.00	4.56
	May	2.61	3.86
	June	2.38	5.15
	July	4.00	3.72
	August	4.00	3.39
	September	4.00	3.38

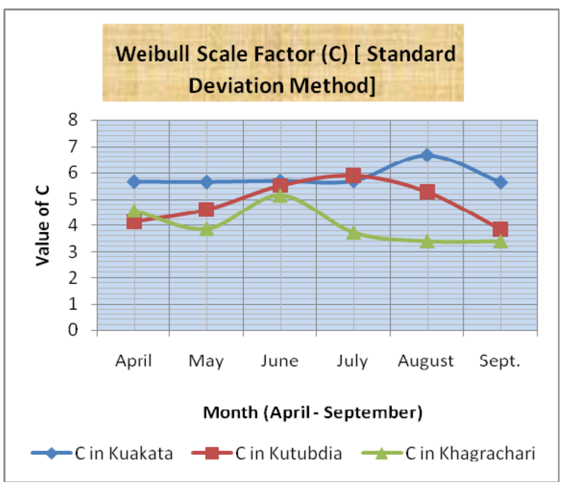
Energy Method

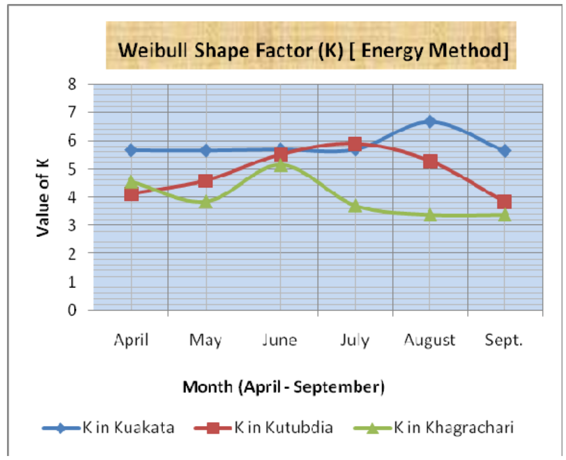
Location	Month	K	C
Kuakata	April	3.19	5.66
	May	3.12	5.65
	June	3.65	5.69
	July	3.65	5.69
	August	2.85	6.67
	September	2.45	5.64
Kutubdia	April	3.21	4.13
	May	3.05	4.60
	June	3.00	5.51
	July	4.00	5.89
	August	3.65	5.28
	September	2.00	3.84
Khagrachari	April	4.00	4.56
	May	2.48	3.86
	June	2.30	5.15
	July	4.00	3.72
	August	4.00	3.39
	September	4.00	3.39

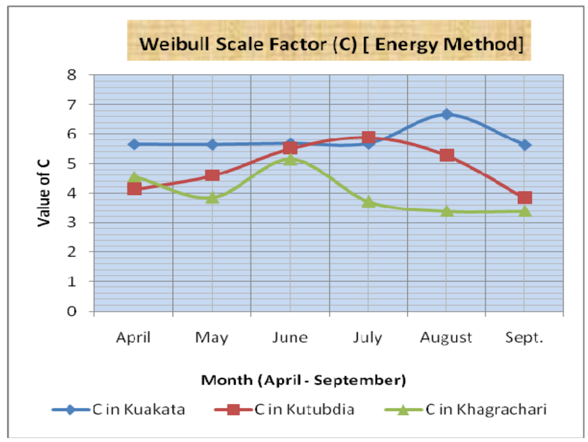












11.1. DISCUSSION

From the tables and graphs the Weibull distribution parameter such as Weibull shape factor (k) and Weibull scale factor (c) are calculated by different methods. It is found that the value of k remains between 1.5 to 4.0 and that of c remains between 3.20 to 6.9. In most cases of the Weibull functions follow very close to the shape factor (k=2) for the selected sites. The mean wind speed (v_{mean}) for each location remains 2.37 to 5.97 m/s and highest two mean wind speed are found in Kuakata (5.74m/s) and 5.97 m/s respectively. The maximum wind power is obtained from Kuakata which is 5895.6 Wh/m^2. In Khagrachari, April 12th to 17th this five days data prediction was done by programming language C which is not shown in this paper.

12. 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. The shape factor (k) and scale factor (c) are determined for each month. It is found that the value of k remains between 1.5 to 4.0 and that of c remains between 3.20 to 6.9.In most cases of the Weibull functions follow very close to the shape factor (k=2) for the selected sites. Although some values are far beyond. The Weibull probability distribution scale parameters (c) are consistently higher in values and variability than the shape parameters (k) monthly distributions.

13. REFERENCES

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14. NOMENCLATURE:

Symbol	Meaning	Unit
K	Shape factor	…
C	Scale factor	m/s
K_E	Energy pattern factor	…
f (v)	Provability density function	…
A	Area	m^2
E	Available energy	wh/m^2
ρ	Air density	Kg/m^3
σ	Standard Deviation	….
v	Velocity of Air	m/s
N	Total number of hours	hurs
T	Total time	hurs
P(v)	Wind Power	W
p(v)	Wind power density	W/m^2
P	Power	wat
V_m	Mean wind Speed	m/sec
R	Correction Co-efficient	…

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