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# UNUSUAL WIND BEHAVIOUR AT SITAKUNDU OF BANGLADESH

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## ABSTRACT

Wind energy is a non polluting cost-effective renewable energy source. The science of exploration of wind power is not a new one. For the past few centuries, people have been extracting energy from the wind in various ways. One means of converting wind energy to a more useful form is through the use of windmills. Wind power technology in Bangladesh has been growning significantly in the last decade. Capacity of wind turbines has been increased significantly and at the same time, the cost of generating power from wind has come down. For the purpose of wind data, 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. During the analysis, it has been found that an unusal wind characteristic at sitakundu on September, 2006 with respect to other month. This unusal wind behavior further analysis for determining wind gusts and Weibull parameters. 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. Although the peak wind velocity, the equivalent pressure on rigid bodies, and the dynamic along wind response of flexible structures are component parts of the gust buffeting problem, different procedures have been developed in the technical literature with reference to each of these subjects.

**Keywords:** Wind energy, Weibull distribution, Weibull shape factor (k), Weibull scale factor (c), Wind Gusts.

## 1. INTRODUCTION

Sitakundu has been developing a wind load meteorological background to support Sitakundu standards. Wind impact is one of the major loads affecting buildings and other constructions, among which the most affected are the power-transmission pylons of the electrical energy network which can be seriously damaged by wind, resulting in serious collateral damage in different areas. Croatia has to harmonise its standards with European standards and one of its biggest problems is that there is an insufficient number of locations with long-term continuous measurements of wind direction and speed averaged to 10-minute intervals. Namely, the pre-drafts of European standards (ENV 1991.2.4, 1995; CENELEC/TC 11 (SEC) 40, 1997) recommend the use of 10-minute averaged wind speed in the calculation of many parameters. In Croatia, such data are available from 21 locations, for periods longer than three but shorter than ten years. They have been used as the basis for the development of a meteorological background for Croatian standards. However, within this project, for the estimation of locally expected maximal wind speeds, it has been decided to also use wind speed and direction averaged over hourly periods. Hourly averaged data for longer periods are available at another 24 locations and they are particularly useful to achieve better territorial coverage of the Croatian area observed.

This paper presents a direct application of hourly averaged wind speed data (instead of the recommended 10-minute average) for defining the maximal local instantaneous wind speed (wind gust). Such application has been researched on the example of hourly data from April to September in Sitakundu, 2006. where some of the strongest Croatian gusts had been measured. It is therefore important to know the persistency of strong wind. To define the wind conditions at the Sitakundu that might jeopardise the power-transmission lines, an analysis has been made of the wind speed data for one day in each month when two kinds of maximal monthly speeds were identified for the same month. These are the maximal monthly mean hourly wind speed and the maximal monthly instantaneous wind speed. The relationship of these two maximal speeds has been analyzed. The analysis has been performed by a methodology derived from the methodology for defining gusts based on mean ten-minute wind speeds as recommended by the pre-draft of European standards for building European power-transmission lines. The simplest form of the relations has been applied to get a first insight into the local gust characteristics and computations. Generally, in attempting to define the local characteristics of gusts in detail, many kinds of analyses have been applied so far. For instance, for an Argentinean location, gusts have been computed for different averaging intervals, their variation with height and the time of year has been analysed, the general form of the vertical wind profile and its dependence on stability conditions have been analysed and compared with those of typical episodes of severe winds (Labraga, 1994). One of the newest physically based parameterization schemes for the computation of wind gusts has been implemented in a numerical Canadian regional climate model (Goyette et al, 2003). A parameterization scheme has been developed in order to use the quantities available at each model time step, including the wind gust computation for each of these time steps. There have been many attempts to relate wind gusts to mean wind speeds averaged over different time scales, and even to mean daily wind speeds.

## 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.

## 3. OUTLINE OF METHODOLOGY

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. During the analysis it has been found that frequently increase the wind characteristic at Sitakundu on August and September,2006 than other months. This abnormal wind behavior further analyzed for determining wind gusts and other Weibull parameters at that unusual wind behavior at Sitakundu. 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.

Except in the short period of gusts, was on the average relatively high over a longer period, i.e. at least over an hour. The days thus chosen are days when substantial material damage can be expected due to the great strength and relatively long duration of strong wind, and this was the main reason for this research.

For application to the building of electrical power-transmission equipment in Europe, the estimation of wind gusts based on mean ten-minute wind speed values has been initially suggested to be processed as follows

$$V_g = K_g V_{mean} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where $V_g$ is the gust speed (m/s), i.e. the instantaneous maximal wind speed in a measuring interval (T) of 2 seconds, $V_{mean}$ is the mean ten-minute wind speed (m s–1) and $k_g$ is the gust factor. The gust factor is defined as:

$$k_g = 1 + \frac{2.28}{\ln\left(\frac{z}{z_0}\right)}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where z (m) is the height above ground and $z_0$ is the roughness length (m), which depends on terrain characteristics. At the Sitakundu and other prospective locations, wind measurements are performed at the usual height above ground, 10m and 20m. i.e. z =10m. The value of the roughness length, $z_0$, has been taken as 0.3 m, which is the value defined in most Asian countries for woodland areas like the Bangladeshi area observed.

In equation (2), the log wind profile is used to define the gust. The mean wind speed as a function of height above the ground can be computed by the logarithmic profile.

$$V_{mean} = \frac{u_*}{k} \ln\left(\frac{z}{z_0}\right), \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where k is the von Karman constant, approximately equal to K= 0.4; u* is the friction velocity; $z_0$ is the surface roughness length; and z is the height above the ground.

The peak gust speed ($V_g$) at height z is computed using Durst's statistical model (Durst, 1960) as follows:

$$V_g(z) = V_{mean}(z) + g(T)\sigma_v(z), \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where T is the averaging period, *g(T)* is the gust peak factor which is a function of T and $\sigma_v(z) = \sqrt{\beta} u^*$ is the root-mean-square value of the longitudinal fluctuating wind speed at height z, in which β is a terrain dependent coefficient. For *g(T)*, the Eurocode uses alternatively factors of 3.7 and 3.5. By including equations (3) and (4) into equation (1), the following gust factor equation is obtained:

$$k_g = \frac{V_g}{V_{mean}} = 1 + g(T)I(z), \quad \ldots\ldots\ldots\ \ \ldots\ldots\ldots(5)$$

where $I(z)$ is the longitudinal turbulence intensity and $I(z)$ is defined as:

$$I(z) = \frac{\sigma_v(z)}{V_{mean}(z)} \text{..........................(6)}$$

Equations (4), (5) and (6) indicate that the constant 2.28 in (2) is calculated as:

$$\mathbf{2.28} = g(T)\,\sqrt{\beta}\,\mathbf{k} \text{.....................(7)}$$

Strong gusts have been assumed to characterize the daily weather conditions which significantly affect the values of the individual mean hourly wind speeds during the whole day and not only the value of the mean ten-minute speed at the time of the gust. Because of this assumption, and because there are no ten-minute data available for many locations in Croatia, the recommended equation (1) has been modified and the following modification has been tested:

$$V_g = k_g \overline{V_{MAX}} \text{.......................(8)}$$

where $k_g$ is the same parameter value as in equation (2), $\overline{V_{MAX}}$ is the maximal mean hourly speed for a particular month and $V_g$ is the expected maximal gust on the same day.

The values of the maximal monthly gusts estimated on the basis of equation (8) have been compared with the measured maximal monthly gusts. It has been established that this equation should be further modified for all maximal mean hourly wind speed classes, for both bura and jugo. The modification of equation (8) has been carried out for all wind speed classes. All equations, derived individually for every maximal mean hourly wind speed class, have the following form:

$$V_g = k_g \overline{V_{MAX}} + \mathrm{C} \text{.....................(9)}$$

where C is the constant, which is different for each particular wind speed class and for the same wind speed. Constant C represents the mean difference between the individual measured wind gusts in the particular speed class considered and the associated wind gusts calculated by using equation (8).

## 4. ESTIMATION OF THE WEIBULL PARAMETERS FROM THE PROCESSED DATA:

he 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.

## 5. RESULT AND DISCUSSION

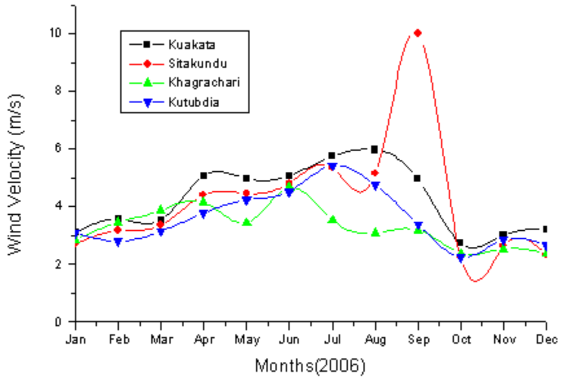

Fig 1. Monthly Average Wind Speed Curve for most Prospective Wind Sides at 2006.

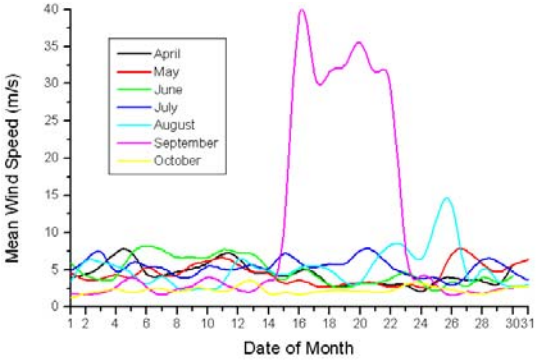

Fig 2: Daily Average Wind Speed Curve at Sitakundu, 2006.

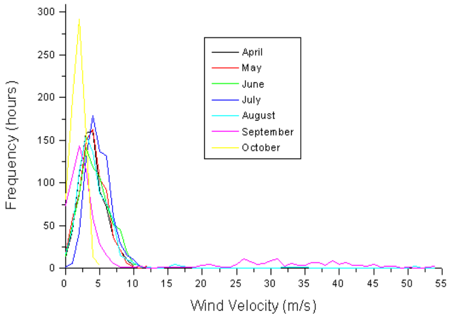

Fig 3: Frequency Vs. Wind Speed Curve at Sitakundu, 2006.

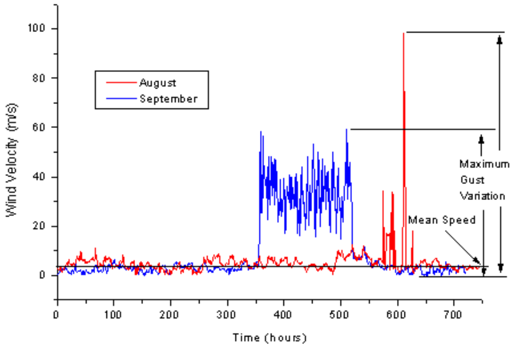

Fig 4: Instantaneous Variation of Wind Velocity at Sitakundu, 2006.

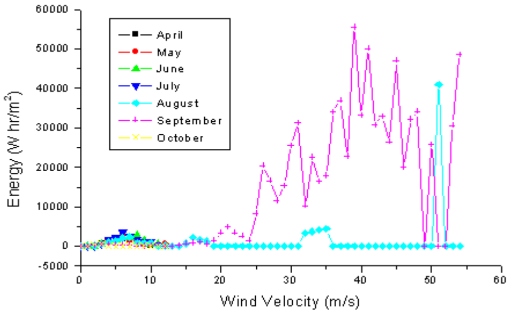

Fig 5. Energy Vs. Wind Velocity Curve at Sitakundu, 2006

### 5.1: Find Out Of Weibull Parameters

Weibull Parameters i.e shape factor ‘*K*’ and scale factor ‘*C*’ is very important for wind data analysis. Where shape factor ‘*K*’ is a dimensionless number and scale factor ‘*C*’ in m/s.

Value of $k$ and $C$ by Various Methods

Table 1: Weibull paper Method.

| Location | Month | K | *C* |
|---|---|---|---|
| Sitakundu,06 | April | 2.10 | 4.97 |
| | May | 1.90 | 5.03 |
| | June | 2.00 | 5.43 |
| | July | 2.20 | 6.02 |
| | August | 1.95 | 5.66 |
| | September | 1.32 | 10.83 |
| | October | 1.90 | 2.56 |

Table 2: Standard Deviation Method

| **Location** | **Month** | **K** | ***C*** |
|---|---|---|---|
| Sitakundu,06 | April | 2.40 | 4.98 |
| | May | 2.41 | 5.04 |
| | June | 2.32 | 5.43 |
| | July | 3.19 | 4.88 |
| | August | 2.09 | 3.47 |
| | September | 1.10 | 2.23 |
| | October | 2.19 | 2.57 |

Table 3: Energy Method

| Location | Month | K | *C* |
|---|---|---|---|
| Sitakundu,06 | April | 2.40 | 4.97 |
| | May | 2.42 | 5.04 |
| | June | 2.28 | 5.43 |
| | July | 3.00 | 5.97 |
| | August | Out of Range | Not Apple. |
| | September | Out of Range | Not Apple. |
| | October | 2.52 | 2.56 |

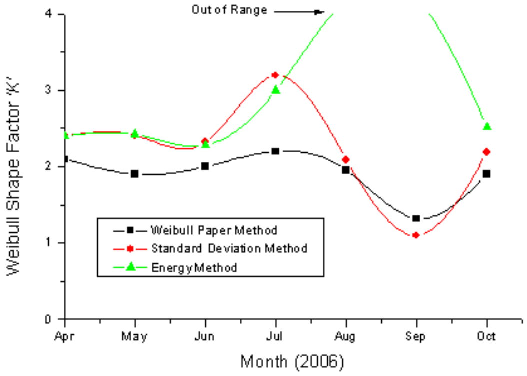

Fig 6: Weibull Shape Factor ‘*K*’ curve by different Methods.

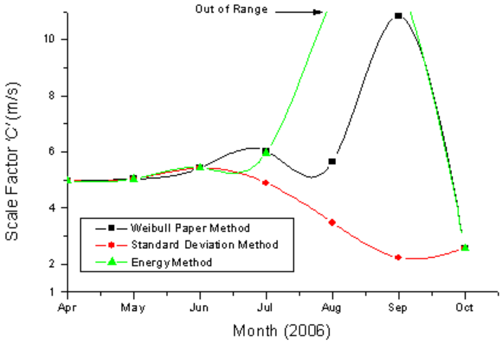

Fig 7: Weibull Scale Factor *'C'* curve by different Methods.

## 6. DISCUSSION

From the Table and graphs, it is clear that the wind behavior at Sitakundu (August to October), 2006 is irregular than any other prospective sides (Fig 1). Then the analysis has been carried out on seven month from April to October. The diurnal variation of wind speed has shown in (Fig 2), where hourly average wind speed has been plotted and it shown that Sitakundu, August and September wind behavior is so rough. At September, 14 to 24 average wind speed is above 32 m/s which is very harm full for wind turbine, constructions and power transmission lines ect. Frequency Vs. Wind Speed Curve shown in (Fig 3:), which shown that most of the month wind speed 2-5 m/s is higher frequency and August and September some frequency have wind speed 10 to 54 m/s. Maximum wind Gust is clearly shown in (Fig 4), where at sitakundu 350th to 530th hours i.e 180 hours wind Gust is higher than 42 m/s. Weibull Parameters i.e shape factor *'K'* and scale factor *'C'* has been calculated by Weibull Paper method (Table -1), Standard deviation method (Table -2) and Energy method (Table -3). By Energy method, both *K* and *C* value at August and September is out of range. Because of the irregularity of wind velocity and high magnitude of wind Gust.

## 7. 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 1.90 to 3.19 and that of c remains between 2.56 to 10.89.The most of the Weibull functions follow very close to the Raleigh function (k=2) for the selected sites. The Weibull probability distribution scale parameters (c) are consistently higher in values and variability than the shape parameters (k) monthly distributions. Both steps of the modification developed proved usable. In the first step, the mean ten-minute wind speed data input in the pre-draft of the European standard model was replaced by a mean hourly data input, because of the availability of long-term hourly averaged data for a large part of the Sitakundu. Long-term data provide an insight in the climatological characteristics of the location observed. Therefore, in the few cases where the derived relations for Sitakundu proved unsuitable (Fig 2,4,5,6 and 7), they point at a cluster of cases which have to be taken as locally exceptional and rare but possible. In further wind gust investigations some other forms of relationship between gust speed and mean hourly speed will be investigated for the Selected location. The intention is to find a universally applicable form of wind gust calculation.

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## 9. 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 | $wh/m^2$ |
| $\rho$ | Air density | $Kg/m^3$ |
| $\sigma$ | 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 |
| $V_{mean}$ | Mean wind Speed | m/sec |
| R | Correction Co-efficient | … |
| $V_g$ | Gust Speed | m/s |
| $K_g$ | Gust Factor | …. |
| Z | Height above the ground | m |
| $Z_0$ | Roughness length | m |
| $g(T)$ | Gust peak factor | …. |
| $I(z)$ | Longitudinal turbulence intensity. | …. |