FABRICATION, INSTALLATION AND PERFORMANCE TEST OF A MODEL TYPE VERTICAL SHAFT WIND MILL

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ABSTRACT
The conventional resources of energy in Bangladesh are depleting at a very high rate. Hence the search as well as utilization entails alternative resources. Wind, likewise a natural resource, is a renewable energy, which can be utilized for electricity generation, pumping water and many other applications. The main objective of this research is to fabricate and install a model type vertical shaft windmill resulting in testing of its performance.

We have fabricated a model type vertical shaft (15 feet) windmill (blade size: 22-inX15-in) with power transmission system. It has been placed on the roof of the EME building of CUET. It observed that the maximum power output is 15V by the DC generator, at the shaft speed of 22 rpm corresponding to the free stream velocity.

Keywords: Windmill, Energy.

1. INTRODUCTION
Wind is the response of the atmosphere to uneven heating conditions. This creates pressure differences in the atmosphere causing the wind to blow from regions of high atmospheric pressure to low atmospheric pressure. The larger the pressure difference the greater the wind velocity. Air pressure represents the amount of atmosphere that is pressing down on the surface of the earth at some point.

Actually wind is a form of solar energy. The uneven heating of the atmosphere by the sun, the irregularities of the earth's surface and rotation of the earth cause winds. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flows or motion energy, when "harvested" by modern windmills can be used to generate electricity [1].

Windmill is a machine that converts wind into useful energy. This energy is derived from the force of wind acting on oblique blades or sails that radiate from a shaft. The turning shaft may be connected to machinery used to perform such work as milling grain, pumping water, or generating electricity. When the shaft is connected to a load, such as a pump, the device is typically called a windmill. When it is used to generate electricity, it is known as a wind turbine generator. Wind energy has the potential to provide mechanical energy or electricity without generation pollutants.

The velocity of wind at which it blows neither repeat in varying pattern, nor in any to places on the earth have the identical values. That is why any wind energy project started without analyzing carefully its varying characteristics, must end in a failure. The key element in successful utilization of wind energy lies in proper understanding of various influencing factors upon which those problems are dependent. Although the variation is almost next to random, it can fit to statistical function called Weibull-distribution function. It has got two important design characteristics, the shape parameter and scale factor. These values are used to select the type of windmill that matches properly with available wind energy to electricity generator or a water pump. Therefore, enormous wind speed data (for 5 to10 years) should be recorded and analyzed to get the characteristic values of the Weibull-distribution parameters to avoid failure due to miss match between the equipment and the windmill [2]. There is very little power in the wind at low speed. So accurate and detailed local wind speed data is necessary to determine the likely energy yield from a given site, and generators should be designed for that particular site. Average wind speed information alone is often of limited value.

2. BASIC AERODYNAMIC OPERATING PRINCIPLES OF WINDMILL
The wind passes over both surfaces of the airfoil shaped blade. It passes more rapidly over the longer (upper) side of the airfoil, creating a lower-pressure area above the airfoil. The pressure differential between top and bottom surfaces results in a force, called aerodynamic lift. In an aircraft wing, this force causes the airfoil to "rise," lifting the aircraft off the ground. Since the blades of a wind turbine are constrained to move in a plane with the hub as its center, the lift force causes rotation about the hub. In addition to lift force, a

"drag" force perpendicular to the lift force impedes rotor rotation. A prime objective in wind turbine design is for the blade to have a relatively high lift-to-drag ratio. This ratio can be varied along the length of the blade to optimize the turbine's output at various wind speeds [3].

3. HOW DO WINDMILL WORK?

Wind energy conversion systems ('wind turbines') are designed to convert the energy of wind movement (kinetic energy) into mechanical power. In windmill generators, this mechanical energy is converted into electricity and in windmills this energy is used to do work, such as pumping water, mill grains or drive machinery. Electricity generated can be either stored in batteries, or used directly. There are three basic physical laws governing the amount of energy available from the wind [4]. The first law states that the power generated by the mill is proportional to the wind speed cubed. The second law states that the power available is directly proportional to the swept area of the blades. The third law states that there is a maximum theoretical efficiency of wind generators of 59%. Practical windmills are designed to work between certain wind speeds. The lower speed, called the 'cut in speed' as there is too little energy to overcome system losses. The 'cut out speed' is determined by the ability of the particular machine to withstand high wind. The 'rated speed' is the wind speed at which the particular machine achieves its maximum rated output. Above this speed, it may have mechanisms that maintain the output at a constant value with increasing wind speed.

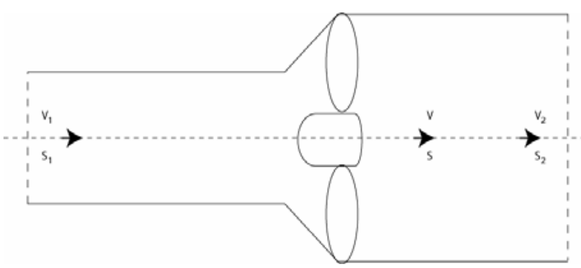

Fig 1: Wind velocity directions

4. THEORY AND GOVERNING EQUATIONS

The machines used to produce power from the wind can be classified mainly in two different groups: horizontal-axis machines and vertical-axis machines. Let us consider an ideal wind rotor at rest, placed in a moving atmosphere as shown in Fig. 1.

Let V_1 be the wind speed at a considerable distance upwind, V the wind speed actually passing through the rotor and assumed to be uniform over the whole area S swept by the blades, V_2 be the wind velocity downwind, far from the rotor. The section of the airflow, which passes through the rotor, is S_1 in upwind and is S_2 in downwind.

The generation of mechanical energy by the rotor is possible only by reducing the kinetic energy of the air. Thus V_2 is necessarily lower than V_1. Consequently, the section of the airflow which passes through the rotor increases from upstream (S_1) to downstream (S_2). If we suppose that the airflow is incompressible, the continuation condition (constant mass flow) can be written as: $S_1V_1 = SV = S_2V_2$

The force exerted on the wind rotor by the wind is given by Euler's theorem. The variation of the kinetic energy from upstream to downstream is

$$\frac{1}{2}\rho SV\left(V_1{}^2 - V_2{}^2\right), \text{ where } V = \frac{V_1 + V_2}{2}$$

The force exerted on the rotor and the power provided is then given by following expressions:

$$F = \frac{1}{2}\rho SV\left(V_1{}^2 - V_2{}^2\right) \qquad (1)$$

$$P = \frac{1}{4}\rho S\left(V_1^2 - V_2^2\right)\left(V_1 + V_2\right) \qquad (2)$$

For a given upstream speed V_1, it is possible to study the variation of the power P as a given function of V_2.

5. CONSTRUCTION, INSTALLATION AND DATA COLLECTION

5.1 Windmill construction

At first two sides of a plastic drum is cut with hacksaw. Two drums are used to make four blades. A 2-ft hollow shaft is welded with 20 inch flat bar. Then the blade is set with the flat bar by nut-bolts.

A hollow G.I. pipe of 15-ft in length with inner diameter (ID) 1-in and outer diameter (OD) 1.35-in is chosen as shaft. Four sockets of ID 1-in and OD 1.35-in are welded on the shaft at 11-in gap from the top where the blade holders are attached. Then one ball bearing with ID 0.78-in and OD 1.96-in is used and fixed it in the bearing casing on the main shaft at 10-ft height from the bottom by machining. The three holders are welded on the bearing casing for alignment of the wire. At the end of the shaft one roller bearing of ID 0.78-in and OD 1.96-in is fixed by machining.

Base is designed to support the weight of the windmill and to resists the moment of the blades during rotation. The length and width of the base are 3.16-ft and 3.16-ft respectively and the thickness is 1-in. A bearing casing is made to hold the main shaft at the middle of the base and it is connected with the base by angle. Three holders are welded on the base for alignment.

5.2 Construction of power transmission system

A pulley of ID 1.35-in and OD 16.5-in is fixed with the main shaft by machining at 16-in from the bottom. A steel hollow pipe of 28-in in length is used as the small shaft. A pulley having ID 0.78-in and OD 1.81 is attached on the small shaft at 16-in from the bottom. Another pulley with ID 0.78-in and OD 8.25-in is attached on the small shaft by cotter pin at 5-in from the bottom. Two bearings are set at the two end of the hollow shaft by machining.

The top and the bottom bearings are attached by adjustment system. Also a DC generator is set by adjustment system. Two flat belts are used to make proper transmission. One belt of length 6.7-ft and width 0.8-in is set and adjusted with the pulley of the main shaft and that of the small shaft. Another belt of length

4.3-ft and width 0.8-in is set and adjusted with pulley of the small shaft and DC generator. Fig. 2 shows a photograph of the power transmission system and the design of the system is shown in Fig. 3.

Fig 2: Photograph of the power transmission system

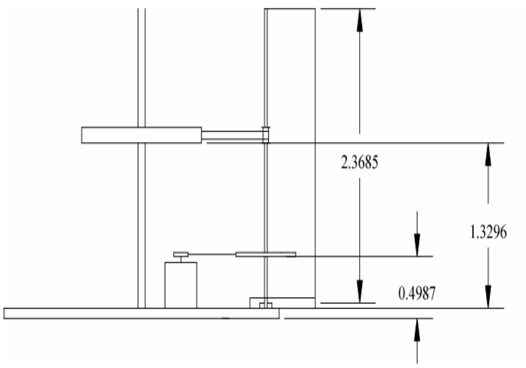

Fig 3: Design of the power transmission system

5.3. Installation of the windmill

Parts of the windmill are brought on roof of the EME building of CUET. At first blades are set on the blade holders by nut-bolts. Then blade holders are joined on the sockets which are welded on the main shaft rigidly.

The base of the windmill is fixed on the roof by nut-bolts. Then the main shaft is set on the base. The alignment of the windmill is done by wire.

The small shaft is set on the base by adjustment system. And also DC generator is set and adjusted by adjustment system. The main pulley of the main shaft and the small pulley of the small shaft are connected with the flat belt. Another big pulley of the small shaft and DC generator are connected with another flat belt. Volt meter is connected with the DC generator. The windmill is shown in the Fig. 4.

5.4 Working principle of the windmill

When wind strikes on the face of the blades, it rotates. Then the pulley of the main shaft rotates. The small pulley of the small shaft rotates which is connected with the pulley of the main shaft with flat belt. The big pulley of the small shaft rotates at the same rpm as small pulley does. DC generator is rotated by the big pulley of the small shaft which is connected with the flat belt. In this way rpm of the main shaft is increased by belt-pulley system.

Fig 4: Photograph of the windmill after installation

5.5 Data collection and analysis

After fabrication, erection and finally installation of the windmill data has been collected and analyzed for few days. Fig. 5 shows the variation RPM of the main shaft with daytime. The RPM ranges from 6 to 18 on the day.

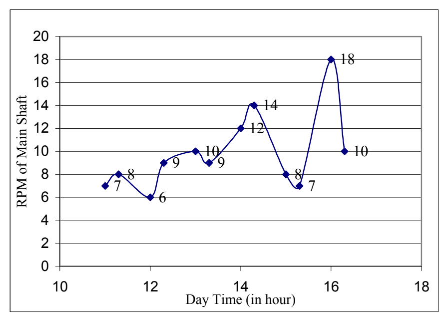

Fig 5: Daytime Vs RPM of the main shaft as on 23 August 2006

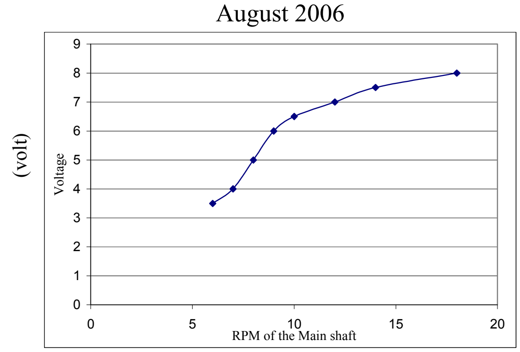

Fig 6: RPM of the main shaft Vs Voltage as on 23 August 2006

The voltage and current generation corresponding to the main shaft rotation are shown in Fig. 6 & 7 respectively. Fig.8 shows the variation of wind speed and rotation of the main shaft with time.

The RPM of the main shaft, wind velocity at the site and DC generator speed of the windmill for the period of 23 - 29 August of 2006 has been shown in Table 1.

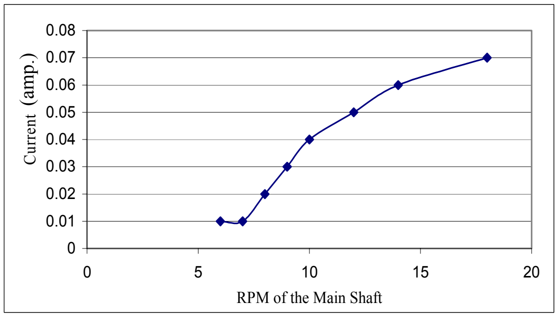

Fig 7: RPM of the main shaft Vs Current as on 23 August 2006

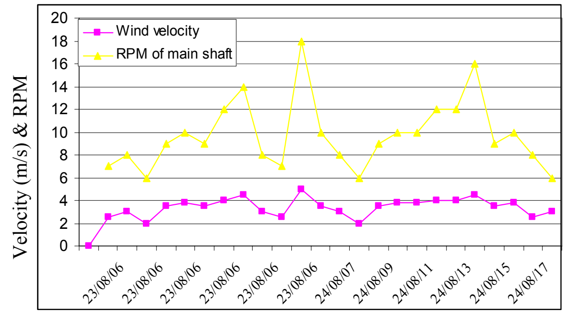

Fig 8: Pattern of RPM of the main shaft and wind speed with time.

Table 1: Data for the windmill

Time and date		11.00	11.30	12.00	12.30	13.00	13.30	14.00	14.30	15.00	15.30	16.00	16.30
23/08/06	RPM of main shaft	7	8	6	9	10	9	12	14	8	7	18	10
	Wind velocity (m/s)	2.5	3	2	3.5	3.8	3.5	4	4.5	3	2.5	5	3.5
	DC generator speed	1052.9	1203.3	902.5	1353.7	1504.1	1353.7	1805.0	2105.8	1203.3	1052.9	2707.5	1504.1
24/08/06	RPM of main shaft	8	6	9	10	10	12	12	16	9	10	8	6
	Wind velocity (m/s)	3	2	3.5	3.8	3.8	4	4	4.5	3.5	3.8	2.5	3
	DC generator speed	1203.3	902.5	1353.7	1504.1	1504.1	1805.0	1805.0	2406.6	1353.7	1504.1	1203.3	902.5
27/08/06	RPM of main shaft	6	8	7	9	10	9	12	14	8	7	12	10
	Wind velocity (m/s)	2	3	2.5	3.4	3.5	3.4	4	4.5	3	2.5	4	3.5
	DC generator speed	902.5	1203.3	1052.9	1353.7	1504.1	1353.7	1805.0	2105.8	1203.3	1052.9	1805.0	1504.1
28/08/06	RPM of main shaft	7	8	9	10	10	9	12	14	8	15	12	10
	Wind velocity (m/s)	2	3	3.4	3.5	3.5	3.4	4	4.5	3	4.8	4	3.5
	DC generator speed	1052.9	1203.3	1353.7	1504.1	1504.1	1353.7	1805.0	2105.8	1203.3	2256.2	1805.0	1504.1
29/08/06	RPM of main shaft	12	15	16	19	10	9	22	18	16	7	12	10
	Wind velocity (m/s)	4	4.8	4.5	5.5	3.5	3.4	7	5	4.5	2.5	4	3.5
	DC generator speed	1805.0	2256.2	2406.6	2857.9	1504.1	1353.7	3309.1	2707.5	2406.6	1052.9	1805.0	1504.1

Table 2: Power generation with corresponding rpm as on 02 September 2006

Time and date		12.00	12.30	13.00	13.30	14.00	14.30	15.00	15.30	16.00	16.30	17.00
02/09/06	RPM of main shaft	12	15	16	19	22	16	12	09	10	11	14
	DC generator speed	1805.0	2256.2	2406.6	2857.9	3309.1	2406.6	1805.0	1353.7	1504.1	1654.6	2105.8
	Power generated by DC Generator	7	7.8	7.9	10	15	7.9	7	6	6.5	6.8	7.5

Table 2 is showing the power generation by the windmill at different rotor speed. From the observation of the data table and figures, it can be said that the windmill is working well. The maximum obtained speed of the main shaft is 22 at the EME building at the noon of a day and the corresponding maximum power output is 15 volt.

There was no uniform flow of wind on the roof of the E.M.E building to rotate the windmill freely. From the measurement by an anemometer, it was found that for one rotation of the blade minimum 2 m/s wind flow was required.

6. CONCLUSIONS

From the analysis of the test data of the windmill installed at the roof of the EME building of CUET we could conclude that

1. The constructed windmill is working well. As the construction is very simple and locally available low-cost materials are used in construction, it could be manufactured in any workshop. Due to its low-cost and simple technology, it is affordable in respect to cost, operation and maintenance by the rural people of Bangladesh.
2. For rotation of the blade, the minimum required wind speed is 2m/s.
3. The maximum obtained rotational speed of the main shaft is 22 at the present location.
4. For maximum 22 rpm of the pulley of the main shaft, the DC generator rotates at 3309.1 rpm and thus the generated power output is 15 volts.

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