

PAPER • OPEN ACCESS

Investigation on wind energy for grid connection in Bangladesh: Case study

To cite this article: N A Madlool *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1127** 012021

View the [article online](#) for updates and enhancements.

You may also like

- [Comprehensive monitoring of Bangladesh tree cover inside and outside of forests, 2000–2014](#)
P Potapov, B N Siddiqui, Z Iqbal et al.
- [Using satellite data and machine learning to study conflict-induced environmental and socioeconomic destruction in data-poor conflict areas: The case of the Rakhine conflict](#)
Thiri Shwessin Aung, Indra Overland, Roman Vakulchuk et al.
- [Climate change-induced challenges to sustainable development in Bangladesh](#)
M A Mojid

Investigation on wind energy for grid connection in Bangladesh: Case study

N A Madlool^{1,*}, M S Hossain^{2,5,*}, M J Alshukri¹, Jeyraj Selvaraj², Ahmed A Taher¹, Vaskar Das Gupta³, Prasun Mazumder³, Nasrudin Abd Rahim^{2,4}

¹Dept. of Mechanical Engineering, University of Kufa, 21 Kufa, Iraq

²Higher Institution Centre of Excellence (HICoE), UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D, University of Malaya, Jalan Pantai Baharu, 59990 Kuala Lumpur, Malaysia.

³Dept. of Electrical& Electronic Engineering, International Islamic University Chittagong, Chittagong, Bangladesh

⁴Renewable Energy Research Group, King Abdulaziz University, Jeddah 21589, Saudi Arabia.

⁵College of Environmental Science and Engineering, Peking University, Beijing 100971, China

E-mail: naseer.alkhalidi@uokufa.edu.iq and engi.shouquat@um.edu.my

Abstract. The increasing demand for energy in Bangladesh as well as all over the world is continuously growing unabated because of the increase of the world population and the countries' fast-developing industrialization programs. In this critical stage of energy crisis, renewable energy is a highly welcome reliable energy source wherein wind energy is the cheapest replenishable and available energy source of the time. Regarding this particular energy source, a feasibility study of the wind energy in Chittagong has been done by analyzing the wind speed data. It is estimated that the maximum practical power output generated can be 124.53 MW at Parky beach. The number of wind turbines, operation and maintenance cost and pay-back period of those sites are also calculated.

1. Introduction

Bangladesh is geographically situated between 20°34' and 26°38' north latitude and 88°01' and 92°41' east longitude with an area of 147,570 sq.km. It has 724 km of the coastal line along the Bay of Bengal [1]. The average population density is about 2,917.6 capita/sq. mile [2]. The electricity demand is nearly 6,000 MW but the country can only currently generate 4,500 MW of electricity [3] from which only 49% of the total population can gain access to the facility which translates into the fact that the per-capita energy usage is 180 kWh which is one of the lowest in the region. To meet this demand it is quite usual to use fossil fuels, like, coal, gas, and diesel which are used as energy sources. However, there are no alternative reliable sources of fossil fuels that are renewable [4]. In Bangladesh, researches within the sphere of wind energy began only a few years ago and it was also found that some southern districts of Bangladesh, especially in the coastal regions, have a very good potential location of wind energy



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

extraction where the seasonal trade-winds blow over the country from March to October for a period of 8 months each year. The wind is enhanced when it enters the V-shaped coastal regions of Bangladesh because as this trade wind strikes the coastal belt of Bangladesh, it carries a lot of kinetic energies [6]. These coastal areas have better opportunities for wind power exploitation in the form of electricity generation which can supply electricity to many production areas [7] in which case it also has the potential to be a source of decentralized energy for Bangladesh, hence, simultaneously solving the critical emerging energy problems. There is no available adequate information on wind speeds over the country, particularly, on wind speeds at hub levels of wind turbines in Bangladesh.

In 2005, for the first time in Bangladesh, Bangladesh Power Development Board (BPDB) had implemented a pilot project of 0.90 MW capacity of the Grid-Connected Wind Energy (GCWE) in the Muhuri Dam areas. The installation, commissioning and erection works of 4 units of the 225 kW GCWE turbine was progressing very fast and after the successful completion of this 0.90 MW pilot project it was further provided with 1 MW unit capacity wind turbines as this site was found to be most suitable for another 100 MW wind energy power production [8]. Nevertheless, this project by the BPDB had not been blessed with success because of the wrong measurement of the wind speeds. An earlier project, located in the southwestern part of Kutubdia Island and fully exposed to the sea, had been completed for a wind-power electricity generation plant.

The wind speeds of the coastal regions of Chittagong have been considered in the present paper and the data obtained shows a prospective source of wind energy in the coastal areas of Chittagong. The data analysis and study of the area show that the seasonal or monthly average wind speed of above 6 m/s is very strong in the coastal regions of Chittagong. During the earlier part of the windy months, the hourly wind speed variations are low, but as time progresses the wind speed remains high during the rest of the months. As energy depends on the 3rd power of speed (v^3), the available energy can be higher in the coastal wind in Bangladesh than for locations having the same annual wind speed with a low-speed variation [9], hence, the possibility of producing power using the wind energy in Chittagong is immensely bright and quite timely.

2. Wind Turbine Systems

A wind turbine is a rotating machine that converts the kinetic energy of the wind into mechanical energy. If the mechanical energy is directly used by machinery, such as a pump or flour grinder, the machine is usually called a wind mill. If the mechanical energy is converted into electrical energy, the machine can then may be called by other names, such as wind generator or wind turbine or wind power unit (WPU) or wind energy converter (WEC) [10]. Figure. 1(A) shows the wind-turbine major components [11, 15].

2.1. Components of a typical Wind Turbine

A wind turbine usually has seven main components, namely, i) the nacelle, ii) the rotor, iii) the gearbox, iv) the generator, v) the control and protection system, vi) the tower and, vii) the foundation.

2.1.1. *Nacelle* It is the box-like structure located behind the rotor blades.

2.1.2. *Rotor* The rotor is an elegantly shaped blade that captures the wind energy and converts its kinetic energy into mechanical energy through connected shafts.

2.1.3. *Gearbox* The gearbox changes the rotational velocity of the shaft to suit the generator [14]. The gearbox increases the slow speed of the main shaft to a speed suitable for the generator to function.

2.1.4. *Generator* The generator is a device that converts mechanical energy to the system into electrical energy. The generator is typically of the induction type, operating at the near-fixed speeds.

2.1.5. *Control and Protection System* The computer-based central control panel of the wind turbine is typically mounted inside the tower (if tubular). The control system monitors the gearbox and the

generator temperatures, wind speed and so on. The protection system protects the turbine from abnormal conditions, such as extremely high wind speeds during stormy periods.

2.1.6. Tower The tower is the main shaft that connects the rotor to the foundation [12, 13]. It also raises the rotor high in the air to capture the strong winds.

2.1.7. Foundation The foundation supports the wind turbine and ensures that it is well established and solidly founded onto the ground all of which usually consist of solid concrete.

With regard to the axis of rotation of the rotor shafts, the wind turbines are separated into two types [13]:

(i) Horizontal.

Horizontal Axis wind Turbines (HAWT).

Figure 1(B) shows a Horizontal Axis Wind Turbine [11, 15].

(ii) Vertical Axis Wind Turbines (VAWT) [14].

Figure. 1(C) shows a Vertical Axis Wind Turbine [11, 15].

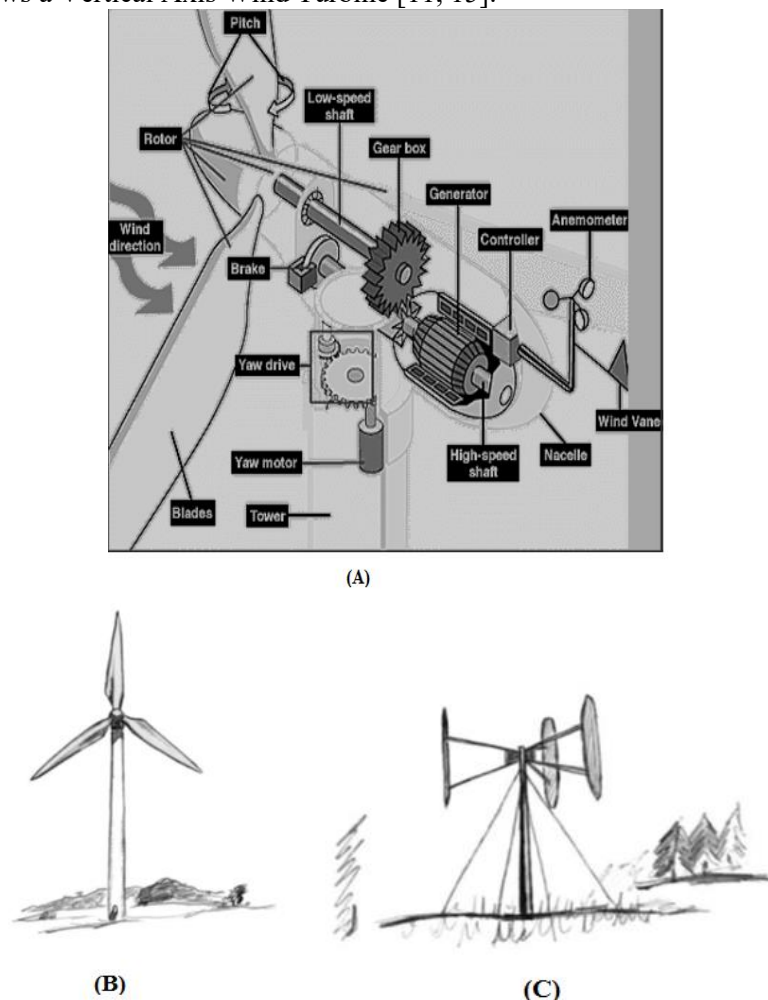


Figure 1. (A) Wind Turbine Major Components, (B) Horizontal Axis Wind Turbine (HAWT), (C) Vertical Axis Wind Turbine (VAWT) [12, 16].

3. Site selection

Around one or two months before and after the Monsoon season, high-speed winds are mainly available in Bangladesh. During the months starting from late October to the middle of February, the wind speed

remains either calm or too low. The peak wind speed occurs during the months of June and July [16]. However, the wind speed of the coastal area holds a good prospect to make the best use of wind energy. Six locations were selected for this investigation and the locations were, namely;

i) Patenga Sea-beach, ii) Parky Beach, iii) Batali Hill, iv) Cox's Bazar, v) IIUC City Campus at Chawkbazar and, vi) Shah Amanat Bridge.

The wind speed data of Patenga Sea-beach, Batali Hill, IIUC City Campus and Shah Amanat Bridges were measured with an Anemometer. A comparison had been made between the measured wind speed data and the collected wind speed data from different research centres.

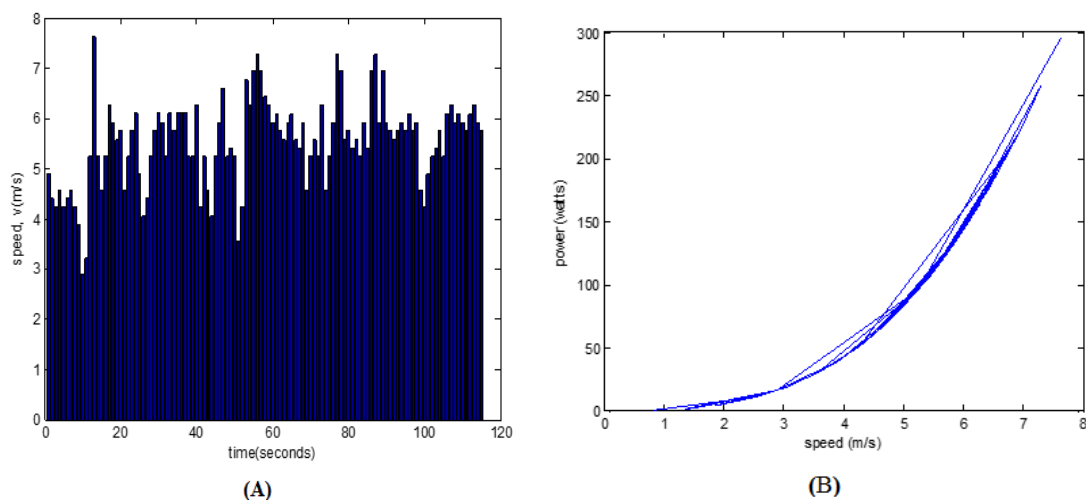
3.1. Patenga Sea-beach

The wind speeds at this site had been measured at a height of 1.62 m in October and the variation of wind speeds for 1.30 hr duration is as shown in Figure 2(A) and (B). From Figure 2(A) it can be seen that the speed of the wind varies with time. The highest value of the wind speed is above 7.5 m/s and the lowest value is around 2.8 m/s while the mean wind speed at this site is around 5.15m/s. Figure 2(B) illustrates a power versus wind speed graph in which as the wind speed increases the power output is also increased. The theoretical power output of the wind at this site at 1.62 m height is around 298 W/m² of wind area.

The speed versus time (months) and power (watts) Vs speed (m/s) graphs of wind speed data of one year at 20 m height collected from the Bangladesh Meteorological Departments (BMD) are shown below respectively as in Figures 2(C) & (D) where Figure 2(C) shows that during the months of May, June, July, August and September, the wind speed is high and in other months it is lower. Figure 2(D) shows that the power output increases as the wind speed increases and by taking the mean wind speed, the theoretical power output is about 389.82 W/m²

3.2. Batali Hill

The wind speed at this site was measured at 1.62 m height in October and the variation of the wind speed for a duration of 1.00 hr is as shown in Figures 2(E) & 3(A) where Figure 2(E) shows that the speed of the wind varies with the time. The highest value of the wind speed was above 5 m/s and the lowest value was around 0.6m/s, while the mean wind speed was around 3.35 m/s. Figure 3(A) shows a power versus wind speed graph in which when there is no wind, the power output is correspondingly zero and as the wind velocity increases, the power output also increases. The theoretical power output at this site at 1.62 m height is around 98 W/m² of wind area.



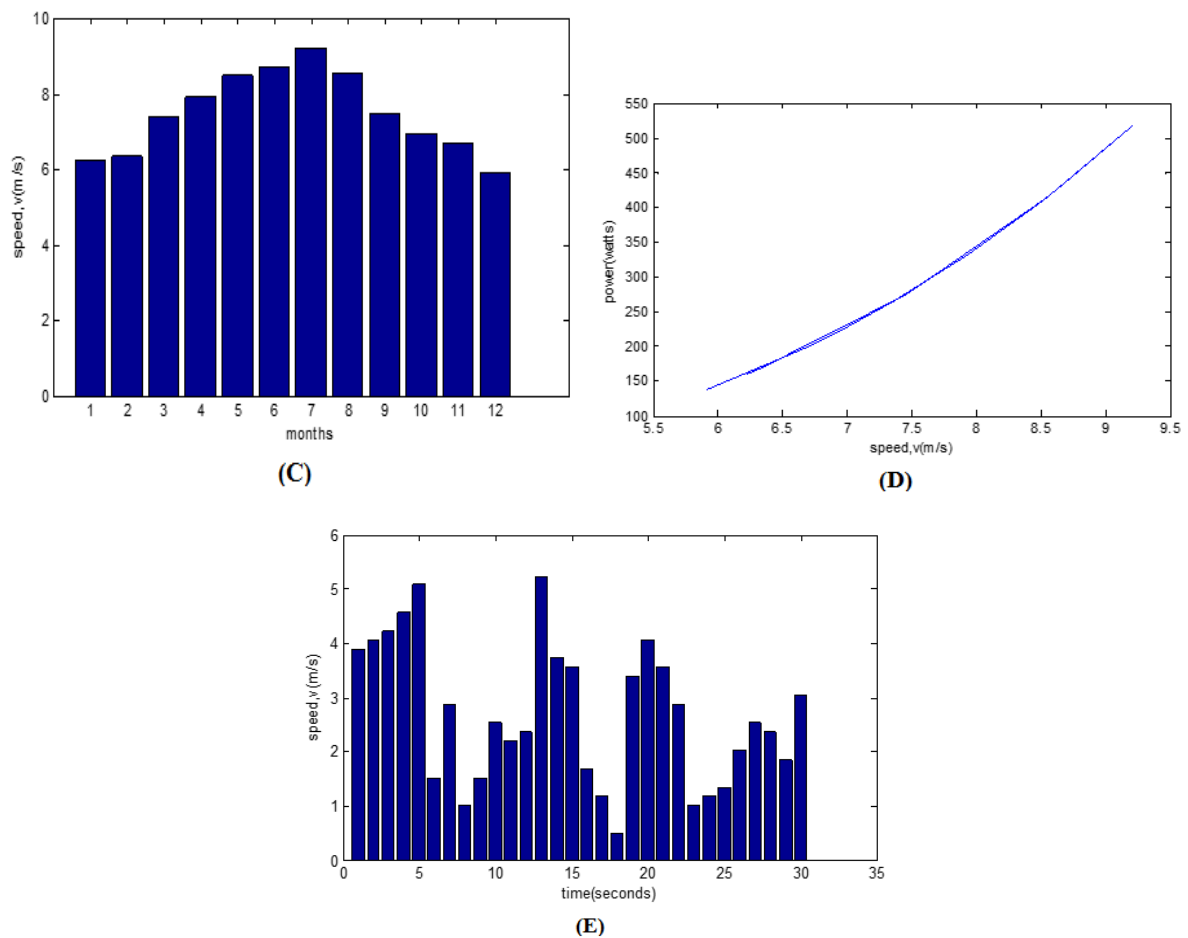


Figure 2. (A) V vs. Time (seconds) graph, (B) Power (watts) vs. Speed (m/s) graph, (C) V vs. Time graph, (D) P vs. Speed (m/s) graph, (E) V vs. Time (seconds) graph.

3.3. IIUC City Campus

Here, the wind speed was measured at 1.62 m height in December and the variation of the wind speed for a duration of 1.00 hr is as shown in Figure 3(B) & (C) where Figure 3(B) shows that the speed of the wind varies with the time. The highest value of the wind speed was above 6.5m/s and the lowest values were around 0.7m/s while the mean wind speed at this site was around 3.6m/s. Figure 3(C) shows a power versus wind speed graph where it illustrates that when there is no wind the power output is correspondingly zero and as the wind speed increases, the power output also increases. The theoretical power output of this site at 1.62 m height is around 192 W/m^2 of wind area.

3.4. New Shah Amanat Bridge at Karnafuly

The wind speed here was measured at 1.62 m height in January and the variation of the wind speed for a duration of 1.00 hr is as shown in Figures 3(D) and (E) where Figure 3(D) illustrates that the speed of the wind varies with the time. The highest value of the wind speed was above 5.6 m/s and the lowest value was around 0.8 m/s while the mean wind speed at this site was around 3.2 m/s. Figure 3(E) shows a power versus wind speed graph where it illustrates that when there is no wind the power output is zero and as the wind speed increases the power output also increases. The theoretical power output at this site at 1.62 m height is around 102 W/m^2 .

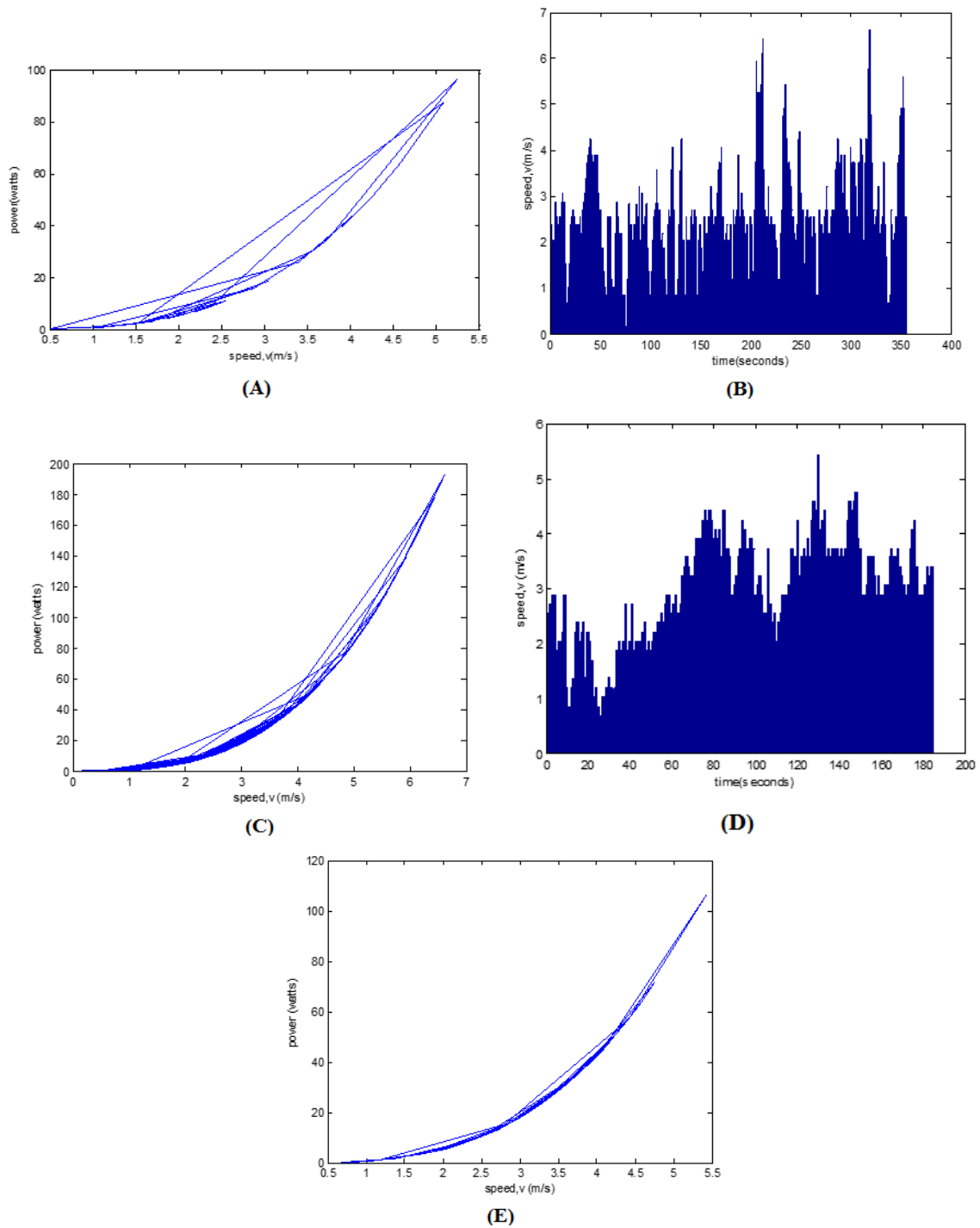


Figure 3. (A) P vs. Speed (m/s) graph, (B) V vs. Time (seconds) graph, (C) Power (watts) vs. Speed (m/s) graph, (D) V vs. Time (seconds) graph, (E) Power (watts) vs. Speed (m/s) graph.

3.5. Parky Beach

The velocity of wind versus time (months) and power (watts) Vs wind speed (m/s) graphs data from one year at 50 m height collected from Pan Asia Power Limited is as shown below respectively in Figures 4(A) and 4(B). Figure 4(A) illustrates that during the months of May, June, July, August and September, the wind speed is high while in other months it is lower with the mean wind speed of 6.73

m/s. Figure 4(B) shows that the power output increases as the wind speed increases. From the mean wind speed, the theoretical power output is about 182.48 W/m^2 .

3.6. Mognamaghat (Cox's Bazar)

The velocity of wind versus time (months) and power (watts) Vs speed (m/s) graphs of wind speed data from one year at 50 m height collected from Pan Asia Power Limited are shown below respectively as in Figures 4(C) and 4(D) where Figure 4(C) shows that during the months of March, April, May, June, July, August, September and October, the wind speed is high and in other months it is lower. The mean wind speed is 6.90 m/s . Figure 4(D) shows that the power output increases as the wind speed increases and from the mean wind speed, the theoretical power output is about 197.11 W/m^2 .

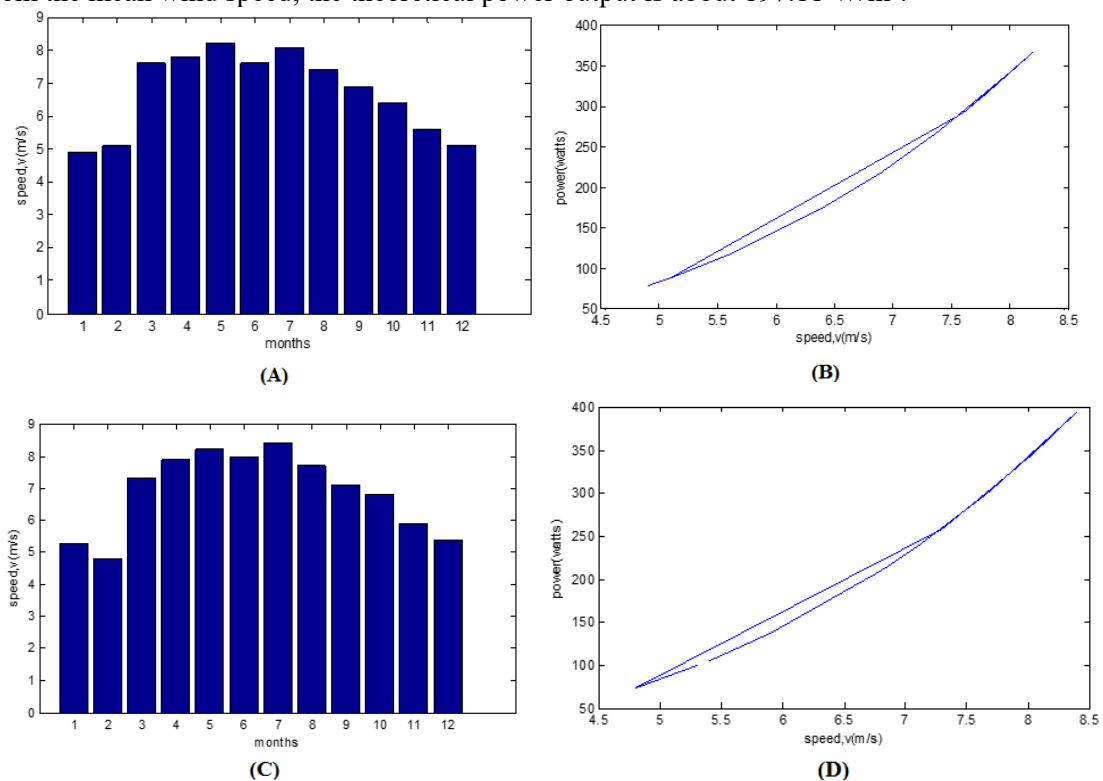


Figure 4. (A) V vs. Time graph, (B) P vs. Speed (m/s) graph, (C) V vs Time graph, (D) P vs. Speed (m/s) graph.

4. Calculation on the number of wind turbines and power generated from the sites

4.1. Parky beach

As Parky beach is in the Anwara Upazilla at Chittagong, it has an area of 173.53 sq.km [17]. As it is quite a populated area, 4% of the area is appropriate for building a wind power plant and calculation wise, the total area is $173.53 \times 0.04 = 6.94 = 7 \text{ sq.km}$ (approximately) whereas this site has a mean wind speed of 6.73 m/s throughout the year at 50m height. Assuming that 15 wind turbines can be installed in each sq.km with a 2 MW of power that can be produced within an area of 7 sq.km, a total of $(15 \times 7) = 105$ wind turbines can be installed giving a maximum theoretical power output of $(105 \times 2) = 210 \text{ MW}$. If the plant capacity factor of 0.593 (Beltz limit) is considered, the maximum practical power output generated can be about $(210 \times 0.593) = 124.53 \text{ MW}$.

4.2. Mognamaghat

Mognamaghat at Pekua, Cox's-Bazar has an area of 6.149 sq.km [18] with a low population density. Considering that 20% of the area is appropriate for building wind power plants, the total area for the

power plants is $= 6.149 \times 0.20 = 1.2298$ sq.km. and as this site has a mean wind speed of 6.90m/s throughout the year at 50m height and assuming that 15 wind turbines can be installed in each sq.km which can produce 2 MW power output, the total number of wind turbines that can be erected in an area of 1.2298 sq.km is $(15 \times 1.2298) = 19$ wind turbines which has the maximum theoretical capacity of $(19 \times 2) = 38$ wind turbines. If the plant capacity factor of 0.593 (Beltz limit) is considered, the maximum practical power output that can be generated is about $(38 \times 0.593) = 22.5$ MW.

4.3. Patenga Sea-beach

Patenga, Sea-Beach has an area of 16 sq.km [19] and considering 10% of the area is appropriate for building the wind power plants, the available total area is $= 16 \times 0.1 = 1.6$ sq.km. As this site has a mean wind speed of about 9.26 m/s throughout the year at 50m height, and assuming that 15 wind turbines can be installed in each sq.km, to produce 3 MW of power output, the total number of wind turbines that can be erected is $(15 \times 1.6) = 24$ wind turbines which can have the maximum theoretical capacity of $(24 \times 3) = 72$ MW of power output. Assuming that the plant capacity factor of 0.593 (Beltz limit) is considered, the maximum practical power output that can be generated is about $(72 \times 0.593) = 42.7$ MW of power output which can be used for centralizing and decentralizing purposes.

4.4. Batali Hill

At a height of 20 m at Batali Hill, a mean wind speed of around 4.036 m/s can be obtained to generate energy which can be used for decentralization programs. Assuming that the plant capacity factor is 0.6 (Beltz limit) and 45% of the area for the power plants is taken into account, the 4 turbines that can produce 3 kW will be $4 \times 0.6 \times (4.036)^3 \times 0.45 = 0.071$ kW of power output generated which can be used for domestic electrical equipment, like, lights, fans, computers, etc.

4.5. IIUC City Campus

At a height of 20 m at IIUC City Campus, the mean wind speed obtainable is about 3.94 m/s that can generate energy for use in the decentralization programs. Assuming that the plant capacity factor of 0.6 (Beltz limit) and 45% of the area for the power plants with 2 turbines can produce 3kW total power output of which will be $2 \times 0.6 \times (3.94)^3 \times 0.45 = 0.033$ kW of power output obtainable from this area which can be used to run domestic electrical equipment, like, lights, fans, computers, etc.

4.6. Shah Amanat Bridge

At a height of 30 m at Shah Amanat Bridge, the mean wind speed is about 4.52 m/s in the month of January. Assuming that the plant capacity factor of 0.6 (Beltz limit) and 45% of the area for the power plants together with 5 turbines can produce 3 kW of power output which is $5 \times 0.6 \times (4.52)^3 \times 0.45 = 0.125$ kW of power output which can be generated for use in lightning the bridge at night.

5. Cost analysis

The total cost analysis, such as investment cost, operation and maintenance cost, cost per kWh and pay-back period of the proposed sites can be done for viability aspect. There is also a comparison between the costs of a wind power plants and the cost of a conventional power plants, such as coal power plants, oil power plants, gas power plant, etc.

The cost of the wind power plant system has two components, namely, the initial installation costs and the operating expenses. The initial installation cost includes the purchase price of the complete system including the tower, wiring, utility interconnection or battery storage equipment, power conditioning unit, etc., plus delivery and installation charges, professional fees and sales tax [20].

The cost per kWh and payback period formulas are as shown below. The calculation for the cost per kWh is a two-step process:

Step 1

$$\text{Annual Cost} = \left(\frac{\text{Initial Cost}}{\text{Expected Life}} \right) + \text{Annual Operating Costs} \quad (1)$$

This formula defines the annual cost over the wind system energy production life span. Assume a 20-year estimate of the wind power plant useful life span.

Step 2

$$\text{Cost Per kWh} = \frac{\text{Annual Cost}}{\text{Annual Energy Output}} \quad (2)$$

5.1. Payback Period

A common and simple way to evaluate the economic merit of an investment is to calculate its payback period which actually is the number of years of energy-cost savings it takes to recover an investment's initial cost. To determine the payback period, the investor first estimates the wind turbine's total initial cost, annual energy cost savings, and annual operating costs. Dividing the total initial cost by the difference between the annual energy cost savings and the annual operating costs gives the payback period:

$$\frac{\text{Total Initial Cost}}{(\text{Annual Energy Cost Saving}) - \text{Annual Operating Costs}} = \text{Payback time, in years} \quad (3)$$

A grid-connected residential-scale system generating of 1-10kW power output generally costs between \$2,400 and \$3,000 per installed kilowatts which come to \$24,000-\$30,000 for a 10 kW system. A medium-scale of a commercial system generating 10-100kW of power output is more cost-effective, costing between \$1,500 and \$2,500 per kW. The cost of large-scale systems of greater than 100kW of power output can be in the range of \$1,000 to \$2,000 per kW, with the lowest costs achieved when multiple units are installed in one location. In general, the cost rates decrease as the machine capacity increases [20]. The other cost components, such as Operation and Maintenance costs are related to a limited number of cost components which are insurance, regular maintenance, repair, spare parts, administration and incidental costs arising therefrom [21]. A rule of thumb estimate for the annual Operation and Maintenance expenses is 2% to 3% of the initial system cost [20].

5.2. Cost of a wind power plant

Generally, 10-15 wind turbines of 2 MW capacity in 1 sq.km area can be installed. If 20% of the total coastal areas are used, about 28,000 MW power output can be obtained from the wind turbines [22].

Investment cost:

Chittagong has a coastal line of about 724 km long, which means an area of $(724 \times 10) = 7240$ sq.km can be mobilized. If 20% of the area is considered to be used for harnessing the wind energy, 10 wind turbines of 1.8 MW capacity in each sq.km area can be installed giving the total generation of wind energy of about $7240 \times 0.2 \times 10 \times 1.8 \times 0.45 = 11,729$ MW and taking into consideration a plant factor of 45%. It is recommended that to gain this generation of wind energy power output from the wind turbine which has been commercially referred to as, V-I 00 1.8 MW, made by the renowned wind turbine manufacturing company, can be made available [8, 23].

At 20 m height at Batali Hill and IIUC City Campus, a mean wind speed around 3.99 m/s was obtainable. The generating energy output from those sites can be used for the decentralization program. If 3 kW rated wind turbines are used in each site, a power output of 0.538 kW generated can be put to use for domestic electrical equipment, such as lights, fans, computers, etc.

At 30 m height at Shah Amanat Bridge, a mean wind speed of about 4.52 m/s is achievable in the month of January where 5 numbers of 3 kW wind turbines can be installed in 5 towers situated on the bridge from which about 1.94 kW of energy output can be generated for use in lightning the bridge at night. The Operation & Maintenance Cost is represented by a pie chart in the operation & maintenance cost for a typical wind power plant as shown in Figure 5.

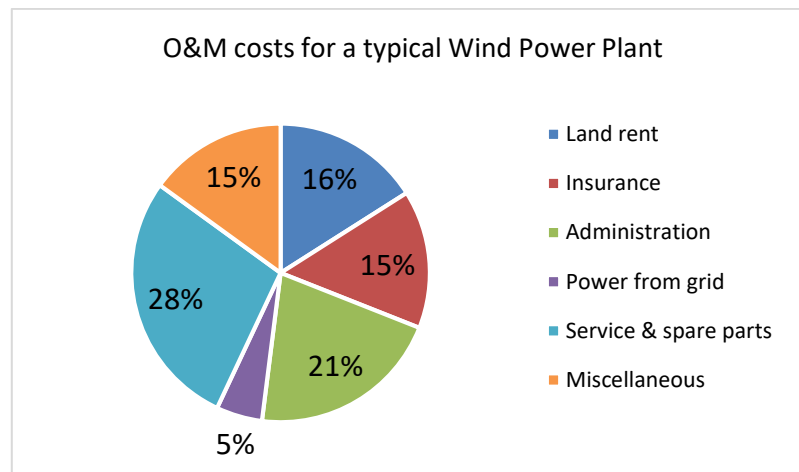


Figure 5. Pie chart of operation & maintenance cost for a typical Wind Power plant.

From the pie chart as given above, it is observed that the total cost of operation & maintenance for a typical wind power plant can be divided into, i) land rental at 16%, ii) insurance protection of 15%, iii) service & spare parts for replacement/repair at 28%, iv) power from grid at 5% and, v) administration cost at 21% [21] where the proportion of percentages can be altered to suit circumstantial requirements when and as necessary.

6. Conclusion

Nowadays, the emission of undesirable and obnoxious carbon dioxide gas is fast growing through the usage of the conventional power plants using fuels, such as, gas, coal, etc. which are creating long term pollutions into the environmental atmosphere. As wind energy is renewable and economical, it can be used as a deciding mitigating factor for a massive reduction of this untenable emission. In this paper, for the sixth sites, the theoretical power output is calculated based on 1.62 m heights which comes to around 298, 389.82, 98, 192 W/m² and at 50 m height is about 102 and 197.11 W/m². Moreover, a feasibility study is conducted on the wind energy project in Chittagong by selecting suitable sites and analyzing the wind speed data of those sites. The number of wind turbines needed is also calculated for the cost of investment, operation and maintenance, cost per kWh and pay-back period of those power plants. It is assumed that the maximum practical power output generated can be 124.53 MW at Parky beach. It is quite evident that there is a great prospect of wind energy abstraction in Chittagong, whilst proactively, Bangladesh Power Development Board has also taken some beneficial steps to develop the wind power plants in the country at the same time encouraging the private sectors to participate and help to contribute to developing this bright sector.

Acknowledgements

The authors would like to thank the financial and technical assistance provided by AUN-SEED/Net Japan ASEAN Collaborative Education Programme (JACEP). The authors thankful to UM Power Energy Dedicated Advanced Centre (UMPEDAC), the Higher Institution Centre of Excellence (HICoE) Program Research Grant, UMPEDAC - 2018 (MOHE HICoE - UMPEDAC), Ministry of Education Malaysia, RU007-2018 and RU012-2019, University of Malaya.

References

- [1] Mominul Islam Mukutl, A.N.M., M. Quamrul Islam, and M.M. Alam, *Anal ysis of wind characteristics in coastal areas of bangladesh*. Journal of Mechanical Engineering, 2008. 39: p. 45-49.
- [2] Department, D.E.a.S.A.P., *World Population Prospects, Table A.1.2008 revision. United Nations*. Department of Economic and Social Affairs Population Division 2009.

- [3] USAID, *From the American people*. <http://www.usaid.gov/bd/programs/energy.html>. Internet source, 2013.
- [4] NASA.gov, *Non-renewable resource*. http://en.wikipedia.org/wiki/Non-renewable_resource. Internet source, 2013.
- [5] Wikimedia., *History of wind power*, http://en.wikipedia.org/wiki/History_of_wind_power. Internet source, 2013.
- [6] Shahed Hossain, M., et al., *Strategy for Promotions and Development of Wind energy in Bangladesh*. National Seminar on Renewable Energy, 2011(Paper ID: 2011-11): p. 1-5.
- [7] Lancashire, S., J. Kenna, and P. Fraenkel, *Wind pumping Hand-book*. IT Publication, London, 1987: p. 1-4.
- [8] MWPC, *Invitation for participation of 100-200 MW offshore grid connected wind power project On a Build Own Operate (BOO) basis - See more at:* <http://www.mywindpowersystem.com/2010/05/08/bangladesh-power-development-boardbpd-announces-100200-mw-project/#sthash.PVg1p4hF.dpuf>. Database, 2013.
- [9] Khadem, K.S., *Feasibility study of Wind Home System in Coastal Region of Bangladesh*, http://homerenergy.com/webcast-downloads/WE58_FeasibilityWHS_Bangladesh.pdf. Renewable Energy Research Centre, 2012: p. 1-7.
- [10] BUET, *Fundamentals of Mechanical Engineering*, Department of Mechanical, 2013.
- [11] EIS., *Wind Energy Basics*, <http://windeis.anl.gov/guide/basics/>. Wind energy development programmatic EIS, 2011.
- [12] Sterzinger, G. and M. Svrcek, *Wind Turbine Development: Location of Manufacturing Activity*. Renewable Energy Policy Project, 2004.
- [13] AL-SHEMMERI, T., *Wind Turbines*, www.bookboon.com. Book, 2010. ISBN: 978-87-7681-692-6.
- [14] R & D notebooks., *Low Power Windmills and Wind Turbine Electrical generators for rural homes*, amper.ped.muni.cz/~miler/indi/docs/.../Turbinearticleinconstruction.doc. The group faisca, catembe, Mozambique, 2008.
- [15] Turbines info., *Horizontal Axis Wind Turbines – HAWT*. Internet source, 2012.
- [16] Ahmmed, S. and M.Q. Islam, *Wind Power for Rural Areas of Bangladesh*. 3rd International Conference on Electrical & Computer Engineering, 2009.
- [17] Wikimedia., *Anwara Upazila*, http://en.wikipedia.org/wiki/Anwara_Upazila. Internet source, 2009.
- [18] Viklund, A., *Free map tools*, www.freemaptools.com/area-calculator.htm. internet source, 2013.
- [19] ConnectBD Ltd., *Bangladesh Navy*, <http://www.bangladeshnavy.org/>. Internet source, 2013.
- [20] WEM., *Wind Energy Manual: Table of contents- Iowa Energy Center Homepage*, http://www.energy.iastate.edu/renewable/wind/wem/wem-13_econ.html. Iowa Energy Center, 2006.
- [21] Morthorst, P.E., *Costs & prices*. Wind energy - the facts, 2008. 2.
- [22] REIN, *Wind Energy Programme by Bangladesh Power Development Board (BPDB)*, <http://www.lged-rein.org/database.php?pageid=67>. Database, Wind Energy Programme in Bangladesh, 2013.
- [23] Bashar, R., *Indo-Bangla Electricity gridline opens*, 15. <http://www.energybangla.com/index.php?mod=article&cat=SomethingtoSay&article=193>. Energy bangla, 2013.