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Performance Analysis of Vertical Axis Wind Turbines

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ABSTRACT

Development of wind energy use in urbanenvironments is of growing interest to industry and local governments as an alternative to utility-based andnon-renewable forms of electric production.

A wind turbine is a device that converts kinetic energy from the wind into mechanical power, further it can be converted to Electrical energy by adding some more components to the experimental setup. Vertical Axis Wind Turbine (VAWT) is one type of wind turbine where the main rotor shaft is set vertically and it can capture wind from any direction.

The aim of this work is to develop a model for the design and performance of a vertical axis wind turbine for small scale energy applications. Based on the wind speed, Small 4 & 8 bladed turbines will be constructed and investigated the performance of turbines at various speeds and will be used to find out the wind velocity, Pressure acting on the turbine, Temperature of the turbine at different wind speeds, Viscosity of the air through the turbines.

The experimental set up has two wind turbines which are made up of DEPRON and are mounted on a frame. An artificial wind speed is created in a closed room to test the Coefficient of Performance of the Wind turbines.

WIND TURBINES

Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. The earth’s surface is made of different types of land and water. These surfaces absorb the sun’s heat at different rates, giving rise to the differences in temperature and subsequently to winds. During the day, the air above the land heats up more quickly than the air over water. The warm air over the land expands and rises, and the heavier, cooler air rushes in to take its place, creating winds. At night, the winds are reversed because the air cools more rapidly over land than over water. In the same way, the large atmospheric winds that circle the earth are created because the land near the earth's equator is heated more by the sun than the land near the North and South Poles.

Humans use this wind flow for many purposes: sailing boats, pumping water, grinding mills and also generating electricity. Wind turbines convert the kinetic energy of the moving wind into electricity.

Wind Energy, like solar is a free energy resource. But is much intermittent than solar. Wind speeds may vary within minutes and affect the power generation and in cases of high speeds- may result in overloading of generator. Energy from the wind can be tapped using turbines.

Setting up of these turbines needs little research before being established. Be it a small wind turbine on a house, a commercial wind farm or any offshore installation, all of them, at first, need the Wind Resource to be determined in the area of proposed site. The Wind Resource data is an estimation of average and peak wind speeds at a location based on various meteorological.

The next step is to determine access to the transmission lines or nearest control centre where the power generated from the turbines can be conditioned, refined, stored or transmitted. It is also necessary to survey the impact of putting up wind turbines on the community and wildlife in the locality. If sufficient wind resources are found, the developer will secure land leases from property owners,

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obtain the necessary permits and financing; purchase and install wind turbines. The completed facility is often sold to an independent operator called an independent power producer (IPP) who generates electricity to sell to the local utility, although some utilities own and operate wind farms directly. Wind mills can be set up ranging scales of:

- On-shore grid connected Wind Turbine systems
- Off-shore Wind turbine systems
- Small Wind and Hybrid Energy Decentralized systems (Floating)

Vertical Axis Wind Turbine (VAWT)

Verticalaxis wind turbines, as shortened to VAWTs, have the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on sites where the wind direction is highly variable or has turbulent winds.

With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier. The main drawback of a VAWT generally creates drag when rotating into the wind.

It is difficult to mount vertical-axis turbines on towers, meaning they are often installed nearer to the base on which they rest, such as the ground or a building rooftop.

The wind speed is slower at a lower altitude, so less wind energy is available for a given size turbine. Air flow near the ground and other objects can create turbulent flow, which can introduce issues of vibration, including noise and bearing wear which may increase the maintenance or shorten its service life. However, when a turbine is mounted on a rooftop, the building generally redirects wind over the roof and this can double the wind speed at the turbine. If the height of the rooftop mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence.

PROPERTIES OF DEPRON

- Depron is an extruded polystyrene foam product, manufactured into sheets of a standard size. It is extremely lightweight and moisture resistant.
- Developed as a high performance Wall and Floor Insulation, now Depron has a wide variety of uses such as food packaging, but more recently in Modeling due to it’s light weight and rigity.
- Depron is available in two colours as well as two different types: Depron and new Depron Aero

1.	Thickness	3mm
2.	Material type	Foamed polystyrene
3.	Water repellent	100%
4.	Density	40 kg/m²
5.	Thermal conductivity	0,035 W/mK
6.	Temperature range	-60° C+70° C
7.	Ignition temperature	355° C
8.	Step sound damping	Water based adhesive without solvent

LITERATURE SURVEY

India is a country with more than 1.2 billion people accounting for more than 17% of world’s population. It is the seventh largest country in the world with total land area of 3,287,263 sqkilometers. India measures 3214 km from north to south and 2993 km from east to west. It has a land frontier of 15,200 km and coastline of 7,517 km. India has 29 states and 7 union territories. It faces a formidable challenge in providing adequate energy supplies to users at a reasonable cost. It has economy which is fastest growing economies in the world and experienced an average 7 % growth rate in the last decade. India accounts for 2.4 % of world energy production and stands at eleventh position in the world in energy production. But the country accounts

A. A. Kadam, et al [5]; has studied about Savonius wind rotors and identify the various performance parameters to increase its efficiency. The experimental results show that two blades rotor is more stable in operation than three or more rotor blades, the power coefficient increases with increasing the aspect ratio. The rotor blades with end plates gave higher efficiency than those of without end plates. CFD analysis was carried out to

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study the flow behavior of a rotating two bucket Savonius rotor. Model the complex flow physics around the rotating rotor was carried out by Fluent 6.3.26 software. For this purpose, data were taken from the experiments conducted earlier on the rotor in a subsonic wind tunnel for five different overlap conditions are 16.2%, 20%, 25%, 30% & 35%. and results shows that the maximum pressure drop is found in case of 16.2% overlap and minimum in case of 35% overlap, means that at 16.2% overlap condition power extraction is maximum from the wind.

Mohammed Hadi Al [6]; has carried out experimental comparison and investigation of performance between two and three blades Savonius wind turbine. Due to this purpose, two models of two and three semi- cylindrical blades were designed and fabricated from Aluminum sheet, with having an Aspect ratio of (As = Fl/D =1), the dimension is (H = 200 mm height and diameter D = 200 mm). These two models were assembled to have overlap zero (e = 0) and a separation gap zero (e' = 0). Subsonic wind tunnel is used to investigate these two models under low wind speed condition, which shows that maximum performance at (/, = TSR = 1) and a high starting torque at low wind speed, and also gives reason for two bladed rotors is more efficient than the three blades, that by increasing the number of blades will increase the drag surfaces against the wind air flow and causes to increase the reverse torque and leads to decrease the net torque working on the blades of savonius wind turbine.

K.K. Sharma, et al [7]; has studied the performance of three-bucket Savonius rotor by Fluent 6.0 Computational Fluid Dynamics software. Moreover, the flow behavior around the rotor was also analyzedwith the help of pressure, velocity and vorticity contours, for different overlap ratios.

Sukanta Roy, et al [8]; has presents effect of overlap ratios in unsteady two-dimensional computational study on static torque characteristics of a vertical axis wind turbine (VAWT) with Finite Volume based computational Fluid Dynamics software package Fluent 6.3. The analysis was carried out for a two-bladed conventional VAWT having overlap ratios of 0, 0.10, 0. 15, 0.20, 0.25 and 0.30. Initially, a comparative analysis was made using various k — e turbulence models and then the results were compared with the experimental data available in literature. The flow field around the turbine model was also studied with the help of static pressure contour analysis. Analysis by the computational study shows an overlap ratio of 0.20 eliminates the effects of negative static torque coefficient, provides a low static torque variation at different turbine angular positions and also gives a higher mean static torque coefficient as compared to the other overlap ratios.

B. Wahyudi, et al [9]; has studied the performance of hydrokinetic turbines of Savonius using a Tandem BladeSavonius (TBS) rotor. There were three types of TBS: Overlap (Type I), symmetrically (Type II) and Convergence (Type III). The simulation work shows the way of the flow characteristic and pressure distribution pattern in and around of the blade swept area. The results show that the convergence TBS (Type III) have a higher gap pressure between upstream and downstream or they have best performance than other types.

SumpunChaitep, et al [10]; has studied the effect of the operating conditions (tip speed ratio) to the starting rotation, reverse up rotation, power and torque coefficients of Curved Blades Vertical Axis Wind Turbine (CB-VAWT). CBVAWT was tested in the laboratory scale in wind tunnel with different velocities of 1.5, 2.0, 3.0, 4.0 and 5.0 m/s.

DESIGN, MODELLING AND CONSTRUCTION OF VERTICAL AXIS WIND TURBINES

DESIGN OF VERTICAL AXIS WIND TURBINES

Thickness of the sheet	=	3 mm
Diameter of the Disk	=	400 mm
Length of the blade	=	600 mm

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Breadth of the blade	=	120 mm
Angle of the blade for 8 blade turbine	=	360/8
	=	45°
Angle of blade for 4 blade turbine	=	360/4
	=	90°
Radius of disc	=	200mm
Height of the wind turbines	=	600mm

3D MODELLING OF VAWT COMPONENTS IN CATIA V5

MODELLING OF 8 BLADE TURBINE

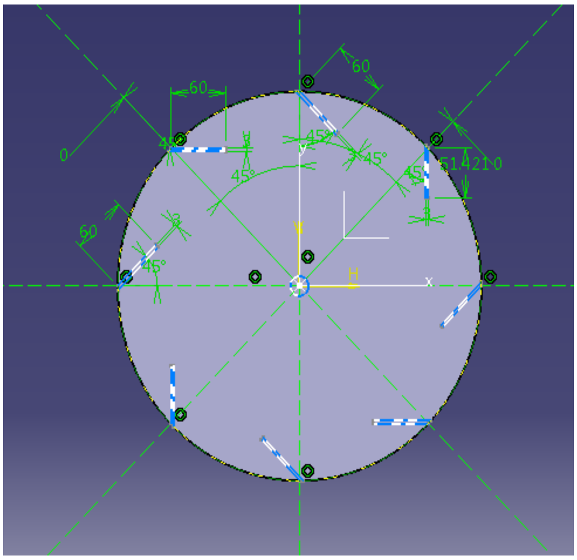

Fig. 1 Modelling Of 8 B VAWT middle Disc

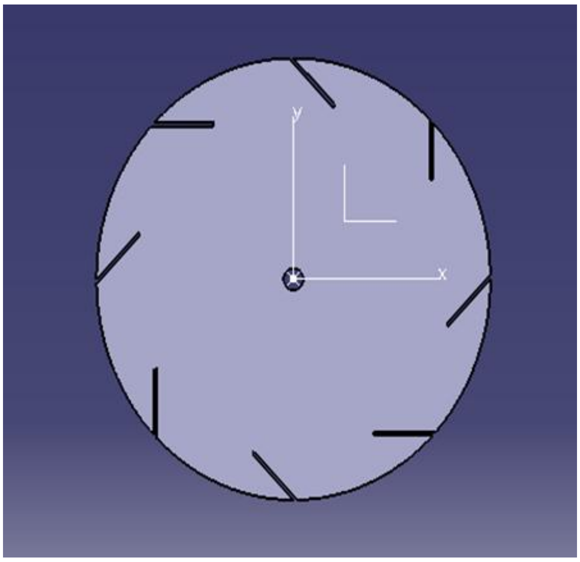

Fig. 2 Modelling Of 8 B VAWT middle Disc

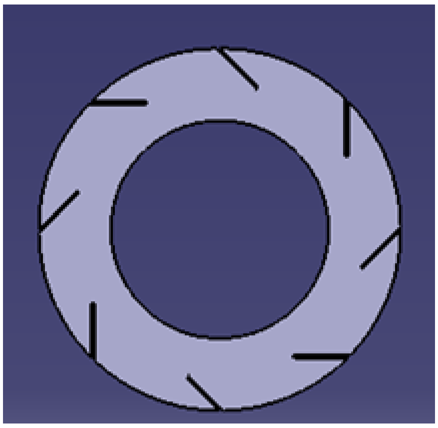

Fig. 3 Modelling Of 8B VAWT upper and lower Disc

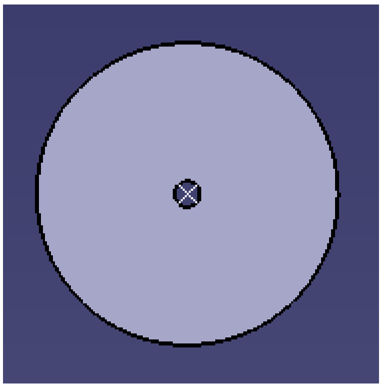

Fig. 4 Modelling Of 8B VAWT centre support

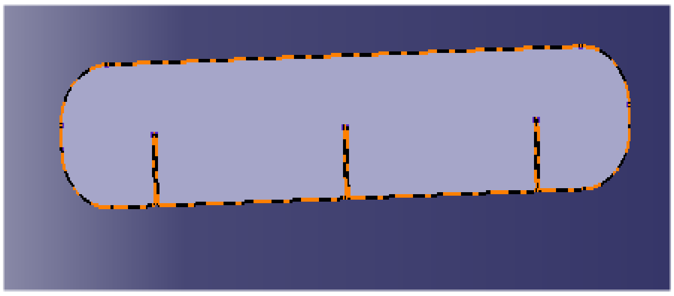

Fig. 5 Modelling Of 8 B VAWT Blade

Fig. 9Modelling Of 8 B VAWT Assembly

MODELLING OF 4 BLADE TURBINE

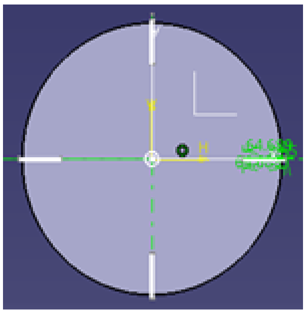

Fig. 10Modelling Of 4 B VAWT Middle Disc

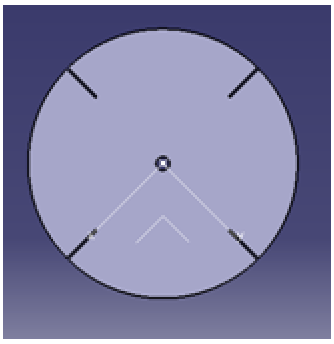

Fig. 11 Modelling of 4 B VAWT middle disc

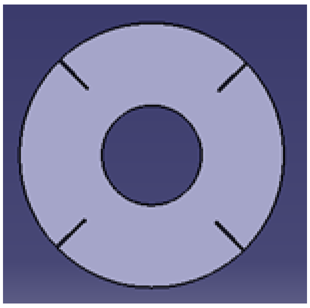

Fig. 12 Modelling Of 4B VAWT upper and lower Disc

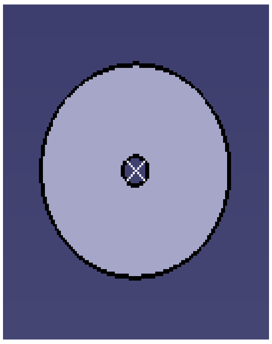

Fig. 13 Modelling Of 4B VAWT centre support

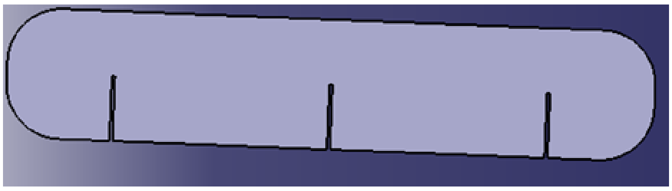

Fig. 14 Modelling Of 4B VAWT Blade

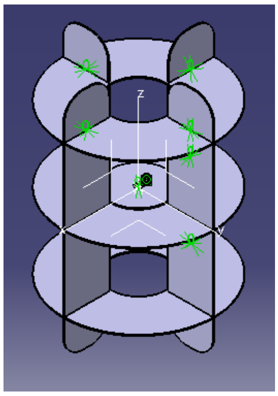

Fig.15 Modelling Of 4 B VAWT Assembly

CONSTRUCTION OF VERTICAL AXIS WIND TURBINE

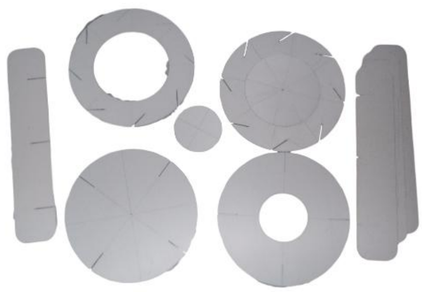

Fig. 16 Cutting of Depron sheets into required shapes

EXPERIMENTAL SETUP

Fig. 17 Assembling of 8B VAWTFig.

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18 Assembling of 4B VAWT

Fig. 19 Assembling of 4B & 8B VAWTS

PERFORMANCE ANALYSIS OF VERTICAL AXIS WIND TURBINES

ANSYS PROCESS

Fluid Flow (CFX) Simulation

The Vertical Axis Wind Turbine (VAWT) model (8-bladed and 4-bladed) was created in CATIA and imported to Geometry part in ANSYS workbench. Computational Fluid Dynamic Analysis was performed on the model. The model was meshed and the details of mesh created for all Domains are as follows

Number of Nodes 98405 & Number of Elements 443975 for 8-bladed VAWT Cylindrical Enclosure,

Number of Nodes 103057 & Number of Elements 467712 for 8-bladed VAWT Cartesian Enclosure,

Number of Nodes 12373 & Number of Elements 54841 for 4-bladed VAWT Cylindrical Enclosure, and

Number of Nodes 11564 & Number of Elements 50190 for 4-bladed VAWT Cartesian Enclosure.

SET-UP FOR 8-BLADED VAWT WITH CYLINDRICAL ENCLOSURE

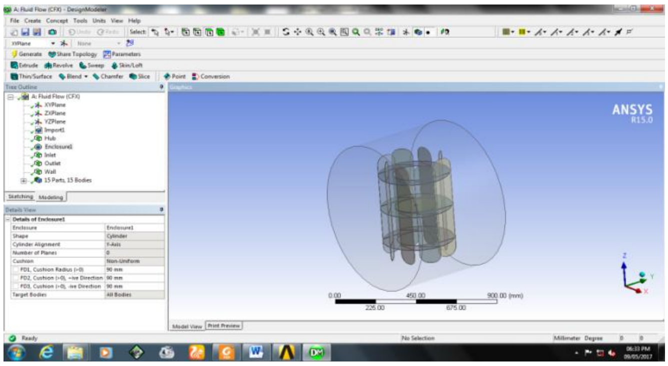

Fig. 20Applying Cylindrical Enclosure to the 8-bladed VAWT

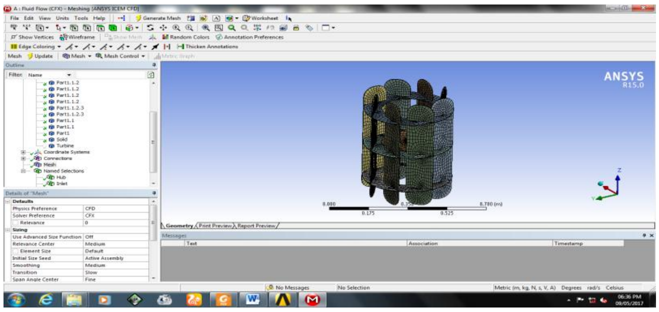

Fig. 21Meshed 8-bladed VAWT

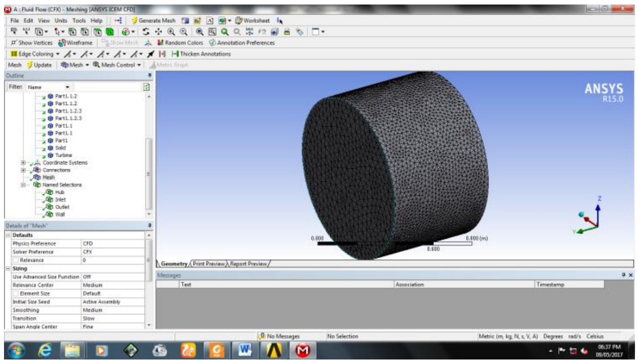

Fig.22Meshed 8-bladed VAWT with its cylindrical enclosure

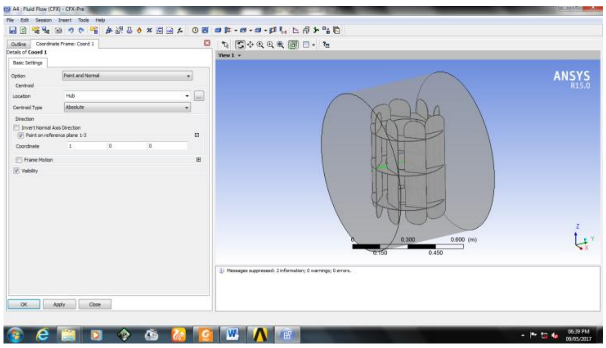

Fig.23Inserting a New Co-ordinate System

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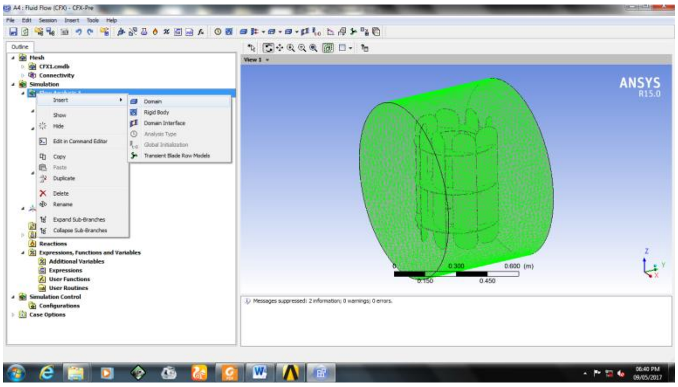

Fig.24Inserting Domain for Analysis

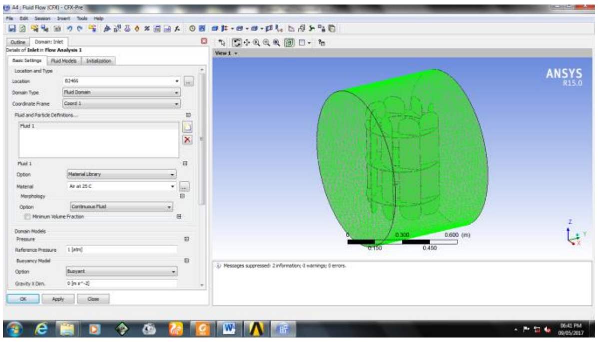

Fig.25Applying set up conditions to the model

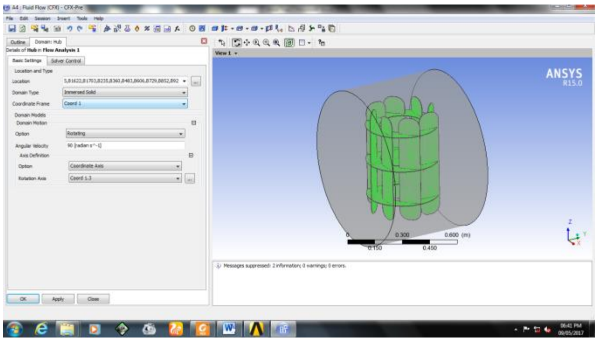

Fig.26Applying set up conditions to the 8-bladed VAWT

Input Data

The performance of the 8-bladed and 4-bladed VAWT will be analyzed at a maximum speed in a Cylindrical Enclosure and Cartesian Enclosure, so therefore the speed of the turbine is 90 radians per second (rad / sec). The analysis is performed for 20 sec of air flow through the turbine. The setup data is common for all conditions. Finally the results plotted were Pressure acting on the turbine, Temperature, Viscosity of air through the turbine, CFX of air Forward Flow through the Turbine, CFX of air Backward Flow through the Turbine, CFX of air Surface Flow on the Turbine.

EXPERIMENTAL PROCESS

A 4- bladed and an 8-bladed Vertical Axis Wind Turbine have been designed and developed using Depron sheets. When these VAWTsplaced against to the wind direction, the kinetic energy of the wind is converted into Mechanical energy further it can be converted to electrical energy by adding some more components to the wind turbines.

We have gathered the information related to the experiment like velocity in kmph, air flow rate in m^3/s, Relative humidity, Dew point and wet bulb temperatures using Anemometer, Psycho-meter, Alcoholic thermometer. The angular speed of the turbines was taken in rpm using Tachometer.

Here we have calculated the Tip speed ratio, coefficient of performance, by calculating power available by the force of wind, power generated by the turbine at various wind speeds.

Tip speed ratio plays a major role in the Experimental context. If the rotor of the wind turbine turns too slowly, most of the wind will pass undistributed through the openings between the blades with the little power extraction. On the other hand, if the rotor turns too fast, the rotating blades act as a solid obstructing the wind flow, again reducing the power extraction. Wind turbines must thus be designed to operate at their optimal wind tip speed ratio in order to extract as much power as possible from the wind stream. Wind tip ratios depend on the particular wind turbine design used, as well as the number of used blades.

RESULTS & DISCUSSION

ANSYS RESULTS

Applying the load data on the imported setup and analyzing the results we get Pressure acting on the turbine, Temperature, Viscosity of air through the turbine, CFX of air Forward Flow through the Turbine, CFX of air Backward Flow through the Turbine, CFX of air Surface Flow on the Turbine.

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RESULTS PLOTTED FOR 8-BLADED VAWT WITH CYLINDRICAL ENCLOSURE

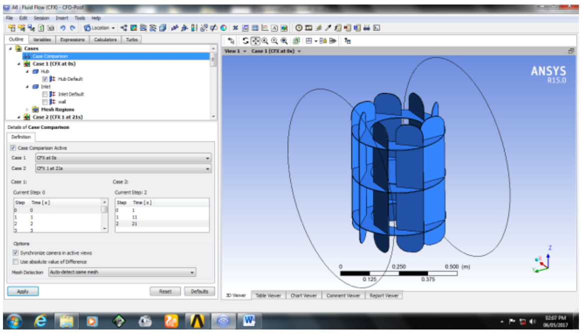

Fig. 27Initial Condition (No Wind Force on the 8-bladed VAWT)

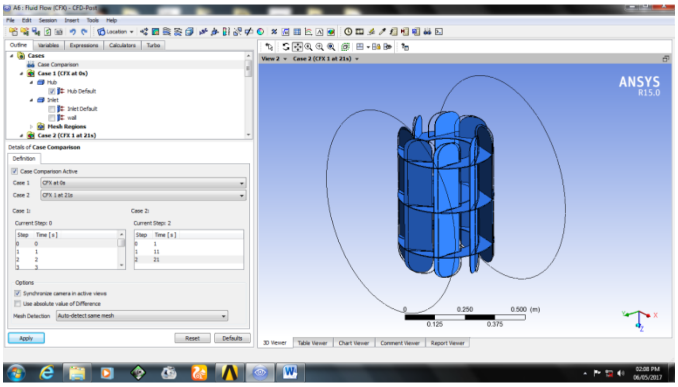

Fig.28 Max. Wind Force applied on the 8-bladed VAWT

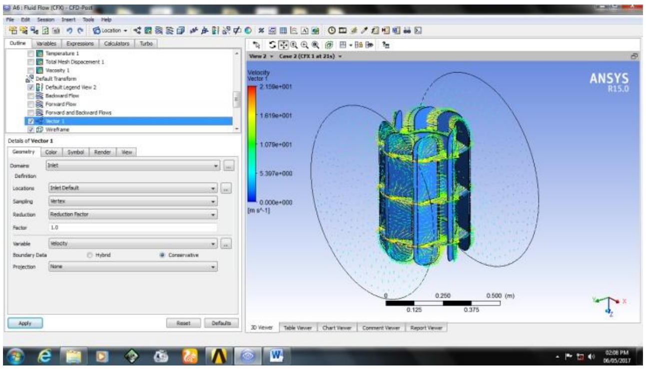

Fig.29Vectors showing the velocity of wind

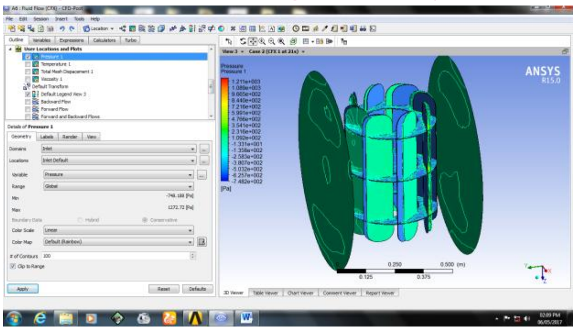

Fig.30Pressure along the Wind Direction

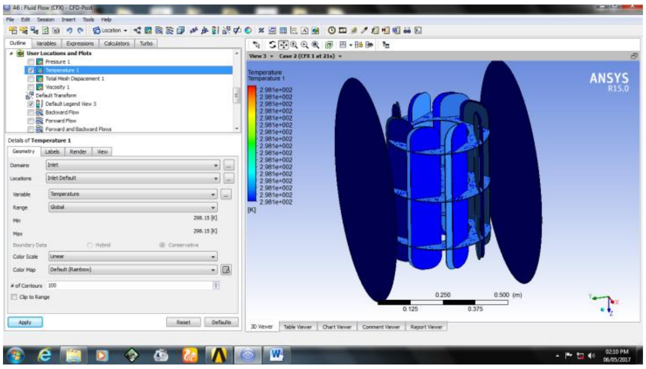

Fig.31Temperature along the wind Direction (remains constant)

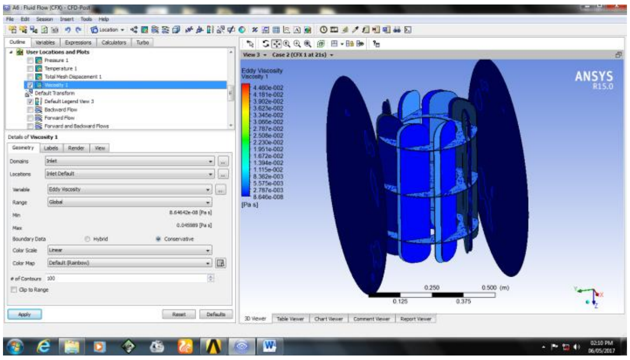

Fig.32Viscosity of air when flow through the 8-bladed VAWT

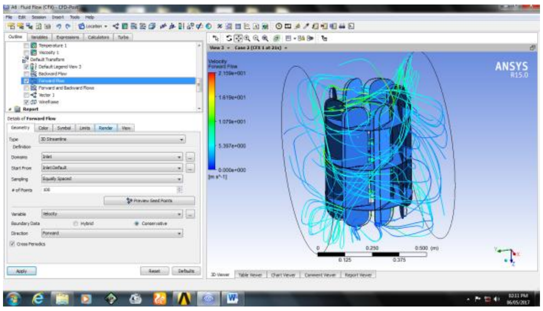

Fig. 33Velocity of Air flows through the 8-bladed VAWT in Stream Lines (Forward Flow)

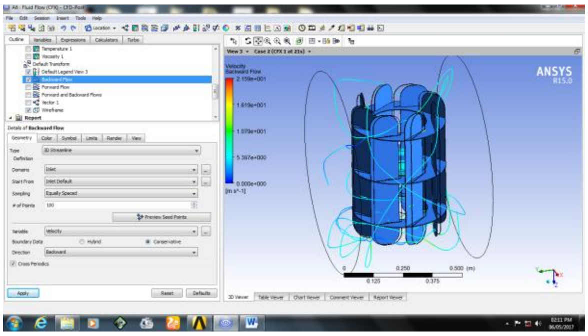

Fig. 34Velocity of Air flows through the 8-bladed VAWT in Stream Lines (Backward Flow)

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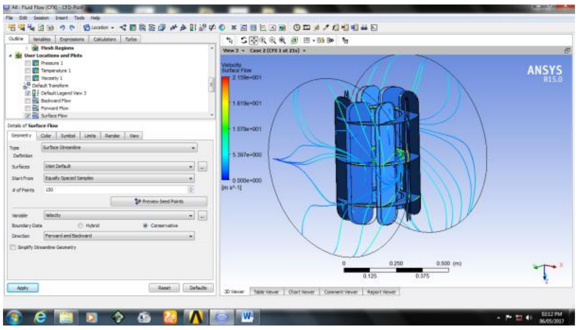

Fig. 35Velocity of Air flows through the 8-bladed VAWT in Stream Lines (Surface Flow)

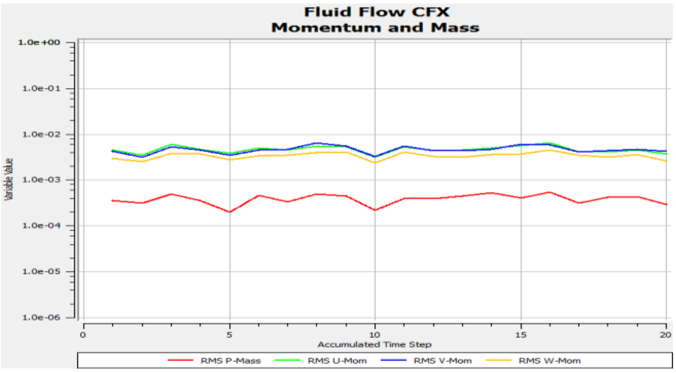

Fig. 36Graph plotted between Accumulated time step, Momentum and Mass Flow Rate

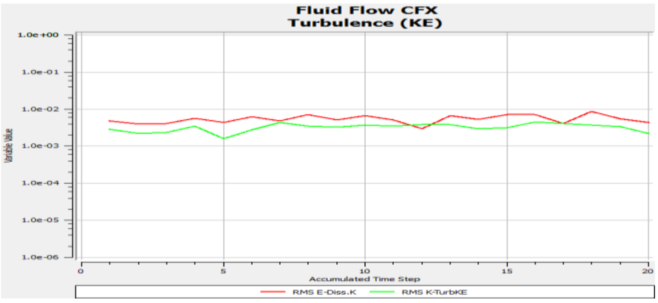

Fig.37Graph plotted between Accumulated time step, Turbulence and Displacement

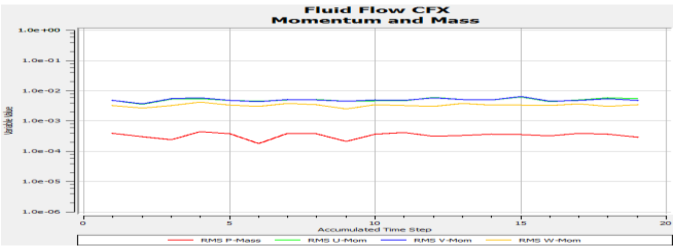

Fig.38Graph plotted between Accumulated time step, Momentum and Mass Flow Rate

EXPERIMENT RESULTS

S.No	Property	
1	Velocity (kmph)	21.02
2	Air flow rate (m^3/sec)	6.06
3	Relative Humidity %	58.7
4	Dew point Temperature (^{0}C)	23.5
5	Wet Bulb Temperature (^{0}C)	26

Table 1: Reading 1

Rpm

8 Blade Wind Turbine - 196

4 Blade Wind Turbine - 85

S.No	Property	
6	Velocity (kmph)	19.71
7	Air flow rate (m^3/sec)	5.85
8	Relative Humidity %	58.7
9	Dew point Temperature (^{0}C)	23.5
10	Wet Bulb Temperature(^{0}C)	26

Table 2: Reading 2

Rpm

8 Blade Wind Turbine - 172

4 Blade Wind Turbine - 63

S.No	Property	
11	Velocity (kmph)	17.82
12	Air flow rate (m^3/sec)	5.53
13	Relative Humidity %	58.7
14	Dew point Temperature (^{0}C)	23.5
15	Wet Bulb Temperature(^{0}C)	26

Table 3: Reading 3

Rpm

8 Blade Wind Turbine - 154

4 Blade Wind Turbine - 57

S.No	Property	
16	Velocity (kmph)	15.48
17	Air flow rate (m^3/sec)	4.73
18	Relative Humidity %	58.7
19	Dew point Temperature (^{0}C)	23.5
20	Wet Bulb Temperature(^{0}C)	26

Table 4: Reading 4

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Rpm

8 Blade Wind Turbine - 126

4 Blade Wind Turbine - 39

S.No	Property	
21	Velocity (kmph)	13.67
22	Air flow rate (m^3/sec)	3.25
23	Relative Humidity %	58.7
24	Dew point Temperature (^{0}C)	23.5
25	Wet Bulb Temperature (^{0}C)	26

Table 5: Reading 5

Rpm

8 Blade Wind Turbine - 112

4 Blade Wind Turbine - 27

S.No	Property	
26	Velocity (kmph)	10.62
27	Air flow rate (m^3/sec)	1.85
28	Relative Humidity %	58.7
29	Dew point Temperature (^{0}C)	23.5
30	Wet Bulb Temperature(^{0}C)	26

Table 6: Reading 6

Rpm

8 Blade Wind Turbine - 87

4 Blade Wind Turbine - 21

PERFORMANCE CALCULATION

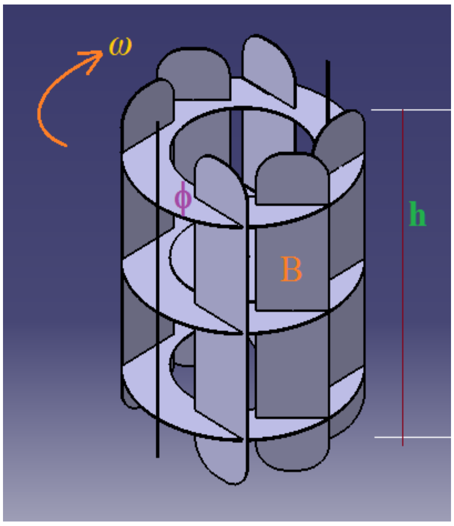

Fig.39 Parameters of 8-bladed VAWT

Power produced by the Turbine, $P_{Turbine}$

Coefficient of Performance $Cp = P_{Turbine} / P_{Available}$

Where $P_{Available}$ - Power available by the force of the wind

$P_{Available} = 1/2\,(m\,v^2) = 1/2\,[\rho A v^3]$

ρ - Density of the air $= 1225\ g/m^3 = 1.225\ kg/m^3$

A – Area of the turbine $= \phi h$

ϕ - Diameter of the circle of the turbine $= 400\ mm = 0.4\ m$

h – Height of the turbine $= 600\ mm = 0.6\ m$

B – Total No. of Blades of the turbine = 8

$\Rightarrow A = 0.4*0.6 = 0.24\ m^2$

v – Velocity of Air / Wind = 21.02kmph = 5.83 m/s

$\Rightarrow P_{Available} = 1/2\,[\rho A v^3] = 1/2[1.225(0.24)(5.83)^3] = 29.1288\ Kg\text{-}m^2/s^3$ or Watts

Therefore Power available through wind force = 29.1288 Watts

Power of the Turbine for available wind force $P_{Turbine}$ = 8.53216 Watts

$\Rightarrow Cp = P_{Turbine} / P_{Available} = 8.5321 / 29.1288 = 0.2929$

Maximum Tip Speed Ratio

Tip Speed Ratio $= v_t / v_w$

v_w – Velocity of air / Wind = 5.83 m/s

v_t – Velocity of Tip $= \omega r$

ω - Angular velocity of the turbine (rad/s) $= 2\pi N / 60$

r – Radius of the Turbine = d/2

$\Rightarrow$ Tip Speed Ratio $= \pi N d / 60\ v_w = \pi(196)0.4 / 60(5.83) = 0.70$

S.No	Velocity of air (kmph)	P_{Avail} (W)	$P_{Turbine}$ (W)	Cp	TSR
1	21.02	29.1288	8.53216	0.2929	0.70
2	19.71	24.1251	6.82740	0.2829	0.67
3	17.82	17.8292	4.58210	0.2569	0.65
4	15.48	11.6875	2.24400	0.1920	0.63
5	13.67	8.0026	1.11237	0.1390	0.61
6	10.62	3.7738	0.34455	0.0913	0.57

Table 7: Wind Speed Calculations for 8-bladed VAWT

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Power produced by the Turbine, $P_{Turbine}$

Coefficient of Performance $Cp = P_{Turbine} / P_{Available}$

Where $P_{Available}$ - Power available by the force of the wind

$P_{Available}$ = $1/2\,(m\,v^2)$ = $1/2\,[\rho A v^3]$

ρ - Density of the air = 1225 g/m^3 = 1.225 kg/m^3

A – Area of the turbine = ϕ h

ϕ - Diameter of the circle of the turbine = 400 mm = 0.4 m

h – Height of the turbine = 600 mm = 0.6 m

B – Total No. of Blades of the turbine = 4

$\Rightarrow$ A = 0.4*0.6 = 0.24 m^2

v – Velocity of Air / Wind = 21.02 kmph = 5.83 m/s

$\Rightarrow$ $P_{Available}$ = $1/2\,[\rho A v^3]$ = $1/2[1.225(0.24)(5.83)^3]$ = 29.1288 Kg-m^2/s^3 or Watts

Therefore Power available through wind force = 29.1288 Watts

Power of the Turbine for available wind force $P_{Turbine}$ = 5.73837 Watts

$\Rightarrow$ Cp = $P_{Turbine} / P_{Available}$ = 5.73837 / 29.1288 = 0.1969

Tip Speed Ratio = v_t/v_w

v_w – Velocity of air / Wind = 5.83 m/s

v_t – Velocity of Tip = ω r

ω - Angular velocity of the turbine (rad/s) = $2\pi N / 60$

r – Radius of the Turbine = d/2

$\Rightarrow$ Tip Speed Ratio = $\pi Nd / 60\, v_w$ = $\pi(85)0.4 / 60(5.83)$ = 0.31

S.No	Velocity of air (kmph)	P_{Avail} (W)	$P_{Turbine}$ (W)	Cp	TSR
1	21.02	29.1288	5.73837	0.1969	0.31
2	19.71	24.1251	4.14951	0.1719	0.27
3	17.82	17.8292	2.17516	0.1219	0.24
4	15.48	11.6875	1.11031	0.0949	0.19
5	13.67	8.0026	0.58579	0.0731	0.15
6	10.62	3.7738	0.20378	0.0539	0.14

Table 8: Wind Speed Calculation for 4-bladded VAWT

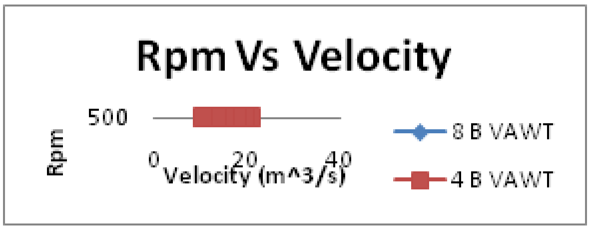

Fig.40graph rpm vs velocity

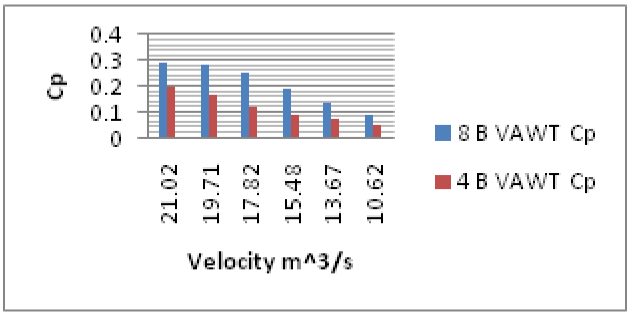

Fig.41 graph cpvs velocity

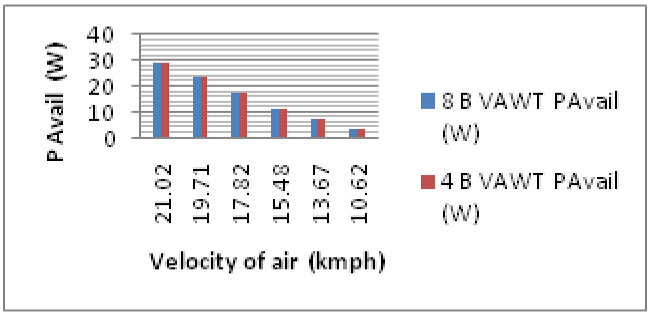

Fig .42 Graph P Available vs velocity

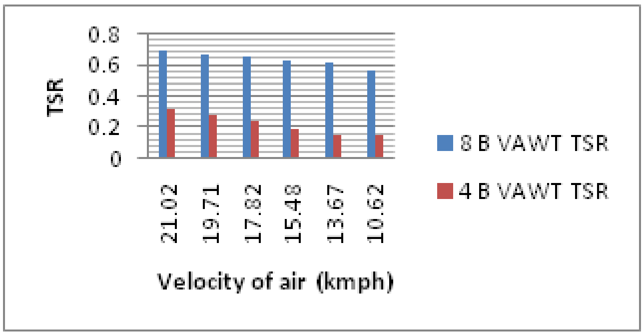

Fig .43 graph TSR vs velocity

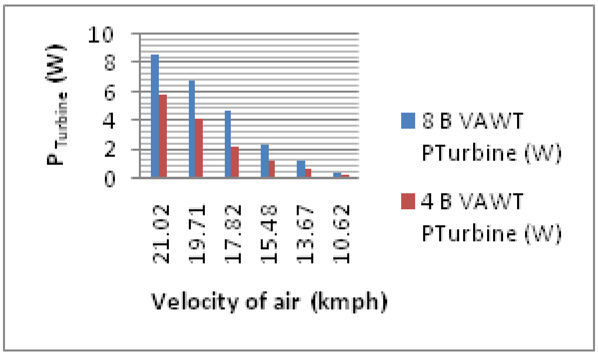

Fig .44 P $_{Turbine}$vs velocity

CONCLUSION

As per the Design & Analysis performed for 8 Bladed and 4 bladed Vertical Axis Wind Turbine the following are the conclusion

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- CFX analysis performed on both 8 Bladed and 4 bladed Vertical Axis Wind Turbines with Cylindrical and Cartesian enclosures for air flow through the enclosures and we have observed that, in 8 Bladed VAWT with Cylindrical and Cartesian enclosures during the forward flow the velocity of the wind through the VAWT is 21.5 m/s. during the back ward flow the velocity of the wind through the VAWT is negligible when compared to forward flow because the air flows in opposite direction makes the turbine idle. The air passes through the turbine without making any angular motion at normal speed whereas we will observe an angular displacement at higher speeds.
- In 4 Bladed VAWT due to the thrust formed by the wind force the turbine got lifted and makes an angular displacement when compared to 8 Bladed VAWT. The lift observed in 4 Bladed VAWT during the angular displacement is directly proportional to wind force. The lift observed is due to high value of Tip speed ratio (TSR) because the gap between the blades are more so wind can easily pass through the turbine.
- By calculating the coefficient of performance for 8 Bladed and 4 bladed Vertical Axis Wind Turbines, we have observed the coefficient of performance for 8 Bladed and 4 bladed Vertical Axis Wind Turbines is 0.29 and 0.19 respectively and TSR for 8 Bladed and 4 bladed Vertical Axis Wind Turbines is 0.7 and 0.31 respectively at a velocity of wind 21.02 kmph or 5.83 m/s, air flow 6.06 m^3/s, relative humidity 58.7%, dew point temperature 23.5^0c, wet bulb temperature 26^0c. Coefficient of performance of 4 bladed VAWT is 65% less than 8 Bladed VAWT.
- Finally the results plotted were Vector Displacement of Wind on the Turbine, Pressure acting on the turbine, Temperature, Viscosity of air through the turbine are listed below

S.No	Type/Properties	Vector Displacement (m/s)	Pressure (Pa)	Temperature (K)	Viscosity (Pa S)
1	8 bladed VAWT with cylindrical enclosure	21.59	1.211E+3	298.15	4.460E-2
2	8 bladed VAWT with cartesian enclosure	24.61	1.572E+3	298.15	4.261E-2
3	4 bladed VAWT with cylindrical enclosure	17.21	5.869E+2	298.15	4.228E-2
4	4 bladed VAWT with cartesian enclosure	19.27	1.292E+2	298.15	4.006E-2

Table19 : Results Plotted in Fluid Flow (CFX)

FUTURE SCOPE

The development of effective alternators and dynamos can be used to harness wind energy from relatively small winds.The use of materials like Acrylic Plastic Sheets can be used to develop low cost VWAT.

Power output can be enhanced by the fallowing ways:

- Optimizing the design of blades so as to give better aerodynamics
- Using a best alternator which produces more voltage for low rpm
- Using gear mechanisms to increase rpm for alternator input and hence can have higher power output.
- Structural fabrication should be more accurate in order to have proper functions of windmill
- Using fixed base system to reduce the weight of the whole system

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