PERFORMANCE OF HORIZONTAL AXIS WIND TURBINE WITH CONICAL WINGLET

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ABSTRACT: The wind flowing through a diffuser-augmented wind turbine travels along the walls of the diffuser causes in the exiting wind to form vortices of wind when exiting and these vortices cause most of the air to be diffused away from the centre of the exit, which creates a low pressure segment of air behind the turbine which accelerates the high pressure air in the front towards the low pressure air in the back, causing a significant increase in rotor speed. A three bladed horizontal axis wind turbine with a diffuser surrounding the blades is considered in the present study to investigate the power enhancement achieved. The wind turbine power output, efficiency with and without augmenting ring is estimated at rotor speeds varying from 0.5 to 2 Rad/sec at wind speeds ranging from 8 to 24 m/s using Ansys 18.1 CFX software. It is observed that at all rotational speeds, the effect of diffuser is less at higher wind velocities (beyond 16 to 18 m/sec) and maximum power augmentation at all rotor speeds is realized only at 16 to 18m/**sec.** For turbines installed on land, the average wind velocity in India ranges from 20 to 40 km/hour (6 to 12 m/sec) and hence using diffuser would be definitely an added advantage without additional investment cost. The power coefficient showed rapidly decreasing trend with increasing wind speed and attains very low values at speeds greater than 20 m/sec. At 8 meters/sec the coefficient exceeded Betz limit of 0.59 at 1. rad/sec and hence running turbine at speed beyond 1 rad/sec is not feasible. With regard to thrust coefficient It is seen that the trend of decreasing value with increasing wind speed is similar to power coefficient and also lower values of both coefficients are realized for lower rotor speeds. It is also noticed from literature that this trend is similar to the other similar wind turbines. Further all the thrust coefficient values for turbine with diffuser indicated more or less same increase for all rotor speeds (20% for 12 m/sec at 2 rad/sec and 18% 12 m/sec at 0.5 rad/sec).

Keywords: **wind velocity, power coefficient, thrust coefficient, torque coefficient, tip speed ratio, output power, betz limit, winglet.**

1.INTRODUCTION

In generally horizontal axis wind turbine is used power generation where wind is working fluid, here aerodynamic lift force is used to extracts the net positive torque on shaft which is caused for mechanical power generation there after modified as direct power generation by electrical control panel. Here horizontal axis wind turbine with and without diffuser at different wind velocity and various angular velocity was produced power generation higher when compared to without diffuser condition. **Rouge Agha** [1] et The DAWT was tested in three wind directions. Wind speeds, wind directions and output power were recorded with and without diffuser. The wind speed of the rotor was increased by 136% from 1.02 m/s to 2.41m/sec. **Jerson R** [2] et al The impact of the diffuser is assessed by the augmentation factor, the ratio of turbine efficiency to the Betz-Jakubowski limit. It is shown, for example, that the augmentation factor exceeds unity only for efficiency greater than 74% when the diffuser thrust is 0.2 of the totals thrust and ratio of the rotor area to diffuser exit area is 0.54. **Mohamed Khaled et al [3]** Power coefficient and thrust force coefficient were investigated for different winglet configurations with speeds varying from cutting speed to 12 meters /sec. **Hasim A et al [4]** Power coefficient is estimated wind speed from 8 to 12 m/sec and flange angle varied from -15 to +15 degrees and hi/D rotor changed through the range of 0 to 0.06. **Nugroho Agung Pambudi [5] et al** investigated power enhancement by using nozzle lens in wind turbines with different diameters and No of blades ranging from 2 to 4 using non twisted NACA 4412 blades. **Uli Goltenbott et al [6]** Power increases of up to 5% and 9% for the two and three rotor configurations are respectively achieved in comparison to a single rotor turbine. **Stefano Letizia et al [7]** developed hybrid CFD-source terms 2D approach, relying on a new experimental-based dynamic stall model for the analysis of a diffuser augmented H-Darrieus wind turbine**. Kosasih et al [8]** It was observed that at low turbulence levels, the diffuser augmented wind turbine showed s peak CP of 0.22, which is about two times greater than that of a bare wind turbine with peak CP of 0.11 in both CFD simulation and experiment.

2.METHODOLOGY

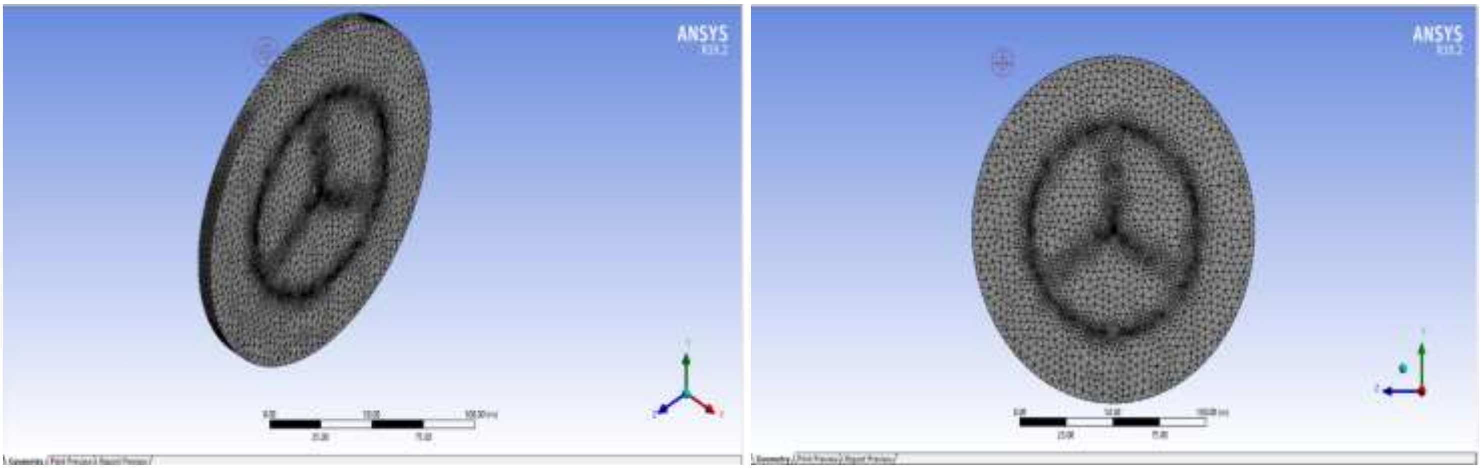

Fig:1 geometry and mesh file of diffuser wind turbine

Table No:1 specifications of wind turbine

S.NO	Parameters	Magnitude
1	Diameter of turbine blade	86m
2	Type of wind turbine	Horizontal type of onshore wind turbine
3	Pitch angle pf blade	$\leq 0^{\circ}$-5°
4	Height of wind turbine	80m
5	Swept Area of rotor	5808.800m²

3.DATA REDUCTION

$$P=0.5\rho*Cp*(\lambda\alpha)Ar*v^3$$

$$Cp=0.5(116/\lambda-0.4\alpha-5)\ e^{\wedge}21/\lambda$$

$$1/\lambda=(1/\lambda+0.08\alpha-0.035/\alpha^3+1)$$

$$\text{Where } \lambda=R\omega/v$$

$$T=P/\omega$$

$$T=0.5*Ar*Cp(\lambda\alpha)*v^3/\omega$$

Here moreover appropriate control techniques used to maximize power output power from abundant wind source in safe operating conditions.

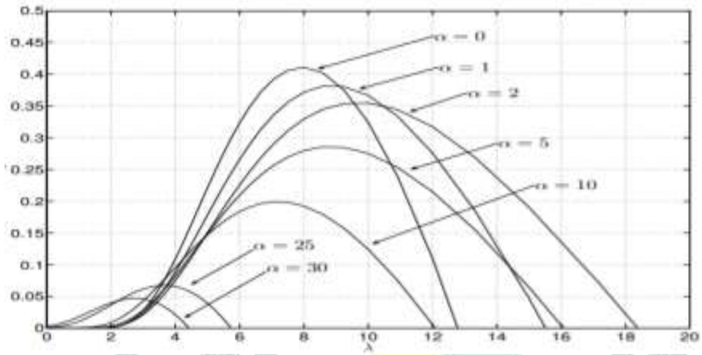

Fig:2 Characteristics Cp Vs λ curves

In the theoretical formulation pitch angle of the blade (α) was founded by the characteristics Cp Vs λ curves [14] which referenced to the proper pitch angle to the aerofoil section of wind turbine blade it was around taken by varying from range of $\leq 0^{\circ}$-5°.

4.REESULTS AND DISCUSSIONS

Table No.2 Wind velocity at 16meter/second of without diffuser

	Theoretical power (P_{the}) KW	Actual power (P_{at}) KW	Tip speed ratio (TSR)	Power coefficient (C_p)	Thrust coefficient (C_t)	Torque coefficient (Ctq)
0.5 rad/sec	14570	285	1.3438	0.0196	0.0913	0.0073
1.0 rad/sec	14570	840	2.6821	0.0576	0.1195	0.0121
1.5 rad/sec	14570	2400	4.0313	0.1647	0.2525	0.0204
2.0 rad/sec	14570	3280	5.3750	0.2251	0.4062	0.0209

Table No.3 Wind velocity at 16meter/second of with DAHAW

	Theoretical power (P_{the}) KW	Actual power (P_{at}) KW	Tip speed ratio (TSR)	Power coefficient (C_p)	Thrust coefficient (C_t)	Torque coefficient (Ctq)
0.5 rad/sec	14570	310	1.3438	0.0200	0.1000	0.0130
1.0 rad/sec	14570	960	2.6821	0.0610	0.1656	0.0204
1.5 rad/sec	14570	2800	4.0313	0.1821	0.4689	0.0317
2.0 rad/sec	14570	3400	5.3750	0.2554	0.6289	0.0419

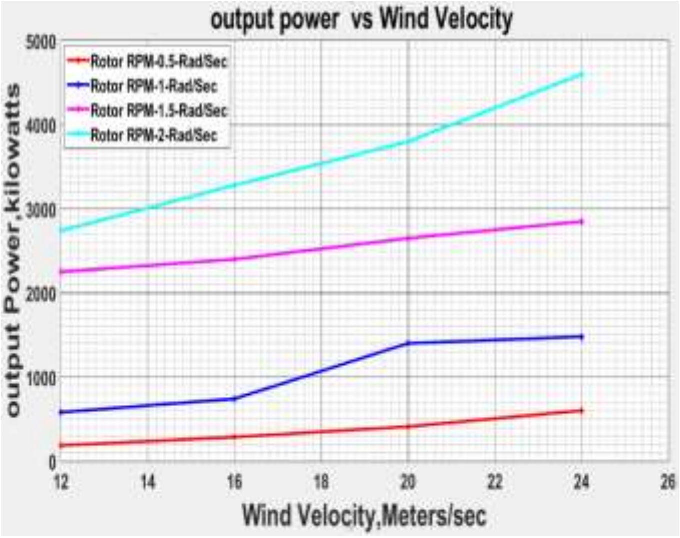

Fig1: OP Vs WV at 0.5,1,1.5,2rad/sec of Without Diffuser

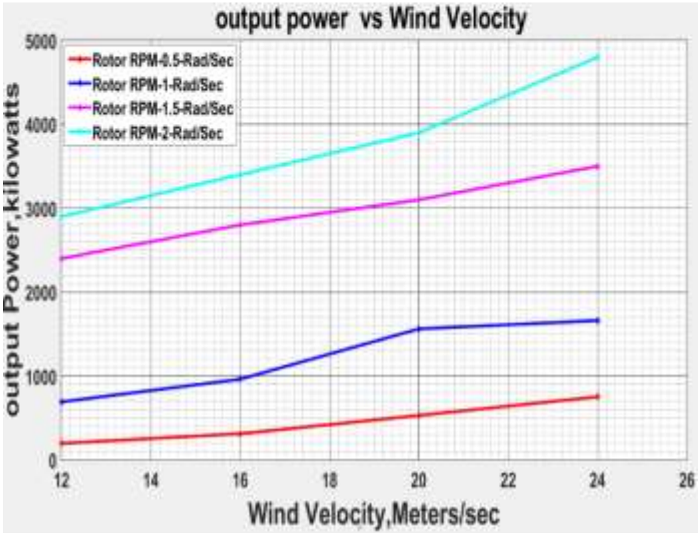

Fig 2.: OP Vs WV at 0.5,1,1.5,2rad/sec of with DAHAWT

At 0.5rad/sec, the output power increases from 99 Kw to 600 Kw with wind speed varying from 8 to 24m/sec. The percentage of increase in power output is 10% at 8m/sec and steadily increases to a maximum % increase of 20 at 16 to 18 m/sec and thereafter drops down The percentage increase at all wind speeds is highest at 0.5rad/sec and lowest value of 5% at 2 rad/sec. resulting in lower wind velocities at the centre It is noticed that at all rotational speeds, the diffuser is less effective at higher wind velocities i.e. beyond 16 to 18 m/sec and maximum power augmentation at all rotor speeds is realized only at 16 to 18m/sec.

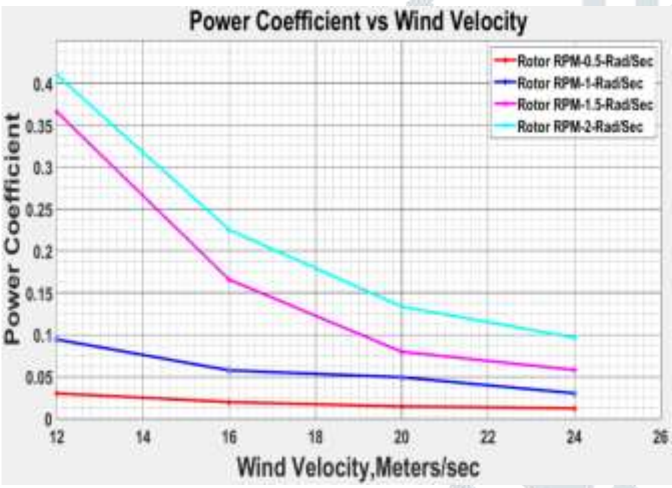

Fig:3 PC Vs WV at 0.5,1,1.5,2rad/sec of Without Diffuser

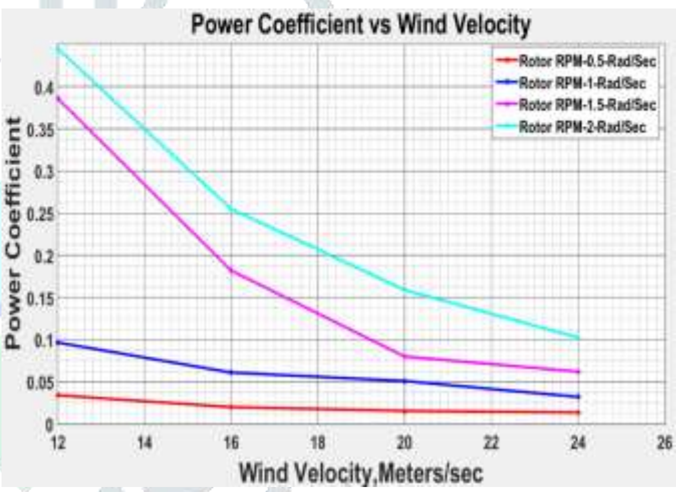

Fig:4 PC Vs WV at 0.5,1,1.5,2rad/sec of with DAHAWT

. It is seen that the coefficient decreases rapidly with increasing wind speed and attains very low values at speeds greater than 20 m/sec. This is due to the rapid increase of theoretical power that can be developed as it is proportional to cube of the velocity for the same case with diffuser slight increase from 0.445 to 0.465 is noticed with diffuser. Also, the increase in power coefficient between 1 and 1.5 rad/sec is more pronounced at lower wind speeds (12 to 16 m/sec) than at higher wind speeds. The Betz limit exceeds the permissible value of 0.59 at 8 m/sec wind speed with 1.5 rad/sec rotor speed which is not feasible and hence of the cut off speed of this bare particular turbine is 9 m/sec.

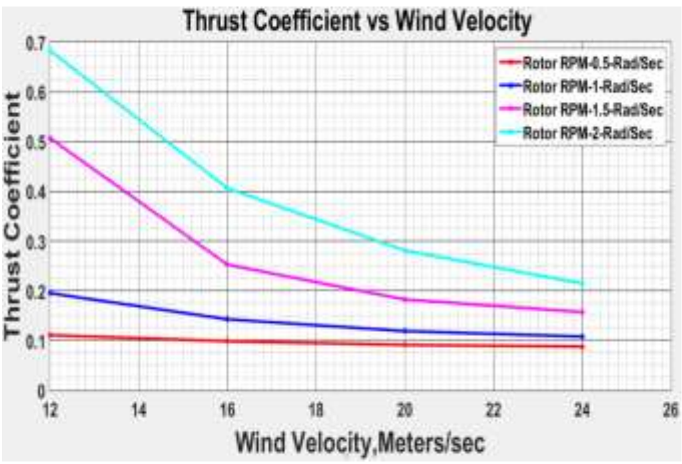

Fig:5 TC Vs WV at 0.5,1,1.5&2rad/sec of without Diffuser

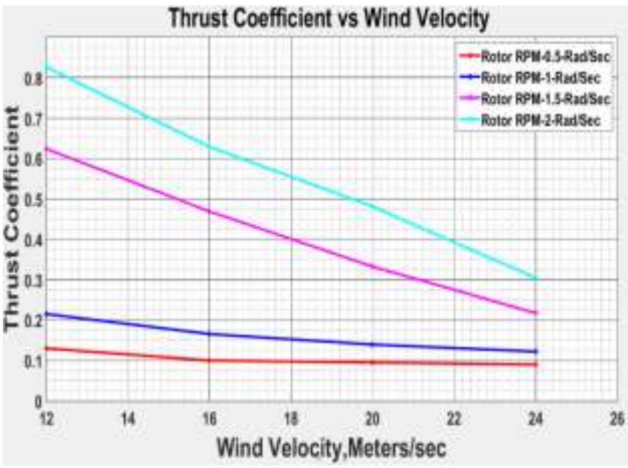

Fig:6 TC Vs WV at 0.5,1,1.5&2rad/sec of with DAHAWT

It is also noticed from literature that this trend is similar to the other similar wind turbines. All the thrust coefficient values for turbine with diffuser indicated more or less same increase for all rotor speeds (20% for 12 m/sec at 2 rad/sec and 18% 12 m/sec at 0.5 rad/sec).

5.CONCLUENCES

In traditional bare wind turbine performance conditions were identical, in practical working situation of real time operation of wind turbine meet realistic output effort for different configurations of turbines. Here that concluded information as:

The following conclusions can be drawn from present study as follows

1) At 0.5rad/sec, the output power increases from 99 Kw to 600 Kw with wind speed varying from 8 to 24m/sec. The percentage of increase in power output is 10% at 8m/sec and steadily increases to a maximum % increase of 20 at 16 to 18 m/sec and thereafter drops down.
2) The percentage increase at all wind speeds is highest at 0.5rad/sec and lowest value of 5% at 2 rad/sec. Possible reason for diminished values with increasing rotor speed could be due to that the vortices created at the center by the exciting wind from the diffuser are not effective in creating sufficient suction pressure segment of air behind the turbine resulting in lower wind velocities at the center
3) It is noticed that at all rotational speeds, the diffuser is less effective at higher wind velocities i.e. beyond 16 to 18 m/sec and maximum power augmentation at all rotor speeds is realized only at 16 to 18m/sec.
4) For turbines installed on land, the average wind velocity in India ranges from 20 to 40 km/hour (6 to 12 m/sec) and hence using diffuser would be definitely an added advantage without additional investment cost. At these available wind speeds in India it is also not recommended to run the rotor at speeds in excess of 2 rad/sec as the noise generated by the turbine blades becomes highly objectionable due to blade tip velocities exceeding 80 m/sec. However, for offshore applications rotor speeds can exceed 2 rad/sec as noise generated is not objectionable at all.
5) The power coefficient is the ratio of actual power developed to ideal power that can be developed. The coefficient cannot exceed the Bertz limit of 0.59 for all wind turbines without diffuser and hence values greater than Bertz limit are infeasible and should be ignored. However, this need not be considered for cases with diffuser since them involves developing suction pressure behind the rotor by creating vortices. It is seen that the coefficient decreases rapidly with increasing wind speed and attains very low values at speeds greater than 20 m/sec. This is due to the rapid increase of theoretical power that can be developed as it is proportional to cube of the velocity.
6) At 0.5 rad/sec the variation with wind speed more or less remains constant at 0.03. Higher values of rotor speeds results in higher values of power coefficient, maximum value of 0.445 realized a t12 m/sec velocity at 2 rad/sec rotor speed for bare turbine. For the same case with diffuser slight increase from 0.445 to 0.465 is noticed with diffuser. Also, the increase in power coefficient between 1 and 1.5 rad/sec is more pronounced at lower wind speeds (12 to 16 m/sec) than at higher wind speeds. The Betz limit exceeds the permissible value of 0.59 at 8 m/sec wind speed with 1.5 rad/sec rotor speed which is not feasible and hence of the cut off speed of this bare particular turbine is 9 m/sec.
7) Thrust coefficient is the ratio of horizontal force developed due to the wind flowing past the swept area of the turbine to the resultant force developed by the wind. It is seen that the trend of decreasing value of thrust coefficient with increasing wind speed is similar to power coefficient and also lower values of both coefficients are realized for lower rotor speeds. It is also noticed from literature that this trend is similar to the other similar wind turbines. All the thrust coefficient values for turbine with diffuser indicated more or less same increase for all rotor speeds (20% for 12 m/sec at 2 rad/sec and 18% 12 m/sec at 0.5 rad/sec).

REFERENCES

[1] ArougeAghaa, Hassam Nasarullah Chaudhrya, FanWangb, Determining the augmentation ratio and response behaviour of a Diffuser Augmented Wind Turbine (DAWT). 37 (2020) 100610.

[2] Mohamed Khaled, Mostafa M. Ibrahim, Hesham E. Abdel Hamed, Ahmed F. Abde Gwad, Investigation of a small Horizontal Axis wind turbine performance with and without winglet. 187 (2019) 115921.

[3] Jerson R.P. Vaz, David H. Wood, Effect of the diffuser efficiency on wind turbine performance. S0960-1481(18)30420-8.

[4] Hasim A. Heikal, Osayed S.M. Abu-Elyazeed, Mohamed A.A. Nawar, Youssef A. Attai, Maged M.S. Mohamed, On the actual power coefficient by theoretical developing of the diffuser flange of wind-lens turbine. S0960-1481(18)30244-1.

[5] Nugroho Agung Pambudi, Danur Lambang Pristiandaru, Basori , Danar Susilo Wijayanto , Husin Bugis , Bambang Dwi Wahyudia, Cyrillus Sudibyo , Karno M.W, Ngatou Rahman , Nyenyep Sriwardani , Subagsono, Experimental Investigation of Wind Turbine Using Nozzle-Lens at Low Wind Speed Condition.105(2017)1063–1069.

[6] Uli G€oltenbott , Yuji Ohya , Shigeo Yoshida , Peter Jamieson, Aerodynamic interaction of diffuser augmented wind turbines in multi-rotor systems. 112 (2017) 25-34.

[7] Stefano Letizia, Stefania Zanforlin, Hybrid CFD-source terms modelling of a diffuser-augmented vertical axis wind turbine.101(2016)1280 –1287.

[8] B. Kosasih, H. Saleh Hudin, Influence of inflow turbulence intensity on the performance of bare and diffuser-augmented micro wind turbine model. 87 (2016) 154-167.

[9] j. villanueva, l. alvarez-icaza, wind turbine torque and wind speed estimation. dscc2011-6063