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Designing of a Small Scale Vertical Axis Wind Turbine & Its Performance Analysis in Respect of Bangladesh

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Abstract- Power crisis is one of the major problems in Bangladesh which is increasing day by day. In such situation renewable sources could be the best possible solution. But the power of the renewable sources varies with day time and climate. Electrical energy plays a vital role in development of civilization. The advancement of a country is measured in terms of per capital consumption of electrical energy. It is quite impossible to solve over all power crisis but possible to control load demand by using compact fluorescent lamp, transferring holiday, transfer from peak to off-peak hour only through proper planning by load management, encouraging Independent Power Producers, reducing transmission loss, more utilization of renewable energy sources. So, vertical axis wind turbine can play a vital role against this power crisis. This system is very much cost effective in the long run and also very much environmental friendly.

Keywords- Energy Crisis; Power; Renewable Energy; Wind Power; Vertical axes wind turbine; Wind Speed.

1. Introduction

Bangladesh is one of the world's poorest and most densely populated nations. Today only an estimated 49% of the Bangladesh population is connected to the electricity grid. The electricity supply is not reliable though and peak demand cannot be met. In the rural areas, where more than 70% of the population lives, only about 25% have electricity. In Bangladesh, 70 million of the populations out of 160 million do not have direct access to electricity and remaining 90 million people have access but reliable and quality power is still beyond their reach (BPDB, 2013). Here is a huge scarcity of electric power. Moreover the demand is increasing day by day. It is essential to set up Renewable plants for over demanding load. So, Vertical axis wind turbine plant can be chose to meet up this demand. This can be chosen because of its advantages in meet up the demand. So a demo of vertical axis wind turbine has been shown which increases its efficiency throughout the project work.

2. Wind Power and Structure of Wind Energy Conversion Systems

Wind power is a power that is producing with a turbine. It rotates by the force of wind and extracts power from the Wind. Wind is a form of solar energy. A Structure is shown in the figure 1, which delineates a simple Wind Energy Conversion process. Wind turbine uses wind force to rotate its blades. Wind turbine is connected through a 3-Phase generator. When the turbine rotates, it develops mechanical power. The mechanical power is then converted into electricity by the generator. The generator is connected with the supply bus with the help of inter connection apparatus. Then through the supply bus the electricity generated from wind power is used for different purposes.

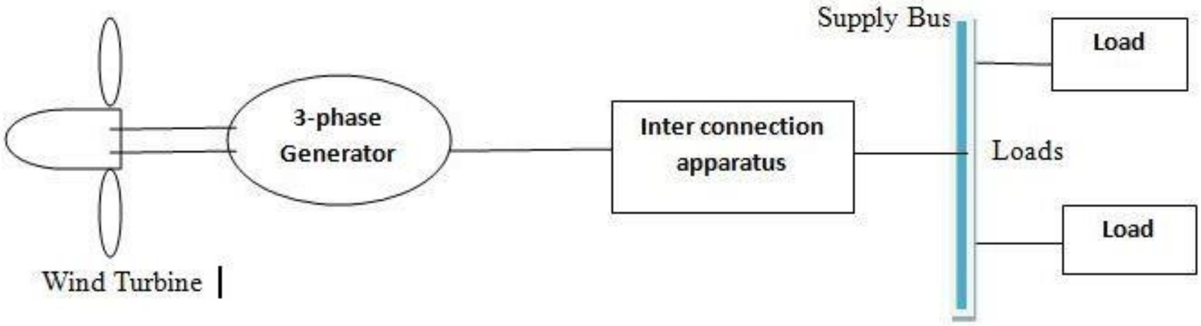


Figure 1. Wind energy conversion process

3. Vertical-axis Wind-Turbine and Basic Working Principle to Power Extraction

The Wind-Turbine which is set as vertically is known as Vertical Axis Wind-Turbine (VAWT). Vertically means, the position of the rotor shaft is vertical and the locations of the main components are at the base of the turbine. There are 3 main types of VAWT exists. They are: Darrieus type, Savonius type and Giromill type.

Figure 2. A simple vertical axes Wind-Turbine

A Wind-Turbine's working principle is quite simple. The mechanism depends on a factor, known as Power co-efficient (Cp). To get maximum power, most specified range of the power co-efficient Cp is 0.41 to 0.43. A block diagram in Figure 3 represents the basic working principle for the kinetic energy conversion system.

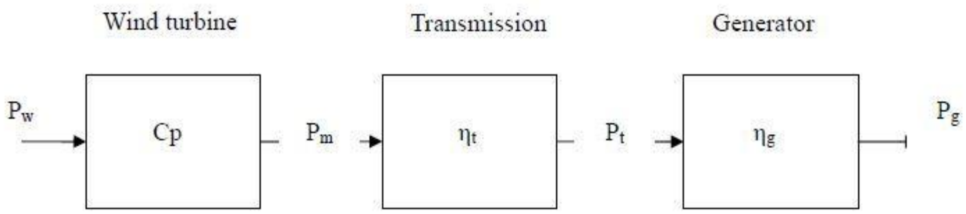


Figure 3. Block diagram of working principle of a wind turbine.

Where:

Pw= Wind Power input= Kinetic Power (P_{kin}) = $(1/2)*m*v^2$

Where: m= Mass flow= $\rho*A*v$ [kg/s]

ρ= Density [kg/m^3]

A= Area [m^2]

v= speed [m/s]

So, Kinetic Power (P_{kin}) can also be written as, $P_{kin}= (1/2)* \rho * A * v^3$

Cp= Power co-efficient

Pm= Mechanical Power output of the Wind Turbine

η_p= Efficiency of the turbine

Pt= Output Power of the turbine

η_g= Efficiency of the generator

Pg= Generator output Power

The mechanical power varies with the wind speed. For different Wind speed, Mechanical Power variations are shown in figure-4.

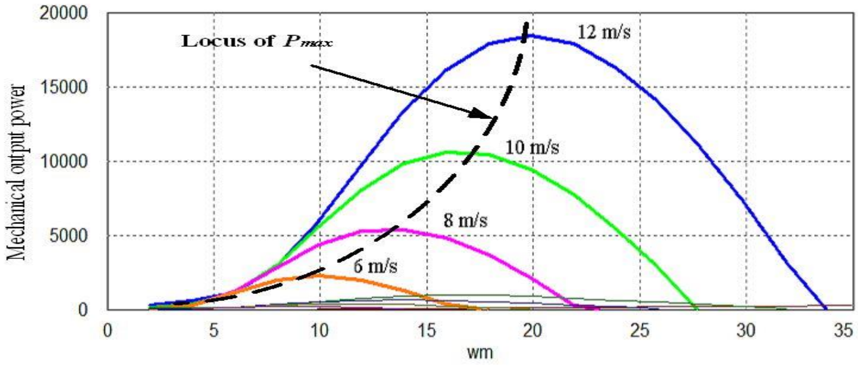


Figure 4. Mechanical power output of the Wind- Turbine for Wind speed variation.

The mechanical power also depends on the Drag and Lift force of the rotor.

Figure 5. Drag Based wind turbine concept

Figure 6. Lift Based wind turbine concept

4. Design Process of Vertical Axis Wind Turbine

4.1. Equipment:

Aluminium Sheet: Wind turbine blades have been fabricated from steel, aluminium, and composite materials such as wood, fibreglass, and carbon fibbers.

Steel Pipe: The tower consists of 2 steel pipe sections that are welded together by 4 gussets, which also act as guy rope attachments. On the top steel pipe a yaw pipe attachment is welded onto which the yaw pipe of the turbine will sit, by the use of 4 gussets with notches cut out of them. The tower is held up by 2 sets of guys, with 4 guys in each set. The guys are attached to the tower via gussets which are welded to the steel pipe sections. The guys themselves are steel wire rope, folded at each end with a thimble and wire rope grips, and attached to the gussets with shackles. The bottom of each guy is attached to a corkscrew anchor via a turnbuckle and short length of chain. The bottom of the tower has a channel of steel out of which the turbines cable can protrude. The bottom channel is attached to a base hinge made from steel angle, which allows the turbine to tilt up and down by the use of a winch and a gin pole.

Bearing: A bearing works as a controller that helps to move the rotating part in its desired motion. It is a machine component that drives the shifting of the moving portion of the turbine.

Dynamo: A dynamo is an electrical generator that produces direct current with the use of a commentator. For the vertical axis wind turbine it is an important component. It actually converts the rotation of the turbine into electrical energy. The main conversion of energy occurs here.

Penium gear: A moving part or circulating part that transmits torque within its adjacent tooth and controls the rotation of the turbine. As the turbine is not rotating that fast, that's why the penium gear was used here. A gear ratio 120/16 was used.

4.2. Designing Process:

The design of a Vertical axis wind turbine has several steps as follows:

Step-1: Lets Get Started

First thing is measuring the aluminium shit and cut the shit with perfect measurement. It was taken 15''/10'' as blade dimension.

Step-1

Step-2: Bending The Blade

Then the blade was bend into a certain angle. careful that the bending angle of every blade is equal. The number of blade used in this turbine was 4.

Step-2

Step-3: Attaching The Blade With Shaft

Then shaft was attached with the blade with the help of refit. A steel pipe with diameter of 25mm was used here.

Step-3

Step-4: Insertion Of Bearing

There is used 2 bearing with inner diameter 25mm. One of them placed 3inch below the blades. Another bearing was placed at the end on the pipe.

Step-4

Step-5: Placing the Penium Gear

Just under the blade gear was placed. The bigger wheel with 120 teeth and the smaller one having 16 teeth. The smaller penium is connected with the dynamo.

Step-5

Step-6: Frame Design

After welding the gear, the frame was designed. The physical model was made with iron. The stand is heavy that's why it can stand even the wind flow is high.

Step-6

5. Simulation and Result

Wind data were collected at Mirpur, Dhaka (Latitude: 23° 47'10.59" N, Longitude: 90° 22'37.06"E) of Bangladesh. Anemometer was used for the data collection.

The data for the last 3 years was collected and complied to get the simulated figure. HOMER was used to compile the data. After the data was compiled it was studied very carefully.

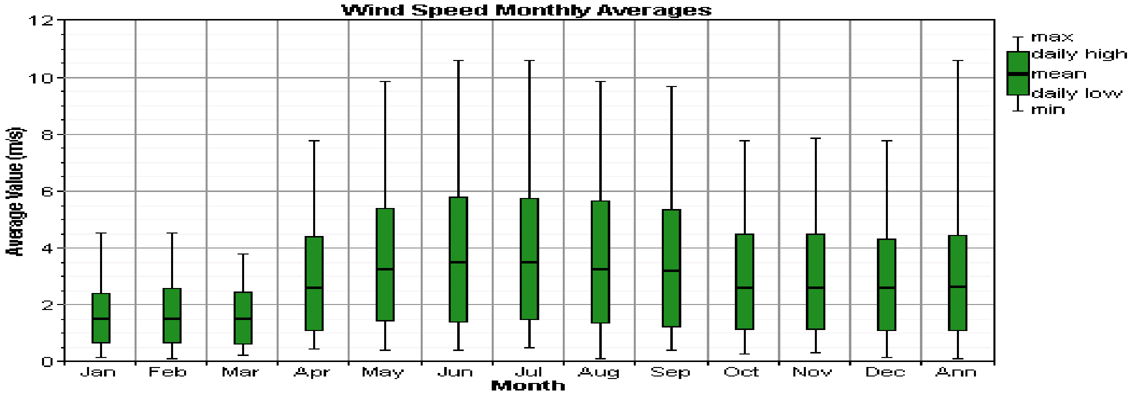


Figure 7. Wind Speed Monthly Average

Sample data & Recorded data for last 3 years were portrayed. Then the data was analysed in Homer and after the analysis several graphs were developed for that particular data. It was observed from the graph that the velocity of Wind is quite low & the maximum velocity of Wind is obtained in summer.

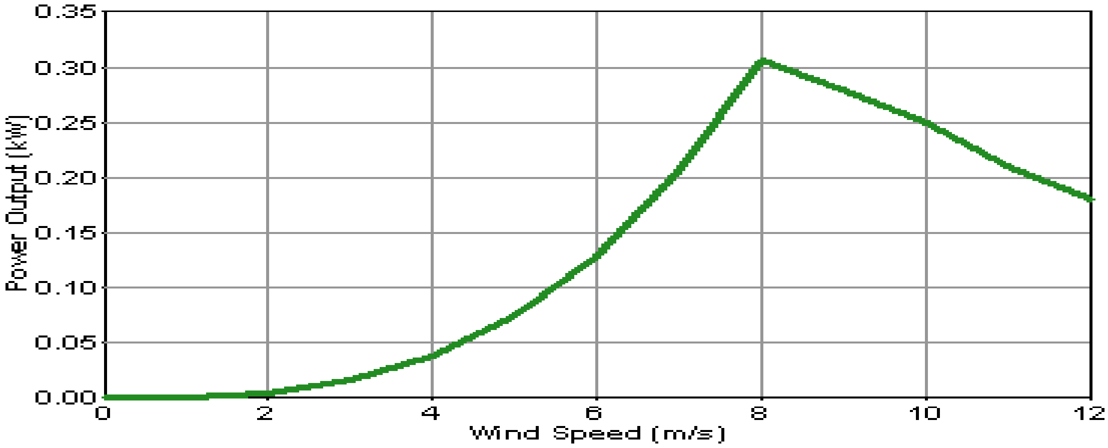


Figure 8. Power curve w.r.t wind speed

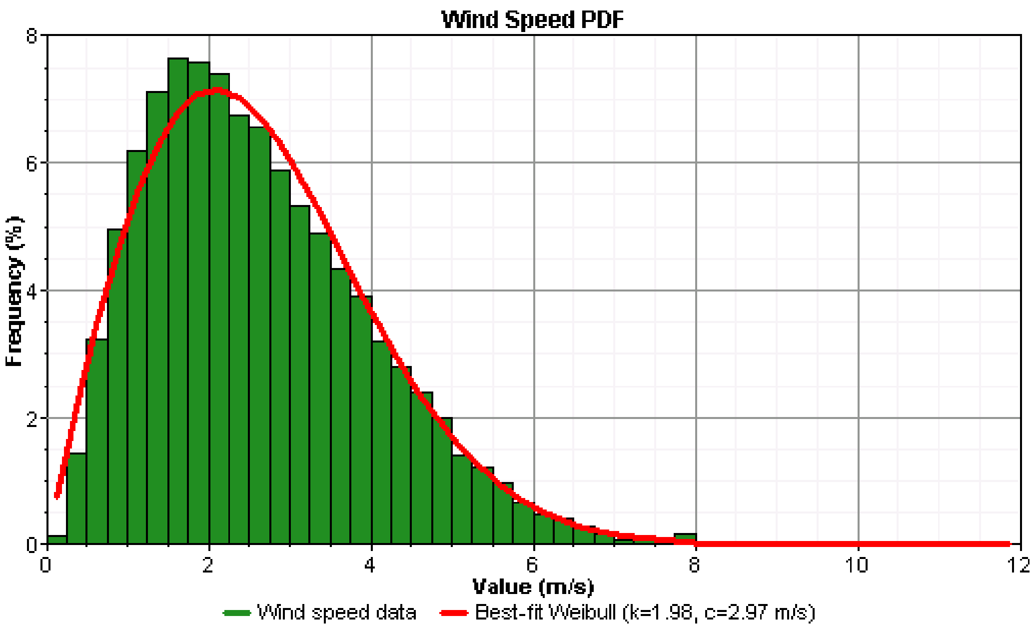
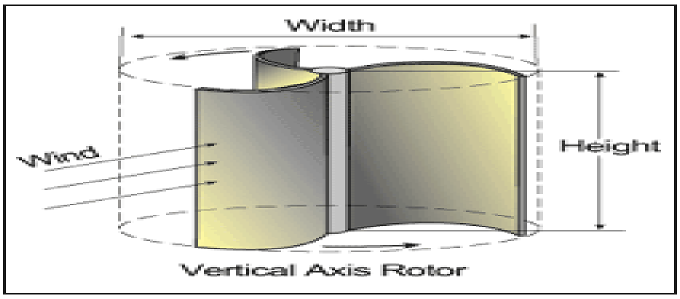
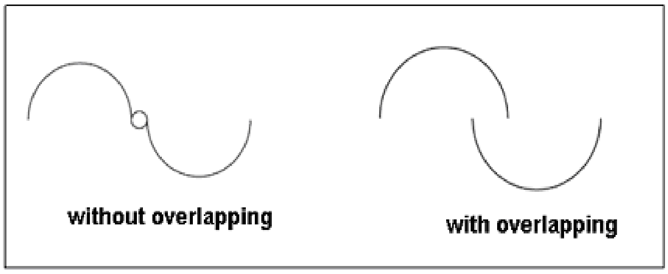


Figure 9. Sample Wind data from Mirpur, Dhaka

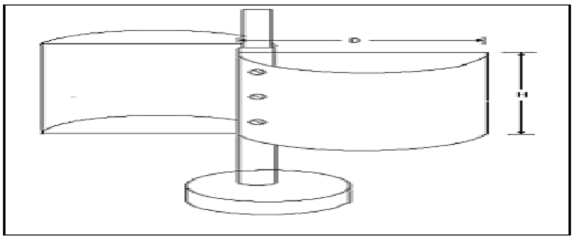
A Savonius rotor model, with and without overlap is shown in figure 10.



(a)



(b)



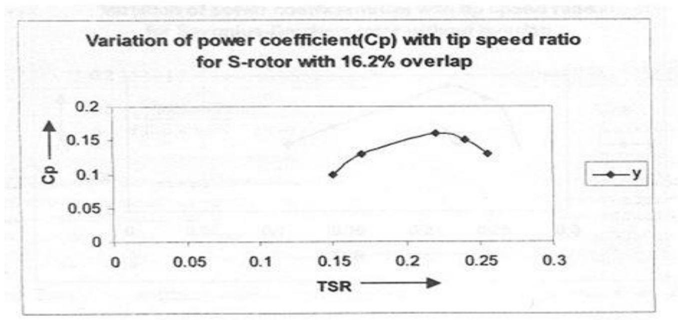
(c)

Figure 10. Savonius rotor model, with and without overlap

The Power coefficient (Cp) varies with the Tip speed ratio (TSR) for different values of overlapping. Experimental results for different overlapping are shown in figure 11.

i) The Power coefficient (Cp) = $\frac{Protor}{.5\rho V^2}$

ii) Tip speed ratio (λ) = $\frac{Velocity\ of\ blade\ tip}{Free\ stream\ velocity}$



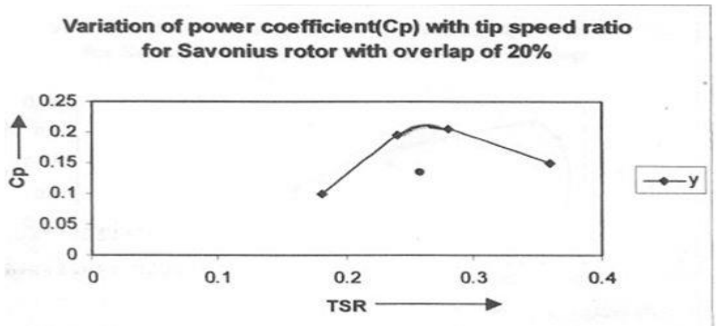


Figure 11. Graphs showing experimental results for different overlapping

From the experimental data and graphs [Figure 11], it is concluded that S-rotor with 20% overlap will give the maximum co-efficient of performance (Cp= 21% at 0.24 TSR)

Experimental result shows that,

Average wind speed at Mirpur, Dhaka is 2.63 m/s

Vertical axes Turbine (SAVONIUS) gives best results with 20% overlapping

Co-efficient of performance of S-rotor is 21% at 20% overlapping.

Construction cost of SAVONIUS Wind Turbine is around Tk: 6000

Figure 12 shows a sample Graphs from HOMER for a SAVONIUS Wind Turbine, 1 Battery and 1 inverter.

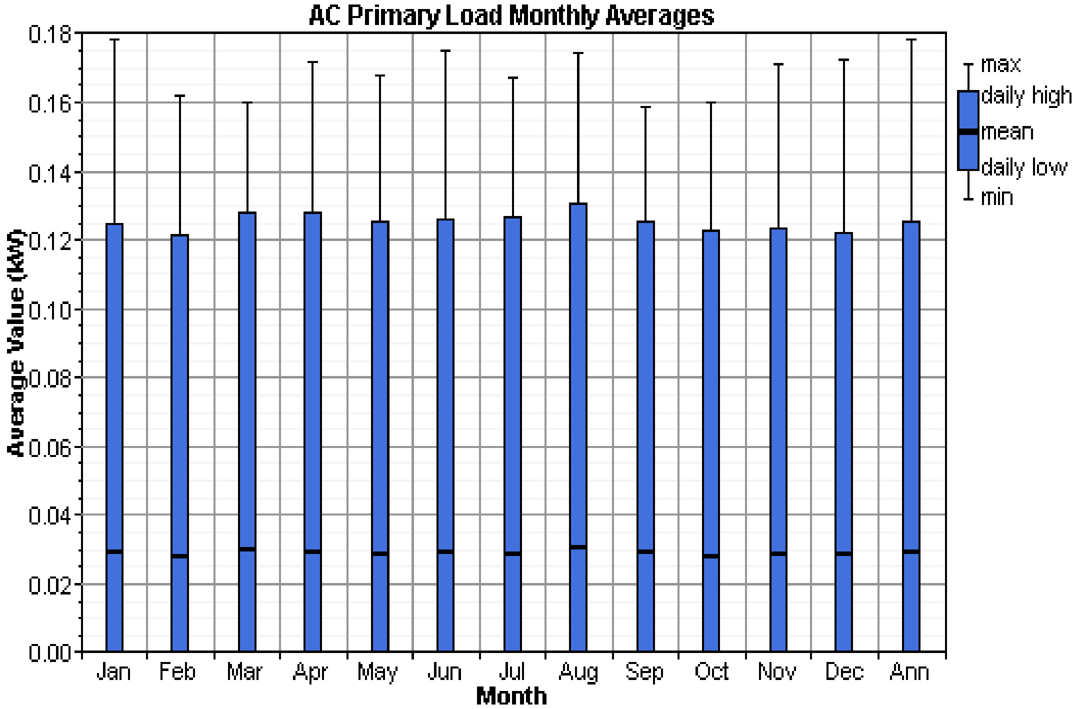


Figure 12. Sample Graphs from HOMER for a SAVONIUS Wind Turbine, 1 Battery and 1 inverter.

6. Conclusion & Future Work

The energy crisis is a vital problem for the development of Bangladesh. As a developing country and the scarcity of the non-renewable resources, Renewable energy is the best alternative to solve the power problem. With the Renewable sources like Solar, Biomass and tidal, wind energy as a non-polluting and non-toxic energy source also play a vital role. However, several Horizontal axis Wind turbine has been designed but the result was not so much encouraging. The problem is that, apart from the coastal area Wind velocity is relatively low and it also depends so much on the seasonal variations. This seasonal variations and low velocity affects the cost of the extraction of wind energy. This is why, a new approach has been tried to demonstrate here. A vertical axis wind turbine has been introduced to solve the energy crisis. The construction .cost of SAVONIUS Wind Turbine is calculated around Tk: 6000. Due to unavailability of necessary equipment total cost increased, as well as per unit energy generation cost increased. During gear design, gear ratio 120/16 was chosen. But if 120/10 that will be more efficient design. Another point is friction in the gear. The gear friction is too high that is why the rotation speed of the turbine is not that high. For overcoming this problem plastic gear can be used. Then the load will be light and the rotation will be smoother. The blade design is not totally perfect, though it was by hand. The curvature in the blade may be improved by designing the blade by using machine. So if this problem can be solved then an efficient VAWT can be built which was the main goal. By building efficient VAWT power problem can be solved.

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