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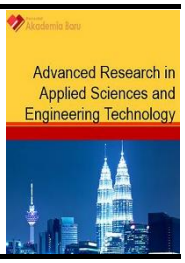

Wind Energy Assessment as a Source of Power Generation in Bangladesh

Mithun Mondal[1], Djamal Hissein Didane[2,*], Alhadj Hisseine Issaka Ali[3], Bukhari Manshoor[2]

[1] Department of Mechanical Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, 86400 Batu Pahat, Johor, Malaysia
[2] Center for Energy and Industrial Environment Studies, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, 86400 Batu Pahat, Johor, Malaysia
[3] Department of Hydrocarbons Exploitation, Higher National Petroleum Institute of Mao Mao, Chad

ABSTRACT

Wind energy has been considered one of the most popular forms of renewable energy. It has been widely considered for the generation of electricity for its low maintenance cost and negligible effect on environmental pollution. The purpose of this research is to evaluate and compare the wind energy potential in seven different districts of Bangladesh including Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur, and Sylhet. Data had been recorded on daily basis for the consecutive five years from 2015 until 2 019 and analysed using Weibull distribution function various essential parameters such as wind speed, wind energy density and wind power density. Results show that the monthly average wind speed varies between 0.5 m/s to 2.10 m/s for all the divisions except Chittagong where it is in the range between 3 m/s and 4.5 m/s. Similarly, the maximum wind power density and wind energy density were also found in the Chittagong division with annual densities that range between 51.86967 W/m^2 to 84.01142 W/m^2 and 454.3783 KWh/m^2 to 753.94 KWh/m^2, respectively. The shape and scale parameters (k and c) are varying between 0.774373 – 1.086069 and 0.684588 – 1.735511 m/s, respectively for all the divisions except Chittagong where it ranges between 1.463098 – 1.625881 and 3.131256 – 4.28601 m/s, respectively. Meanwhile, the prevailing wind directions vary from one division to another but mainly between south and east. This, this study strongly recommends the Chittagong division for the utilization of the potentiality of wind energy.

Keywords:
Wind energy; Wind Conversion Energy System; Weibull Distribution, Bangladesh

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1. Introduction

The sources of electricity production such as coal, oil, and natural gas have contributed to one-third of global greenhouse gas emissions. It is essential to raise the standard of living by providing cleaner and more reliable electricity. The world has an increasing energy demand to fulfill the economic development plans that are being implemented. The provision of increasing quantity of energy is a vital pre-requisite for the economic growth of the world [1], [2]. Nonetheless, depletion of conventional energy sources and associated environmental sustainability issues has put up new

* *Corresponding author.*
E-mail address: dhdfils@gmail.com

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strategies for researchers and policymakers to explore and discover renewable energy sources such as solar, wind, geothermal, tidal, biogas, biofuels, etc. Among these, the usage of wind energy has become a promising resource due to its competitive nature as a clean, abundant, easily harvestable, inexhaustible, and affordable resource [3]–[6]. Certainly, irrespective of rampant irregularities existing in the global renewable energy market, overall installed capacity for wind power has rapidly increased over 104% during the last decade which is clearly indicative of an increasing role of wind power in fulfilling future energy demands. Recently, China and the USA upgraded their installed capacity within one year by 23.328 GW and 8.203 GW, respectively, meanwhile the global wind power installed capacity showed a remarkable rise of 12.5% during the same period [7].

In Bangladesh, power generation is mostly dependent on natural gas, around 76.74 % of electricity is being produced from gas reserve and this percentage of electricity generation uses 37% of total gas consumption, while demand for gas consumption is increasing by about 8% per year [8]. Bangladesh is still far behind its expected growth of renewable energy, i.e., target 1000-1200 MW to ensure the electrification for all [9]. According to Bhuiyan et al. [10], renewable energy is essential for economic growth, sustainable development of the country, and socio-economic development. Approximately 6% of power and energy belongs to renewable energy and the rest 94% are from fossil fuels [11]. Musial & Ram [12] mentioned about the possible potential of solar photovoltaic and wind energy are estimated at 50174 MW and 4614 MW, respectively, while the potential of energy from biomass and small hydropower plants is estimated to be 566 MW and 125 MW respectively.

Bangladesh already sets its goal for renewable energy to reduce the carbon footprints on the environment by avoiding the emission of greenhouse gasses. Wind, solar and biomass can be targeted as the source of renewable energy. Hydropower does not have much potential since the height of the land from sea level does not vary largely throughout the country. Since the available land area is mostly used for agriculture, hence the production of biomass on a large scale is not possible. Solar energy has great potential and has had a successful rollout so far. Nonetheless, the main drawback of solar energy is that it is difficult to produce solar energy at large scale due to its requirement of the huge area to install the PV-panels and hence, its use is limited mostly to the households of such areas where it is not possible to supply the grid power [13]. Therefore, like biomass energy, for solar energy also it is not possible to use the agricultural land in Bangladesh.

Wind energy is an interesting option as it needs significantly less space and can easily be combined with agriculture [14], [15]. The government of Bangladesh has set each year's targets for renewable energy development through several technologies from 2015 to 2021 and it is known as "RE Development Targets" that require an extra capacity of 3,100 MW renewable energy [13]. This increased capacity must be completed by 2021 and it is a challenge. Most of the new capacity should be provided by solar (1,676 MW, or 54 percent) and wind (1,370 MW, or 44 percent). However, if the data from 2016 to 2018 are analyzed, then it seems that it is tough to achieve the target for wind energy. Thus, from the existing literature it is clear that, wind farms in Bangladesh are still limited and the wind assessment for a longer duration is unavailable for specified heights. Therefore, this study will help to establish a clear map for suitable areas for wind farms.

2. Materials and Methods

2.1 Wind Data and Site Description

The wind data for this study were collected from the Bangladesh Meteorological Department and which is the national meteorological organization of Bangladesh. This data covers a wide range of five years (2015-2019) and has been reported on average every month, at a standard height of 10 m above ground level. These locations reflect distinct geographical and climatological conditions in

seven divisions, namely the divisions of Rajshahi and Rangpur in the north-western part of Bangladesh; the divisions of Chittagong and Sylhet in the south-eastern part of Bangladesh; and the divisions of Dhaka in the central part of Bangladesh; the divisions of Barisal and Khulna in the south-western part of Bangladesh.

2.2 Weibull Distribution Function

The characteristics of the wind speed and the wind power capacity of any given region can be calculated using several statistical methods, among which the Weibull distribution is the most commonly acceptable technique [16]–[19]. Therefore, to statistically analyze the meteorological data, the two-parameter Weibull distribution function, which is versatile, simple, and can show good agreement with the data observed was implemented in this work [20]–[22]. By applying this approach, the density of wind energy and the characteristics of wind speed can be effectively studied. In addition, this two-parameter Weibull distribution function is also used for the estimation of annual energy output in most commercially available applications [23], [24].

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{E}\right)^{k}\right]_{1} \quad (1)$$

where V is the probability of observing the wind speed V. c is the Weibull scale parameter and k is the dimensionless Weibull shape parameter and they are given by [25] as follows:

$$k = 0 \cdot 83\ \bar{V}^{0 \cdot 5} \quad (2)$$

$$C = \frac{\bar{v}}{\Gamma\left(1+\frac{1}{k}\right)} \quad (3)$$

Γ is the gamma function and $\bar{V}$ is the average wind speed and can be expressed as:

$$\bar{V} = \frac{1}{n}\left[\sum_{i=-1}^{n} v_i\right] \quad (4)$$

The cumulative distribution, as given in the below equation, is the integral of the probability density function:

$$F(v) = 1 - e^{-\left(\frac{v}{c}\right)^{k}} \quad (5)$$

3. Results and Discussion

3.1 Monthly Wind Speed Variation

The monthly variations in mean wind speed are shown in Figure 2. It is observed that the values of the monthly average wind speed during the period of the study (five years), do not vary too much and it was almost in the range of 0.5 m/s to 2.10 m/s for all the divisions except Chittagong. The range of average wind speed for the Chittagong division was between 3 m/s and 4.5 m/s. The highest average wind speed for the Chittagong division was in April (4.5m/s) and the lowest was in October (2.5m/s). The average wind speed for the Sylhet division was nearly the same all over the year, only a bit higher in March and April than other months and it had the second-highest average wind speed compared to other divisions. November showed the lowest mean wind speed for Barisal and Khulna division of value 0.4 m/s. The analysis also reveals that the lowest and highest wind speeds were

prevailed due to the dry winter and hot summer from October to February and March to June, respectively for the complete study period.

The highest mean speed of different divisions is not at the same time, even not in the same year. For example, the highest mean wind speed was observed in Barisal in May 2019 whereas the same in Chittagong was in April 2016. It is also evident from the five-year analysis that the range of the wind speed does not vary much for most of the divisions, except Chittagong which is 3.60 m/s to 5.70 m/s unlike others, i.e., 0.5 m/s to 2.10 m/s. The analysis also reveals that the lowest and highest wind speed prevailed due to the dry winter and hot summer from October to February and April to August, respectively for the complete study period.

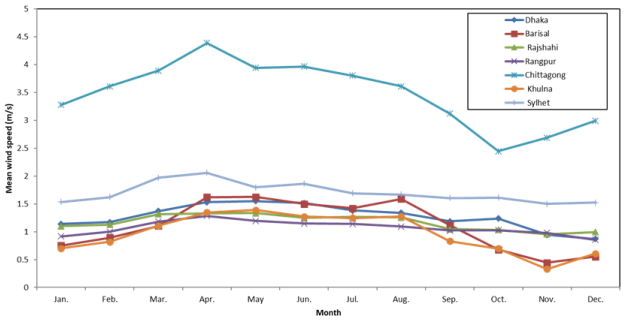

Fig. 2. Monthly variation of wind speeds for all division

3.2 Wind Power Density

The wind power density, wind energy density was also found at their high values for all the years in the Chittagong division and they are quite high than any other division of Bangladesh. Annual wind power density and wind energy density are ranged between 51.86967 W/m^2 to 84.01142 W/m^2 and 454.3783 KWh/m^2 to 753.94 KWh/m^2. In April 2017, the wind power density was the highest during the studied period, as seen in Figure 3.

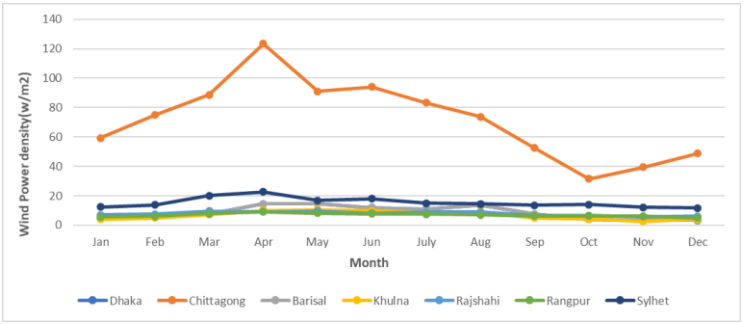

Fig. 3. Monthly variation of the wind power density in seven divisions of Bangladesh

3.3 Weibull parameters

For all the stations under analysis, the monthly mean scale parameter c (m/s) and form parameter k (dimensionless) of the Weibull distribution have been calculated and they are tabulated in Table 2. For almost all the divisions, the monthly values of parameter k ranged between 0.27 and 1.18, with the exception of Chittagong, where it was between 1.28 and 1.73. This indicates that this division has high stability and high persistence compared to the others. The scale parameter c, which was slightly greater than the average wind speed, ranged from 0.54 to 2.18 m/s for nearly all the divisions and from 2.61 to 4.91m/s for the Chittagong division. The highest and lowest values of the dimensionless

shape parameter k were observed as 1.73 and 0.27, respectively, at Chittagong and Barisal. This is because the Chittagong division is near the Bay of Bengal Sea with lots of open and flat areas and hence, these higher values of the scale parameter denote that these sites are windy.

Table 2
Monthly Weibull parameters (k, c)

Division	Parameter	Month											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Barisal	*k*	0.71	0.77	0.86	1.04	1.04	1.01	0.98	1.04	1.61	1.04	0.52	0.27
	c	0.62	0.78	1.02	1.65	1.65	1.50	1.41	1.61	1.11	0.67	0.44	0.54
Chittagong	*k*	1.50	1.57	1.63	1.73	1.64	1.64	1.61	1.57	1.46	1.28	1.35	1.42
	c	3.63	4.01	4.34	4.91	4.40	4.43	4.24	4.01	3.44	2.61	2.91	3.27
Dhaka	*k*	0.88	0.89	0.96	1.02	1.02	1.01	0.96	0.95	0.89	0.91	0.82	0.79
	c	1.07	1.11	1.35	1.54	1.56	1.52	1.36	1.31	1.13	1.19	0.92	0.86
Khulna	*k*	0.69	0.74	0.87	0.96	0.97	0.92	0.92	0.93	0.75	0.67	0.48	0.62
	c	0.55	0.69	1.03	1.32	1.37	1.23	1.19	1.23	0.69	0.54	0.16	0.47
Rajshahi	*k*	0.86	0.88	0.95	0.93	0.95	0.90	0.93	0.92	0.84	0.84	0.81	0.82
	c	1.02	1.06	1.28	1.23	1.30	1.13	1.22	1.21	0.96	0.94	0.85	0.89
Rangpur	*k*	0.79	0.82	0.90	0.93	0.90	0.88	0.88	0.86	0.83	0.83	0.81	0.76
	c	0.80	0.90	1.12	1.24	1.13	1.08	1.07	1.01	0.93	0.93	0.87	0.72
Sylhet	*k*	1.02	1.05	1.16	1.18	1.11	1.13	1.07	1.07	1.04	1.05	1.01	1.01
	c	1.54	1.65	2.07	2.18	1.86	1.94	1.74	1.71	1.63	1.64	1.50	1.48

4. Conclusion

The Weibull distribution function was used in this study for statistical analysis to assess the potentiality of wind energy. Comparing the potential of wind energy in the seven divisions of Bangladesh, the objectives of this study were achieved through the analysis of the results. The results show that the monthly average wind speed during the five years of the study is in the range of 0.5 m/s to 2.10 m/s for all the divisions except Chittagong where it was between 3 m/s and 4.5 m/s. Accordingly, the wind power density and wind energy density were also found in the Chittagong division with annual values that ranged between 51.86967 W/m^2 to 84.01142 W/$m^2$and 454.3783 KWh/m^2 to 753.94 KWh/m^2, respectively. In terms of Weibull parameters, the shape and scale parameters (k and c) are varying between 0.774373 – 1.086069 and 0.684588 – 1.735511 m/s, respectively for all the divisions except Chittagong where it ranges between 1.463098 – 1.625881 and 3.131256 – 4.28601 m/s, respectively.

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