100. Design and Development of Prototype Wind Concentrator Turbine

Daniya Khan, Muhammad Shahzad Jamil. Muhammad Aqeel Tariq*
[a]*Department of Energy Engineering Hamdard University Main campus Karachi, Pakistan*
E-mail address: dnkhan06@gmail.com

Abstract

Non-renewable energy resources have fueled the world's industrial compound for far too long. It has reached a point where the world is facing fast starvation in this sector. There are also other associated effects too which also need to be carefully looked at just to make sure things are running smoothly. With increased exploitation of these fossil fuels there are many environmental concerns like land pollution and air pollution which in turn affect whole ecosystem. Therefore a trend is observed that these non-renewable energy resources are replaced by renewable energy resources as Renewable energy is reliable, plentiful and will potentially be very cheap once technology and infrastructure is installed. Wind energy is a clean fuel source as it does not disturb the air quality like power plants that rely on combustion of fossil fuel. Therefore efforts are made to improve the efficiency of wind turbines. A wind concentrator is an enhancement made to wind turbine as it is a more efficient way to grasp wind energy. In the present study performance of savinious wind turbine with wind concentrator was studied experimentally. Lab scale test setup was developed and the experiments were performed by using forced air flow. It was observed that the application of concentrator is resulted in improvement of coefficient of performance of the system. The present system generated a power of 20 watt.

Keywords: *wind turbine, wind concentrator, renewable energy, coefficient of performance*

1. Introduction

Energy resources such as coal and oil are used to produce electric power since long time ago. But, this process produce tremendous amount of greenhouse gases that primarily have serious environmental impacts. These gases have terribly disturbed our ecosystem [1]. Due to these sever problems associated with health and environment these fossil fuel are being depleted ,therefore scientists are showing their concerns towards alternative energy resources such as solar , wind , hydro , biomass etc. These, alternatives are intended to overcome the concerns related to fossil fuel. An important factor in global warming is carbon dioxide gas emissions which are a major component of fossil fuel burning. So, energy extracted from renewable energy resources (alternative energy resources) is produced without the undesirable out-turn innate in fossil fuel use. In the search of clean and safe renewable energy sources wind power is undoubted one of the most beneficial solutions [2]. But, the most irregular behaviour for the wind is its erratic nature. In addition, this variability exists over an extensive diversity of scales both in space and time. This is important because energy that is extracted from the wind varies with cube of wind velocity. Generally more wind is received on the top of mountains rather than low level areas. The power of the wind is proportional to the cube of wind velocity. The general formula for wind power is

$$P = \frac{1}{2}\rho A V^3 \quad (1)$$

As wind energy is a clean fuel therefore efforts are made to improve the efficiency of wind turbines [3]. So with relative and comparative studies of different research work done in past about the augmentation of wind turbines efficiency include wind turbine concentrators and diffusers as well which were able to increase wind velocity by 2 to 6 times [4]. The basic idea behind the concept is that wind concentrators are designed to overcome the problems associated with the turbulent wind flow and low velocity regions by providing structural and aerodynamic advantages. So it increase the velocity at outlet where turbine is placed.

2. Aims and Objective of Our Project

Objectives of the present projects are

- The objective of this project is to design and build a concentrator that will increase the wind velocity with factor of two. And is capable of producing power by using savonius wind turbine.
- To study performance of savonius wind turbine , installed in the concentrator frame work
- To measure the power output, torque and rotational speed.
- Performance, testing, analysis of designed wind turbine in natural as well as in forced air.

3. Design and Fabrication of Test-Setup

The whole concept of concentrator is based on the duct and nozzle theory which helps to enhance the wind speed by two times of the inlet velocity. The inlet velocity strikes the wind turbine. Larger the mass of air it will increase its inlet velocity.

Through various studies of preceding concentrator designs it was intended to design a duct type structure that may be effective for either one-dimensional or multi-dimensional concentration of incoming air. The design consists of conical frustums and a symmetric quad arrangement of rhombus plates. Figure 1 represents the assembly of the whole test setup with labelled part. Figure 3 represents the structure of actual model.

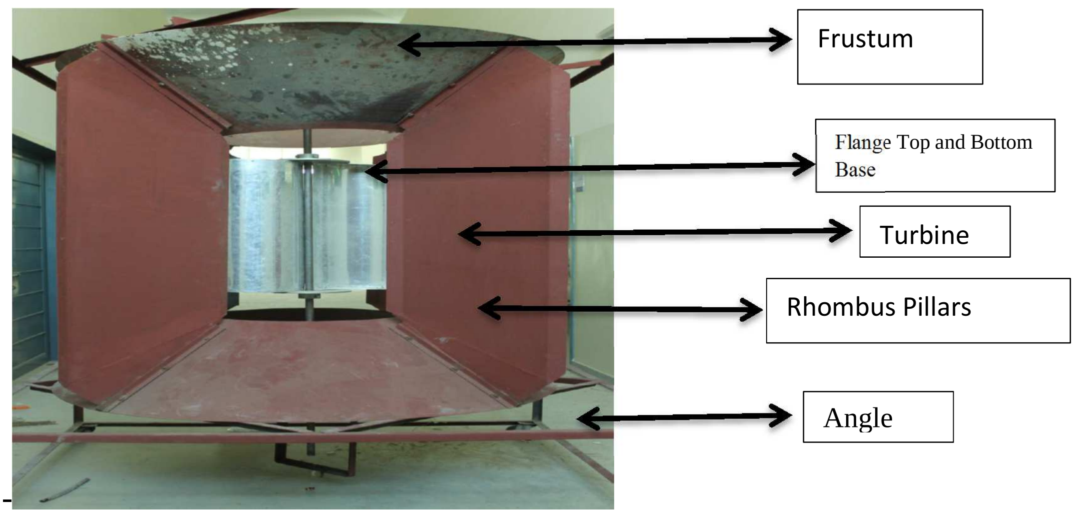

Fig. 1. Design Model of Test Setup

3.1 Dimension & Calculation

The formula for calculating frustum is:

$$V = \frac{1}{3} \times \pi \times h\left(R_2{}^2 + R_2 \times R_1 + R_1{}^2\right) \quad (2)$$

As, the volume of frustum with thickness 2.5 mm,

Slope = 23 inch

$R_1 = 29.5 + 2(0.0984) = 29.6968$ inch, $R_2 = 11.5 + 2(0.0984) = 11.6968$ inch, $h = 15$ inch

$$V = \frac{1}{3} \times \pi \times 15(11.6968^2 + (11.6968)(29.6968) + 29.6968^2)$$

$$V = 21458.218 \text{ m}^3$$

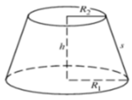

Fig. 2. Graphical Representation of Frustum

3.2 Design of Rhombus Pillars

The pillars are like rhombus shape welded with angle which is used to join the two frustums together one at the top and one at the bottom. Figure 3 represents

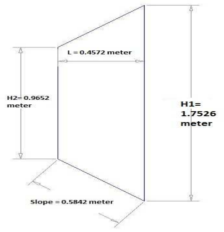

Fig.3. Front Views of rhombus pillars

3.3 Flange top and bottom base

Sleeve length=0.0508 meter**,** Sleeve thickness = 0.0127 meter**,** Plate thickness =5x10ˆ-3 meterThe pictorial view of flange top and bottom base is illustrated in figure 4.

Fig.4. Flange top and bottom base

3.4 Dimension of Shaft Used

Height = 2.4384 meter, Diameter = 0.0254 meter

3.5 Dimensions of pulley

Small Pulley Diameter: 12 x 10^-3 Meter

Large Pulley Diameter: 241.3 x 10^-3 Meter

Fig.5. Pulleys

3.6 Specifications of Permanent Magnet Generator Used

RPM = 2720 RPM, Power = 30 Watts, Voltage = 24 Volts, Current = 1.25 Ampere

3.7 Analysis of Concentrator

Larger Radius (R_1) = 29.5 inch, Circumference = $\mathbf{2\pi R_1 = 2\pi\ (29.5)}$ = **185.354 inch**

Smaller Radius (R_2) = 11.5 inch, Circumference = $\mathbf{2\pi R_2 = 2\pi\ (11.5)}$ = **72.256 inch**

3.8 Area at the inlet of air

Height = 69 inch, R_1 = 29.5 inch, Width = $\frac{2*\pi*R_1}{4} = \frac{2*\pi*29.5}{4}$ = **46.347 inch**

$A_1 = h \times b$

$= 69 \times 46.347 =$ **3197.943 inch²**

3.9 Area at the outlet

Height = 38 inch, R_2 = 11.5 inch , Width = $\frac{2*\pi*R_2}{4} = \frac{2*\pi*11.5}{4}$ = **18.064 inch**

So, $A2 = h \times b = 38 \times 18.064 =$ **686.432 inch²**

Theoretical assumption is to be made for concentrator design. The wind speed is to be assumed 2m/s. Thus the concentrator will concentrate it by according to continuity equation;

$\rho A_1 \overline{V_1} = \rho A_2 \overline{V_2}$

Hence the equation remains:

$A_1 \overline{V_1} = A_2 \overline{V_2},$

Where,

A_1 = Area at the inlet of air = **3197.943 inch²** **(Calculated),** A_2 = Area at the outlet of air = **686.432 inch²** **(Calculated),** V_1 = velocity at inlet =2 m/s (assumed),V_2 = velocity at outlet

$$V_2 = \frac{A_1}{A_2} * V_1$$

$$V_2 = \frac{3197.943 \times 2}{686.432}$$

$$V_2 = \mathbf{9.3176\ m/s}$$

4. Material Selection

Factors that considered in selection of material are cost, strength, toughness, corrosion, reliable considering all these factors mild steel is selected.

5. Blades of Savonius Wind Turbine

Blades of savonius wind turbine are made up of aluminum sheets figure 6 represents the four blade geometry of designed savonius wind turbine. The length of each blade is 0.6858 meter.

Fig. 6 Blades of wind turbine

6. Results and discussion

The aim of this project was to study the various factors on the performance of wind concentrator turbine in the local wind at Hamdard University and with forced wind as well. Test results prove that the concentrator is able to increase the wind velocity 2 times at the outlet of the duct where savonius turbine is placed on the shaft between flange top and bottom space. The concentrator is tested with local wind to attain the optimum concentration rate. As the wind fluctuates every single moment due to the power generation rate will not be achieved. Due to this reason axial blower was used to get best power output. The designed test setup is able to produce 20 watt of electricity. The concentrator is tested by using variable blades of savonius wind turbine to study the effect of concentrator by varying blades the results in the graph as well as in tabular forms are given below. The system developed for the present study was designed to provide flexibility for the change of no of blades for savonius wind turbine. With this provision three different configuration of savonius turbine were achieved i.e two blade, three blade and 4 blades. Experiments were conducted for all three setups by varying the wind speed from the cut in speed 0.5 m/s to be maximum of 6.2 m/s.

Average Wind Speed at Hamdard University

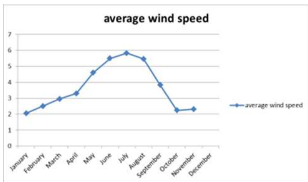

Fig. 7. Average wind speed available in Hamdard University for 12 months [5].

6.1 Concentration ratio in natural wind without connecting load on 3rd march 2016

The setup was placed in open air to find the concentration ratio of the concentrator. The wind velocity at the inlet of the concentrator and the outlet of the concentrator was recorded. The results are given in graphical form below.

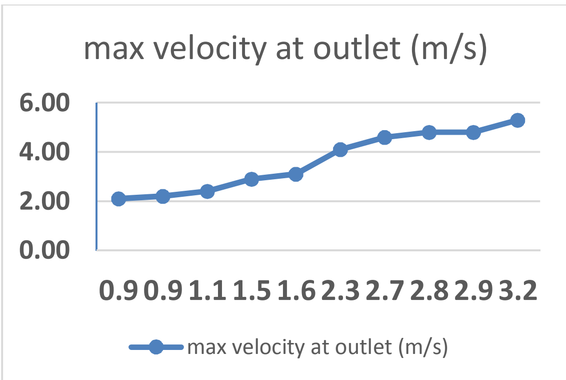

Fig. 8. Concentration rates in natural wind on 3rd march 2016

From the above results it was observed that for all the rated wind speed the concentration ratio is about twice the inlet air which is nearly 50% of the theoretical calculation. This could be fiction effect of material used.

6.2 Testing with two blades of turbine in forced air

Savonius wind turbine with two blades was placed in concentrator and the results obtained are represented in and graphical form

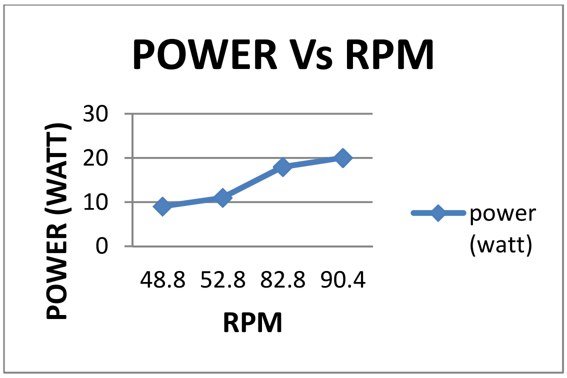

Fig. 9. Graph of Power Vs RPM with two Blades

From the results it was found that the turbine can produce 9 watt at the 48.8 RPM with cut-in speed of 2.1 m/s which was observed by anemometer at the time of experiment and 20 wattat 90.4 RPM for the higher speed of 6.2 m/s(noted with anemometer).

6.3 Testing With 3 blades in forced air

Savonius wind turbine with three blades was placed in concentrator and the results obtained are, represented in and graphical form.

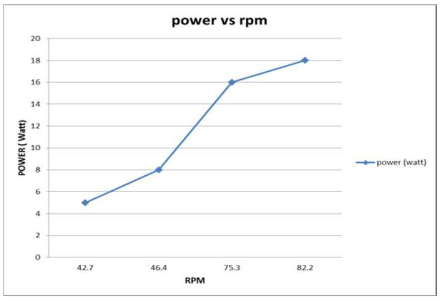

Fig. 10. Graph of RPM Vs Power with 3 blades

From the results it was found that the turbine can produce 5 watt at 42.7 RPM with the cut-in speed of 2.1 m/s and 18 watt for the higher speed of 6.2 m/s which was observed at the time of experiment with 82.7 RPM.

6.4 Testing with 4 Blades in Forced Air

Savonius wind turbine with four blades was placed in concentrator and the results obtained are represented in and graphical form

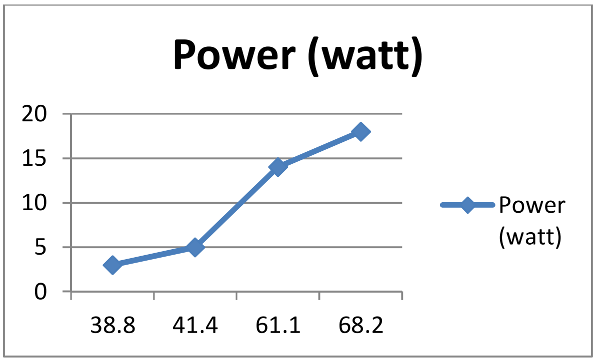

Fig. 11. Graph of Power Vs RPM with 4 Blades

From the result it was found that the turbine can produce 3 watt at 38.8 RPM with the cut-in speed of 2.1m/s and 15 watt for the higher speed of 6.2m/s at 68.2 RPM where cut-in speed is observed with anemometer at the time of experiment.

7. Conclusions

From the experimental results it was concluded that

- The concentrators have a beneficial effect on the performance of savonius wind turbine in terms of cut in speed.
- 2-blade configuration was found more efficient as compared to the other configurations.
- The performance of 3-blade configuration lies intermediate between 2 and 4-blade configurations.
- Cut-in speed= 0.5 m/s (for LED) at a distance of 4.2672 meter.
- Cut off speed=6.2 m/s (for 40 LED), at a distance of 0.9144 meter.

Acknowledgements

Dr. Ahmed Hussain (tenure track professor at NED)

Muhammad Shahzad Jameel

Muhammad Aqeel Tariq

References

[1] Non-Renewable energy Sources. [online] http://www.conserve-energy-future.com/NonRenewableEnergySources.php.

[2] Importance of Renewable energy Sources. [online] http://homeguides.sfgate.com/importance-renewable-resources-energy-79690.html.

[3] Wind Energy. [online] http://wind-energy.ucoz.com/.

[4] Wind Concentrator. [online] http://www.technology.stfc.ac.uk/ERU/testfacility_windconcentrator.html.

[5] Average Weather for Karachi Pakistan. [online] https://weatherspark.com/averages/32864/Karachi-Sindh-Pakistan.