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Design and Fabrication of Modified Savonius Vertical Axis Wind Turbine

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ABSTRACT
A vertical axis wind turbine (VAWT) is a type of wind turbine where the main rotor shaft is oriented in a vertical plane, perpendicular to the ground. This arrangement allows the turbine to capture wind from any direction, making it less dependent on the wind direction compared to horizontal axis wind turbines (HAWT). VAWTs have a number of advantages over HAWTs, including a more compact size, a lower profile, and a simpler design with fewer moving parts. However, they are also generally less efficient at converting wind energy into electricity compared to HAWTs, and they are more susceptible to interference from nearby structures. Despite these limitations, VAWTs have gained some popularity in recent years due to their ability to operate in urban and other low wind speed environments. Wind power is a type of renewable energy where we make use of wind velocity as the driving force. There are two types of wind turbines horizontal axis wind turbine and vertical axis wind turbine. Horizontal axis wind turbine is relatively larger than vertical axis wind turbine and it is used in areas where wind velocity is relatively slower. In our project work we design, fabricate, balance and demonstrate a vertical axis wind turbine. We go for two plane rigid rotor balancing in a balancing machine and utilize a cycle dynamo to light a lamp.

Keywords**—** Vertical axis wind turbine, Horizontal axis wind turbine, Wind energy

I. INTRODUCTION

Wind power or wind energy is mostly the use of wind turbines to generate electricity. Wind power is a popular sustainable renewable energy source that has a much smaller impact on the environment than burning fossil fuels. Historically wind power has been used in sails windmills and windpumps but today it is mostly used to generate electricity. Wind farm consists of many individual wind turbines which are connected to the electric power transmission network. New onshore wind farms are cheaper than new coal or gas plants but expansion of wind power is being hindered by fossil fuel subsidies. Onshore wind farms have a greater visual impact on the landscape than some other power stations.

Vertical axis wind turbines (VAWTs) are a type of wind turbine where the main rotor shaft is oriented in a vertical plane, perpendicular to the ground. This design is in contrast to horizontal axis wind turbines (HAWTs), which have a horizontal rotor shaft and are the most common type of wind turbine. VAWTs have been around for many years and have been used for a variety of applications, including pumping water, grinding grain, and generating electricity.

One advantage of VAWTs is that they can capture wind from any direction, making them less dependent on the wind direction compared to HAWTs.

II. LITERATURESURVEY

A. Aerodynamic design and performance parameters of a lift-type vertical axis wind turbine

For a large-scale offshore floating VAWT, the fixed-pitch straight-bladed configuration (i.e., H-rotor) with integrated tip-speed ratio control is the best design and operational setup. It has been established that controlling the power output at high wind speeds can be accomplished with reliability using the passive stall-regulation of the H-rotor. Optimal values for a variety of VAWT aerodynamic design parameters, such as the blade airfoil geometry, the quantity of struts, and their orientation, have been established. While it is advised that each blade be attached to the struts at its aerodynamic centre and have a toe-out pitch angle of 2°. Depending on the application, the VAWT recommends using two or three blades. In comparison to a three-bladed turbine, a two-bladed turbine is more effective and has a stiffer structural design. As opposed to the two-bladed turbine, the three-turbine has a reduced shaft torque ripple and improved self-starting abilities.

B. Performance improvement of Savonius VAWT using porous deflector

It has been shown that the Savonius turbine with a porous deflector performs better than the normal Savonius turbine with and without a solid deflector. When compared to a solid deflector and a typical Savonius turbine, using a porous deflector allowed the advancing blade to generate a higher positive torque while also reducing the negative torque produced by the returning blade. The right porosity value, location, and deflector height can further enhance the porous deflector's performance. Regarding the flow structure, the stagnation zone was moved closer to the tip of the returning blade by moving the stagnation zone upstream using a porous deflector, which reduced the negative torque. In addition, there were less variations and a greater regularity in the flow structures.

C. Determination of the number of VAWT blades based on power spectrum

The goal of the study was to establish the ideal quantity of blades for a vertical axis wind turbine. On the basis of thrust on the still blade, studies were conducted. For this study, the scientists chose to focus on the intricate phenomena that surround the blades, such as the aerodynamic shadow, turbulence, and other aerodynamic forces. simple (sinusoidal) change of thrust is envisioned, and all wind energy is delivered to the blade. Consequently, Betz's limit might be avoided.

D. Straight-bladed VAWT rotor design guide based on aerodynamic performance and loading analysis

It has been noted that there is no documentation of a thorough design that takes into account all significant elements in the SB-VAWT literature. As a result, in order to determine the appropriate range of various parameters that have already been adjusted, researchers and manufacturers who want to explore a new element of the subject must deal with a lot of data. This work has developed an effective design method for SBVAWTs that can save future researchers a substantial amount of time and money during the initial design stage. Additionally, it may discourage manufacturers from spending money on a design whose parameters are outside of the ideal range. This article includes a design flowchart that explains the design process mentioned here.

III. DESIGN AND FABRICATION

A carousel vertical-axis wind turbine (VAWT) is a type of VAWT that consists of a vertical shaft with blades attached to it, mounted on a horizontal axis that can rotate around a central point. The blades are typically shaped like airfoils and are mounted at an angle, so that the wind pushes against the flat side of the blade and causes the turbine to rotate. The horizontal axis is supported by bearings and is connected to a generator, which converts the mechanical energy of the rotating blades into electrical energy.

One advantage of carousel VAWTs is that they can operate effectively in low-wind conditions. Because the blades are mounted at an angle, they can capture wind from a wide range of directions, rather than just the wind coming directly from the front as with horizontal-axis wind turbines. This makes them well-suited for use in locations where the wind direction can vary significantly.

A. Working of turbine

Wind Capture: As the wind blows, it encounters the blades of the VAWT. The blades are designed to capture the wind's kinetic energy and convert it into rotational motion. The shape, curvature, and angle of the blades are optimized to maximize lift and generate torque.

Rotation: The wind causes the blades to rotate around a vertical axis. The rotor shaft, connected to the blades, also rotates as a result. The rotation can occur regardless of the wind direction, as the vertical axis allows the turbine to capture wind from any angle.

Power Generation: The rotor shaft of the VAWT is connected to a generator. The rotational motion of the shaft spins the generator's rotor, which contains coils of wire and magnets. As the magnets pass by the wire coils, the changing magnetic field induces an electrical current in the coils, generating electricity. The generated electricity can be used immediately or stored for later use.

Control Systems: VAWTs may incorporate control systems to optimize their performance and ensure safe operation. These systems can include mechanisms for starting the turbine at lower wind speeds, adjusting the blade pitch to regulate rotational speed, and governing systems to control the turbine's output in response to varying wind conditions

Transmission and Distribution: The generated electricity from the VAWT is transmitted and distributed through electrical cables to power consumption points. This can include local use, such as powering buildings or charging electric vehicles, or feeding the electricity into a larger power grid for wider distribution.

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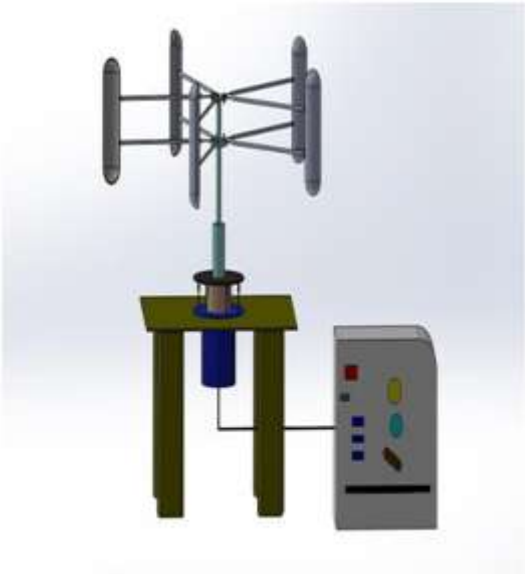

Fig. 1. Components of vertical axis wind turbine

B. Calculation of surface area of the turbine

Considering the specifications of the blade, it is noted that the blade has a cylindrical shape with a height of 650 mm and a radius of 150 mm. Additionally, the blade possesses a dome-shaped structure on both the top and bottom with a radius of 150 mm.

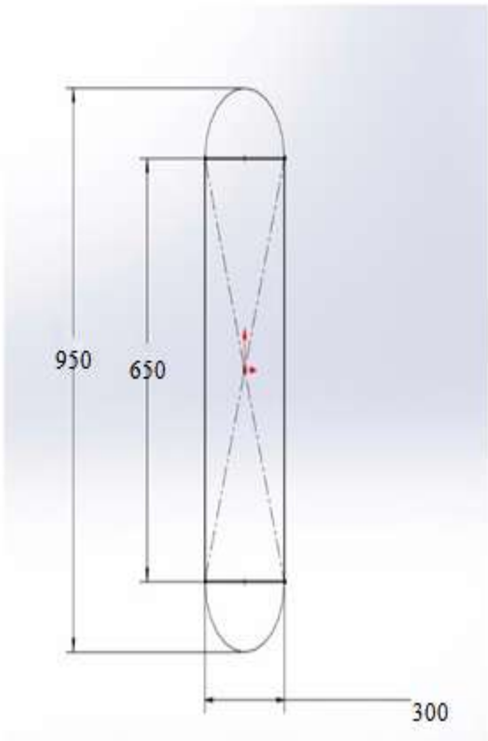

Fig. 2. Dimension of the turbine

Taking into consideration that the thickness of the blade is 2.5mm The formula for the internal surface area of a cylindrical blade:
Surface Area = $0.5(2\pi r^2 + 2\pi rh)$ Half the surface area is taken because the selected model has half cylindrical shape
π (pi) is a mathematical constant approximately equal to 3.14159 , r is the radius of the circular base, h is the height of the cylinder.
We can substitute the given values of the height and radius:Surface Area = $0.5(2\pi(147.5)^2 + 2\pi(147.5)(650)$
Surface Area = $0.5(43512.5\pi + 191750\pi)$
Surface Area = $117631.25\ \pi$ Surface Area ≈ 670749.67 mm2
For the design we are using ¼ of the sphere on the top and bottom of the blade. So, we are taking half sphere for the calculation. Using the formula for the internal surface area of a sphere:
Surface Area = $2\pi r^2$
Where:π (pi) is a mathematical constant approximately equal to 3.14159, r is the radius of the sphere
We can substitute the given value of the radius:
Surface Area = $2\pi(147.5)^2$
Surface Area = $2\pi(21756.25)$
Surface Area = $43512.5\ \pi$
Surface Area ≈ 136698.55 mm2.
Total surface area of a Single blade = 670749.67 mm2 +136698.55 mm2
Total surface area of a Single blade = 0.80744 m2
For our design we are using 5 Blade , So the total surface are is 4.03741 m2

I. Design of motor

Our aim is to generate an electricity of 12v and 2A from a DC motor. So, we are selecting a motor which can generate this much of energy.250W 24V 2750RPM DC Motor is the selected motor for our operation. So, we need to step down the voltage to 12 v and reduce the output wattage.

Specification :
Operating Voltage (VDC)=24
No-Load Current (mA)=1000
Loaded RPM=2600-3000
Efficiency =70%
watt =250w

To step down the voltage from 24V to 12V, we can use a voltage regulator or a DC-DC converter that is designed for this purpose.

LM2596 DC-DC Buck Converter: This is a popular and inexpensive converter that can handle up to 3A of current. It has an adjustable output voltage and includes over-current and over-temperature protection.

To step down the wattage from 250W to 24W, we will need to reduce the load on the motor or use a gear reduction system to decrease the speed and torque of the motor. This will decrease the power output of the motor and allow we to operate it at a lower wattage.
Assuming the efficiency of the motor remains constant at 70%, we can calculate the new operating current required to achieve a power output of 24W as follows:
Power output = Voltage x Current x Efficiency
24W = 12V x Current x 0.70
Current = 24W / (12V x 0.70)
Current = 3.43A

Therefore, we will need to limit the current draw of the motor to approximately 3.43A in order to achieve a power output of 24W at 12V. We need to consider the torque requirements of our application and the specifications of the motor.To find that we first need to find the average velocity of the wind in kerala:

The windier part of the year lasts for 4.9 months, from May 9 to October 4, with average wind speeds of more than 9.5 miles per hour. The windiest month of the year in Kerala is June, with an average hourly wind speed of 12.7 miles per hour (5.677408 m/s)
To find the force acting on the blade of a wind turbine, we can use the formula:
F = 0.5 * ρ * A * v^2 * C

where:
F is the force in Newtons (N)
ρ is the density of air (1.225 kg/m^3 at sea level)
A is the area of the blade in square meters
v is the velocity of the wind in meters per second
C is the coefficient of lift (a dimensionless constant that depends on the shape and angle of attack of the blade)
Assuming a coefficient of lift of 1.5 for a typical wind turbine blade, we can plug in the given values to find the force on one blade:
F = 0.5 * 1.225 kg/m^3 * 0.80744 m^2 * (5.677408 m/s)^2 * 1.5
F ≈ 23.911 N
Since there are 5 blades on the wind turbine, the total force on the turbine would be 5 times this amount:
Total force = 5 * 23.911N
Total force ≈ 119.55 N
Therefore, the force acting on the blade of a vertical wind turbine with 5 blades, each blade having an area of 0.80744 square meter and a wind velocity of 5.677408 m/s, is approximately 23.911 N per blade or 119.55 N for all 5 blades.

II. Calculation of torque
To find the torque, we can use the same formula as before:
455 mm is the length of the arm, which is connecting the blade and motor
Torque = force x radius
where force is the force acting on the blade and radius is the distance from the center of the wind turbine to the blade.
Plugging in the given values, we get:
Torque = 23.911N x 0.455 m Torque ≈ 10.87 Nm
Therefore, the torque on the wind turbine with a force of 23.911 N and a radius of 455 mm is approximately 10.87 Nm.

IV. FABRICATION
Fabrication of modified savonious vertical axis wind turbine was done during the month of March and April of 2023.
The fabrication process was divided into various sections:

- Procurement of suitable materials: According to the design and specifications of the turbine, right materials were purchased in order to fabricate the VAWT.
- Fabrication of mould for the blade: The mould of the blades were made using mild steel and cement for the dome
- Fabrication of blades: The blades are made using fiber glass and polyester resin. As shown in fig 6.5.
- Gear assembly: The gear assembly consist of two gears. The main gear consist of 66 teeth while the secondary gear consist of 22 teeth thereby achieving a gear ratio of 0.333.
- Motor selection: The selection of motor depended on 2 factors : The total power of the motor and the rated RPM. A 250 w 2500 RPM motor was selected for the VAWT.

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Fig.3.Mould for the blades

Fig.4.Moulding using cement

Fig.5. Finished Blades

Fig.6. Gear assembly of the turbine ,

Fig.7. 250w 2500rpm induction motor

Fig.8. Finished vertical axis wind turbine

Fig.9. Top view of the VAWT

ADVANTAGES

Advantages of VAWTs:

- They can operate effectively in low-wind conditions, as they can capture wind from a wide range of directions.
- They are relatively simple in design and are relatively easy to manufacture, which can make them a cost-effective option for small-scale power generation.
- They take up less space and are less obtrusive than HAWTs, which can make them a more suitable option for some locations.
- They are less affected by turbulence, as the blades are closer to the ground where the

wind is smoother.

Disadvantages of VAWTs:

- They are generally less efficient than HAWTs, so they may not be the best choice for large-scale power generation.
- They can be more expensive to maintain, as the blades are closer to the ground and are more susceptible to damage from debris.
- They can be more prone to structural failure, as the entire turbine rotates and is subjected to more stress than a stationary HAWT.
- They may not be as visually appealing as HAWTs, as they have a more unusual and less familiar appeararance

V. CONCLUSION

Vertical-axis wind turbines (VAWTs) are a type of wind turbine that has a vertical shaft with blades attached to it, mounted on a horizontal axis that can rotate around a central point. VAWTs have several advantages, including the ability to operate effectively in low-wind conditions, a relatively simple design, and a low profile that makes them less obtrusive than horizontal-axis wind turbines (HAWTs). They are also well-suited for use in locations where the wind direction can vary significantly.

However, VAWTs also have a number of disadvantages. They are generally less efficient than HAWTs, which can limit their usefulness for large-scale power generation. They can also be more expensive to maintain and are more prone to structural failure due to the rotational forces they experience.

Overall, VAWTs can be a useful option for small-scale power generation in some applications, but they may not be the most appropriate choice in all cases. The most suitable type of wind turbine for a particular application will depend on the specific site conditions, power requirements, and available budget..

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