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An Investigation of Wind Power Utilization for Irrigation in Bangladesh

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ABSTRACT

In Bangladesh, farmers need adequate supply of irrigation water at right time and in sufficient quantities for maximum agricultural production. In the year 2007, only 60.01% of total cultivated areas were irrigated by different mechanized equipments. Numbers of benefited farmer through mechanized equipment were reduced by 1.01% from the year 2006 to 2007 due to increased price of oil, fuel and scarcity of electricity. In the wake of the increasing world energy crisis, which mostly affected the least developed countries, the interest in alternative energy resources has been increased considerably. In this regard, Wind as a source of energy can hold good prospect for an underdeveloped country like Bangladesh. In this paper, a statistical analysis of Wind characteristics and investigation of feasibility of Wind energy to drive a hand-pump have been carried out. Weibull probability density functions of the locations are calculated in the light of observed data and Weibull shape parameter and scale parameter are also calculated. The main objective is to find out Wind energy potential for irrigation purposes.

Keywords: *Irrigation water, Minor irrigation, Wind energy, Hand-pump.*

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1 INTRODUCTION

Bangladesh is situated in the latitude between 20°34' - 26°38'N and longitude between 88°01'-92°40'E. The country has a 724 *km* long coastal line along 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, enter into Asia over the coastal area of Bangladesh. This Wind blows over Bangladesh from March to September with a monthly average speed 3 *m/s* to 6 *m/s* [1]. The Wind speed is enhanced when it enters the *V*-shaped coastal region of the country. According to preliminary studies from Meteorological Department, Bangladesh Centre for Advanced Studies (BCAS), LGED and BUET, Winds are available in Bangladesh mainly during the monsoon and around one to two months before and after the monsoon (7 months; March to September). During the months starting from late October to February, Wind speed remains either calm or too low. The peak Wind speed occurs during the months of June and July [1]. Besides these, there are a lot of hilly and remote areas with a great open space island where the Wind speed remains 2 *m/s* to 5 *m/s* in Bangladesh. The recent development of Wind rotor aerodynamics makes it feasible to extract energy from Wind speed as low as 2.5 *m/s*.

Bangladesh is an agricultural land. The agriculture needs supply of water at right time for better yielding. Bangladesh Government has already undertaken many irrigation and canal digging projects to supply water. Many power pumps and hand pumps have been distributed to the farmers. A study of Bangladesh Agricultural Development Corporation (BADC) shows that Low Lift pump (LLP) of about 40 *feet* head and 2 ft^3/s discharge were in operation. It is claimed that there is surface water potential for 54,700 LLP of 2 ft^3/s capacity. Recently, man-powered (TARA PUMP) water pumps have become very popular for irrigation and every year its supply is increasing. About 66% of irrigated area is covered using Shallow Tube Well which is basically diesel operated. Among the Shallow Tube Well, 50% of these are operated at a head of 6 *m* or less, so this percentage of pump can be easily drive using locally made Wind power pump.

The non-availability of electricity and irregular supply of diesel fuel in rural areas have adversely affected the existing schemes of irrigation. The installation of Windmills will be very much convenient for operating the pumps. The application of Wind power for operating man-powered water pumps will also be very convenient and it will save energy. The preliminary study shows that for electricity generation, Wind energy technology is suitable in the coastal islands and some remote areas with a great open space. Previous research [2] shows that locally made mechanical Wind driven pump can be used for water pumping for irrigation, where average speed of Wind is 2.5 *m/s* or more.

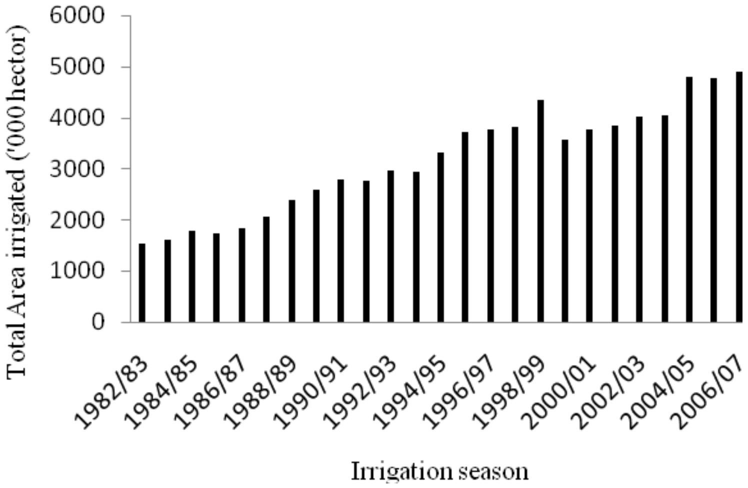

Figure 1: Trends in irrigation area.

2 MINOR IRRIGATION SCENARIO OF BANGLADESH

Minor irrigation is defined in Bangladesh as irrigation by means of pumps, driven by either diesel or electric power. The common methods of minor irrigation technology are either diesel or electric powered pumps, for pumping water from surface source and from deep ground water or flow usually by gravity; which may also be assisted by pumps. Due to the need of increased food production, numbers of total area irrigated by different modes have increased which are shown in **Fig.1**. The survey for the year 2006-2007 carried out by BADC, Directorate of Agricultural Extension (DAE) and Barind Multipurpose Development Authority (BMDA) jointly shows that out of 8640727 *hectare* net cultivated area only 4882879 *hectare* are irrigated by different equipments which is 56.51% of total cultivated area. Number of benefited farmers of 2005-06 year through mechanized equipments was 12651320 but in 2006-07 year the number is 12523612 which is 1.01% less than last year. Number of benefited farmer decreased due to rise of price of oil, fuel and scarcity of electricity. The marginal farmers were found disinterested to irrigate their land.

3 MODE OF IRRIGATION

During irrigation season, huge number of both manually and power operated irrigation equipment are used all over the country which are shown in **Table.1**. Power operated equipments are operated by either diesel or electricity. **Fig.2** shows the percentage of diesel and electricity used by Deep Tube Well (DTW),

Table 1: Mode of irrigation (Irrigation equipment survey 2007)

Mode of irrigation	Number of equipment	Area irrigated	% of total irrigated area (*ha*)	Area irrigated per equipment
A. Ground Water Irrigation				
Deep Tube Well irrigation	29177	725258	14.85	24.86
Shallow Tube Well (STW) irrigation	1202728	3196127	65.46	2.66
Manual, Traditional method and Artesian irrigation (don, dug well, treadle pump, rower pump, hand tube well)	-	14403	0.29	-
Sub Total	1231905	3935788	80.60	-
B. **Surface Water Irrigation**				
Low Lift pump irrigation	107293	810027	16.59	7.55
Gravity flow Irrigation	-	137064	2.81	-
Sub Total	107293	947091	19.40	-
Grand Total	1339198	4882879	100	-

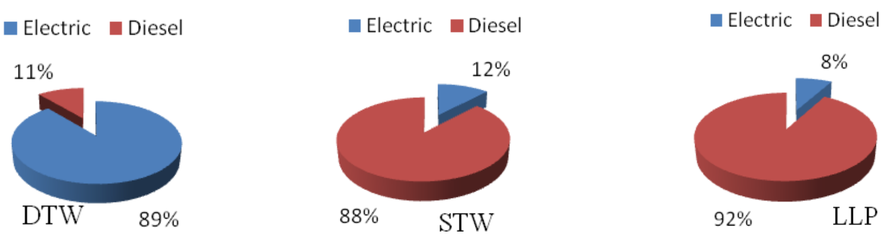

Figure 2: Consumption of power source (in percentage), used by different irrigation equipments.

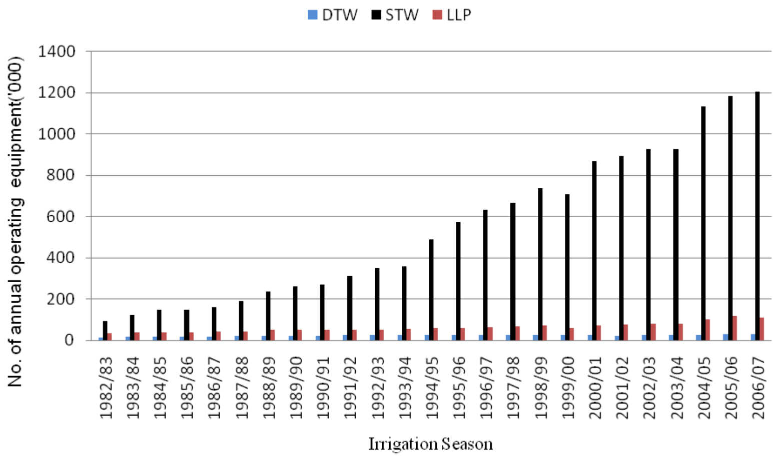

Figure 3: The trend in minor irrigation equipment.

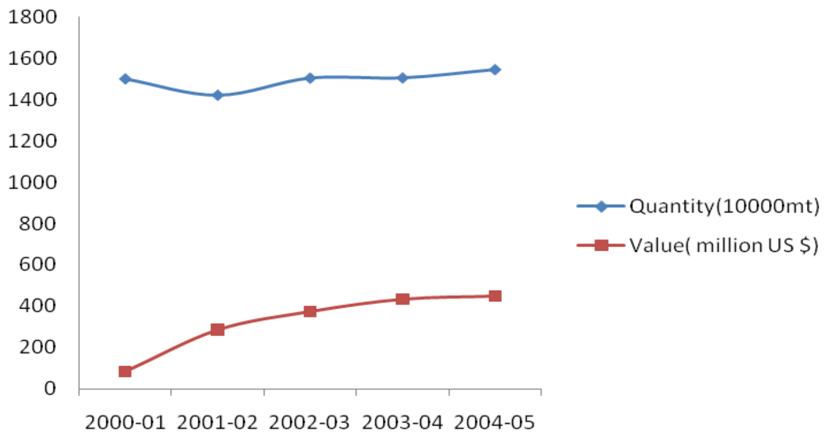

Figure 4: Quantity and value of diesel fuel imported in different years.

Shallow Tube Well (STW) and LLP in the year 2007 [3]. As there is a scarcity of electricity and high capital cost involved, number of DTW does not increase so much. Among different mode of irrigation, the number of Shallow Tube Well increased rapidly as shown in **Fig.3**. Almost 90% of equipment is diesel powered due to shortage of electricity. So every year increased amount of diesel need to be imported from overseas. But price of diesel is increasing very rapidly as shown in **Fig.4**.

4 ANALYSIS OF WIND CHARACTERISTICS

There are several density functions, which can be used to describe the Wind speed frequency curve. The most common is the Weibull functions. The studies using this function can be found in the following section. The Weibull distribution is characterized by two parameters: the shape parameter *k* (dimensionless) and the scale parameter *c* (*m/s*). The cumulative distribution function or Weibull function [4] is given by

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

And the Weibull density or Probability density function can be written as below:

$$f(v) = \frac{dF(v)}{dv} = (\frac{k}{c})(\frac{v}{c})^{k-1} \times e^{-(\frac{v}{c})^k} \quad \ldots \quad \ldots \quad (2)$$

There are several methods to calculate the Weibull parameter *k* and *c* such as Weibull paper method, Standard deviation method, Energy pattern factor method etc. Here only Weibull Paper Method is used.

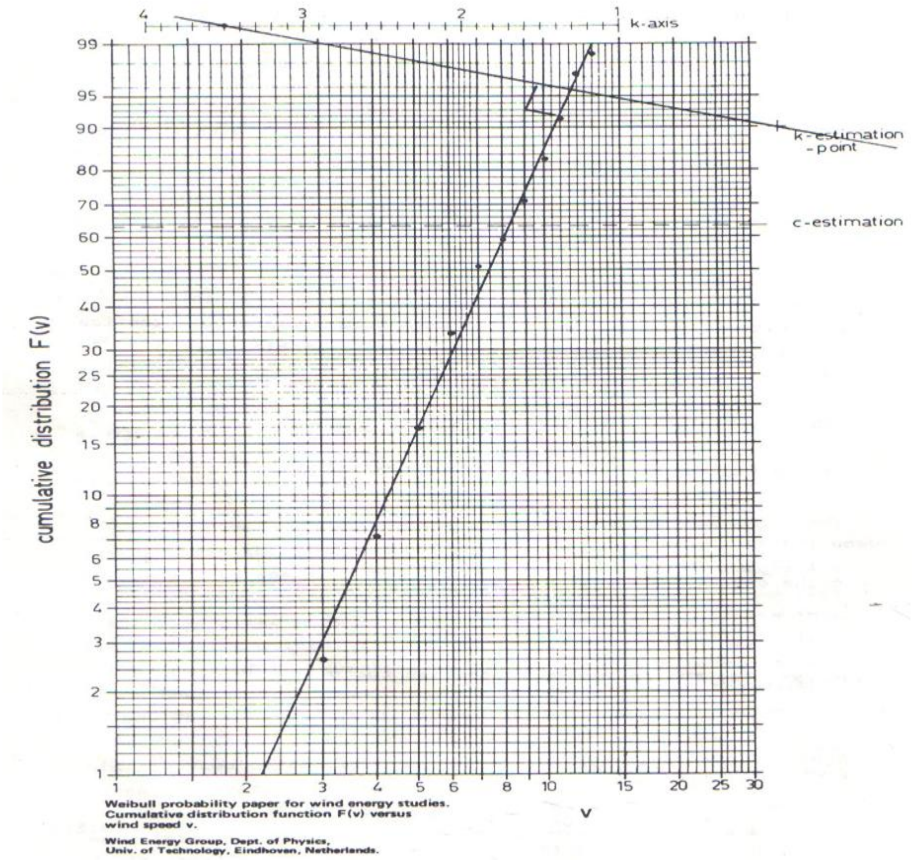

Figure 5: Cumulative distribution .vs. Wind speed graph.
[*Source: Wind Energy Group, Dept. of Physics. University of Tech., Edinburgh, The Netherlands*]

5 WEIBULL PAPER METHOD

In this method, at first percentage of cumulative distribution have been calculated [5] and then these are plotted for corresponding Wind speed as shown in **Fig.5**. A straight line has been drawn in such a way that it can cover maximum points and from this line an intersection with *c* estimation line (dotted mark) gives the corresponding value of *c* for the location. A normal from "+" of the graph has been drawn upon the previous straight line; the point of intersection with the "*k*" axis line (top) gives the value of *k*. The Wind power per unit area of approach is proportional to the cube of Wind speed [6] and it can be expressed as $P/A = 0.6\ V^{3}$, where P/A is in $Watt/m^2$ and V is in *m/s*. This Wind power represents the strength of Wind and theoretically maximum 59% of this power can be extracted.

Table 2: Mean speed for each location

Locations	Teknaf	Kutubdia	Sandwip	Kuakata	Mongla	Barisal	Rangamati	Sylhet	Khagrachari
Mean(*m/s*)	3.22	5.17	4.89	3.58	3.44	2.88	2.40	2.54	3.1

6 WIND PUMPING SYSTEMS FOR ANALYSIS PURPOSE

For analysis purpose, a typical rotor pump set was used as shown in **Fig.6**. It consists of a Horizontal axis rotor made from discarded ceiling fan blade and coupled with no.6 hand tube well which is suitable for our climatic condition. Annual useful energy is calculated by

$$15.77\times\left(\eta_{p,wind}\gamma c_p\rho_a AK \big/ c^K\right)\left[\int_{v_{ci}}^{v_r} v^{k+2}\, e^{-\left(v/c\right)^k} dv + v_r^3 \int_{v_r}^{v_o} v^k\, e^{-\left(v/c\right)^k} dv\right] \quad \ldots \quad (3)$$

Where, $\eta_{p,Wind}$ represents the efficiency of pump used with the Wind rotor, γ the mechanical availability factor of the Windmill pump accounting for downtime during maintenance etc., C_p the coefficient of performance of the Wind rotor, ρ_a the density of air, A the swept area of rotor, k the shape parameter, c the scale parameter, v the Wind speed, v_{ci} the cut-in Wind speed, v_{co} the cut-out Wind speed and v_r the rated Wind speed of the Windmill.

By using Wind pumping system the amount of diesel or electricity is calculated based on 5 *HP* Diesel and Electric pump. The annual amount of diesel saved (A_{ds}) by a Wind pumping system can be estimated by the following equation,

$$A_{ds}=AUE/(CV_d\eta_{p,dep}) \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

Where, CV_d represents the caloric value of diesel, and p_d the market price of diesel. Similarly, the annual amount of electricity saved (A_{es}) by a Wind pumping system can be estimated by the following equation,

$$A_{es}=AUE/(3.6\eta_{p,emp}) \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

7 RESULTS AND DISCUSSION

The mean Wind speed for each of the different locations is shown in **Table.2** by analyzing the Wind data taken from the project work financed by LGED in year 2003-2005. As can be seen in **Fig.7**, the mean Wind speed varies is above 2.6 *m/s* in almost all stations. The above average Winds are available during the hottest and the driest months of March, April and May. During this period, Windmills may be used for pumping water for irrigation if it had been previously stored in a reservoir during the monsoon. Also locally made Wind pump can be used to drive hand pump as shown in **Fig.6**. During the operating seasons,

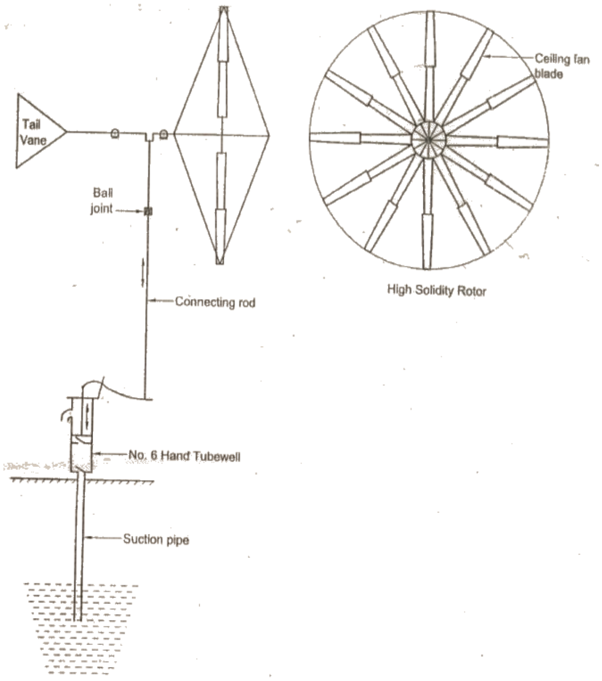

Figure 6: High solidity Wind turbine with *No.* 6 hand tube well.

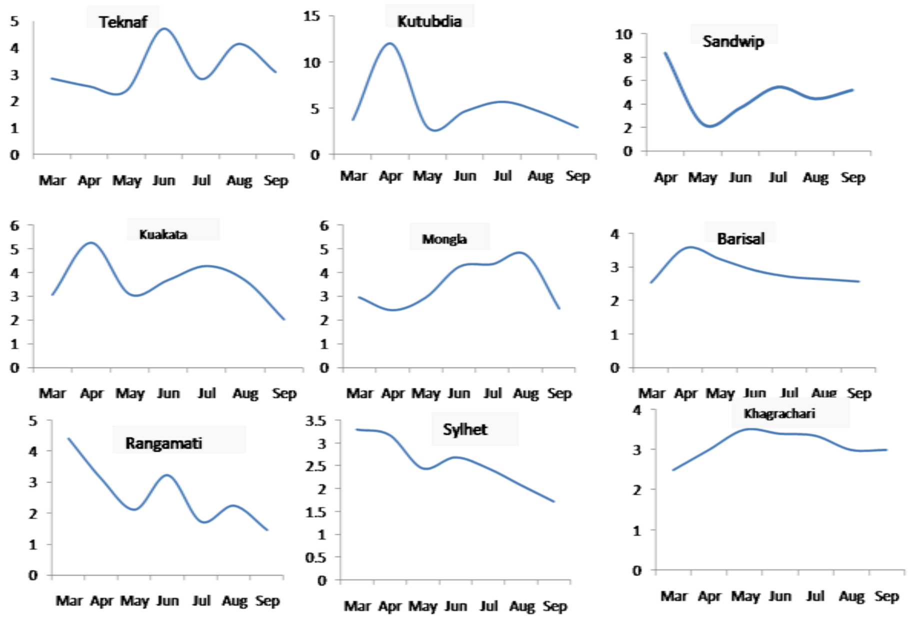

Figure 7: Monthly average velocity for different locations.

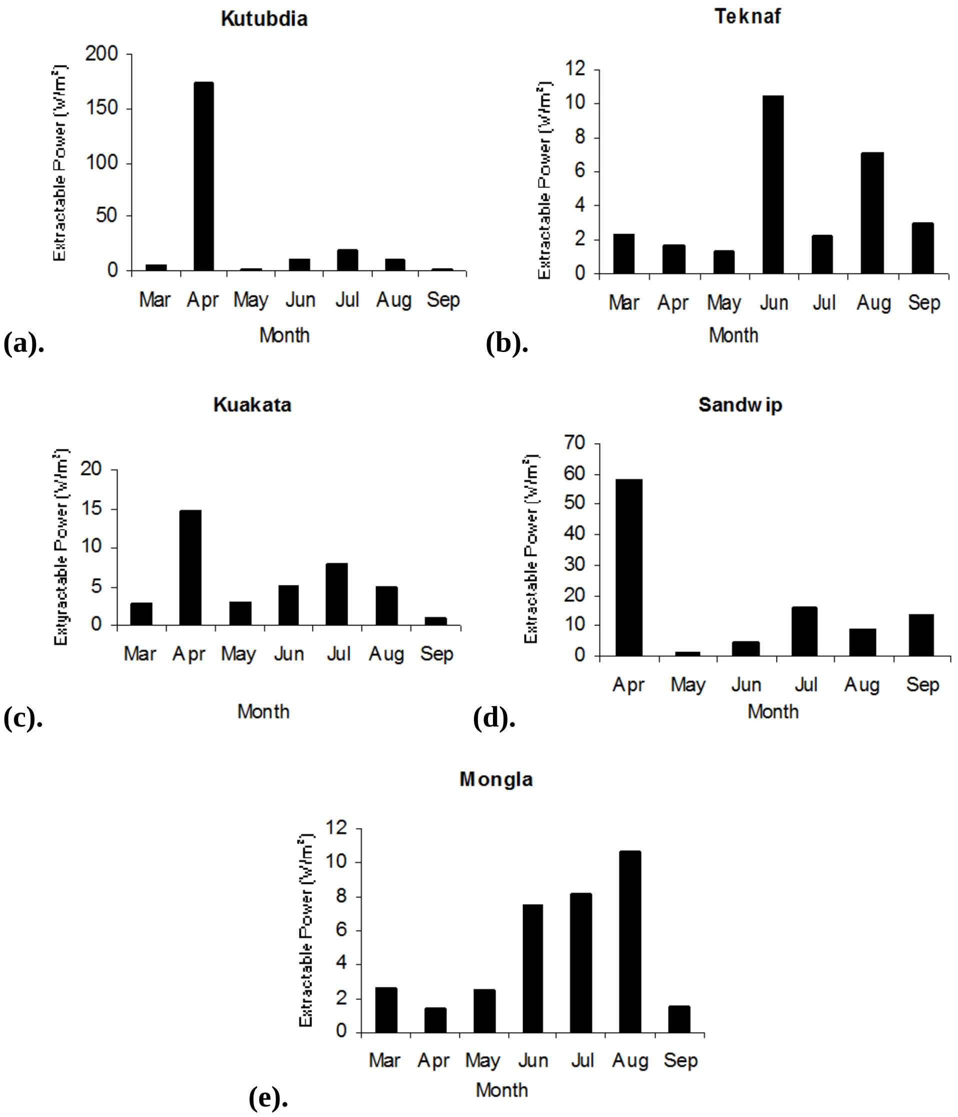

Figure 8: Monthly Average Extracted Power at Different Regions (Year 2003-2005).

subsoil water from shallow wells can also be pumped up by Low Lift pumps run by Windmills.

Practically, extractable power by any type of Windmill can be written approximately as [4], $P_e = 0.1\ AV^{3}$ (*watt*), where A is the total swept area of the rotor blades and V is Wind speed (*m/s*). Extracted power per square meter of swept area for different months for above noted locations in Bangladesh is shown in **Fig.8 (a)-(e)**. From this figure it can be seen that Wind energy can be used in the hottest months i.e., March, April and May for irrigation purposes. The Wind data at other locations also show similar strength of Wind energy.

Annual useful amount of energy shown in **Fig.9** is calculated based on a high solidity Wind turbine with No. 6 hand tube-well by developing Computer program using **Eq.3**. Taking same cut-in Wind speed V_{ci} = 2.5 *m/s*, the cut-out Wind speed V_{co} = 7 *m/s* and the rated Wind speed of the Windmill, v_r =3 *m/s*.

Fig.10 and **Fig.11** show frequency occurs, energy histogram and Velocity Duration Curves for kutubdia station at the month of March. It is seen that

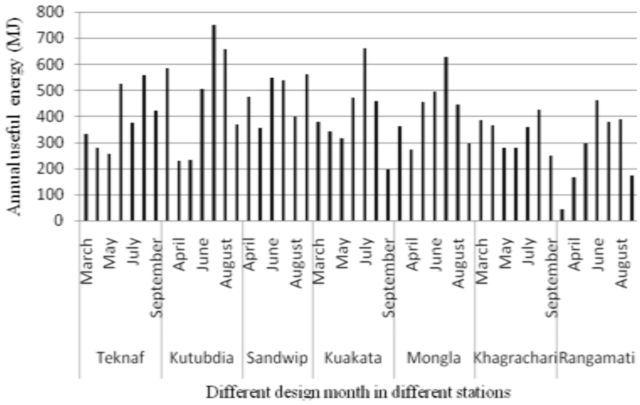

Figure 9: Annual useful energy by Wind pump based on different month for different stations.

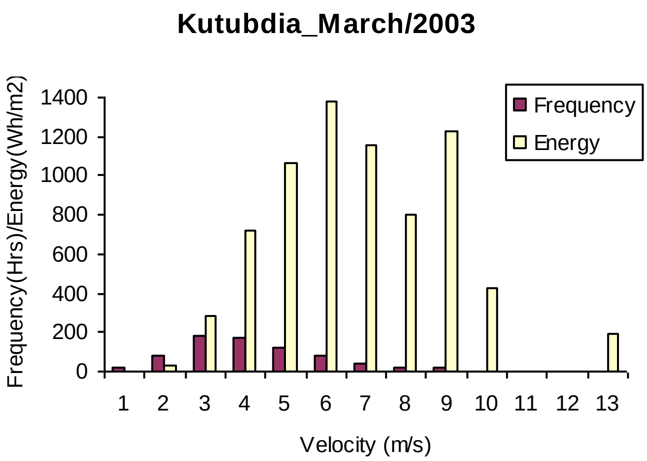

Figure 10: Velocity Frequency and Energy Histogram.

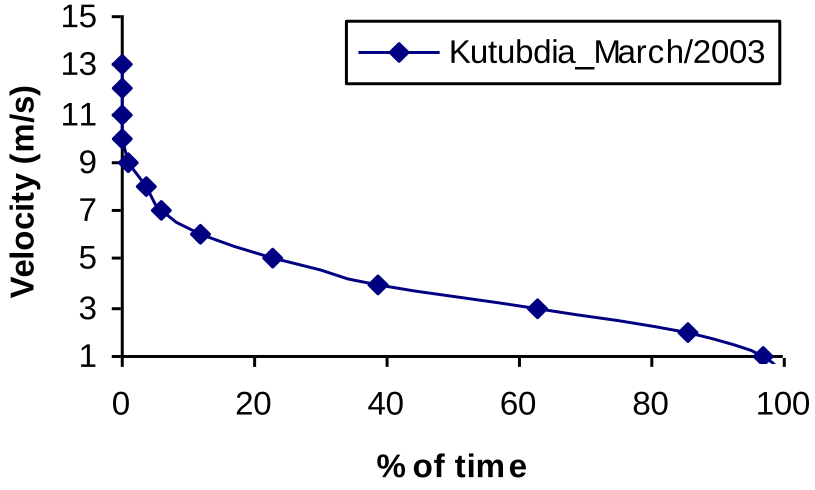

Figure 11: Velocity Duration Curve.

maximum velocity frequency occurs at *V* = 3 *m/s* and maximum energy occurs at *V* = 6 *m/s*. The duration of the velocity above *V* = 3 *m/s* is 62.50% of total time (744 *hrs*). All other stations show similar trend that means Wind speed is above 3 *m/s* or more about 2400 *hr* in the month of March to September. This speed is suitable for irrigation purposes.

8 CONCLUSIONS

The following conclusions can be drawn from the present analysis:

(i) The Wind data analyzed here may be helpful for lifting water for irrigation which can solve the energy problem in the country to some extent.

(ii) For remote areas where Wind speed is 2.5 *m/s* or above, indigenously made Wind pumping system can be used efficiently for irrigation purposes in plane lands with wide space.

(iii) In Bangladesh, about 30 % of total irrigated area is irrigated by hand pumps. So the Wind turbine-pumping set may be useful by replacing hand-pumping system for irrigation purposes in rural areas.

(iv) Large amount of diesel and electricity can be saved using Wind powered pump.

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