An Analysis of Selecting Proper Locations for Installment of Wind Power Plant Considering Terrain Effect

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***Abstract*-- This paper presents the analysis of wind speed data of eight different sites collected from the Meteorological Department of Bangladesh by choosing the proper sites at best possible seasons of the year at different heights with the terrain effect consideration to show the prospect of utilizing the wind power by installing wind turbine effectively. This proposal is expected to make the best use of reasonable wind speed available in these sites for particular seasons of the year to extract power to contribute by reducing country's power crisis. Again the proposed system can be of hybrid type (i.e. solar-wind or wind-tidal) to make the best use of the plant when there is not adequate wind speed to extract power from it.**

Index Terms-- Wind speed; Terrain effect; Wind turbine; Wind power

I. INTRODUCTION

Bangladesh is experiencing a severe electric power capacity crisis that is only likely to worsen over the next 15 years. Further, over fifty percent of Bangladesh's population still lives with no electricity, and the rate of grid expansion to connect rural villages is threatened by the looming capacity shortage. There are a number of underlying reasons for the crisis, but ultimately the country lacks the fossil fuel resources i.e. natural gas, required to conduct a large scale grid expansion program. Recently the electricity supply deficiency is about 2000 MW/day i.e. the total supply is 3500 MW/day within the demand of 5500MW/day. Alternative approaches to electrifying the country must be found and thus the importance of utilizing renewable energy has come into concern where wind energy is one of the most promising sectors in Bangladesh.

Recently a project on wind energy discovered that the average wind speed in sea shore is 4 m/s. This speed is enough to generate electricity requiring some design change from the wind mill of other countries. Already a wind farm of 1 MW has been setup in Kutubdia spending 110 Million Taka. There is another wind farm of 0.9 MW in Feni. These wind farms proves the potential of producing huge amount of electricity from wind. The main problem is the multi directional wind during cyclone season. If some technical change can be made then our next wind generators will be much more reliable.

In this paper, we analyze on some collected wind speed data of eight different sites of our country to find out the wind energy potentials to be properly utilized at particular land type (i.e. terrain) during the best possible seasons of the year when the available wind speed is adequate enough to produce electricity from it. We also propose the prospect of wind turbine installation of some suitable selected sites among these eight along with concept of wind-solar or wind-tidal hybrid power system where the wind speed is not adequate enough all through the year.

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II. THEORY

Wind energy is the kinetic energy of the moving air mass. The power, P, in watts, possessed by wind blowing with a velocity of V, in meters per second, is directly proportional to the rotor swept area and to the cube of the wind speed, and is given by;

$$P = (½).\rho.A.v^3 \text{ (in Watts)} \quad (1)$$

where, A is the area perpendicular to the direction of flow, meter^2, ρ, density of air, kgm^{-3}, is approximately 1.2 kg/m^3, v, wind velocity, meters per second. Only a part of the total available power calculated by equation 1 can be extracted and is given by;

$$P = (½).\rho.A.v^3.Cp \text{ (in Watts)} \quad (2)$$

Cp, the power coefficient, is the ratio of power extracted by a wind turbine to power available in wind at that location. A theoretical maximum of 59.3% of available power can be extracted; i.e. Cp is 0.593. Practically a typical maximum of 40% is achievable. Now the power per unit area of wind cross-section is given by

$$P = (½).\rho.v^3.Cp \text{ (in Watts)} \quad (3)$$

The collected raw data has been processed to compare the wind speed among the sites over one year. The raw data which were in knot, are transferred into m/s using following conversion formula:

$$1 \text{ knot} = 0.514 \text{ m/s} \quad (4)$$

The wind speeds are measured at height of 2m above ground level. But the speed changes with height. So this data have been converted to get wind speed at those different heights where the installation of wind turbine is usually feasible. The rate of increase of velocity with height depends upon the roughness of the terrain. The variation of average wind speed can be determined from the following power law expression,

$$V_z/V_{ref} = (h/h_{ref})^{\alpha} \quad (5)$$

where V_z and V_{ref} are the average speeds at height 'h' in meter and at the reference height of h_{ref} = 2m above the ground respectively and α varies from 0.1 to 0.4 depending on the nature of the terrain.

III. Wind Data Collection & Analysis

From collected data, the following information about the wind climate in Bangladesh has been found:

i) Wind speeds appear to be higher in the east of the country than the west.

ii) Wind speeds in the coastal areas appear to be higher than inland.

iii) Wind speed exhibits a strong seasonal cycle, lowest in the winter and higher in the summer.

iv) Wind speed exhibits a diurnal cycle, generally peaking at noon and weakest at night.

Collected data for eight different sites in Bangladesh are shown in table 1.

A. *Monthly Wind Speed for Different Areas*

Wind speed for eight different sites has been collected from the Meteorological department of Bangladesh. The wind speed that has been shown in table 1 is for a duration of twelve months for eight different sites which is the most recent data from the Meteorological department of Bangladesh. The wind speed shown in the table is from July 2008 to May 2009.

The wind speed shown in table is for a height of 2m except the site Feni which is for a height of 10m. The rightmost column of the table shows the average wind speed of every month.

TABLE I. TABLE 1 MONTHLY AVERAGE WIND SPEED (KNOT) AT A HEIGHT OF 2M ABOVE GROUND LEVEL FOR EIGHT DIFFERENT SITES OF BANGLADESH

	Shrimangal	Ishordi	Hatia	Shitakunda	Sandwip	Rangamati	Mongla	Feni	Avg
2008-Jul	1.94	1.14	2.23	2.01	2.31	1.05	1.63	1.30	1.70
August	1.83	1.27	1.95	1.85	2.09	1.02	1.55	1.44	1.62
September	1.61	1.35	1.91	1.38	1.51	1.12	1.41	1.23	1.44
October	1.41	1.13	1.23	1.13	1.15	1.02	1.31	1.15	1.19
November	1.17	1.06	0.79	0.68	0.80	0.92	1.42	0.89	0.97
December	0.79	0.86	0.84	0.81	0.87	0.60	1.11	1.06	0.87
2009-Jan	1.75	0.98	0.89	1.03	0.74	0.71	1.32	0.81	1.03
February	2.16	1.29	1.31	1.56	1.01	0.98	1.42	1.23	1.37
March	1.74	1.13	1.16	1.30	1.08	1.08	1.45	1.27	1.28
April	1.59	1.49	2.04	1.91	1.55	2.11	1.89	1.46	1.75
May	1.56	1.50	1.83	1.98	1.50	1.59	2.11	1.43	1.69

B. *Proposed Time Duration*

From the average wind speed data (table1) it is observed that average wind speed from the month of October to January is relatively low compared to the other average wind speed. That is why months from October to January have been eliminated keeping it in mind that the average wind speed data from the month of October to January is not sufficient enough for the installment of wind power plants.

Wind speed of eight different sites eliminating the months from October to January has been in plotted in figure1.

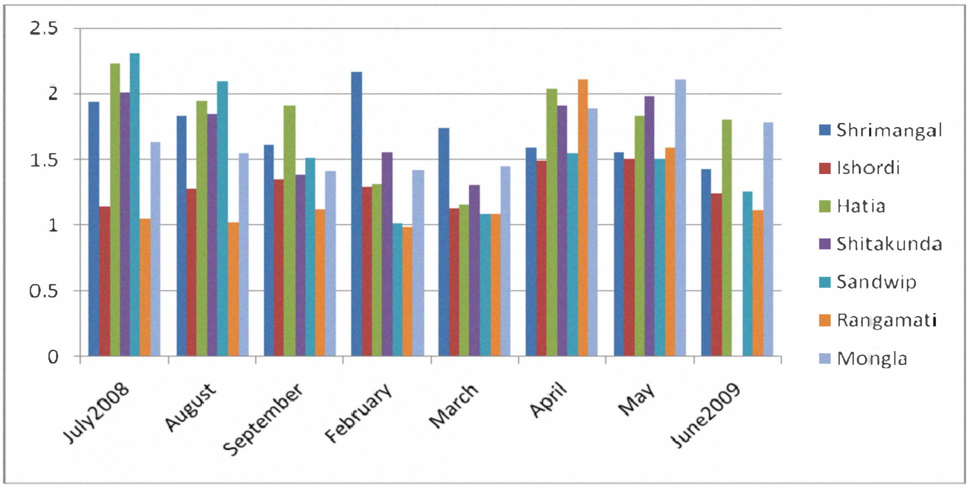

Figure 1. Adequate wind speed for different sites during proposed time duration

C. *Selection of Areas by Analyzing Standard Deviation*

In table 2, standard deviation, maximum and average wind speed has been shown for eight different sites. Based upon these values area is selected for the installment of wind power plant. The last row is the remarks of different sites in terms of wind speed.

The site Rangamati has the lowest average wind speed as well as high standard deviation. Though the site's maximum speed is high enough but due to lowest average and high standard deviation the site has been regarded as the worst one and hence the site is eliminated.

TABLE II. COMPARISON OF VARIATION OF WIND SPEED FOR DIFFERENT SITES IN TERMS OF STANDARD DEVIATION, AVERAGE AND MAXIMUM VALUE

Sites	Standard Deviation of Wind Speed	Maximum Wind Speed	Average Wind Speed	Remarks
Shrimangal	0.24	2.16	1.73	Best
Ishordi	0.14	1.5	1.3	Worse
Hatia	0.36	2.23	1.78	Better2
Shitakunda	0.66	2.01	1.5	Bad
Sandwip	0.46	2.31	1.54	Good
Rangamati	0.39	2.11	1.26	Worst
Mongla	0.25	2.11	1.66	Better1

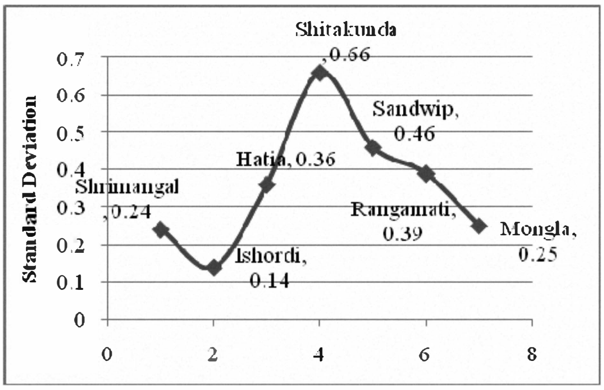

Figure 2. Standard Deviation of wind speed for different sites

D. *Selection of Turbine Height*

The minimum wind speed for generating usable power typically lies between 3.75 m/s to 4.5 m/s. Again the turbine height is usually selected between 25m to 40m above the sea level. So after considering the standard deviation of wind speed, we calculate the wind speed for selected sites for different heights ranging from 25m up to 39m using the equation (5) taking α value as 0.3. These values are shown in table 3.

Now from table 3, we eliminate those heights for which the wind speed values are lesser than 3.75 m/s and taking

those heights for the sites having speed equal to or greater than 3.75 m/s. The site 'Sitakunda' is totally eliminated as the speed for this site is always less than 3.75 m/s up to turbine height of 39 m. If we would have wanted to include this site, then we had to install our wind turbine at a height higher than 40m or so which is not economically feasible.

TABLE III. WIND SPEED FOR DIFFERENT TURBINE HEIGHTS

Turbine Height in meter	Wind Speed in m/s				
	Shrimangal	Hatia	Shitakunda	Sandwip	Mongla
25	3.96	3.75	3.27	3.31	3.84
27	4	3.78	3.3	3.33	3.87
29	4.02	3.8	3.32	3.36	3.89
31	4.05	3.83	3.34	3.38	3.92
33	4.08	3.85	3.36	3.4	3.94
35	4.1	3.87	3.38	3.42	3.97
37	4.12	3.9	3.40	3.44	3.99
39	4.15	3.92	3.42	3.46	4.01

IV. TERRAIN EFFECT

Terrain, or **land relief**, is the third or vertical dimension of **land surface.** No matter what the nature of the ground level for instance sea, lake, crops, trees, buildings, etc is, near the ground level the wind speed is always reduced, for a reason of air rubbing against impediments though roughness is infinitesimal. This effect is shown in figure 3.

A. Flat Terrain Turbulences

Flat terrain can be considered as a flat circular area which can be assumed a radius of approximate 1000 m without any slopes, impediments or constructions. The turbulence is very little (less than 10%) above flat terrain.

i) Human Structures:

In case of installing a wind turbine on a flat terrain it should be kept in mind that it should not be installed on the leeside of house as the turbulence can make a problem. For this reason, it is not safe to install any turbine on the leeside of a building as the turbulence creates trouble for the wind turbine rather it should be installed upwind of the impediments so the turbulence effect is minimized.

ii) Trees:

The turbulence effect is less in case of tress than the buildings as wind transparency is higher than the buildings. During winter as the trees have no leaves in that duration effect is even lesser.

B. Complex Terrain Turbulences

Normally the turbulence is quite high above the complex terrain. It is better to install wind turbines on the rounded hill tops with smooth surfaces as there is induction of very strong vertical shears with a sharp change in terrain like cliff edge which causes high turbulences.

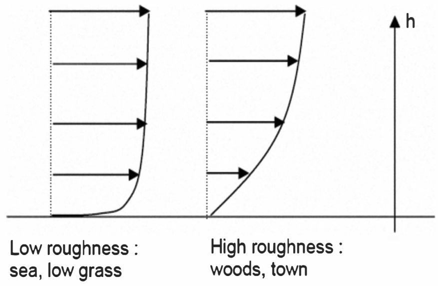

Figure 3. Effect of roughness of the surface on wind speed

TABLE IV. VALUE OF ALPHA FOR DIFFERENT LAND ROUGHNESS

Roughness description	alpha α
Very low roughness (flat ice, calm sea)	0.10
Low roughness (meadows, lowland, open fields)	0.16
Average roughness (bush, sparse trees)	0.20
Average roughness (villages, spread houses)	0.28
High roughness (town with high buildings)	0.40

C. Selection of Areas by Analyzing Terrain Effect

Wind speed of different sites of different turbine heights from 25 m to 39 m with all terrain effects has been shown in figure 3. The graph gives us the information to choose the best plant considering Terrain effect as well as turbine height. In the figure all five sites that have been selected from table 2 contains wind speeds with all terrains. In order to install a wind turbine in any of these sites we can use this graph to select the terrain with selected height.

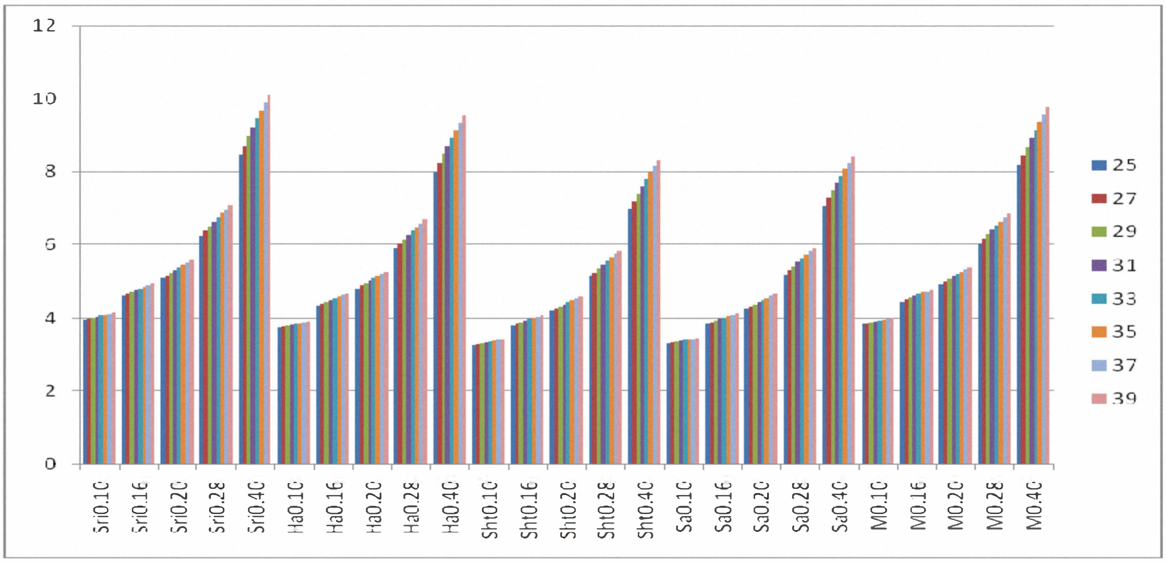

Figure 4. wind speed for different sites with different terrain values

V. CONCLUSION

Our study was concentrated on the prospect of wind energy in our country to utilize properly so that we can get maximum possible efficiency with considerably low cost considering the effect of terrain. In conclusion, from above mentioned terrain effect, we can summarize that for any case, we need to apply wind energy if possible in a flat terrain to increase energy yield. In complex terrain we will avoid near the ground turbulence and try to install a tower as high as possible. The other time of the year when the wind speed is not adequate enough we can think of wind-solar or wind-tidal (in some special sites) hybrid system to ensure that the power plant is not out of order during that particular time period. Since solar or tidal energy can be used as an alternative source of energy to run the plant all through the year.

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