Research Article

Wind resource assessment for southern part of Bangladesh

Mohammad Nasirul Hoque¹, Sanjoy Kumar Nandi²*, Himangshu Ranjan Ghosh³

¹Department of Physics, University of Chittagong, Chittagong, Bangladesh.
²Department of Physics, Primeasia University, Dhaka, Bangladesh.
³Renewable Energy Research Centre (RERC), University of Dhaka, Dhaka, Bangladesh.

*Author to whom correspondence should be addressed, email: skumarnandi@yahoo.com

Abstract

In this study wind speed data from Sustainable Rural Energy (SRE) of the Local Government Engineering Department (LGED) for Kutubdia, Sitakunda, Khagrachari, CUET and Kuakata from June 2005 to December 2006 have been assessed to determine the potential for wind power generation. The variations of wind speed with year, season and time of day are discussed for these sites as proper positioning of turbines is important for the wind industry. From five LGED stations it was found that the average annual wind speed values at different heights for the five wind stations vary from 1.73 m/s to 4.17 m/s. The highest average annual wind speed (4.17 m/s) was observed in Kuakata and the lowest value (1.32 m/s) was observed at Khagrachari. Maximum wind power density was in Kuakata (88kW/m²) at height 30m and minimum in Khagrachari (13kW/m²) at a height of 10m. The highest potential was found for Kuakata and Kutubdia, whereas Khagrachari and CUET have low potential for wind electricity generation. Weibull parameters, namely c and k, were determined using Weibull distribution which is considered useful and appropriate for wind energy as it is one of the easiest methods used to identify the wind potential of a specific site, since it allows for estimation of the probability density function.

Keywords: Kutubdia, Chittagong, Sitakunda, Khagrachari, Kuakata, Weibull probability density function, renewable energy
**Introduction**

Previous studies have shown that off-shore islands have sufficient wind speed to produce electricity from wind in Bangladesh [1]. A previous study showed that for 31 wind monitoring stations of the Bangladesh Meteorological Department (BMD), situated in built up areas, wind speed is low near the ground level at the height of around 10 metres [2]. Potential assessment of wind energy in Bangladesh has been slow mainly due to lack of adequate wind data. However, recent measurements in some places have shown significant wind energy potential. In 1996-97 under the WEST project, the Bangladesh Centre for Advanced Studies (BCAS) with support from the Local Government Engineering Department (LGED) measured wind speed and direction at 25m height for seven locations near the coast while GTZ, a German organization, also measured wind speeds for another three coastal locations at a height of 20m. The Bangladesh Council for Scientific and Industrial Research (BCSIR) measured wind speed for Dhaka, Teknaf and Saint Martin Island locations from 1999–2001 [2]. Presently, the LGED is measuring the speed and direction at 20 locations all over Bangladesh under the WERM project at different heights. Unfortunately, assessment results of these locations are not currently available for all sites. Nandi et al. [3, 4, 5] describe the wind potential for Sitakunda for LGED wind monitoring stations. Annual average wind speed at 30 m height along the coastal belt is above 5 m/s, northeastern areas is above 4.5 m/s, while inland wind speed is around 3.5 m/s for most parts of Bangladesh [6]. Different studies [7, 8] describe wind potential for Kutubdia Island for different sites. In the present study wind speed data from Sustainable Rural Energy (SRE) of the LGED for Kutubdia, Sitakunda, Khagrachari, Chittagong University of Engineering and Technology (CUET) and Kuakata from June 2005 to December 2006 have been assessed to determine the potential for wind power generation.

**Data Collection and Methodology**

Wind energy varies with year, season and time of day, elevation above ground and form of terrain. Proper positioning of the turbine, in windy sites, away from large obstructions, improves the wind turbine’s performance.

Commonly, the dual-parameter Weibull probability density function is used to represent wind speed distributions [9]. Weibull probability distribution is used to determine the parameters of wind speed. The Weibull distribution is a mathematical expression, which provides a good approximation to many measured wind speed distributions. The Weibull distribution is therefore frequently used to characterize a site. Such a distribution is described by two parameters: the Weibull ‘scale,’ parameter which is closely related to the mean wind speed and the ‘shape’ parameter, which is a measurement of the width of the distribution. This approach is useful since it allows both the wind speed and its distribution to be described in a concise fashion.

For the various sources of data the Weibull probability function was utilized to approximate the probability of the occurrence of wind speeds. Weibull distribution [10] is

\[
P(v) = \frac{k}{c} \left( \frac{v}{c} \right)^{k-1} e^{-\left( \frac{v}{c} \right)^k} \quad v > 0
\]

\[
= 0 \quad \quad v \leq 0
\]
This distribution is given by Eq. (1) where $k$ is the shape parameter and $c$ the scale parameter. Wind power density, expressed in watts per square metre (W/m²), takes into account the frequency distribution of the wind speed and the dependence of wind power on air density and the cube of the wind speed. Therefore, wind power density is generally considered as a better indicator of the wind resource than wind speed. The mean wind power density available over a period $T$ is given by Equation 2. In this equation $\rho$ is the air density and $E$ is given in (W/m²).

\[
E = \frac{1}{2} \frac{1}{T} \int_0^T \rho v^3(t) dt
\]  

$\rho$ may be taken as a constant with an error of a few percent [11]. It should be noted that the velocity expression of Eq. (2) is based on values of average speed not instantaneous values. Also sitting within dense vegetation such as a forest or an orchard requires establishment of a new effective ground level at approximately the height where the branches of adjacent trees touch, below this level there is a little wind. In a dense cornfield wind, this height would be the average corn height or average height of the tree canopy for a forested area. In areas of high wind, wind power can be quite reliable and inexpensive. However, based on current turbine technology, for wind energy to be economically viable it has to deliver to a wind turbine an average annual wind speed of at least 5.36 m/s and above [11].

**Results and Discussion**

In general, daily and seasonal changes, as well as wind direction are important considerations while siting wind systems. From five LGED stations it was found that the average annual wind speed values at different heights for the five wind stations vary from 1.73 m/s to 4.17 m/s. The highest average annual wind speed (4.17 m/s) was observed in Kuakata and the lowest value (1.32 m/s) was observed at Khagrachari. The analysis showed that highest wind speed was found during summer at Kutubdia and Kuakata. The annual cycle of monthly average wind speed shows fairly large seasonal variation, the appearance of which is typical for measurement sites, with minimum values in winter (October–March) and maximum values during summer (April–September, Fig. 1.a). Similar variations were also observed for BCAS, Kutubdia and Kuakata stations [7, 8]. The analysis of the daily cycle of wind speed at different time instants, however, suggests that the dominance of daytime winds over night winds that is characteristic of mainland measurement sites also contributes to this feature. While there is almost no dependence of the wind speed on the measurement time for Kuakata and a weak maximum becomes evident at afternoon for all stations. Such a variation is similar to that observed for BCAS wind monitoring stations at Kutubdia and Kuakata sites [7, 8]. A part of this cycle is obviously due to the local sea breeze. The typical spatial scale for changes of the diurnal cycle apparently depends on many factors such as the area covered by sea breeze, the geometry of the coastal region, or the mutual orientation of the land and sea and the direction of air flow. From the above analysis it might be concluded that the daily cycle of wind speed should be taken into account when a wind farm is planned in the vicinity of a specific site.

A wind rose is the term given to the way in which the joint wind speed and direction distribution is defined. The wind speed data for LGED stations were grouped into twelve directional sectors: north-north west (NNW), north (N), north-north east (NNE), east-north east (ENE), east (E), east-south east (ESE), south-south east (SSE), south (S), south-south west (SSW), west-south
west (WSW), west (W) and west-north west (WNW). Each one extended over 30° according to the direction from which the wind blows. The design of a wind farm is sensitive to the shape of the wind rose for the site. In some areas, particularly where the wind is driven by thermal effects, the wind can be very unidirectional. Wind roses providing the percentage of wind direction for different stations for the whole year have been constructed as shown in Fig.2. The coastal and mainland wind are less directionally homogeneous and only show a slight prevalence of south-east and north winds respectively. The coastal winds are mostly driven by large-scale atmospheric dynamics and are less affected by local orography and obstacles, whereas the inland sites (CUET and Khagrachari) are strongly affected by orography and obstacles.

![Figure 1. Monthly (a) diurnal (b) variation of wind speed for sites at different heights.](image)

In this study the Weibull parameters were calculated by least square method [4, 12]. Table 1 shows the corresponding values of k and c for each location for each month. From Table 1, it is found that the value of k during summer for all stations is higher and that of winter is lower. A small value of k indicates widely dispersed data, i.e., the data tend to distribute uniformly over a relatively wide range of wind speed. If mean wind speed is low, this has a negative implication on wind power generation because the station does not experience enough wind speed to operate a wind turbine. For large values of k, the majority of wind speed data tend to fall around the mean wind speed, and if the mean wind speed is high, then the station experiences enough wind speed to operate a wind turbine at least for a short period of time. The frequency distribution functions for different stations and heights are shown in Fig. 3 enable one to estimate the probability of exceeding certain wind speed thresholds that could be important for wind farm planning.
Table 1. Weibull parameters for different locations and different heights.

<table>
<thead>
<tr>
<th></th>
<th>Kutubdia 10m</th>
<th>Kutubdia 20m</th>
<th>Sitakunda 20m</th>
<th>CUET 30m</th>
<th>Khagrachari 20m</th>
<th>Kuakata 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1.38</td>
<td>1.43</td>
<td>3.07</td>
<td>1.43</td>
<td>1.76</td>
<td>1.68</td>
</tr>
<tr>
<td>February</td>
<td>0.96</td>
<td>1.45</td>
<td>2.78</td>
<td>1.07</td>
<td>2.18</td>
<td>1.37</td>
</tr>
<tr>
<td>March</td>
<td>1.24</td>
<td>1.47</td>
<td>3.09</td>
<td>1.19</td>
<td>1.68</td>
<td>1.90</td>
</tr>
<tr>
<td>April</td>
<td>1.63</td>
<td>2.04</td>
<td>4.11</td>
<td>1.92</td>
<td>4.48</td>
<td>4.18</td>
</tr>
<tr>
<td>May</td>
<td>1.51</td>
<td>1.89</td>
<td>4.39</td>
<td>1.90</td>
<td>4.67</td>
<td>4.39</td>
</tr>
<tr>
<td>June</td>
<td>1.78</td>
<td>2.07</td>
<td>4.99</td>
<td>1.92</td>
<td>5.47</td>
<td>5.19</td>
</tr>
<tr>
<td>July</td>
<td>2.33</td>
<td>2.44</td>
<td>5.56</td>
<td>2.22</td>
<td>6.38</td>
<td>5.76</td>
</tr>
<tr>
<td>August</td>
<td>1.76</td>
<td>1.77</td>
<td>4.83</td>
<td>1.72</td>
<td>5.67</td>
<td>5.56</td>
</tr>
<tr>
<td>September</td>
<td>1.47</td>
<td>1.29</td>
<td>3.27</td>
<td>1.24</td>
<td>2.77</td>
<td>2.27</td>
</tr>
<tr>
<td>October</td>
<td>1.08</td>
<td>1.40</td>
<td>2.38</td>
<td>1.38</td>
<td>2.52</td>
<td>2.52</td>
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<tr>
<td>November</td>
<td>1.24</td>
<td>1.34</td>
<td>2.77</td>
<td>1.59</td>
<td>2.94</td>
<td>2.56</td>
</tr>
<tr>
<td>December</td>
<td>1.30</td>
<td>2.52</td>
<td>3.62</td>
<td>2.27</td>
<td>3.84</td>
<td>3.40</td>
</tr>
<tr>
<td>Annual</td>
<td>1.26</td>
<td>2.27</td>
<td>3.69</td>
<td>1.30</td>
<td>1.83</td>
<td>1.57</td>
</tr>
</tbody>
</table>
Figure 3(a). Actual and predicted wind speed probability for CUET, Khagrachari, Kutubdia stations at 10m and 20m heights.
Figure 3(b). Actual and predicted wind speed probability for Kuakata and Sitakunda stations at 20m and 30m heights.

Wind power density is considered to be the best indicator to determine the potential wind resource, which is critical to all aspects of wind energy exploitation, from the identification of suitable sites and predictions of the economic viability of wind farm projects through to the design of wind turbines themselves. Monthly and diurnal variation of wind power density is shown in Fig.4. The power density was calculated using Eq. (2). As wind power density depends on the cube of speed $v^3$, the available wind energy is much higher during the windy months. Maximum wind power density is observed during June and July. Maximum wind power density was in Kuakata (88kW/m²) at a height of 30m and minimal in Khagrachari (13kW/m²) at a height of 10m.
Figure 4. Monthly (a) and hourly (b) variation of wind power density for different stations and heights.

Conclusions

This study reveals that Kutubdia and Kuakata have potential for wind power and data is consistent with other studies such as the BCAS measurement sites. Only short term data has been used for the analysis. There is a general claim that a minimum of ten years data are required for proper assessment of wind resource at a particular site. It is required to measure long term wind speed for different heights and terrain effects to find out the exact potential of each site. In the end the present work is only a preliminary study in order to assess wind energy analysis of the selected sites and give useful insights to engineers and experts dealing with wind energy.

Acknowledgments

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