EXPERIMENTAL INVESTIGATION ON A CONVERGENT-DIVERGENT SHROUDED SMALL SCALE WIND TURBINE

Dr. E. S. Prakash[1], Dr. Madhukeshwara N[2], Veeresh G. Gunjalli[3], Dadapeer D[4]

[1] *Professor, Studies in Mechanical engineering, U.B.D.T.C.E., Davangere, karnataka, India*
[2] *Professor, Mechanical engineering, K.L.E.I.T., Hubballi, karnataka, India*
[3] *Assistant Professor, Mechanical engineering, K.L.E.I.T., Hubballi, karnataka, India*
[4] *Assistant Professor, Mechanical engineering, A.G.M.R.C.E.T., Hubballi, karnataka, India*

---***---

Abstract - *As the scarcity of fossil fuels are increasing day by day, importance of renewable energy sources are playing a significant role. Various renewable energy sources such as solar, wind, tidal, ocean thermal are contributing as alternative to fossil fuels, among which wind is playing an important role. In the present work, the wind turbine model is created and convergent-divergent type of shroud is designed in order to augment the velocity of the wind and in turn the power output of the turbine. Analysis is carried out on a bare wind turbine with different angle of attacks and power output is tabulated. Then, the shroud is created for increasing the velocity of wind and now analysis is carried as on wind turbine along with shroud. With results obtained it can be concluded that for present work power output can be increased approximately 3 times with the help of shroud.*

Key Words: Shroud.

1. INTRODUCTION

For the application of an effective energy resource in the future, the limitation of fossil fuels is clear and the security of alternative energy sources is an important subject. Furthermore, due to concerns for environmental issues, i.e., global warming, etc., the development and application of renewable and clean new energy are strongly expected. Among others, wind energy technologies have developed rapidly and are about to play a big role in a new energy field. However, in comparison with the overall demand for energy, the scale of wind power usage is still small; it is becoming necessary to fully understand how to improve wind turbine efficiency, as energy consumption and cost reaches record-breaking levels.

One such method of improving turbine efficiency is a Diffuser augmented wind turbine (DAWT) as an improvement to the conventional horizontal axis wind turbine (HAWT). DAWTs are simply a HAWT with a trumpet-bell-shaped diffuser surrounding the rotor blades. A DAWT is claimed to have a greater efficiency than conventional HAWTs, even possibly higher than the Betz limit, because the diffuser allows for a greater pressure drop across the rotor blade. DAWTs offer additional advantages in addition to increased augmentation, including minimal tip speed losses; a small rotor diameter that increases RPM, and being less yaw sensitive than HAWTs. However, there are many issues with DAWTs that need to be addressed to fully understand them before their greatest power output can be achieved.

Wind power generation is proportional to the wind speed cubed. Therefore, a large increase in output is brought about if it is possible to create even a slight increase in the velocity of the approaching wind to a wind turbine. If wind speed can be increase by utilizing the fluid dynamic nature around a structure or topography, namely by concentrating the wind energy locally, the power output of a wind turbine can be increased substantially.

2. OBJECTIVES AND METHODOLOGY

2.1 Objectives

The main aim of the project is to design a small wind turbine that can generate electricity for home appliances. The thought of design directs to look into the various aspects such as manufacturing with shroud, cost which leads to additional aim of analyzing the system to overcome the usual technical glitches. Some of the objectives of this work are

1. To develop much cleaner cost effective way of power generation method, which in turn helps to bring down the global warming as well as reduce the power shortages.

2. To increase the wind velocity before striking the blades which help in more power output, by using the convergent portion of shroud (diffuser)

3. To draw the more wind as a result of pressure drop, which helps in more power output, by using the divergent portion of shroud (diffuser).

4. To make the project, cost effective by using the low cost materials like GI sheet, PVC pipe, mild steel material etc.

5. To generate the power at the smaller wind velocities.

2.2 Methodology

The first step in this work is designing of principal components of wind turbine

1. The design consists of the following components:
    - Rotor blade
    - Rotor Hub
    - Main Bearing
    - Main Shaft
2. The next step is to assemble these components with additional accessories like
    - Alternator
    - Control Panel
    - UPS
    - Battery
3. Once fabrications is over performance analysis will be done without shroud
4. Now shroud (Diffuser) will be designed and fabricated to the wind turbine
5. Again performance analysis will be done with shroud and conclusions can be drawn
6. Depending on the results for both the cases, decision can be made and for the better one the battery charging arrangement can be made

3. EXPERIMENTATION AND ANALYSIS

The turbine blades with hub and alternator arrangements supported in hemispherical cup which is made to rest on a stand frame as shown in the fig 3.1. Now the experimental setup is subjected to various wind velocities and the respective rotational speed will be recorded and power outputs will be tabulated from table 4.1 to table 4.3.

Fig -3.2: Experimental setup of bare wind turbine

Now the shroud arrangement will be made for the wind turbine and the experimental setup is subjected to same wind velocities and the respective rotational speed will be recorded and power outputs will be tabulated from table 4.4 to table 4.6.

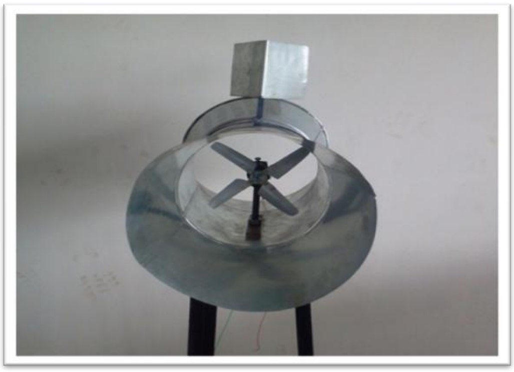


Fig -3.2: Experimental setup of wind turbine with shroud

3.1 Working Principle

The basic working principle is that as wind strikes on the blades it exerts impulse force on the blade as it moves over the length of blades and this force causes the blades to rotate which results in the generation of power.

Shroud will augment the velocity of the wind which in turn increases the force exerted on the blade and the increased power output.

4. RESULTS AND DISCUSSIONS

Table 4.1: The rotational speeds and power outputs for various velocities at 30deg angle of attack without shroud

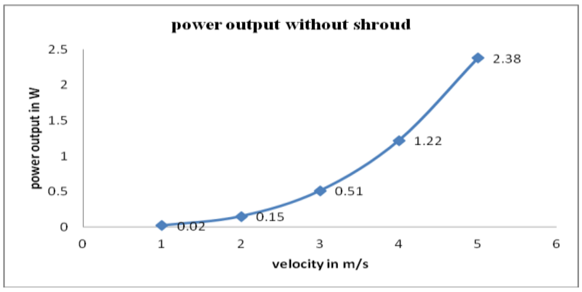
V m/s	RPM	Power ($P= ½ * \rho AV^3$) in Watts
1	-	0.02
2	600	0.15
3	750	0.51
4	1125	1.22
5	1250	2.38

Table 4.2: The rotational speeds and power outputs for various velocities at 60deg angle of attack without shroud

V m/s	RPM	Power ($P= ½ * \rho AV^3$) in Watts
1	-	0.02
2	75	0.15
3	125	0.51
4	200	1.22
5	650	2.38

Table 4.3: The rotational speeds and power outputs for various velocities at 90deg angle of attack without shroud

V m/s	RPM	Power ($P= ½ * \rho AV^3$) in Watts
1	375	0.02
2	750	0.15
3	1125	0.51
4	1250	1.22
5	1500	2.38

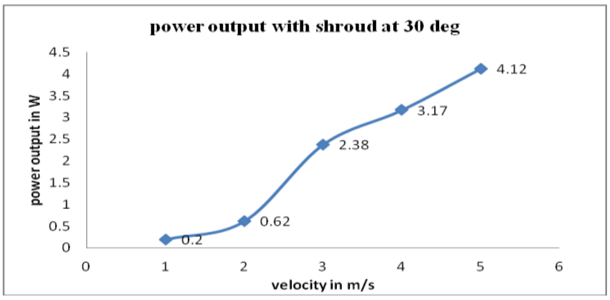


Graph 4.1 variation of power output for different velocities without shroud

It is clear from tables 4.1, 4.2 and 4.3 that the rotational speeds are more for 90 deg angle of attack. As the power outputs are same for all the angle of attacks the graphical variation of power outputs for different velocities is shown commonly in graph 4.1

Table 4.4: The rotational speeds and power outputs for various velocities at 30deg angle of attack with shroud

V m/s	V_{actual} m/s	RPM	Power (P= ½*ρAV³) in Watts
1	2.2	500	0.20
2	3.2	950	0.62
3	5.0	1300	2.38
4	5.5	1625	3.17
5	6	1800	4.12

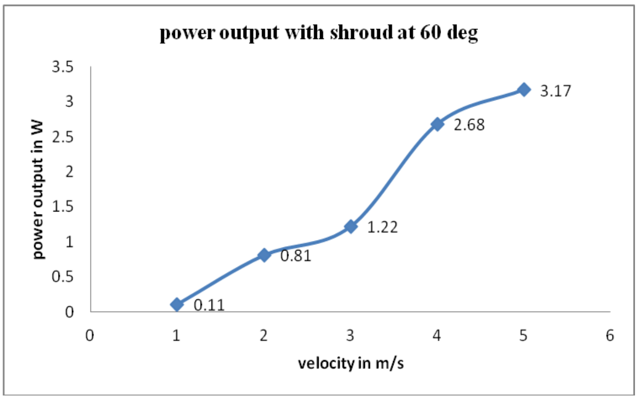


Graph 5.2 variation of power output for different velocities with shroud at 30deg angle of attack

It is observed from the table 4.4, there is a increase in velocity of the wind passing through the shoud and in turn the power output of the turbine. The power output is ranging from 0.2 to 4.12 W for 30^0 angle of attack.

Table 4.5: The rotational speeds and power outputs for various velocities at 60deg angle of attack with shroud

V m/s	V_{actual} m/s	RPM	Power (P= ½*ρAV³) in Watts
1	1.8	450	0.11
2	3.5	800	0.81
3	4.0	1100	1.22
4	5.2	1125	2.68
5	5.5	1500	3.17

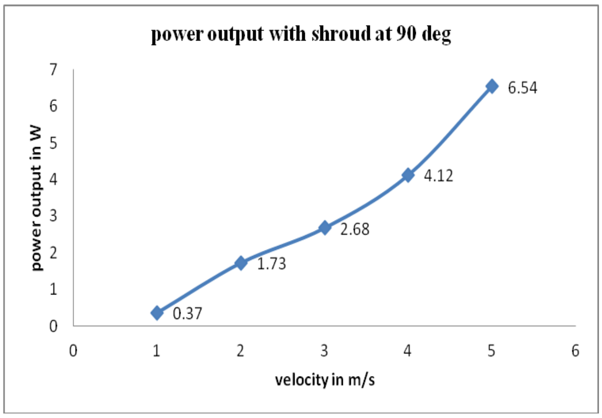


Graph 5.3 variation of power output for different velocities with shroud at 60deg angle of attack

It is observed from the table 4.5, there is a increase in velocity of the wind passing through the shoud and in turn the power output of the turbine. The power output is ranging from 0.11 to 3.17 W for 60^0 angle of attack.

Table 4.6: The rotational speeds and power outputs for various velocitiesat 90deg angle of attack with shroud

V m/s	V_{actual} m/s	RPM	Power (P= ½*ρAV³) in Watts
1	2.7	600	0.37
2	4.5	1000	1.73
3	5.2	1375	2.68
4	6.0	1750	4.12
5	7.0	2250	6.54

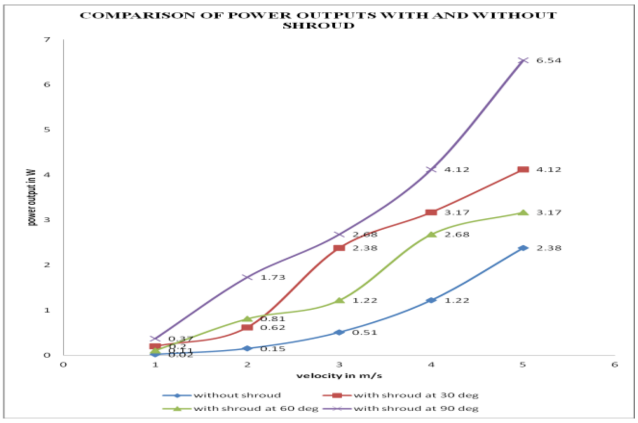


Graph 5.4 variation of power output for different velocities with shroud at 60deg angle of attack

It is observed from the table 4.6, there is a increase in velocity of the wind passing through the shoud and in turn the power output of the turbine. The power output is ranging from 0.37 to 6.54 W for 90^0 angle of attack.

Table 4.7: Comparison of power outputs without shroud and with shroud for different angle of attacks

Velocity	Without Shroud	With Shroud		
		30-deg	60-deg	90-deg
1	0.02	0.2	0.11	0.37
2	0.15	0.62	0.81	1.73
3	0.51	2.38	1.22	2.68
4	1.22	3.17	2.68	4.12
5	2.38	4.12	3.17	6.54



Graph 4.5 Comparison of power outputs without shroud and with shroud for different angle of attacks

It is observed that in each case with increase in velocities there is an increase in power output. Comparing with and without shroud more power output is observed in case of with shroud. Comparing in with shroud at 30-deg, 60-deg and 90deg angle of attack, smaller at 60-deg angle of attack then little more at 30-deg of attack, but more power output is observed with shroud at 90-deg angle of attack.

5. CONCLUSIONS

- As per the theoretical calculations and analysis done, with the input air velocity in the range of 1m/s to 5m/s, the power output generated is 6.54 W.
- It is giving more outputs at 90 deg angle of attacks
- Also the output obtained with shroud is approximately proportional to three times that without shroud
- From the table 4.3 and 4.6 for 90-deg of attack and wind velocity of 5 m/s with and without shroud the power outputs are 2.38 and 6.54
- it can be concluded that with the use of the shroud the power output can be increased by 3 times compared to the power output without shroud in this present work.

REFERENCES

[1]. William David Lubitz, Adam Shomer, " Wind Loads and Efficiency of a Diffuser Augmented Wind Turbine (DAWT)", Proceedings of The Canadian Society for Mechanical Engineering International Congress 2014, June 1-4, 2014,

[2]. Shailesh P. Patankar, Samir J. Deshmukh, Rucha R. Kolhekar, " Theoretical Analysis of Horizontal Axis Wind Turbine for Low Wind Velocity", International Journal of Innovative and Emerging Research in Engineering Volume 2, Special Issue 1 MEPCON 2015, p-ISSN: 2394 – 5494

[3]. Chen Yaqionga, Fang Yuefa, "Design and Analysis of Small-scale Diffuser Augment Wind Turbines", International Industrial Informatics and Computer Engineering Conference (IIICEC 2015).

[4]. Kazuhiko Toshimitsu, Hironori Kikugawa, Kohei Sato, Takuya Sato, "Experimental Investigation of Performance of the Wind Turbine with the Flanged-Diffuser Shroud in Sinusoidally Oscillating and Fluctuating Velocity Flows", Open Journal of Fluid Dynamics, 2012, 2, 215-221.

BIOGRAPHIES

Dr. E. S. Prakash

Dr. Madhukeshwara N.

Veeresh G. Gunjalli

Dadapeer D.

