Design, Analysis and Fabrication of Vertical Axis Wind Turbine

Swami Karan[1] Yadav Arpit[2] Zala Yuvraj[3] Prajapati Siddharth[4] Prof. Dharmendra Sapariya[5]
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Indus Institute of Technology & Engineering, Ahmedabad, India

Abstract— We know that the world electrical consumption is increasing day by day. Wind and Solar are the two-main renewable source which can help face this electricity crisis. HAWT are efficient but they require high velocity wind and high altitude to work. On the other hand, VAWT can produce electricity at lower altitude. As we know, vehicle plays an important role in providing short range high velocity wind flow. This wind flow can be effectively used by placing a VAWT on the median of the road and capturing wind energy and converting it into rotational energy and then to electrical energy. The aim of this work is to design and develop a new Savonius type vertical axis wind turbine which uses wind flow from vehicle and convert it into electrical energy for small scale energy applications.

Key words: Energy Generation, Renewable Energy, Vertical Axis Wind Turbine, Wind Energy

I. INTRODUCTION

Renewable energy is normally defined as the energy which comes from naturally replenished resources on a human time scheme as like that wind, tides, sunlight, rain, geothermal heat and waves. Around 16% of the global annual consumption of energy comes from renewable energy sources. About 30 countries all over the world have renewable energy contribution greater than 20% of their energy supply. Development of wind energy use in urban environments is of growing interest to industry and local governments as an alternative to utility-based and non-renewable forms of electric production. In future, the use of wind turbine is going to increase and especially vertical axis wind turbine as it has number of advantage over horizontal axis wind turbine.

A. Electricity Consumption

Electricity consumption of a street light varies from area to area. Usually lamps in street light vary both in size and consumption ranging from 30W to 250W. But nowadays, new LED bulb of 60W capacity which are quite efficient are used in street lights.

A detailed data shows that around 18-20% of electricity bills in 90% of countries go towards street light. So, it is a major problem and thus VAWT can be useful in powering the street light.

In India, the electricity demand is more than electricity production and so is the reason of unavailability of electricity in villages. So, if we use VAWT for small scale application, we can satisfy this need to a great extent.

B. Review of existing work

Before proceeding with the conceptual studies, a study about the few types of VAWT had been carried out in order to choose the suitable VAWT as the base design and come out of the conceptual design with modification on it. The types of VAWT are listed below in figure 1.0

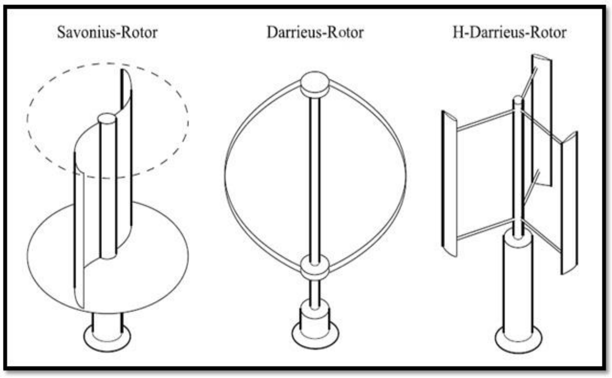


Fig. 2.1.1: Types of VAWT

C. Advantages

1) Independence on wind direction, no additional control mechanisms are required.
2) Ability to operate in a wide range of wind conditions (turbulence level, wind speed).
3) Electrical equipment can be placed at ground level.
4) Low noise emission.
5) High starting torque.
6) Compact size.
7) Simple and cheap construction.

D. Selection Criteria

Selection was based on different criteria, such as Self-starting, Noise, Cost, Efficiency and Stability of structure. Savonius Wind turbine is self- starting, low in noise compared to others. But, there are some demerits like low efficiency. But, as it has more advantage that is why, Savonius type VAWT is used.

The Savonius rotor is widely considered to be a drag driven device. This indicates that the wind drag, acting on its blades, is the only driving force. However, it has been observed that at low angles of attack the lift force also contributes to the overall torque generation.

Thus, it can be concluded that the Savonius rotor is not a solely drag driven machine but a combination of a drag-driven and lift-driven device. Therefore, it can go beyond the limit of Cp established for the purely drag-driven machines (0.08). The idea of this turbine was proposed by Sigurd Johannes Savonius in 1922. But for many years it was not widely applied. However, recently its popularity has steadily grown. This results from the increasing significance of urbanized areas, which have specific demands. The Savonius rotor seems to satisfy these particular expectations.

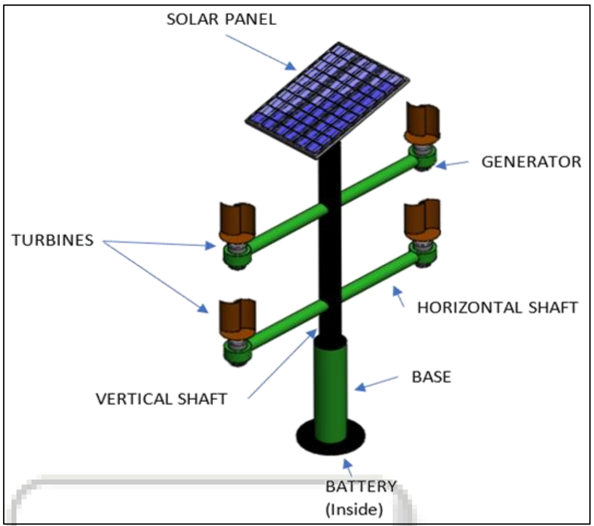
II. DESIGN OF SAVONIUS TURBINE

Following things were considered in making a VAWT.

1) Wind speed – It is the main factor as power is only generated due to wind flow. Greater the velocity of wind more the power generated.

2) Blade Length – Larger blade length is directly proportional to swept area. More the swept area more wind captured and more torque generated.
3) Base Height – Base height is an important factor. If the height is in max wind flow altitude then it will give optimum results.
4) Base design – A strong design is must in order to sustain weight of components and drag of the wind.

A. *CAD design*



B. *Parts*

– Shaft – They acts as a supporting structure or frame.
– Rotor – It is the main part which rotates in wind and is connected to generator.
– Generator – It converts rotational energy into electrical energy.
– Solar Panel – It is used to produce additional power and utilize the space.
– Battery – It is used to store electricity generated.
– Diode – It is used so that current from battery does not flow reverse direction.

C. *Aspect Ratio*

Aspect Ratio is an important factor to evaluate aerodynamic performance of Savonius rotor. Johnson (1994) suggested that with rotor height twice its diameter, the stability of rotor increases with proper efficiency. It is dimensionless.

$$A.R. = H/D$$

Where, A.R. – Aspect Ratio.
H – Height of Rotor.
D – Diameter of Rotor.

D. *Tip Speed Ratio*

Tip Speed ratio, λ is defined as the ratio of linear speed of rotor blade (ω*R) to the undistributed wind speed (V).

$$\lambda = \omega*R/V$$

Where, λ – Tip Speed Ratio.
ω – Angular velocity.
V – Wind speed.
R – Radius of revolving part of turbine.
For, 2 bladed rotor – 6-7 T.S.R.
3 bladed rotor – 5-6 T.S.R.
5 bladed rotor – 2-3 T.S.R.

E. *Solidity*

According to Manwell, solidity is related to tip speed ratio. A high tip speed ratio will result in a low solidity. Musgrove defines solidity as the ratio of blade area to the turbine rotor swept area.
For VAWT, the solidity is defined as: -

$$\sigma = n*d/R$$

Where, n – Number of blades.
d – Chord length or can be defined as the diameter of each half cylinder.
R – Radius of wind turbine.

Many researchers have proved that the higher the number of blades, the higher the performance of most wind turbine. However, Saha et al., (2008) and Zhao et al., (2009) found that the two-bladed Savonius rotor has higher performance than three-bladed Savonius rotor. Referring to Saha then the two-blade rotor has been chosen for this project.

F. *Calculation*

As, we know we have a power requirement of 60 W/hr. We can find the diameter and height of rotor from that.
– Number of blades (N) = 2.
– Density of air (ρ) = 1.225 kg/m^3.
– Po = 60 W/hr.
– Co-efficient of performance (Cp) = 0.4 (for 2 bladed rotor).
– T.S.R. (λ) = 6.
– A.R. = 1.
– Average velocity of vehicle on highway (Vo) = 60 km/hr = 16.67 m/s.

Now, A.R. = H/D = 1.
So, H=D.
S = Swept Area = H*D = D^2.
Cp = Po/Pw.
Pw = Po/Cp.
= 60/0.4 = 150 W/hr.
So, Pw = 0.5*ρ*S*(Vo^3)
150 = 0.5*1.225*(D^2) *(16.67^3)
D = 230 mm = H.

Here, the material used for making rotor is plastic fibre. It is used because it is light weight and high strength.

G. *Design of frame*

As we know,
Average height of a car = 5 – 6 ft.
Average height of a truck/bus = 10 – 12 ft.
Height of the divider on a highway = 2 – 3 ft.
Width of the divider = 3 – 4 ft.
So, Min altitude for turbine should be = 5 ft.
Max width of turbine should be = 4 ft.
Here, we are using 4 VAWT to make effective use of wind flow from truck and buses.
Height of base = 1.5 ft.
Diameter of base = 0.3 ft.
Height of vertical shaft = 3.18 ft.
Diameter of vertical shaft = 0.2 ft.
Length of horizontal shaft = 3.2 ft.
So, altitude of bottom turbine = 5.5 ft.

Here, the material used for base and other supporting structure is MS-E250 because of it good machining properties and strength.

H. Design of Generator

Generator is required to convert the mechanical energy generated by the turbine into electrical energy. In this application, since the wind speed is not constant, the rotational speed of the turbine will be varying frequently. Therefore, variable speed generators should be used here. In wind turbine applications the commonly used generators are DC generators or permanent magnet synchronous generators. Also, since the rotational speed of the turbine will be low, the generator should be of low rpm rating.

Here, a single phase PMSG of ratings 10A, 12 V, 30 rpm is used for conversion of electrical energy into mechanical energy.

I. Solar panel.

Solar panel is used to effectively use the solar panel and to produce additional power. Here, a 5W rated solar panel is used.

III. CONCLUSION

Even with the development of more efficient and less electricity consuming device, the need for electricity is increasing day by day. So, the proposed model of Vertical Axis Wind Turbine will be good source of renewable energy on highway. The wind energy from vehicle running on highway can be effectively utilized and converted into electric energy which can be stored in a battery and used for small scale purpose like street lightning, traffic light, traffic cameras, Railway crossing etc. This design concept is sustainable and environmentally friendly. In future, they might be very much helpful in overcoming the energy crisis in the world.

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