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Performance Analysis of a Vertical Axis Wind Turbine With Different Shapes of Blades

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Abstract:

Wind energy is the kinetic energy associated with the movement of large masses of air. These motions result from uneven heating of the atmosphere by the sun creating temperature, density, pressure differences. It is an indirect form of solar energy. The device used to convert the kinetic energy of wind into electrical power is called a wind turbine. Vertical Axis wind power generators represent a very promising future for wind power generation. In the present study, an attempt is made to utilize at low-velocity wind below 4m/s for useful power generation using magnetic levitation for vertical axis wind turbine (VAWT) termed as Maglev turbine. The efficiency of the turbine is increased by replacing the conventional bearings with magnets in repulsion; the magnetic levitation helps the turbine to spin at a much faster rate as it eliminates the stresses on the shaft of the turbine. The major components are placed at the ground level which ensures the safety of the turbine.

In this project, we attempt to design and fabricate in a vertical axis wind turbine with the help of interfaces software CatiaV5.

Keywords — **Design, Fabrication, Vertical axis Wind Turbine.**

I. INTRODUCTION

Design, fabrication, and testing of a Vertical Axis Wind Turbine (VAWT) with wind deflectors will be the ongoing final year undergraduate project of us. Here, the main purpose will be enhancing the performance of the VAWT by designing guide vanes and fabricating with a low cost and get more shaft torque and rpm. And also, it is supposed to be a portable wind turbine.

II. IMPORTANCE OF PROJECT

Energy is a hot topic in the news today: increased consumption, increased cost, depleted natural resources, our dependence on foreign sources, and the impact on the environment andthe danger of global warming. Something has to change.

Wind energy has great potential to lessen our dependence on traditional resources like oil, gas, and coal and to do it without as much damage to the environment.

Alternative energy sources, also called renewable resources, deliver power with minimal impact on the environment. These sources are typically more green/clean than traditional methods such as oil or coal. Also, alternative resources are inexhaustible.

III. THE POWER IN THE WIND

The power in the wind can be computed by using the concepts of kinetics. The windmill works on the principle of converting the kinetic energy of the wind to mechanical energy. The kinetic energy of any particle is equal to one half its mass times the square of its velocity, or ½ mv^2.

The amount of air passing in unit time through an area A, with velocity V, is AV& its mass M is equal to its Volume multiplied by its density ρ of air, or

$$\mathbf{m} = \rho \, \mathbf{AV} \ldots\ldots \quad (1)$$

(m is the mass of air transferring the area A swept by the rotating blades of a windmill type generator)

Substituting this value of the mass in the expression of K.E.

$= ½\ \rho\ AV.V^2$ watts

$= ½\ \rho\ AV^3$ **watts**... (2)

The second equation tells us that the power available is proportional to air density (1.225 kg/m^3) and is proportional to the intercept area. Since the area is normally circular of diameter D in horizontal axis aero turbines, then,

Put this quantity in equation second the

$$A = \frac{\pi}{4} D^2 (\text{Sq. m})$$

Available wind power Pa = $\frac{1}{2} \times \rho \times \frac{\pi}{4} D^2$

$= 1/8\ \rho\ \pi\ D^2\ V^3$ **watts**

"Wind machines intended for generating substantial amounts of power should have large rotors and be located in areas of high wind speed".

The Source of Winds:

In a macro-meteorological sense, winds are movements of air masses in the atmosphere mainly originated by temperature differences. The temperature gradients are due to uneven solar heating. The equatorial region is more irradiated than the polar ones. Consequently, the warmer and lighter air of the equatorial region rises to the outer layers of the atmosphere and moves towards the poles, being replaced at the lower layers by return flow of cooler air coming from the Polar Regions.

This air circulation is also affected by the Coriolis forces associated with the rotation of the Earth. These forces deflect the upper flow towards the east and the lower flow towards the west. The effects of differential heating dwindle for latitude greater than $30^{\circ}N$ and $30^{\circ}S$, where westerly winds predominate due to the rotation of the Earth. These large-scale flows that take place in the entire atmosphere constitute the geostrophic winds. The lower layer of the atmosphere is known as the surface layer and extends to a height of 100 m. In this layer, winds are delayed by frictional forces and obstacles altering not only their speed but also their direction. This is the origin of turbulent flows, which cause wind speed variations over a wide range of amplitudes and frequencies. Additionally, the presence of seas and large lakes causes air masses circulation similar in nature to the geostrophic winds. All these air movements are called local winds.

IV. DESIGNING OF WINDMILLS

A windmill is a machine for wind energy conversion. A wind turbine converts the kinetic energy of the wind's motion to mechanical energy transmitted by the shaft. A generator further converts it to electrical energy. So, it is necessary to keep in mind, while designing the windmill's structural part.

1. **Design of Base:** In this project, there is a pole base that is made up of mild steel that can withstand, in a large force of the wind. The base & its height are related to cost and transmission system incorporated. So, the height of our base is 150cm, width at the bottom is 61cm & at the top is 31cm.

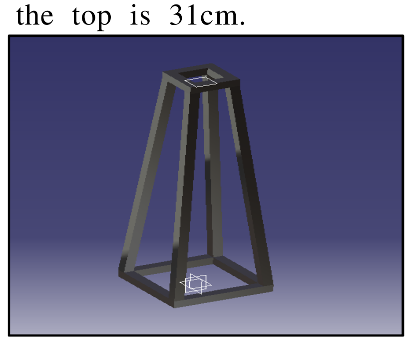
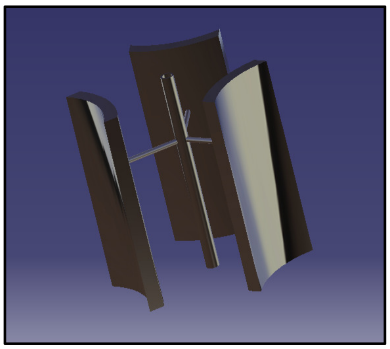
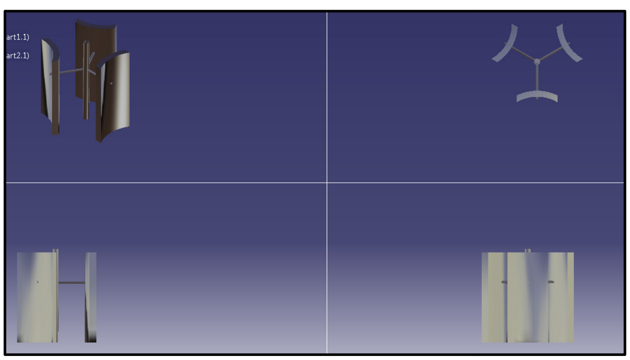


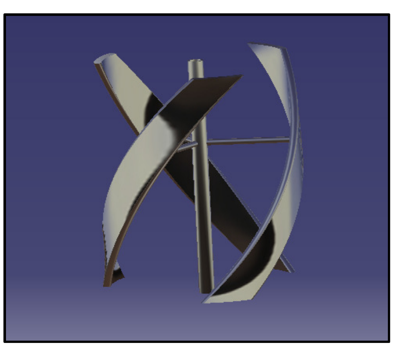
Fig 1-Design of base

2. **Design of blade:**

Wind turbine blades have on aerofoil – type cross-section and a variable pitch. While designing the size of the blade it is must to know the weight and cost of blades in the project three blades with vertical shaft are used, it has a height & width of 73cm & 122cm respectively. The angle between the two blades is 60^0. So, if one Blade moves other blades come in the position of the first blade, the speed isincreased.







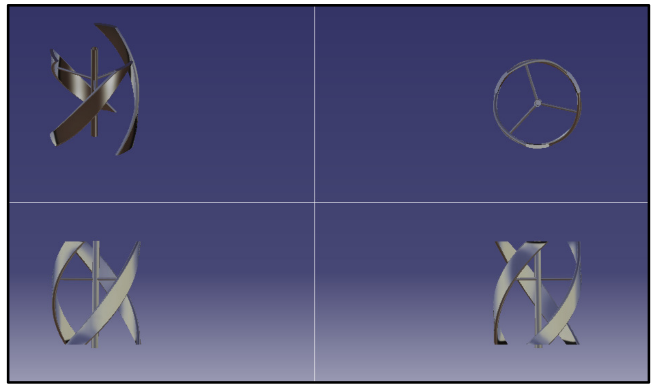
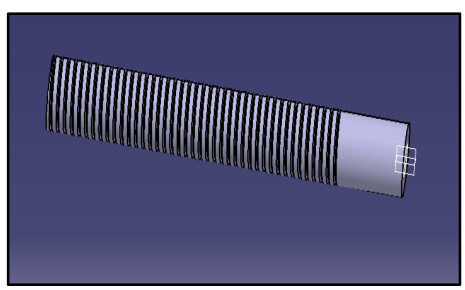


Fig 2-Design of blades

3. Shaft Designing

While designing the shaft of blades it should be properly fitted to the blade. The shaft should be as possible as less in thickness & light in weight for the six blades, the shaft used is very thin in size are all properly fitted. So, no problem of slipping & fraction is created, it is made up of hollow Aluminum which is having very lightweight. Length of shaft & diameter are 91.44cm& 2.54cm respectively and at the top and bottom ends mild steel of length 8cm and 15cm respectively are fixed to give strength to the hollow shaft.



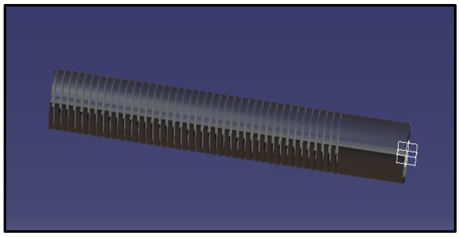


Fig 3-Design of Shaft

4. Design of Bearing

For the smooth operation of the Shaft, the bearing mechanism is used. To have very less friction loss the two ends of the shaft are pivoted into the same dimension bearing. The Bearing has a diameter of 2.54cm. Bearing is generally provided for supporting the shaft and smooth operation of the shaft. Greece is used for bearing maintenance.

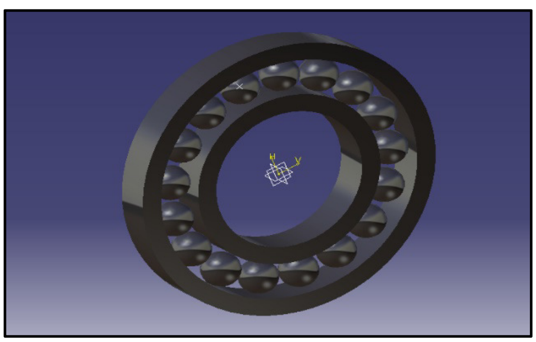


Fig 4-Design of Bearing

SPECIFICATIONS OF THE WIND TURBINE

BASE DIMENSIONS

Height	150cm
Bottom Width	61cm
Top Width	31cm

H-SHAPE BLADE DIMENSIONS

Height	73cm
Diameter	130cm
Thickness	0.1cm

HELIX BLADE DIMENSIONS

Height	73cm
Diameter	122cm
Thickness	0.1cm

SHAFT DIMENSIONS

Diameter	2.54cm
Length	91.44cm

Total Height of the assembly

198cm

V. CALCULATIONS

$$K\ E = \frac{1}{2}\ \rho\ AV^3 \text{ watts}$$

ρ = density of air (1.225 kg/m^3)

$A = \pi D^2 / 4$ (Sq. m)

D = diameter of the blade

$$A = \pi*(1.30)^2 /4$$

$$A = 1.32 \text{ Sq.m}$$

Available wind power Pa = $\frac{1}{2}\ \rho\ \pi\ A\ V^3$

$$P = \frac{1}{2}\ \rho\ \pi\ A\ V^3 \text{watt}$$

Rotor H-Blade Calculations:

Diameter D = 1.30m

Radius R = 0.65m

Area A = $\pi \times R^2$

A = $\pi \times 0.65^2$

A = $1.32m^2$

For velocity V = 2m/sec

Torque T = $60 \times \frac{P}{2\pi N}$ N-m

T = 1.3 N-m

Speed N = 25rpm

$\omega = \frac{2\pi N}{60}$

$\omega = \frac{2 \times \pi \times 25}{60}$

$\boldsymbol{\omega = 2.61 rad/sec}$

The input power of the turbine P_{in} = $0.5\times \rho \times A \times V^3$Watt

P_{in} = $0.5\times 1.225 \times 1.32 \times 2^3$Watt

P_{in} = 6.468Watt

The output power of the turbine P_{out} = $T\times \omega$Watt

P_{out} = 1.3×2.61Watt

P_{out} = 3.393Watt

Coefficient of power $C_p = \frac{\text{Pout}}{\text{Pin}}$

$C_p = \frac{3.393}{6.468}$

C_p = 0.52

The efficiency of the turbine $\eta = 100 \times \text{Cp}$

$\eta = 100 \times 0.52$

$\boldsymbol{\eta = 52\%}$

Tip speed ratio TSR = $\frac{\omega \times R}{V}$

TSR = $\frac{2.61\times 0.65}{2}$

TSR = 0.84

Coefficient of torque $C_T = \frac{T}{0.5\times\rho\times\pi\times R^3\times V^2}$

$C_T = \frac{1.3}{0.5\times 1.225\times\pi\times 0.65^3\times 2^2}$

C_T = 0.61

Helicoidable Blade Calculations:

Diameter D = 1.22m

Radius R = 0.61m

Area A = $\pi \times R^2$

A = $\pi \times 0.61^2$

A = $1.168m^2$

For velocity V = 2m/sec

Torque T = $60 \times \frac{P}{2\pi N}$ N-m

T = 1.22 N-m

Speed N = 26rpm

$$\omega = \frac{2\pi N}{60}$$

$$\omega = \frac{2 \times \pi \times 26}{60}$$

$\boldsymbol{\omega = 2.72 rad/sec}$

The input power of the turbine $P_{in} = 0.5\times \rho \times A \times V^3$ Watt

$P_{in} = 0.5\times 1.225 \times 1.168 \times 2^3$ Watt

P_{in} = 5.72Watt

The output power of the turbine $P_{out} = T\times \omega$ Watt

$P_{out} = 1.22\times 2.72$ Watt

P_{out} = 3.32Watt

Coefficient of power $C_p = \frac{Pout}{Pin}$

$C_p = \frac{3.32}{5.72}$

C_p = 0.58

The efficiency of the turbine $\eta = 100 \times Cp$

$\eta = 100 \times 0.58$

$\eta = 58\%$

Tip speed ratio TSR = $\frac{\omega \times R}{V}$

TSR = $\frac{2.72\times 0.61}{2}$

TSR = 0.82

Coefficient of torque $C_T = \frac{T}{0.5\times\rho\times\pi\times R^3\times V^2}$

$C_T = \frac{1.22}{0.5\times 1.225\times\pi\times 0.61^3\times 2^2}$

C_T = 0.69

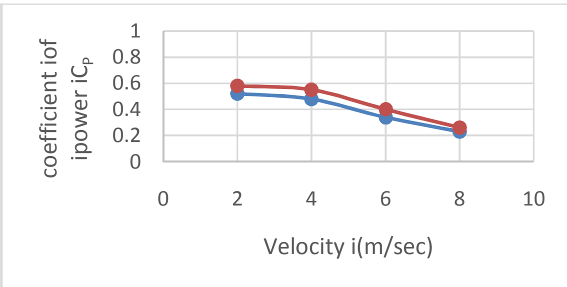
H-Shape blade Table column:

Sl.no	Velocity m/sec	Speed rpm	Input power P_{in} (W)	Output Power P_{out} (W)	Coefficient of power C_P	Efficiency $\eta(\%)$	Torque T(N-m)	Tip speed ratio TSR	Coefficient of Torque C_T
1	2	25	6.468	3.393	0.52	52	1.3	0.84	0.61
2	4	92	51.74	25.08	0.48	48	2.6	1.56	0.30
3	6	148	174.6	60.41	0.34	34	3.9	1.67	0.20
4	8	175	413.9	95.26	0.23	23	5.2	1.48	0.15

Helicoidal blade Table column:

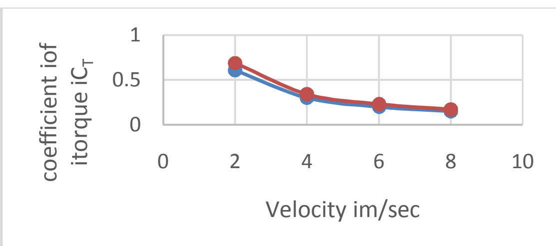
Sl.no	Velocity m/sec	Speed rpm	Input power P_{in} (W)	Output Power P_{out} (W)	Coefficient of power C_P	Efficiency $\eta(\%)$	Torque T(N-m)	Tip speed ratio TSR	Coefficient of Torque C_T
1	2	26	5.72	3.32	0.58	58	1.22	0.82	0.69
2	4	98	45.47	25.03	0.55	55	2.44	1.35	0.34
3	6	162	153.4	62.07	0.40	40	3.66	1.27	0.23
4	8	188	363.7	96.07	0.26	26	4.88	1.22	0.17

Comparison between velocity vs coefficient of power:



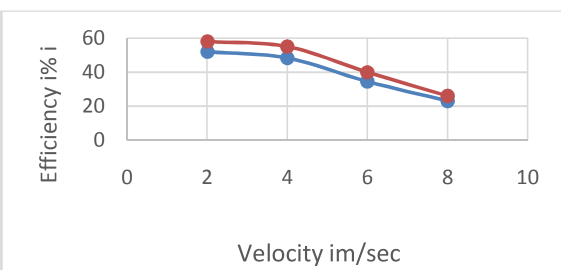
. Helicoidable blade .H-shape blade

Comparison between velocity vs coefficient of torque:



. Helicoidal blade .H-shape blade

Comparison between velocity vs efficiency:



. Helicoidable blade .H-shape blade

VI. CONCLUSION

The project "**PERFORMANCE ANALYSIS OF VERTICAL AXIS WIND TURBINE WITH DIFFERENT SHAPES OF BLADES**" is very encouraging and reinforces the conviction that vertical axis wind energy conversion systems are practical and potentially very contributively to the production of clean renewable electricity from the wind even under less than ideal sitting conditions. Vertical axis wind turbine compared to the Horizontal axis wind turbine has more effective efficiency output. The helicoidal blade has curves like aerodynamic structure, So the Performance analysis of the Helicoidable blade is better than that of the H-shape blade.

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