THE PERFORMANCE OF SHROUDED WIND TURBINE USING CYCLE DYNAMO

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Abstract - *Wind energy is transformed into electrical energy by wind turbines for distribution. Propeller-like blades turn when the wind blows, capturing wind energy to drive the generator and produce power. Horizontal-axis turbines and vertical-axis turbines are the two main types of wind turbines on the market. The power output of small wind turbines is 10 kW, whereas the power output of large-scale wind turbines ranges from 5000 to 8000 kW. It is crucial to realize that wind turbines cannot function in either excessively high or excessively low wind conditions. Only 59.3% of the kinetic energy is transformed into electricity output utilizing wind turbines, which is below the Betz limit. The cubic power of velocity directly relates to the wind power generated by a wind turbine. Therefore, a small increase in velocity might result in a significant increase in power production. In shrouded wind turbines, this idea is applied. The pressure gradient produced by a diffuser shroud increases the speed of the approaching wind. Additionally, because of the growing sophistication of engineering and technology, the rotor size of a wind turbine grows in direct proportion to its swept area. In this project, we create a shrouded wind turbine with which we run several tests with various specs and blade counts. It aids in comprehension of the various outputs and efficiencies offered by a wind turbine. The output of a wind turbine increases as its efficiency rises. and contributes to boosting energy production.*

Keywords: vertically inclined winds, Betz limit, shroud, nozzle, diffuser.

1. INTRODUCTION

In order to generate, transmit, and integrate wind turbines into the power system, electrical engineering is used in conjunction with a variety of multidisciplinary and broad technological disciplines, including aerodynamics, mechanics, structure dynamics, and meteorology. The most promising and dependable kind of renewable energy today is wind turbine technology, which has improved over time. Since the early 1980s, the transition from small wind turbines with a few kilowatts to the multimegawatt wind turbines of today has happened quite quickly. Wind turbines transform wind's kinetic energy into useful electrical energy. Propeller-like blades turn when the wind blows, capturing wind energy to drive the generator and produce power. There are two main types of wind turbines on the market: horizontal-axis turbines and turbines with vertical axes. Large-scale wind turbines can produce power up to 5000–8000 kW, whereas small wind turbines have production capability of 10–20kW.

To ascertain whether the wind flows are adequate for generating power, the location for placing wind turbines must also be adequately examined. A suitable wind turbine system for the location is also found with the aid of the evaluation. The quality of the wind resources at the area of installation considerably affects the efficiency of wind energy, which can reach more than 40% if the location of the wind energy system is correctly chosen. It is crucial to realize that wind turbines cannot function in either too high or too low wind conditions.

Wind power is inversely correlated with wind speed cubed. The output power of a wind turbine can be significantly improved if we can harness the fluid dynamics surrounding a structure to increase the wind speed, specifically if we can catch and concentrate the wind energy locally. When compared to an open turbine with a rotor of an equivalent size, a shroud in a shrouded wind turbine serves to enhance the velocity of the air travelling through the rotor plane.

As the size of the wind turbine increases, its cost rises and its failure rate rises in conventional wind turbines. Additionally, those enormous wind turbines cause social issues like increased noise (aerodynamic noise) as a result of the turbines, an increase in the risk of bird strikes, deterioration of the surrounding scenery as a result of the turbines' size or their sharp blades, and more. As a result, it is challenging for the local population to accept such enormous wind turbines, which makes it challenging to build such wind turbines. Scaling of blades has limitations, as several recent investigations have shown.

In this paper, we develop a shrouded wind turbine which is used to perform different tests according to different specifications and number of blades. It helps in understanding the different outputs and efficiencies in the given specifications.

1.1 Objectives

•To find out the most optimum arrangement in a shrouded wind turbine.

•To study the difference between the performance of conventional horizontal axis wind turbines and shrouded wind turbines.

•To study the changes in different output parameters of a shrouded wind turbine at different wind speeds.

•To understand the difference between usage of three bladed and five bladed rotors in horizontal axis wind turbines.

1.2 Scope

•This turbine will be capable of producing more power than conventional horizontal axis wind turbines.

•A clear-cut image of the most optimum geometrical arrangement to produce electricity efficiently in a shrouded wind turbine is obtained.

•Increase in the volume of swept wind by the use of nozzle and diffuser.

•Can be used as wind guidance system for larger wind turbines.

2. THEORY OF WIND TURBINES

2.1 POWER IN THE WIND:

When one comprehends how the speed influences the power, the significance of correct wind speed data becomes apparent. Take into account a disc of area "A" with air mass "dm" moving through it. The mass will travel a distance of 'U dt' in time dt, resulting in the formation of a cylinder with a volume of 'A x U x dt' and a mass of 'dm = A x ρ x U x dt', where " denotes the air density. The temporal rate of change in kinetic energy, or the power contained in the moving mass, is given by $P = d(KE) / dt = d (½ x mU^2)/ dt = ½ x U^2 dm / dt = ½ x A x ρ U^3$.

As a result, power is inversely related to wind speed cubed. The wind speed must be precisely known because any inaccuracy in the power calculation is amplified.

2.2 BETZ'S LAW:

Independent of the design of a wind turbine operating in open flow, Betz's law identifies the maximum power that may be obtained from the wind. For all Newtonian fluids, including wind, Betz's law is applicable. The wind speed would decrease to zero if all of the energy from wind movement via a turbine were collected as useable energy. A blockage would prevent any additional fresh wind from entering if the wind stopped blowing at the turbine's exit. There must be some wind movement, however slight, on the opposite side with some wind speed greater than zero in order to maintain the wind going through the turbine. According to Betz's law, as an area's airflow increases and as energy is lost during energy extraction from a turbine, wind speed drops, requiring airflow to be distributed across a larger region. Geometry therefore restricts turbine efficiency to a maximum of 59.3%.

2.3 BETZ LIMIT:

The Betz limit is based on an open-disk actuator. More energy can be obtained if a diffuser is employed to gather more wind and route it through the turbine, but the limit still applies to the cross-section of the overall structure.

The Betz Limit is the most energy that can be extracted from a fluid moving at a specific speed using an infinitely thin rotor.

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Assumptions:

1. The rotor is ideal, without a hub, and has an infinite number of blades that are completely free of drag. Any ensuing drag would only make this ideal value smaller.

2. Axial flow enters and exits the rotor. In order to create a solution for this control-volume analysis, the control volume must include all incoming and outgoing flow; otherwise, the conservation equations would be broken.

3. There is no compression of the flow. There is no heat transfer, and the density does not change.

4. The disc or rotor is subjected to a uniform thrust.

2.4 THEORY OF SHROUDED TURBINES:

The theory behind revealed that a diffuser-shaped structure can accelerate the wind at the entrance of the body. Using a nozzle will reduce the pressure and increase the velocity of air intake and cuts the blades. As the air leaves through the diffuser the pressure is increased reducing the velocity. Since the change in pressure is continuous a smooth flow of air occurs.

3. METHODOLOGY

The fabrication work began with the production of two type of blades; 5-blade and 3-blade, made of PVC. Then they were bolted onto a bearing housing made of cylinder pipe of diameter 50mm and a bearing of internal diameter 16mm (SKF 6202) was fixed into the cylindrical pipe, as shown in fig 1.

Fig – 1: Rotor

For power generation a standard bicycle dynamo of head diameter of 20mm is used. The typical electrical output produced from a bicycle dynamo is 12 volts. Dynamos have traditionally been used to power lights with alternating current (AC). There have been sufficient advancements in battery technology, LED light technology, and charging technology as we have moved into a world of communication and become more efficient. The bicycle dynamo was coupled to a wheel of diameter 100mm for speed addition to the dynamo as shown in fig 2. A speed ratio of 5:1 is achieved on the dynamo.

Fig - 2: Wheel and dynamo (speed addition)

The shroud was clipped onto the outer peripherical ring of the arrangement to complete the fabrication work. A bulb was connected to the dynamo using a regulator IC (IC 7305) in series with two resistors in parallel (630 ohm) to the dynamo. The completed fabrication of shrouded wind turbine producing an output using dynamo is shown in fig 3.

Fig – 3: Shrouded wind turbine

Specifications Of the Fabricated Wind Turbine:

- Throat diameter = 710mm
- Length of the blades = 310mm
- Rotor diameter = 705mm
- Tower Height = 1210mm
- Nozzle inlet diameter = 760mm
- Diffuser outlet diameter = 850mm
- Bearing housing diameter = 50mm
- Dynamo rotating ridged knob diameter = 20mm
- Addition wheel diameter = 100mm
- L/D Ratio, L/D = 0.44

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4. RESULT AND DISCUSSION

The various tests are conducted with the use of wind tunnel at constant wind speed. A constant wind speed is obtained by setting a constant value for rpm of the wind tunnel. After setting a constant wind speed the different parameters like variation in output voltage, variation in rpm of the rotor shaft, cut-in wind speed, etc. are recorded for different arrangement of the blades, nozzle and diffuser. Two sets of wind speeds are used – 6.3m/s and 5.1m/s.

4.1 VOTAGE VARIATIONS AT 6.3 m/s

The wind speed is set to a constant value of 6.3m/s by setting the wind tunnel to 625rpm and the voltage variations of the 3-blade and 5-blade arrangement are recorded by using a multimeter for the below shown geometrical parameters.

Table 1 below shows the values obtained in volts(V) for different geometrical parameters.

Table -1: Voltage variations at 6.3m/s

TESTS	5 BLADE	3 BLADE
REFERENCE TEST	4.0V	5.5V
NOZZLE ONLY	7.8V	7.1V
NOZZLE+ DIFFUSER	8.8V	9.7V
DIFFUSER ONLY	6.9V	6.1V

A chart is plotted showing the voltage variations at 6.3m/s as shown in chart 1 below:

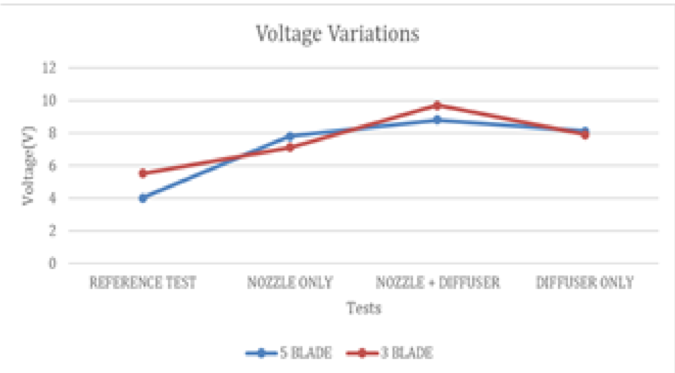

Chart 1: Voltage variation graph at 6.3m/s

Here the reference test or the test without the addition any nozzle or diffuser has the least output. With the addition of nozzle, a marginal increase in voltage output is seen. Diffuser alone has lesser output than nozzle alone since the intake of air is less in the beginning. The intake of wind is increased with nozzle. The diffuser alone arrangement can only reduce the pressure but the pressure reduction can only happen with the use of nozzle. But with the help of both nozzle and diffuser the pressure reduction and addition can happen simultaneously in both nozzle and diffuser arrangement (shroud). The value has significantly increased with the use of shroud to approximately from 4V to 10V. Shroud arrangement offers higher output and load carrying capability. With the increase in output gives more power.

4.2 RPM VARIATIONS AT 6.3 m/s

The wind speed is set to a constant value of 6.3m/s by setting the wind tunnel to 625rpm and the rpm variations of the 3-blade and 5-blade arrangement are recorded by using a tachometer for the below shown geometrical parameters.

Table 2 below shows the values obtained in revolutions per minute(rpm) for different parameters.

Table -2: RPM variations at 6.3m/s

TESTS	5 BLADE	3 BLADE
REFERENCE TEST	220 rpm	250 rpm
NOZZLE ONLY	230 rpm	260 rpm
NOZZLE+ DIFFUSER	360 rpm	410 rpm
DIFFUSER ONLY	300 rpm	320 rpm

A chart showing the variations of rpm at 6.3m/s is shown in chart 2 above.

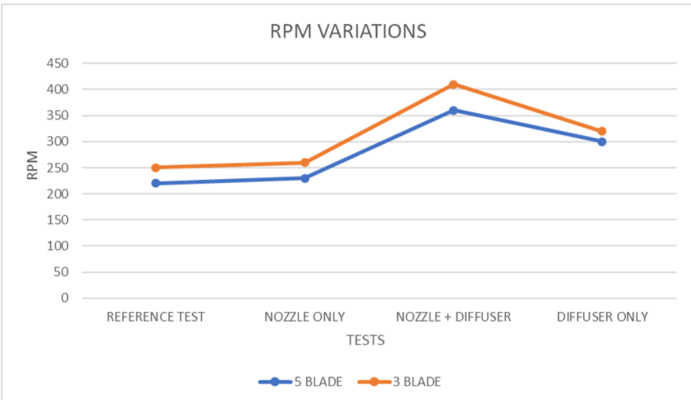

Chart 2: RPM variation graph at 6.3m/s

Here the reference test has the least output. With the addition of nozzle, a marginal increase in rpm output is seen. Diffuser alone has lesser output than nozzle alone since the intake of air is less in the beginning. The intake of wind is increased with nozzle. The diffuser alone arrangement can only reduce the pressure but the pressure reduction can only happen with the use of nozzle. But with the help of both nozzle and diffuser the pressure reduction and addition can happen simultaneously in both nozzle and diffuser arrangement (shroud). The value has significantly increased with the use of shroud to approximately from 220 rpm to 410 rpm. Shroud arrangement offers higher output and load carrying capability. With the increase in output gives more power.

4.3 VOTAGE VARIATIONS AT 5.1 m/s

The wind speed is set to a constant value of 5.1m/s by setting the wind tunnel to 555rpm and the voltage variations of the 3-blade and 5-blade arrangement are recorded by using a multimeter for the below shown geometrical parameters.

Table 3 below shows the values obtained in volts(V) for different parameters.

Table -3: Voltage variations at 5.1m/s

TESTS	5 BLADE	3 BLADE
REFERENCE TEST	3.8V	5.2V
NOZZLE ONLY	4.2V	5.7V
NOZZLE+ DIFFUSER	6.8V	8.9V
DIFFUSER ONLY	3.9V	5.3V

A chart showing the voltage variations at 5.1m/s as shown in chart 3 below:

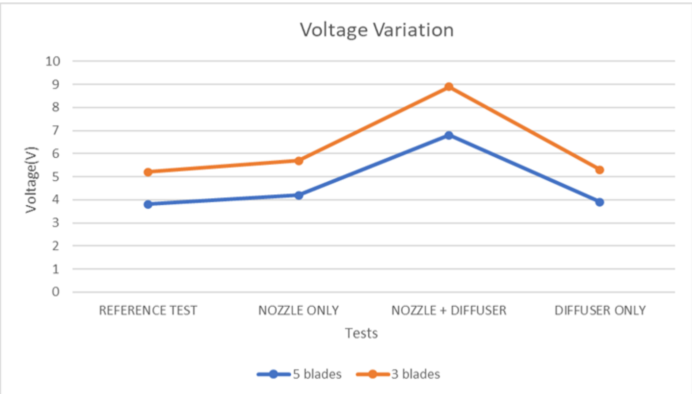

Chart 3: Voltage variation graph at 5.1m/s

4.4 RPM VARIATIONS AT 5.1 m/s

The wind speed is set to a constant value of 5.1m/s by setting the wind tunnel to 555rpm and the rpm variations of the 3-blade and 5-blade arrangement are recorded by using a tachometer for the below shown geometrical parameters.

Table 4 below shows the values obtained in revolutions per minute (rpm) for different parameters.

Table -4: RPM variations at 5.1m/s

TESTS	5 BLADE	3 BLADE
REFERENCE TEST	215	245
NOZZLE ONLY	220	255
NOZZLE+ DIFFUSER	285	410
DIFFUSER ONLY	225	280

A chart is plotted showing the rpm variations at 5.1m/s as shown in chart 4 below:

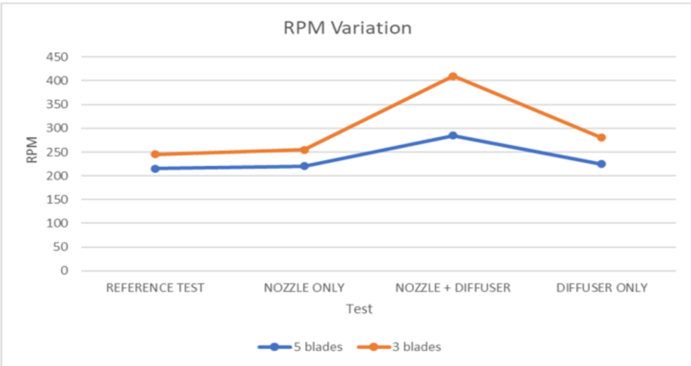

Chart 4: RPM variation graph at 5.1m/s

- CUT-IN WIND SPEED

- Reference test - 4.2m/s
- Nozzle only - 3.6m/s
- Diffuser only - 3.8m/s
- Nozzle+ Diffuser - 3.0m/s

5. CONCLUSIONS

To increase the output of the HAWTs we proposed the design of shroud into the system. By doing so we were able to increase the output by 2-3 times. Since this project used a cycle dynamo the varying output was limited. The output was limited to 12V maximum. Although, the range of output was limited, the increase in voltage and rpm were significant. The output varied from 4V to 10V and the rpm from 215 – 410 rpm. Among the various arrangements we used the nozzle and diffuser arrangement was the best suited to produce the best result. It gave an output voltage of 9.7V and 410rpm. Wind turbines with nozzle-diffusers can significantly improve rotor performance. This is because the wind turbine inside the diffuser is drawn to more mass flow by a low-pressure area created by a strong vortex formation behind the broad diffuser. The ability of creating a pressure difference produces an output that far exceeds the normal HAWTs. Even for a slight variation in applied wind load a significant output can be produced. Improved research will be fruitful in utilizing the unlimited resources that are free and bountiful in nature. Since the usage of fossil fuels are very high, developments in wind energy production can be very resourceful

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