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DESIGN OF WIND TURBINE AND PROSPECT OF WIND ENERGY IN BANGLADESH

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ABSTRACT

Global industrialization in world wide specially in developing nation set a huge requirement of energy. Bangladesh is one of the leading developing nation in the world and its energy demand has risen sharply over the years. Power is the backbone of development for a country. There had been a significant growth of electrical power generation is past few years, but still due to growth rate of industrialization power sector is falling behind. To meet the high demand of electrical energy now it is the time to explore renewable sources of energy. Wind could be a good sources of renewable energy for Bangladesh since it has long coastal areas. In this paper we shall mostly discuss on the working principle & design of wind turbine and this prospect of wind energy in Bangladesh specially its coastal areas. At the moment government of Bangladesh is also looking for the renewable sources of energy to meet up the total power demand. This study will discuss and asses the wind energy potential in Bangladesh as a sustainable solution to overcome the energy crisis. This paper will also focus on the environment impact, advantage & disadvantage of wind energy. The current renewable energy agenda of Bangladesh force the specialization of renewable energy generation budget by decreasing global pollution with saving movement of renewable sources of energy.

KEYWORDS: Wind tunnel, Coastal area of Bangladesh, Renewable energy, wind energy, Power generation.

1. INTRODUCTION

Bangladesh is one of the fast growing nation in the world and energy demand is increasing rapidly every year for this country. Power is the backbone of development for any country and for Bangladesh it is most important factor for the development. There had been a significant growth of electrical power generation is past few years, but still due to growth rate of industrialization power sector is falling behind. To meet the high demand of electrical energy now it is the time to explore renewable sources of energy. Wind could be a good sources of renewable energy for Bangladesh since it has long coastal areas. In this paper we shall mostly discuss on the working principle & design of wind turbine and this prospect of wind energy in Bangladesh specially its coastal areas. At the moment government of Bangladesh is also looking for the renewable sources of energy to meet up the total power demand. This study will discuss and asses the wind energy potential in Bangladesh as a sustainable solution to overcome the energy crisis. This paper will also focus on the environment impact, advantage & disadvantage of wind energy. Government of Bangladesh set a target to generate 24,000 MW electricity by 2021. With this goal the government has increases the no of power plant, transmission line and distribution lines. Government is planning to take up large scale renewable energy project specially on wind energy sector.

2. Back Ground Study

Bangladesh situated in Bengal delta and consist of flatland and also having large amount elevated land in Chittagong division which is in the south eastern part of the country. For geographical position of Bangladesh wind power system has a good potential. Bangladesh Power Development Board (BPDB) and Local Government Engineering Department (LGED) have committed lots of research work on wind power system. There is a project in Muhuri which have a rated capacity of 0.99 MW. All the research works in Muhuri indicate that it has a potential of 100 MW wind power capacity. In Bangladesh, winds are available mainly during the Monsoons and around one to two months before and after the Monsoons. During the months starting from late October to the middle of February, winds either remain calm or are too low to be of any use by a traditional windmill. Except for the above mentioned period of four months, a windmill if properly designed and located, can supply enough energy.

3. Design Consideration of Wind Turbine

Site selection is the most important issue. Site of a wind turbine should have steady and strong wind flow. To have excellent power extraction, the site should have at least 7 m/s wind

velocity. But in Bangladesh, there is hardly any sight which has such potential. With recent development in wind turbine design, it is possible to extract energy from wind having a velocity of 2.5 m/s too. Coastal areas, islands and top of mountains are suitable places for wind mills. Height of wind turbine is also important. Wind power is directly proportional to the cube of its velocity. Wind blows in larger velocities in higher altitudes. Blade area needs to be as large as possible to extract more power at same height. The recommended tower height is 24-37 meter. Spacing between adjacent turbines needs to be at least several times the length of the turbine blades to prevent lowering the efficiency of the turbines due to one stealing wind from or causing turbulence for another. One rule of thumb is that placement between turbines should be about 3 to 7 times of diameters between adjacent turbines in a direction perpendicular to the wind, and 10 times of diameters spacing in a direction of the wind. Wind plants should be kept nearer to grid line to increase cost effectiveness. In coastal zones, the maximum wind speed goes up to 250 km/hr. So, wind turbines should have the capacity to wind speed against this heavy wind speed.

3.1 Working principle of wind turbine

Wind turbine converts the kinetic energy of wind to generate electric or mechanical energy. The uneven heating of the atmosphere causes temperature gradient at the surface of the earth, which results in the wind flow. Wind is actually another form of solar energy. The rotation of earth and irregularities of earth has vital impacts on wind velocity. Wind passes over the blades exerting a turning force. The rotating blades turn a shaft inside the nacelle, which goes into a gearbox. The gearbox increases the rotation speed for the generator, which uses magnetic field to convert the rotational energy into electrical energy. The power output goes to a transformer, which converts the electricity from the generator to the right voltage for the distribution system. In simplistic view, working principle of wind turbine is just opposite to that of a fan. Figure 1 shows the flow diagram of a wind turbine system.

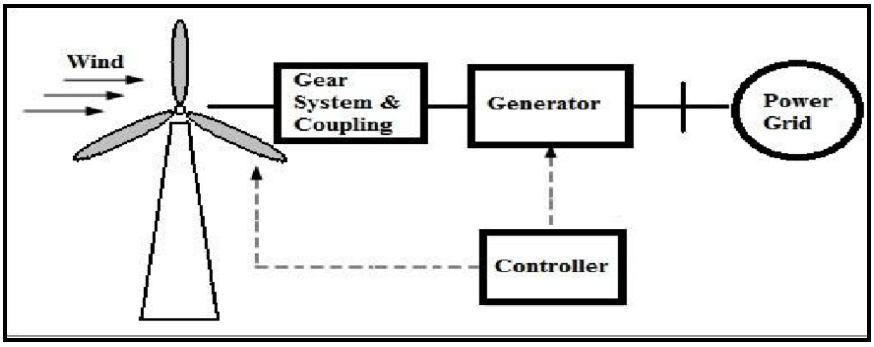

Figure 1: Flow Diagram of a Wind Turbine System.

Here,

1) Wind Turbine: Converts wind energy into rotational (mechanical) energy
2) Gear system and coupling: It steps up the speed and transmits it to the generator rotor
3) Generator: Converts rotational energy into electrical energy.
4) Controller: Senses wind direction, wind speed, generator output and temperature and initiates appropriate control signals to take control action. There are two basic types of wind turbines (WT): horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). Figures 2(a) and 2(b) show HAWT and VAWT respectively.

Figure 2(a): HAWT. **Figure 2(b): VAWT.**

HAWT (more common) need to be aimed directly at the wind. Because of this, they come with a tail vane that will continuously point them in the direction of the wind. VAWT work whatever direction the wind is blowing, but require a lot more ground space to support their guy wires than HAWT. Figure 3 is the details of a WT with its components.

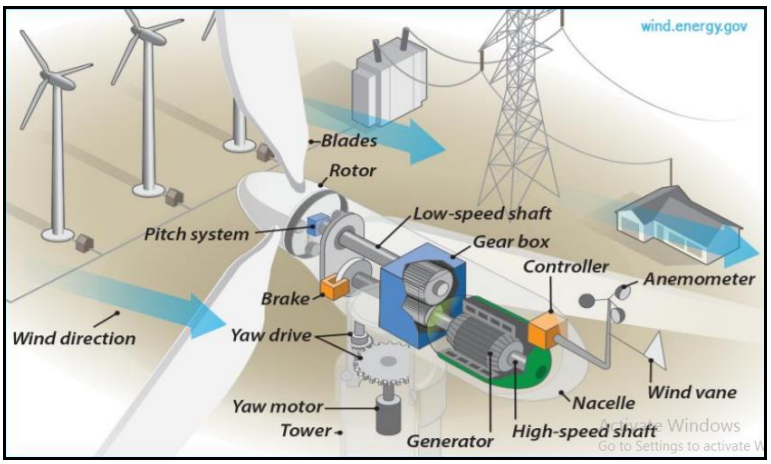

Figure 3: Components of a WT.

3.2 Theory of wind turbine

WT works by converting the kinetic energy of wind to electrical energy. The energy available for conversion mainly depends on the wind speed and the swept area of the turbine.

The power can be defined as

$$P=\frac{1}{2}\,pAV^3C_p$$

Here,

P= Power generation (W)

p= Density of wind (kg/m3)

A= Swept area (m2)

r = Radius (m)

V= Velocity of wind (m/s)

C_p=Power coefficient

For our purpose of power generation, a near shore wind farm like this has been considered along the coastal zones of Bangladesh with 4 rows of HAWT with two rows of turbines in water and two rows of HAWT on land. The turbines are spaced 7D apart in the prevailing wind direction, and 3D apart in the perpendicular direction, where D is rotor diameter. Our Total coastal zone is 574 km (574000 m). We have taken 50% of the coastal zone (287000 m) for wind turbine and considering 30% more area for operation flexibility, office building and responsible personnel's residence & other facilities.

It has been observed that, average wind speed is higher as the height is increased. As a result, extractable power is increased. Average wind speed at 25 m height at Kuakata is approximately 4.463 m/s. Increasing the height to 50 m the average wind speed becomes 6.734 m/s. Obviously, the wind power generation at higher altitude will be more. It supports the relation between tower height and wind power. The maximum height of the turbines known is 140 m and the rotor diameter is 107 m. Estimation of power generation using WT in our near shore wind farm has been done first with Hub height, H = 35 m and Blade diameter, D = 25 m for an average wind speed of 5 m/sec. Then estimation have been done also for H = 60 m, D = 50 m; H = 80 m, D = 60 m and H = 100 m and D = 75 m. Wind speed at these three heights have been taken as 7 m/sec.

4. Energy Supply and Demand

Energy peak demand in Bangladesh is increasing rapidly (more than 10% average over the last 9 years) and energy production cannot keep up with this demand, as shown in table.

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Peak demand (MW)	5.569	6.066	6.454	6.765	7.518	9.268	10.283	11.484	13.088
Peak generation (MW)	4.036	4.296	4.698	5.174	6.350	7.356	7.817	8.619	9.516

The primary electricity generation increased rapidly. With natural gas and coal consumption growing at the fastest rates. The amount of natural gas is not enough to support the present energy demand. Moreover, this demand is constantly increasing. Government of Bangladesh has set a target to generate 24,000 mw electricity by 2021. With this goal the Government of Bangladesh has to increase the number of power plants, transmission lines and distribution lines. Government of Bangladesh is planning to take up more large-scale renewable energy projects. Bangladesh began its first wind power project in 2005. There are two wind power generation projects in Bangladesh, the Muhuri Dam wind power project and the project in Kutubdia Island. Muhuri Dam Project is the first grid-connected wind plant in Bangladesh.

5. Out line of Wind Energy in Bangladesh

At a glance, references show that with a population of 146.2 million electrification rate is 59.60%. Total electrical energy installed capacity is 12229 MW and total installed wind energy is 1.9 MW. Wind energy potential in Bangladesh is over 20,000 MW, the wind speed being < 7 m/sec. In Bangladesh, research in the field of wind energy began only a few years ago, which had shown that some southern districts of Bangladesh have a very good potential of wind energy. Bangladesh Centre for Advanced Studies (BCAS) in collaboration with Local Government and Engineering Department (LGED) and an international organization namely Energy Technology and Services Unit (ETSU) from UK with the funding from Department of Foreign and International Development (DFID) has attempted to monitor wind conditions at seven coastal sites for a period of one year in 1996-97. They measured wind parameters at a height of 25 m.

At present, several wind resource work is ongoing in the country by Bangladesh Power Development Board (BPDB), Bangladesh Council of Scientific and Industrial Research (BCSIR), Local Government Engineering Department (LGED) and Bangladesh University of Engineering and Technology (BUET). They have already started measuring wind speeds at some typical locations of Bangladesh. In Bangladesh firstever generation of electricity from

wind is at Muhuri Dam, Feni having a capacity of 0.9 MW (225 KW, 4 Turbines) and another one at Kutubia Island (20 KW, 50 turbines) with a capacity of 1 MW. Vesta Company of Denmark will invest 100 MW wind power plant which will be made in Patuakhali. This will be the largest wind power plant of Bangladesh.

Bangladesh is situated between 20.30 - 26.38 degrees North latitude and 88.04 - 92.44 degrees East. Analysis of upper air data by Center for Wind Energy Technology (CWET) India shows that wind energy resource of Bangladesh for electricity production is not good enough (< 7m/s) in most of the region of the country for grid connected wind parks. This sector is under research mainly at coastal zone. Bangladesh has a total of 574 km long coast line in the Bay of Bengal. The strong south/south-westerly monsoon wind coming from the Indian Ocean, after travelling a long distance over the water surface, enters into the coastal areas of Bangladesh. This trade wind blows over the country from March to October. This wind speed is enhanced when it enters the V-shaped coastal regions of the country. This wind blows over the surface of Bangladesh, having an average speed of 3 m/s to 6 m/s. During October to February, wind speed remains relatively lower. The maximum wind speed is gained during June-July. Along the coastal area of Bangladesh, the annual average wind speed at 30 m height is more than 5 m/s. Wind speed in northeastern parts in Bangladesh is above 4.5 m/s while for the other parts of the country wind speed is around 3.5 m/s. To have excellent power extraction, the site should have at least 7 m/s wind velocity. For proper operation of the wind turbine, hub-height generally ranges from 20 to 40 m. After height correction, it has been observed that at 30 m there is a great potential for harnessing wind power for electricity generation in some regions like Patenga, Cox's Bazar, Teknaf, Char Fassion, Kuakata, Kutubdia, etc.

5.1 Study on wind energy

Bangladesh government had a project named as Wind Energy Study Project (WEST). A year-long systematic wind speed study at seven coastal sites in 1996-97 at a height of 25 m was done. Figures 4(a) – 4(f) show monthly average wind speed from six WEST stations Patenga, Cox's Bazar, Teknaf, Char Fassion, Kuakata and Kutubdia at 25 m height.

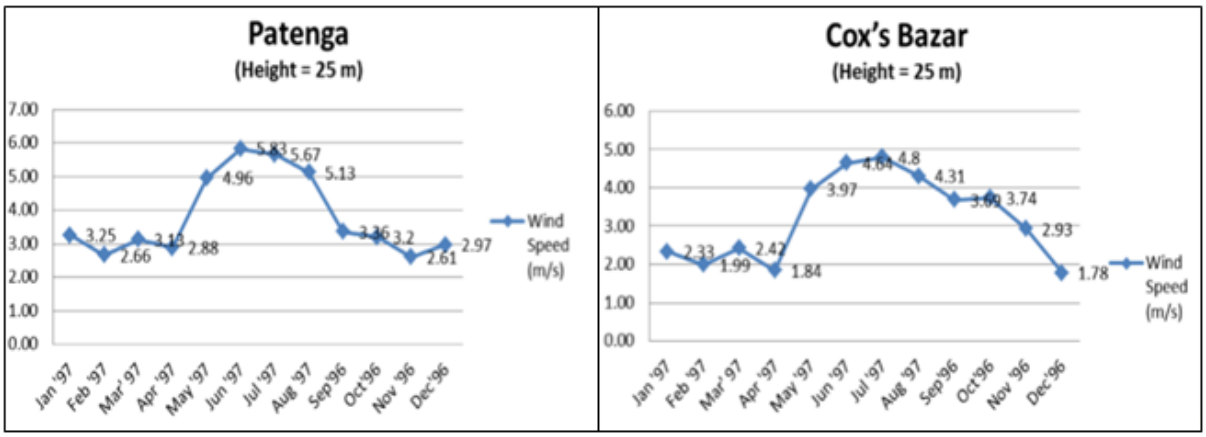

Figure 4(a): Monthly average wind speed at Patenga. **Figure 4(b): Monthly average wind speed a Cox's Bazar.**

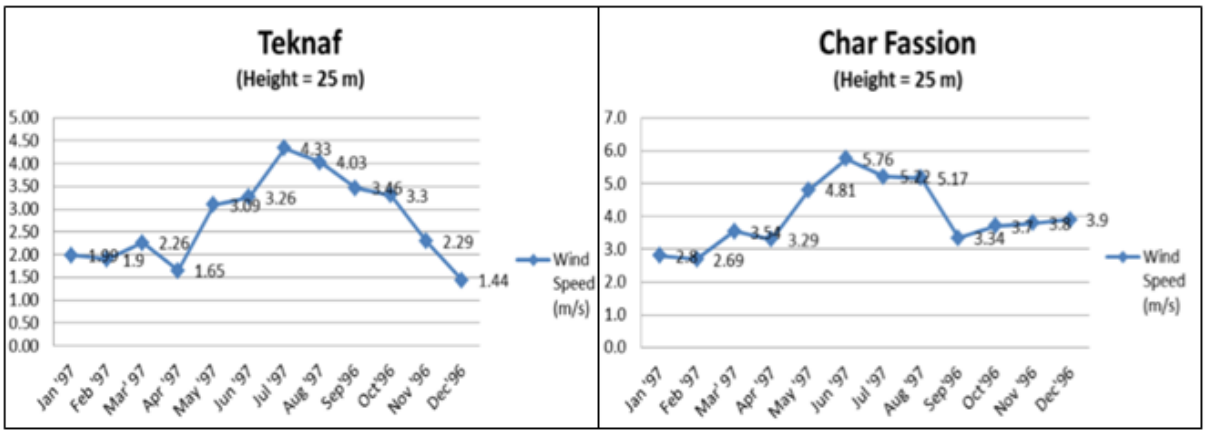

Figure 4(c): Monthly average wind speed at Teknaf **Figure 4(d): Monthly average wind speed at Char Fassion.**

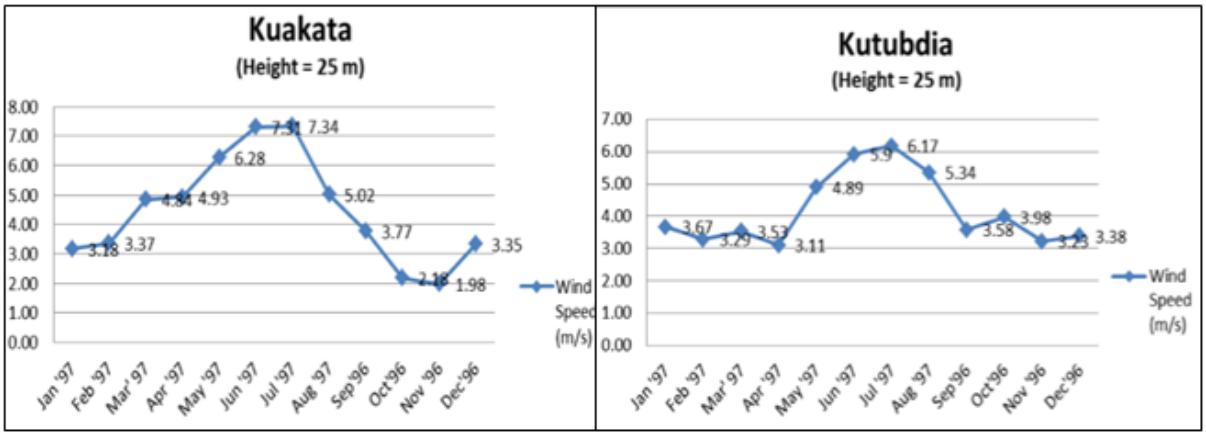

Figure 4(e): Monthly average wind speed at Kuakata. **Figure 4(f): Monthly average wind speed at Kutubdia.**

5.2 Wind data in coastal area

Wind speed for eight different sites has been collected from the Meteorological department of Bangladesh shown in following table.

WIND SPEED OF DIFFERENT SITES AT DIFFERENT HEIGHT

SL.	LOCATION	HEIGHT	AVERAGE SPEED (M/S)	REMARKS
1	COX'S BAZAR	25m	3.792	GOOD
2	CHARFESSION	25m	4.433	BETTER
3	CHITTAGONG	25m	4.367	BETTER
4	KUAKATA	20m	3.135	GOOD
5	KUAKATA	30m	4.146	BETTER
6	KUAKATA	20m	3.642	GOOD
7	SITAKUNDA	20m	3.015	GOOD
8	SITAKUNDA	30m	3.554	GOOD

The wind speed is for a duration of twelve months for eight different sites which is the most recent data from the Meteorological department of Bangladesh. The coastal area includes Saint Martein, Teknaf, Cox'sBazar, Patenga, Chittagong, Sitakunda, Kuakata, Kutubdia, Hatiya, Sandwip, Mongla etc. In this section the wind speeds of these locations are shown at different heights.

5.3 Opportunities in offshore wind energy

Regarding the prospects of wind resources, offshore wind could be the highest potential in Bangladesh for large scale wind developments. The Government of Bangladesh intends to tender a 100 to 200 MW wind farm east of Chittagong (BPDP, 2016) The actual status and long term prognoses of this project is unclear at the moment. The Government of Bangladesh could learn from the latest developments and experiences in the European countries in setting up a tender system. A prerequisite for such a system is an extensive knowledge on wind resources, bathymetry, geo-technical and geo-physical conditions, shipping safety, ecology et cetera. This will require years of study and monitoring. Collaboration in this field could lead to many opportunities active in offshore wind. A first step here is also to start wind resource mapping and assessing the feasibility of offshore wind projects. After that a small scale pilot project is a logical follow up.

6. Impact of Wind Energy

6.1 Economic impact

Wind energy, at its current technological capacity, has seen to provide doubts to stakeholders as to whether it is a worthy investment or not. This is because wind energy systems come with a very high start-up cost, and would usually depend on large investments from the government and/or public. However, once installed, the long term benefits are said to give a better return on investments as compared to coal and fossil fuels. In order to see if the

implementation of wind turbines is a worthwhile investment, some basic calculations need to be done as a preliminary assessment. The factors that should be accounted in calculations include the following:

a. Cost of the individual wind turbines.
b. Cost of installation (onshore/offshore).
c. Acquisition / leasing of land for wind farm.
d. Operation and maintenance costs.
e. Wind turbine lifetime vi. Bulk electricity generated from the turbines.

Several research papers have come up with ball park figures for these costs, as they tend to vary with time and the advancement of technologies, as well as the country.

6.2 Environment impact

There are several aspects that surround how the environment is influenced by the generation of wind energy. It has been proven that wind energy is among the cleanest energy sources with zero carbon emissions. There are various environmental advantages that follow the use of wind turbines to generate electricity. Among them is that wind energy creates no harmful emissions, hence the carbon footprint from generating power can be reduced. Doing this not only improves the lives of our rural counterparts, it will do so without heavily impacting the environment.

7. Advantage of Wind Energy

Wind energy has a huge advantages over the other sources of energy. Few are discussed below:

a. Wind power produces no water or air pollution that can contaminate the environment, because there are no chemical processes involved in wind power generation. Hence, there are no waste by-products, such as carbon dioxide.
b. Power from the wind does not contribute to global warming because it does not generate greenhouse gases.
c. Wind generation is a renewable source of energy, which means that we will never run out of it.
d. Wind towers can be beneficial for people living permanently or temporarily, in remote areas. It may be difficult to transport electricity through wires from a power plant to a faraway location and thus, wind towers can be set up at the remote setting.
e. Farming and grazing can still take place on land occupied by wind turbines.

f. Those utilizing wind power in a grid-tie configuration will have backup power in the event of a power outage.
g. Because of the ability of wind turbines to coexist within agricultural fields, siting costs are frequently low.

8. Disadvantage of Wind Energy

In spite of having unfathomable advantages of wind energy over others but still it has some disadvantage. Those are discussed below:

a. Wind is unpredictable; therefore, wind power is not predictably available. When the wind speed decreases less electricity is generated.
b. This makes wind power unsuitable for base load generation.
c. Wind farms may be challenged in communities that consider them an eyesore or obstruction.
d. Wind farms, depending on the location and type of turbine, may negatively affect bird migration patterns, and may pose a danger to the birds themselves (primarily an issue with older/smaller turbines).
e. Wind farms may interfere with radar creating a hole in radar coverage and so affect national security.
f. Tall wind turbines have been proven to impact Doppler radar towers and affect weather forecasting in a negative way. This can be prevented by not having the wind turbines in the radar's line of sight.

9. RESULTS AND DISADVANTAGE

The policy has set up targets for developing renewable energy resources to meet 5% of the total power demand by 2015 and 10% by 2020. The electrical load Peak demand of Bangladesh as on 2016 is nearly 11,405 MW. Maximum generation in 2016 is 8088 MW leaving a shortage of 3317 MW. With H = 35 m, D= 25 m and V= 5 m/sec in 4 rows of the near shore wind farm considered a total of 15308 turbines will be required which will generate total power of 225.33 MW from wind energy. This is 6.79 per cent of the shortage of 3317 MW. Government's plan is to produce 19000 MW within 2021. This 225.33 MW is only 1.19% of 19000 MW. With H = 60 m, D= 50 m and V= 7 m/sec in 4 rows of the near shore wind farm considered a total of 7656 turbines will be required which will generate total power of 1236.83 MW from wind energy. This is 37.29 per cent of the shortage of 3317 MW. This is 6.5 per cent of the total power to be produced within 2021.

With H = 80 m, D= 60 m and V= 7 m/sec in 4 rows of the near shore wind farm considered a total of 6380 turbines will be required which will generate total power of 1484.24 MW from wind energy. This is 44.75 per cent of the shortage of 3317 MW. This is 7.81 per cent of the total power to be produced within 2021. With H = 100 m, D = 75 m and V= 7 m/sec in 4 rows of the near shore wind farm considered a total of 5104 turbines will be required which will generate total power of 1855.25 MW from wind energy. This is 55.93 per cent of the shortage of 3317 MW. This is 11.19 per cent of the total power to be produced within 2021. We know, Bangladesh has 15MW solar energy capacities through rural households. Besides, energy production in Bangladesh from solid biomass and hydropower are 37 MW and 230 MW respectively. Using 5104 WT with H = 100 m, D = 75 m and V= 7 m/sec power generation of 1855.25 MW is possible. So, from renewable energy sources of wind energy, solid biomass and hydropower a total of (1855.25 MW + 15 MW + 37 MW + 230 MW) = 2137.25MW power generation can be achieved. This is 2137.25 MW / 19000 MW = 11.25 per cent by 2020.

A wind speed of 7 m/sec has been considered at H = 60 m and also at higher altitudes. There is possibility that we may expect much for higher wind speed with the increase of height, which would result more power generation. In addition to that increasing rotor diameter more power production is possible. To meet the present energy crisis, it is very needed to go for renewable energy. With the use of wind power we can minimize the problem to great extent. Wind energy is more reliable because it is totally free and pollution free. Now the most frequent current use of wind energy is electricity production. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation. As a result, interest upon wind as a source of energy is increasing day by day.

10. CONCLUSION

Wind energy is a great source of renewable energy and its implementation around the globe would undoubtedly bring a great change in terms of electricity generation. In the coastal area of Bangladesh and the isolated Island where grid connection is not feasible, alternate electric source like wind power system can be very cost effective. Coastal zones should be kept in focus as wind potential is more there than any other zones. Kuakata has been found the most promising spot than others. June-August is the most suitable period for extracting wind power. On the other hand, October-December is the period of probability of having lowest or

no wind energy. Wind turbines should be established as high as possible, since wind velocity increases as the height increases. Cost comparison shows producing electricity by wind is much cheaper than diesel and solar PV. The main reason of reluctance of investing in wind energy is higher initial cost. Initial cost is almost 4-5 times higher for wind sector that of in gas sector. If we can establish wind turbines in mass scale, unit electricity generation cost will surely reduce. In near future, wind will be the major source of energy in Bangladesh as well as all over the world since the stock of fossil fuels is diminishing day by day. It will be more encouraging if Bangladeshi government provide easy loans to investors for investing in wind energy. Wind energy can really take part in power generation to help the Bangladeshi government.

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