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Research article

EFFECT OF PERTURBATION FACTOR AND SOLIDITY ON PERFORMANCE ANALYSIS OF WIND TURBINE

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Abstract

This study focuses on Performance prediction of wind turbine at different Perturbation Factor. It is an analysis of various parameters of Wind Turbine under upstream and downstream condition. It also covers Solidity of Wind Turbine and its effect over the various parameters. The present work investigates also the influence of the solidity of wind turbine on the rotor speed using Horizontal axis wind Turbine (HAWT). A model of wind turbine has been prepared for the experiment and observation. Wind Turbine model has been tested for solidity and perturbation Factor in which three- four cases are considered of single blade and multi blade cases. Solidity of wind turbine and its effects over the other parameters change according to various situations. The number of blades on the rotor increases, the rotor blade material increased and solidity of wind turbine increased proportionally. **Copyright © IJRETR, all rights reserved.**

Keywords: Wind Energy, Solidity, Perturbation Factor, Power Co-efficient, Horizontal Axis Wind Turbine.

I. INTRODUCTION

In recent scenario, applications of wind energy based technologies increased widely. The power efficiency of wind energy systems has a high influence in the economic analysis of wind energy systems. The power efficiency in these systems depends on many elements of wind turbine. Some factors that are involved in blade efficiency are the wind feature, e.g. its probabilistic distribution, the mechanical interaction of blade with the electric generator, and the strategies dealing with pitch and rotational speed control. Solidity and Perturbation factor are important tools which effect to efficiency of wind turbine. Proper modeling of the aerodynamic aspects of wind energy systems is very important for successful design and analysis of wind turbines. Wind energy conversion system aerodynamic models are used to obtain wind inflow conditions from load which is applied on the turbine. Recent research and developments came up with various types of wind turbines out of which Horizontal Axis Wind Turbines (HAWTs) and Vertical Axis Wind Turbines (VAWTs) are the most commonly used turbines. Horizontal Axis Wind Turbines have some drawbacks and more advantages that make HAWTs widely used commercially. [1]

The power produced by wind turbine depends on number of factors such as wind speed, height of the wind turbine, air density, geographical location of the wind turbine, texture of the land over which wind turbine is installed, and number of other factors. [2]

In this study we are using Horizontal Axis Wind Turbines (HAWT). The focus of this research work is based on the performance analysis of designed wind turbine. This work also include to the effects of solidity and perturbation factor on the performance of wind turbine. Variation in power coefficients for different wind speed and for different Perturbation factor is analyzed.

The effect of perturbation factor on the power extraction from the wind found that for values of zero perturbation factors there was no power generation and similarly for a Perturbation Factor of unity stall condition was achieved. Maximum value was achieved at 1/3 of the value. This wide variation in power extraction on account of a change in perturbation factor was what prompted us to take up the research. [3] Similarly the effect of change in perturbation factor on axial thrust and the torque development by the turbine was much more significant to take up the issue in the 1930’s Glauert applied classical aerodynamic methods to airplane propeller designs in an effort to optimize performance of the horizontal axis machine for propulsion. [4] The solidity is one of the most important factor which greatly affects the performance of the horizontal axis wind turbine (HAWT).The numerical result shows that the solidity for two blades is minimum and for this the power coefficient, rotor shaft torque and power extracted by the wind turbine is minimum while the rotor speed is maximum. The solidity for six blades is maximum and for this power coefficient, rotor shaft torque and power extracted by the wind turbine is maximum while the rotor speed is minimum. [5]

II. DESIGNING OF EXPERIMENTAL SET UP

The experimental model of small scale horizontal axis wind turbine has been setup at the Energy Centre, MANIT Bhopal. The model has been built for variable number of blades such as 2,3,4,5 and 6 blades on the rotor of wind turbine. The wind turbine rotor diameter for this model is 1.23 m and swept area is 1.188 m2. The tower of wind turbine has four supports at the bottom. Main content is given below-

1. Blade- The blade is demarked to have three sections which include a mounting section and two airflow sections.

S.No.	Property	Specification
01	Length of Blade	0.48 mm
02	Width of Blade	0.13m and 0.11m
03	Area of Blade	0.57 m^2

2. Tower- Tower is the important component of a wind turbine and it provides to the whole structure of horizontal axis wind turbine on the top. It also keeps the wind turbine in front to the wind. In this model the material used for tower is mild steel. Tower has four base supports horizontal to the surface of ground. There is also a thin rod support inclined at 45^0 to the horizontal support on each. The height of tower is **2** meters.

3. Hub- In a small scale horizontal axis wind turbine hub is a disc shape component on which the blades are directly bolted and hence are stalled.

S.No.	Property	Specification
01	Material of hub	Fiber glass
02	Thickness of sheet	0.27 m
03	Area of hub	0.57 m^2

4. Rotor Shaft- The rotor shaft of wind turbine is made up of a iron rod which has a length of 0.35 m and diameter of 0.01m. It has two bearings at a distance of 0.07m. One end of shaft is connected to the hub and the other is to the gear

5. Gear Box- A gearbox is a mechanical system of transferring energy from one device to another and is used to increase torque while reducing speed. The one end of rotor shaft of wind turbine is coupled to the DC permanent generator through the two gears. In this model we have used two gears to increase the rotor shaft speed one is of 36 teeth and other is of 96 teeth.

6. Bearings- Ball bearings used in this model to friction on the shaft of wind turbine. In this model two ball bearings have been used. The bearings, are substandard units that are not salvageable. Bearings can be very expensive, and for our particular setup we will require 2 roller bearings that are going to primarily centralize the shaft, and a turntable bearing to take the majority of the weight. This combination will provide the least amount of friction, while maximizing bearing life and maintaining safe operating conditions.

7. **DC Permanent Magnet Generator-** The DC permanent magnet generator used in this model has the rating of 12 V, 1000 rpm and 3.6W (max). It has 4mm shaft diameter with internal hole and 125gm weight with 1kgcm torque. In No-load current it is 60 mA(Max) and in Load current 300 mA(Max).
8. **Instruments-** Multimeter, Techometer & Anemometer are used for taking various types of readings. We have used Fluke 87-V Digital Multimeter for the measurement of voltage and current. Fluke 87-V Digital Multimeter is a versatile True-RMS meter. The Fluke 87-V measures up to 0 A, upto 20 A for 30 seconds, and 1,000-volt AC and DC. The Fluke records Min/Max/Average and has a Min/Max alert that automatically captures variations. Fluke 87-V is accurate to 0.05% DC and also, True-RMS AC voltage and current provide accurate measurements. A digital tachometer is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. An anemometer or wind meter is a device used for measuring wind speed, and is a common weather station instrument. Thermal anemometry is the most common method used to measure instantaneous fluid velocity.

III. PARAMETRIC EVALUTION OF PROPOSED WIND TURBINE SYSTEM

1. Solidity:

Solidity is usually defined as the percentage of the circumference of the rotor which contains material rather than air. High-solidity machines carry a lot of material and have coarse blade angles.

Solidity, $\sigma = \frac{N \times A}{\pi R^2}$ (1)

Where, N is blade number, A is blade area (m^2), R is wind turbine radius (m).

2. Rotor Swept Area

The rotor swept area depends upon the chord of rotor blade and it can be increase by increasing the chord of blades. The rotor swept area greatly affects the size and performance of horizontal axis wind turbine. Rotor swept area,

$A = \pi R^2$ (2)

3. Wind Power

The power available in the wind is equal to the kinetic energy associated with the mass of moving air. Although the power available is proportional to the cube of wind speed, the power output has a lower order dependence on wind speed. This is because the overall efficiency of the windmill changes with wind speed.

Wind Power, $P_0 = 1/2\ \rho A V^3$ (3)

where, ρ= Air density, A= Rotor swept area, V= Speed of free wind.

4. Coefficient of Power (CP)

The coefficient of power of a wind turbine is a measurement of how efficiently the wind turbine converts the energy in the wind into electricity. To find the coefficient of power at a given wind speed, all you have to do is divide the electricity produced by the total energy available in the wind at that speed.

$$C_P = \frac{\text{Electricity produced by wind turbine}}{\text{Total Energy available in the wind}} \quad (4)$$

5. Tip Speed Ratio

The tip speed ratio is defined as the ratio of the speed of the extremities of a windmill rotor to the speed of the free wind. It is a measure of the ‘gearing ratio' of the rotor. Drag devices always have tip-speed ratios less than one and hence turn slowly, whereas lift devices can have high tip-speed ratios and hence turn quickly relative to the wind.

Tip speed ratio, $\lambda = \frac{\text{Blade tip speed}}{\text{Wind speed}} = \frac{R\Omega}{V_0}$ (5)

(5)

6. Rotor Shaft Torque

A blade which is designed for high relative wind speeds develops minimal torque at lower speeds. This results in a higher cut in speed and difficulty self-starting. A noise increase is also associated with increasing tip speeds as noise increases approximately proportionately to the sixth power.

The speed of rotor, $\omega = \frac{2\pi n_s}{60}$ (6)

The proportion of the power in the wind that the rotor can extract is termed the coefficient of performance (or power coefficient or efficiency; symbol Cp) and its variation as a function of tip speed ratio is commonly used to characterize different types of rotor.

Mechanical torque developed

$$T_M = \frac{P_0}{V_0} R \qquad (7)$$

Maximum torque coefficient,

$$C_{T\max} = \frac{C_{P\max}}{\lambda} \qquad (8)$$ ($Cpmax$=0593)

The maximum torque produced at the shaft, $T_{sh} = T_M \times C_{T\max}$ (9)

Power extracted by the wind turbine is-

$$P_0 = \omega \times T_{sh} \qquad (10)$$

7. Reynolds Number (R_E)

Reynolds number (Re) is defined as the ratio of inertia force to the viscous force. Reynolds number signifies the relative predominance of the inertia to the viscous forces occurring in the flow system. The higher the value of Re. greater will be the relative contribution of inertia effect.

Reynolds number as given by equation

$$R_e = \frac{\rho L V}{\mu} \qquad (11)$$

Where,

V = velocity of the flow of the fluid (air)
L= length of the blade
ρ = mass density of fluid (air)
μ = viscosity of fluid (air)
ω = is the angular speed [rad/s],
N = Turbine Speed (rpm),

$$\omega = \frac{2\pi N}{60} \qquad (12)$$

8. Lift Force

Lift force is defined to be perpendicular to direction of the oncoming airflow. The lift force is the consequence of the unequal pressure on the upper and lower airfoil surfaces.

Lift = $C_l \rho/2 AV^2$ (13)

Where, C_l =chord length (m)

9. Drag Force

Drag force is defined to be parallel to the direction of oncoming airflow. The drag force is due both to viscous friction forces at the surface of the airfoil and to unequal pressure on the airfoil surfaces facing toward and away from the oncoming flow.

Drag = $C_d \rho/2 AV^2$ (14)

Where, C_D = drag coefficient

10. Actuator Disc Theory

The power produced by wind turbine can be obtained by multiplying the power available in wind by power coefficient, the power available in wind depends on air density, rotor swept area and cubic free stream wind velocity, thus the turbine power can be expressed as.

$$P = \frac{1}{2} \rho A U_\infty^3 C_P \qquad (15)$$

The axial induction factor α indicates the degree with which the wind velocity at the upstream of rotor slowed down by the turbine. Thus:

$$\alpha = \frac{U_\infty - U_R}{U_\infty} \qquad (16)$$

Wind velocity before and after the actuator disk equal to wind velocity at rotor plane. Thus:

$$U_2 = U_3 = U_R \qquad (17)$$

The power of turbine can be expressed in terms of axial induction factor as follow:

$$P = 2\rho A\alpha(1-\alpha)^2 U_\infty^3 \quad (18)$$

The power coefficient can be expressed in terms of axial induction factor as follow:

$$C_P = 4\alpha(1-\alpha)^2 \quad (19)$$

The power coefficient can be presented as a function of free stream wind velocity and velocity at rotor plane by substituting equation (16) into equation (19).

$$C_P = 4\left[\left(\frac{U_\infty - U_R}{U_\infty}\right) - 2\left(\frac{U_\infty - U_R}{U_\infty}\right)^2 + \left(\frac{U_\infty - U_R}{U_\infty}\right)^3\right] (20)$$

The amount of power produced by wind turbine can be presented by substituting equation (20) into equation (15)

$$P = 2\rho A(U_\infty - U_R)[U_\infty - 2U_\infty(U_\infty - U_R) + (U_\infty - U_R)^2\} \quad (21)$$

The torque developed by turbine shaft can be obtained by multiplying theoretical torque by thrust coefficient, theoretical torque depends on air density, rotor swept area, rotor radius and squared free stream wind velocity, thus the turbine torque can be expressed as:

$$T = \frac{1}{2}\rho A U_\infty^3 R C_T \, (22)$$

It also can be presented in terms of axial induction factor as follow:

$$T = 2\rho A\alpha(1-\alpha)U_\infty^2 \quad (23)$$

The thrust coefficient in terms of axial induction factor can be presented as follow:

$$C_T = 4\alpha(1-\alpha) \quad (24)$$

The thrust coefficient can be presented as a function of free stream wind velocity and velocity at rotor plane by substituting of equation (16) into equation (24).

$$C_T = 4\left[\left(\frac{U_\infty - U_R}{U_\infty}\right) - \left(\frac{U_\infty - U_R}{U_\infty}\right)^2\right] (25)$$

The torque of wind turbine can be re-written in terms of free stream wind velocity and velocity at rotor plane by substituting equation (25) into equation (23).

$$T = 2\rho U_R(U_\infty - U_R) \quad (26)$$

Tip speed ratio can be expressed as the ratio of power coefficient to thrust coefficient. Thus:

$$\lambda = \frac{C_P}{C_T} \quad (27)$$

It can be expressed in another formula as follow:

$$\lambda = \left[1 - \left(\frac{U_\infty - U_R}{U_\infty}\right)\right] \quad (28)$$

11. Aerodynamics

Aerodynamic performance is fundamental for efficient rotor design. Aerodynamic lift is the force responsible for the power yield generated by the turbine and it is therefore essential to maximize this force using appropriate design. A resistant drag force which opposes the motion of the blade is also generated by friction which must be minimized. It is then apparent that an aerofoil section with a high lift to drag ratio, typically greater than 30 be chosen for rotor blade design.

Lift to Drag Ratio$=\frac{Coefficientoflift}{Coefficientofdrag} = \frac{C_L}{C_D}$ (29)

12. Betz' Law Verification

Betz' law is a theory about the maximum possible energy to be derived from a wind turbine. It was developed in 1919 by German physicist Albert Betz. According to the rule, no turbine can capture more than 59.3 percent of the potential energy in wind

$$P = \frac{1}{2}\rho A S V_1^3 C_P \ldots\ldots\ldots\ldots(30)$$

IV. RESULT AND DISCUSSION

(A) EFFECT OF NUMBER OF BLADES ON SOLIDITY

It is shown in the graph that as the number of blades on the rotor increases, the rotor blade material increased and solidity of wind turbine increased proportionally.

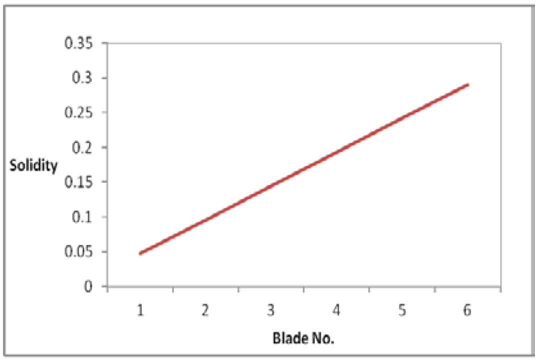

Figure 1.1 Solidity with different number of blades.

The higher rotor solidities require a lower angular velocity to obtain the maximum amount of power produced for a certain wind speed. Moreover, a slight reduction in rotor efficiency with the increase of rotor solidity can be observed.

Table 1.1 Blade number, Solidity, Wind Turbine Power, Rotor Speed And Shaft Torque

Blade No.	Solidity	Pt	Rotor speed	Tsh
2	0.096	43.92	280	0.459
3	0.145	90.27	204	0.823
4	0.193	145.2	156	1.148
5	0.242	228.4	115	2.761
6	0.29	306.4	99	3.541

(B) EFFECT OF SOLIDITY ON THE ROTOR SPEED

The present work investigates the influence of the solidity of wind turbine on the rotor speed. This shows that as the solidity of wind turbine increases, the rotor speed get reduced. The rotor speed for this model is highest for two blades and for the solidity of 9.60%. The turbines with high solidity have the advantage of enabling the rotor to start rotating easily because more rotor area interacts with the wind initially.

Table 1.2 Solidity and Rotor speed of wind turbine

Rotor speed	Solidity
161	0.048
280	0.096
204	0.145
156	0.193
115	0.242
99	0.29

The turbines with high solidity have the advantage of enabling the rotor to start rotating easily because more rotor area interacts with the wind initially.

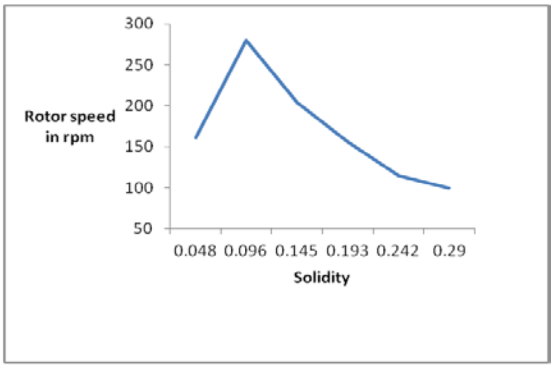

Figure 1.2 Solidity and rotor speed

(C) EFFECT OF SOLIDITY ON THE ROTOR SHAFT TORQUE:-

The following graph shows the effect of solidity on the rotor shaft torque. As the solidity of turbine increases the rotor shaft torque also increases. This is because the more area of rotor strikes with wind.

Table 1.3 Solidity and Rotor Shaft Torque of wind turbine

Tsh	Solidity
0.161	0.048
0.459	0.096
0.823	0.145
1.148	0.193
2.761	0.242
3.541	0.29

By increasing the turbine solidity; it increases the static torque coefficient. High solidity HAWT turbine has a self-starting capability, because it has higher static torque coefficient than the low solidity turbines.

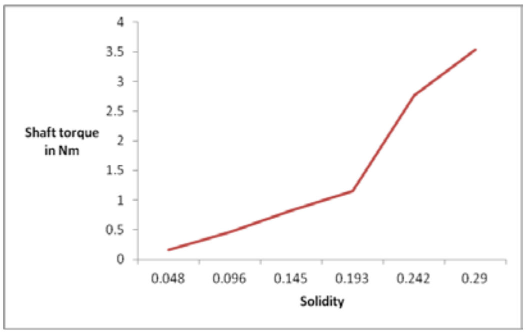

Figure1.3 Solidity and rotor shaft torque.

(D) EFFECT OF SOLIDITY ON POWER EXTRACTED BY THE WIND TURBINE

The following graph shows that as the solidity of the wind turbine increases ,the power extracted by the wind turbine also increases. The power extracted by the wind turbine is maximum for the solidity of 29% for this model.

Table 1.4 Solidity and Power extracted by wind turbine

Power extracted by wind turbine	Solidity
43.92	0.096
90.27	0.145
145.2	0.193

228.4	0.242
306.4	0.29

The peak power appears to be augmented with increasing the solidity till σ = 0.25; then, the peak seems to be decreased with further increasing the solidity from σ = 0.25 to σ = 0.5. Moreover, the blade speed range, in which the power can be generated, is considerably reduced with increasing the solidity.

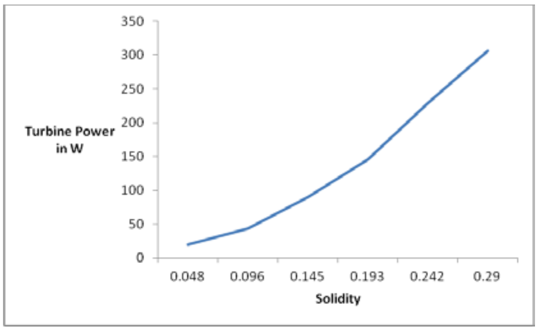

Figure 1.4 Solidity and power extracted by the wind turbine

(E) EFFECT OF SOLIDITY ON POWER COEFFICIENT

This is shown in the graph that as the solidity of wind turbine increases, the power coefficient of turbine also increases.The study shows that the greatest power coefficients result from increased blade number and greater rotor solidity, both of which contribute to the added torque that improves cut-in wind speed. Consequently there is a maximum value of Cp of 59.3% (known as the Betz limit), although in practice real wind rotors have maximum Cp values in the range of 25%-45%.. The theoretical results predict a 30% increase in C_p going from a 3 bladed rotor to 12, at equal solidities of 0.27. Even at σ = 0.14, an increase from 3 to 6 blades provides 10% greater $C_{p.}$

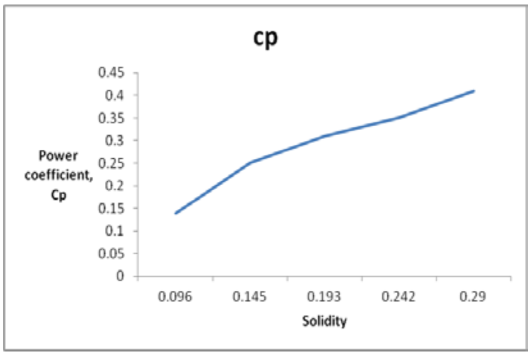

Figure 1.5 Solidity and power coefficient.

(F) PERTURBATION FACTOR AND POWER COEFFICIENT

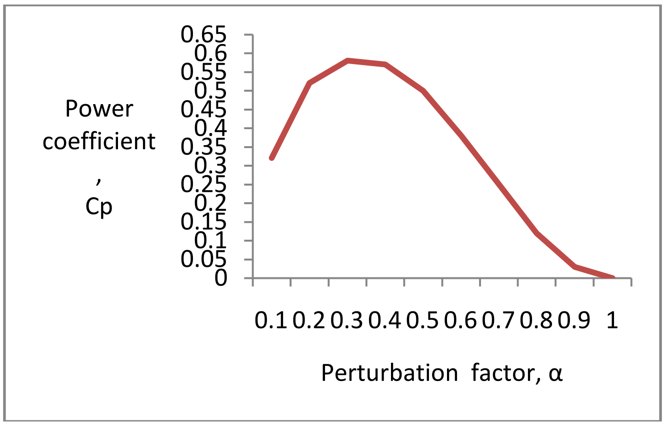

Figure 1.6 Perturbation factor and power coefficient

It can be seen from the graph that power coefficient greatly vary with the perturbation factor. For this model power coefficient minimum when the perturbation factor is 0.1. The maximum power coefficient is 0.58 when the perturbation factor is 0.3.

Table 1.5 Perturbation factor and power coefficient

α	Cp
0.1	0.32
0.2	0.52
0.3	0.58
0.4	0.57
0.5	0.5
0.6	0.38
0.7	0.25
0.8	0.12
0.9	0.03
1	0

(G) VARIATION OF ROTOR SPEED WITH DIFFERENT NUMBER OF BLADES

In the study it is found that as number of blades on the rotor of wind turbine increases, the rotor speed get decreased. The graph shows that the rotor speed is maximum for two blades and the rotor speed is minimum for six blades.

Table 1.6 Wind speed and rotor speed for different number of blades

wind speed	**Rotor 2**	**Rotor 3**	**Rotor 4**	**Rotor 5**	**Rotor 6**
2.4	238	150	116	85	44
3.7	271	172	122	87	75
3.9	285	185	132	90	78
4.3	320	190	150	97	92
4.5	338	201	161	102	94
4.5	351	215	172	105	96
4.9	358	215	178	107	110
5	360	219	180	109	122
5.1	365	224	187	112	136

5.2	368	239	195	125	148

So from this study it is clear that for low speed we will use maximum number of blades and for high speed minimum number of blades.

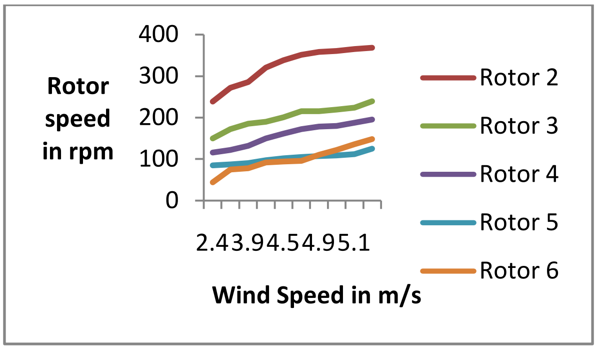

Figure 1.7 Rotor Speed with Different Number of Blades

From the graph it is clear that for medium rotor speed three blades wind turbine is most suitable.

(H) VARIATION OF SHAFT TORQUE WITH DIFFERENT NUMBER OF BLADES

From the study it is clear that when the number of blades on the rotor is more, the torque is more and when the number of blades on the rotor is low, the torque is low.

Table 1.7 Shaft Torque of Wind Turbine Rotor for Different Number of Blades

wind speed	Tsh 2	Tsh 3	Tsh 4	Tsh 5	Tsh 6
2.4	0.24	0.74	1.16	2.56	2.96
3.7	0.25	0.86	1.25	2.65	3.19
3.9	0.3	0.97	1.41	2.68	3.227
4.3	0.31	1.15	1.65	2.7	3.28
4.5	0.32	1.38	1.69	2.75	3.36
4.5	0.33	1.61	1.83	2.78	3.43
4.9	0.41	1.7	1.85	2.83	3.44
5	0.48	1.84	2.11	2.85	3.47
5.1	0.72	2.01	2.25	2.87	3.6
5.2	0.94	2.01	2.35	2.96	3.95

So this study suggests that for high torque requirement we will use maximum number of blades such as for water pumping and for grinding the grains. For low torque such as for electricity generation we will use lower number of blades because it requires lower torque.

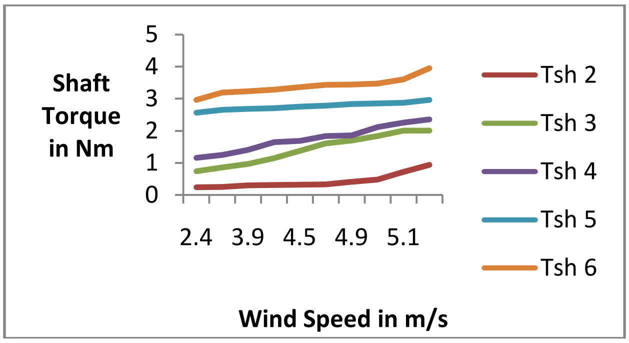

Figure 1.8 Shaft Torque with Different Number of Blades

(I) VARIATION OF WIND TURBINE VOLTAGE WITH DIFFERENT NUMBER OF BLADES

Table 1.8 Output Voltage of Turbine With Different Blades

Blade	Voltage
2	7.511111
3	6.955556
4	4.951111
5	3.577778
6	3.072237

It has been observed from the graph that as we increase the number of blades on the rotor of wind turbine, speed of rotor decreases and the output voltage of turbine also decreased with the speed.

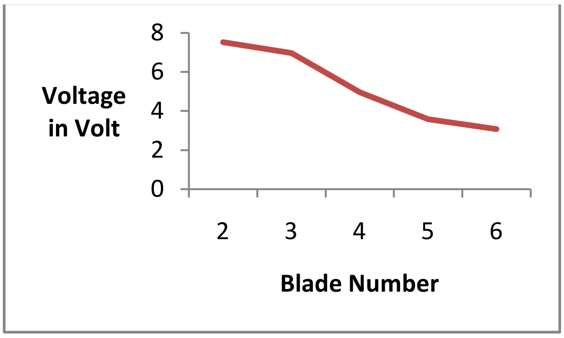

Figure 1.9 Variation of voltage with number of blade

(J) VARIATION OF WIND TURBINE VOLTAGE WITH DIFFERENT NUMBER OF BLADES

The following graph shows that as the tip speed ratio of wind turbine increases, the power coefficient also increases and it is maximum for 6 numbers of blades on the wind turbine rotor. Thus the tip speed ratio plays an important role in the wind turbine system.

Table 1.9 Power coefficient and tip speed ratio

Blade	Cp	λ
2	0.144	4.031
3	0.125	4.184
4	0.316	1.835
5	0.35	1.585

6	0.416	1.432

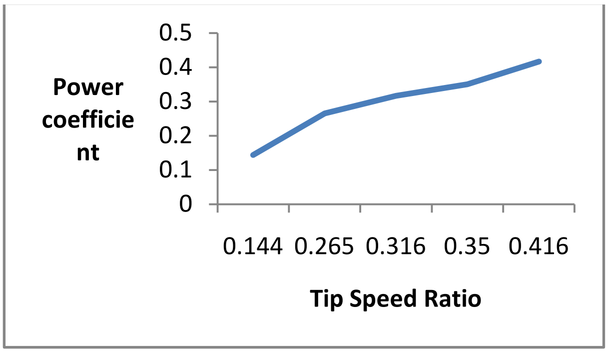

Figure 1.10 Variation of power coefficient with tip speed ratio

V. CONCLUSION

Thus from the above observation & calculation we have shown how important the effect of perturbation factor has in the harnessing of wind power. Torque available at the blades is also very high. When the air just passes through the turbine blades in this case without any reduction in velocity and thus the turbine taps no wind power. It was found that maximum axial thrust occurs at a perturbation factor of 0.58. This is the condition for maximum power extraction, it related to the ideal case that is nothing but the Betz criterion. Perturbation factor increases when downstream is reduced. Power coefficient greatly varies with the perturbation factor. For this model power coefficient minimum when the perturbation factor is 0.1. The maximum power coefficient is 0.58 when the perturbation factor is 0.3.

Solidity of wind turbine and its effects over the other parameters change according to various situations. The number of blades on the rotor increases, the rotor blade material increased and solidity of wind turbine increased proportionally. The present work investigates the influence of the solidity of wind turbine on the rotor speed. This shows that as the solidity of wind turbine increases, the rotor speed get reduced. The rotor speed for this model is highest for two blades and for the solidity of 9.60%. As the solidity of turbine increases the rotor shaft torque also increases. This is because the more area of rotor strikes with wind.

By increasing the turbine solidity; it increases the static torque coefficient. As graph shows that as the solidity of the wind turbine increases, the power extracted by the wind turbine also increases. The power extracted by the wind turbine is maximum for the solidity of 29% for this model. The peak power appears to be augmented with increasing the solidity till $\sigma = 0.25$; then, the peak seems to be decreased with further increasing the solidity from $\sigma = 0.25$ to $\sigma = 0.5$. Moreover, the blade speed range, in which the power can be generated, is considerably reduced with increasing the solidity. as the solidity of wind turbine increases, the power coefficient of turbine also increases. The study shows that the greatest power coefficients result from increased blade number and greater rotor solidity, both of which contribute to the added torque that improves cut-in wind speed. Consequently there is a maximum value of Cp of 59.3% (known as the Betz limit), although in practice real wind rotors have maximum Cp values in the range of 25%-45%.

As number of blades on the rotor of wind turbine increases, the rotor speed gets decreased. The graph shows that the rotor speed is maximum for two blades and the rotor speed is minimum for six blades. So from this study it is clear that for low speed we will use maximum number of blades and for high speed minimum number of blades. From the graph it is clear that for medium rotor speed three blades wind turbine is most suitable.

From the study it is clear that when the number of blades on the rotor is more, the torque is more and when the number of blades on the rotor is low, the torque is low. So this study suggests that for high torque requirement we will use maximum number of blades such as for water pumping and for grinding the grains. For low torque such as for electricity generation we will use lower number of blades because it requires lower torque. It has been observed from the graph that as we increase the number of blades on the rotor of wind turbine, speed of rotor decreases and the output voltage of turbine also decreased with the speed.

Future scope of the work may be applicable for the Vertical Axis Wind Turbines (VAWTs) on same condition. Design also may change as per the need.

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