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ELECTRICITY GENERATION USING VERTICAL AXIS WIND TURBINE:DESIGN AND DEVELOPMENT

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ABSTRACT

The goal of this work is to build avertical axis wind turbine and measure the power generated. The model uses aSavonius type of VAWT.TheSavonius model can be adjusted to change the number of scoops (blades). Savonius wind turbines are used for converting the force of the wind into torque on a rotating shaft. The Savonius turbine is one of the simplest turbines. The current scenario of electricity in our country is quite low, especially in the rural area.The aim of this study to provide a platform for the person or individual use such as household electricity.In India, there ismuch use of petroleum and other conventional sources such as coal,etc., due to thehuge demand of these resources the shortage of coal and other resources may occur shortly. Keeping in our mind the current situation of our country especially rural areas, we construct a VAWT for the individual user. The main advantage of our project is that it is very low in price and easy maintenance.

Keywords:VAWT, Savonius, Wind Turbine

I. INTRODUCTION

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.The Wind is a form of solar energy.Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity.The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity as shown in figure 1. Wind turbines convert the kinetic energy in the wind into mechanical power.This mechanical power can be used for specific tasks (such as grinding grain or pumping water), or a generator can convert this mechanical power into electricity to power homes or social purposes.

Figure 1. Rotation of wind turbine

The wind in India are influenced by the strong south-west summer monsoon, which starts in May-June, when cool, humid air moves towards the land and the weaker north-east winter monsoon, which starts in October, when cool, dry air moves towards the ocean. During the period March to August, the winds are uniformly strong over the whole Indian Peninsula, except the eastern peninsular coast. Wind speeds during the period November to march are relatively weak, though higher winds are available during a part of the period on the Tamil Nadu coastline.

II. WORKING PRINCIPLE

The Wind is caused by the uneven heating of the atmosphere by the sun, variations in the earth's surface, and rotation of the earth. Mountains, bodies of water, and vegetation all influence wind flow patterns. Wind turbines convert the energy in the wind to electricity by rotating propeller-like blades around a rotor. The rotor turns the drive shaft, which turns an electric generator. Three key factors affect theamount of energy a turbine can harness from the wind are wind speed, air density and swept thearea.

The equation for Wind Power is:

$$P= \underline{1}\rho\ AV^{3}2$$

Wind speed

The amount of energy in the wind varies with the cube of the wind speed, in other words, if the wind speed doubles, there is eight times more energy in the wind. Small changes in wind speed have a large impact on the amount of power available in the wind.

Density of the air

Thedenserthe air, the more energy received by the turbine. Air density varies with elevation and temperature. Air is less dense at higher elevations than at sea level, and warm air is less dense than cold air.

Swept area of the turbine

The larger the swept area (the size of the area through which the rotor spins), the more power the turbine can capture from the wind. Since the swept areais

$$A = pir^2,$$

where r = radius of the rotor, a small increase in blade length results in a larger increase in the power available to the turbine.

Types of wind turbine

1) horizontal axis wind turbine
2) vertical axis wind turbine

Horizontal Axis Wind Turbine

The rotor of the horizontal axis wind turbine rotates around a horizontal axis, and during working, the rotating plane is vertical to the wind direction. The blades of the wind turbine are installed perpendicularly to the rotating axis, and form a certain angle.The number of the blades depends on the function of the wind turbine. The wind turbine with more blades is often called as the Low-speed Wind Turbine, and when it works at low speed, it will gain a high ratio of utilization of the wind and high torque. The wind turbine with fewer blades is often named as the High-speed Wind Turbine, and when it works at high speed, it will gain a high ratio of utilization of the wind, but the starting wind speed should be high. Because of its fewer blades, in the same condition of power, the rotor of the Low-speed is much lighter, so it is suitable to generate power.The horizontal axis wind turbine can also be divided into the Lift-type Wind Turbine and the Resistance-type Wind Turbine, and the former has a high rotating speed, while the latter has a low rotating speed.

Vertical Axis Wind Turbine

The other major classification for wind turbines is vertical axis wind turbines. These turbines spin on a vertical axis.

This turbine is an example of a commercially used vertical axis turbine. One of the major problems with vertical axis wind turbines is that an initial force is required to start the turbine's spinning. Another issue is that they are difficult to be designed for high altitudes.The blades on a vertical axis wind turbine can utilize an airfoil design like the VAWT; however, a VAWT can also use blades that directly face the wind.VAWT come in different types,but all share the feature that the main rotor shaft is arranged vertically (and not horizontally).VAWT are considered easier to install and maintain as the generator, and other primary components can be placed near the ground.

Savonius Application for Domestic Purpose

- Savonius turbines are used whenever cost or reliability is much more important than efficiency.
- Most anemometers are Savonius turbines for this reason, as efficiency is irrelevant to the application of measuring wind speed.
- Much larger Savonius turbines have been used to generate electric power on deep-water buoys, which need small amounts of power and get very little maintenance.
- The design is simplified because, unlike with horizontal axis wind turbines (HAWTs), no pointing mechanism is required to allow for shifting wind direction and the turbine is self-starting.
- Savonius and other vertical-axis machines are good at pumping water and other high torque, low rpm applications and are not usually connected to electric power grids. They can sometimes have long helical scoops, to give smooth torque.Small Savonius wind turbines are sometimes seen used as advertising signs where the rotation helps to draw attention to the item advertised

Principles of Savonius Rotor Wind Turbine

Savonius turbines are one of the simplest turbines. Aerodynamically, they are drag-type devices, consisting of two or three blades. A two blades savonius wind turbine would look like an "S" letter shape incross-section.The savonius wind turbine works due to the difference in forces exerted on each blade. The lower blade caught the air wind and forcedthe blade to rotate around its central vertical shaft. Whereas, the upper blade hits the blade and causes the air wind to be deflected sideways around it. Experimental Comparison Study for Savonius wind Turbine of two andthree Blades at Low wind speed because of the curvature of the blade, the blades experience less drag force when moving against the wind than the blades when moving with the wind. Hence, the half cylinder with theconcave side facing the wind will experience more drag force than the other cylinder, thus forcing the rotor to rotate.The differential drag causes the Savonius turbine to spin. For this reason, Savonius turbines extract much less of the wind's power than other similarly sized lift type turbines because much of the power that might be captured has used up pushing the convex half, so savonius wind turbine has a lower efficiency. Similarly, the threebladessavonius wind turbine is constructed from three half cylinders, they are arranged at (120^o) relative to each other.

Basic Concept of Savonius VAWT

The performance of savonius wind turbine can be explained according to the following three basic rules that are still applicable.

1. The speed of the blade tips is ideally proportional to the speed of thewind.

2. The maximum torque is proportional to the speed of wind squared.

3. The maximum power is proportional to the speed of wind cubed.

The performance of any wind turbine can be expressed in the form of torque coefficient (Ct) and the coefficient of power (Cp) versus the tip speed ratio (γ).

The swept area (A_s)

As the rotor turns, its blades generate an imaginary surface whose projection on a vertical plane to wind direction is called the swept area.

The amount of energy produced by a wind turbine primarily depends on the rotor area also referred to as cross-sectional area, swept area, or intercept area.

The swept area for theSavonius wind turbine can be calculated from the dimensions of the rotor.

Savonius area = The swept area = As = H * D

Where: H = the rotor height (m). D = the rotor diameter (m)

The Tip speed ratio ($\boldsymbol{\lambda}$)

The tip speed ratio is the ratio of the product of blade radius and angular speed of the rotor to the wind velocity [10]. Theperipheral tip velocity of the rotor (V_{rotor}) is defined

Whereas, V_{rotor} = the tip speed (the peripheral velocity of Savonius rotor) (m/sec) ω = the angular velocity of Savonius rotor (rad/sec). D = the diameter of the semi-cylindrical Savonius rotor (m). Now the Tip Speed Ratio (TSR) of a turbine is expressed as:

Tip speed Ratio, TSR = $\boldsymbol{\lambda} = \frac{V\ Rotor}{V} = \frac{\omega * d}{V}$, Where V = the wind speed (m/sec)

Power Coefficient (Cp) Analysis

Power coefficient, (Cp) of a wind turbine is the ratio of maximum power obtained from the wind to the total power available in the wind.

This hypothesis shows the relationship between the power coefficient (Cp).

The wind speed (V), which expresses the basic theory of the Savonius wind turbine. Principally the power that the savonius rotor can extract from the wind (Pw) is less than the actual available from the wind power (Pa).

The available power (Pa), which is also the kinetic energy (KE) of the wind, can be defined as:

$$\boldsymbol{KE = P = 1/2ma.\ V^2}\textbf{(Watt)}$$

$$\boldsymbol{P = 1/2\rho\ .\ As\ .\ V^3}$$

Where: ma = wind mass flow rate striking the swept area of the wind turbine (kg/sec). = ρ.As. V

However, the swept area (As = H * D),therefore the actual power becomes:

$$\boldsymbol{P = 1/2\rho\ .\ H\ .\ D\ .\ V^3}$$

The power that the rotor extracts from the wind are:

$$\boldsymbol{Pw = T * \omega}\textbf{(Watt)}$$

Where: Pw = the power that the rotor extracts from the wind (Watt).

The power coefficient (Cp) is given by:

Cp =extracted power from the wind to the available power of the wind

$$\boldsymbol{C_p = Pw/P}$$

The theoretical energy possessed by the wind flowing at a certain velocity 'v' can be expressed mathematically,

$$P = \frac{1}{2}\,\rho\,A\,V^3$$

The performance of the Savonius wind turbine is determined by the coefficient of performance (Cp). It is theoretically defined as the ratio of the aerodynamic power generated by the wind turbine to the power possessed by the wind incoming on the surface of the rotor.

Savonius wind rotor is constructed simply of two vertical half cylinders, as shown in Figure 1.

The ratio between rotor height (H) and rotor diameter (D) is called the aspect ratio (α).

Some parameters can be defined through the following relations:

$$\text{Tip Speed Ratio } (\gamma) : \gamma = \frac{\omega R}{V}$$

$$\text{Aspect Ratio } (\alpha) = \frac{\text{rotor height (H)}}{\text{diameter (D)}}$$

$$\text{Overlap Ratio } (\beta) = \frac{\text{overlap (e)} - \text{diameter of the shaft (a)}}{\text{rotor diameter (D)}}$$

From the measured values of mechanical torque and rotational speed, the mechanical power can be estimated at each wind speed.

III. RESULT AND ANALYSIS

The experiment's procedure was carried out and tested in the wind tunnel, and the required measurement was obtained to study the performance of the two blades and three blades savonius wind turbine and makes the comparison between them to see which one is better in performance than the other. The performance [the dimensionless parameters torque coefficient (*Ct*) and power coefficient (*Cp*)] was evaluated as afunction of the dimensionless parameter the tip speed ratio (λ) at low wind speeds regarding starting acceleration and maximum no-load speed.It observed that the plot between the wind (air) speed and the rotor revolution (rpm) for both two and three blades savonius wind turbine; it appears that as the wind speed increases from [(0 m/s) to (3 m/s)] where the savonius wind turbine is initiated and starts to move. At this wind velocity where the wind turbine starts to move, the wind velocity is called the cut in speed, the low cut-in speed for this type of wind turbine which is about (2.5 m/s) and two blades savonius is a little bit lesser than three blades.Savonius turbines are much less efficient than HAWT and the Darrieus VAWT (around 15%, see below Calculating wind power) but contrary to the former; they perform well in turbulent wind conditions and, contrary to the latter, they are self-starting. Structurally they are resilient, resist high winds well without being damaged and are quiet compared to other types.As opposed to the Darrieus which uses lift, the Savonius is a 'drag' device. It consists of 2-3 "scoops": curved structures that experience less drag when moving against the wind than when moving with the wind because of the scoops' curved shape. From an aerodynamic perspective, it is this differential drag that causes the Savonius turbine to spin.

Selection of No. of Blades

The high rotational speed, the cause is that slim rotor with a small diameter can get higher rotational speed but lower torque**,** and vice versa rotor with bigger rotational diameter produces a bigger torque but a lower rotational speed. It is observed that static torque for two blades savonius wind turbine varies with the angle of attack [angle of rotation (α)] for a wind speed of (V = 5.3 m/s) , the static torque was measured at every (30^o to 360^o), it appears the torque that can be produced during each revolution is an oscillatory torque.It shows the static torque coefficient for two blades savonius wind turbine for different wind speed (5.3 & 4.6 m/s), the static torque coefficient varies with increasing the angle of rotation, it starts to increased from (0^o to 30^0) to reach its maximum value of (0.83 & 0.65) respectively and then goes down to decrease from (30^o to 150^o) to get it lowest value of (0.11 & 0). It is noticeable that torque values are yielding the symmetry for flow angles higher than (180° to 360^o). At an angle of (150^o and 330^o), the static torque coefficient has its lowest value, and for lower wind speed it may have a negative torque.The static torque coefficient for three blades savonius wind turbine for (5 m/s) wind speed, the static torque coefficient varies with increasing the angle of rotation, it starts to increased from (0^o to 60^0) and then goes down to decrease from (60^o to 120^o), It is noticeable that torque values are yielding the symmetry for flow angles higher than (120°) from (120^o to 210^o) and (240^o to 330^o). The static torque for both two and three bladesis found to be positive at any angle, high enough to obtain self-starting conditions.

Figure 2.savonius wind turbine

Blade Design

Rotor dia. D =520mm,

Height of blade H =800mm,

Bearing distance = 1000mm,

Thickness = 30gauge = .315mm

Swept Area = H * D

A_s = 800 * 520 = .43 m^2

P (available) = $\mathbf{1}/\boldsymbol{As}.V^3$

= ½*1.2*.43*(7.5*7.5*7.5)= 108.84 Watt

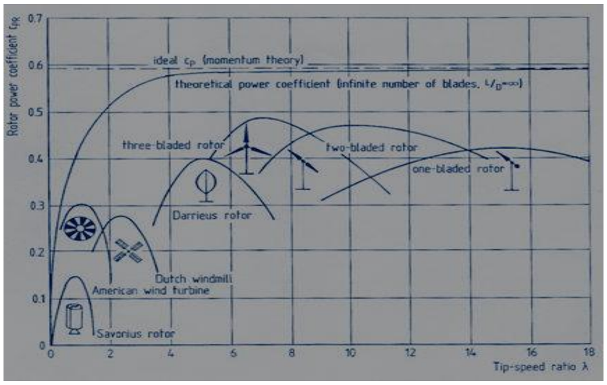

Figure 3. Graph showing coefficient of performance

From the figure 3, we consider the value of Cp= 0.3

$C_p = \boldsymbol{Pw}/\boldsymbol{P}$

$0.3 = \boldsymbol{Pw}/108.84$

$\boldsymbol{Pw} = 32.65$ Watt

Tip Speed Ratio, TSR = $\boldsymbol{\lambda} = \frac{V\ Rotor}{V} = \frac{\omega * d}{V}$

$\boldsymbol{\lambda}$= 1: For savonius VAWT

$1=(\omega*.26)/7.5$

$\omega=27.77$ rpm

$\boldsymbol{Pw}= T^*\ \omega$

T= 1.17 N-m

Table 1. Wind blades specification

Blades	S-Shaped	30 Gauge	28 Gauge	26 Gauge
Quantity				
Weight (N)	3	3	4	5

Density of material (ρ) = $2.7*10^3$ kg/m^3

Weight of Blades = ρ * h * v * g

W = 7.17 N

Moment = (W * L)/4

= (7.17 * 0.8)/4

=1.43N-m

Design of Shaft

According to Maximum Shear Stress Theory

$d_o^3 = [\frac{16}{(\pi*\tau_{max})}.\sqrt{M^2+T^2}\ [1/(1-K^4)]$

Let, k = d_o/d_i = 0.5

d_o= 5.607mm

d_i= 2.80mm

Specification of motor

Volts = 12V $P = V * I = 36$ watt

N = 200rpm$T_{electrical} = P/W = 1.719$N-m

I = 3amp$T_{wind} \geq T_{electrical} + T_{req.\ for\ blade}$

$\geq 1.719 + 1.93$

≥ 3.649

IV. CONCLUSION & DISCUSSION

The design concept is meant to be sustainable and environmentally friendly. It concluded that it has asimple geometry and cheap construction with moderate output. It also starts rotating at lower wind speeds and required less power than others similarlysized lift-type turbines.The emerging trends in the technology have shown a way to the use of non-conventional energy source are more efficiently regarding power generation on the basis of societyperspective.

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