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Design and Fabrication of Vertical Axis Wind Mill Turbine

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Abstract: ***The principle objective of this project is Rural Electrification via hybrid system which includes wind and solar energy. Our intention is to design a wind turbine compact enough to be installed on roof tops. So we decided to design a vertical axis wind turbine (VAWT) over Horizontal Axis Wind Turbine (HAWT). Advantages of VAWT over HAWT are compact for same electricity generation, less noise, easy for installation and maintenance and reacts to wind from all directions. The wind turbine designed to generate electricity sufficient enough for a domestic use. The electricity generated will be stored in the battery and then given to the load. This project emphasizes on electrification of remote areas with minimum cost where load shading still has to be done to meet with demand of urban areas.***

Keywords: Vertical axis, Number of Blades, Electricity, Kinetic Energy

1. Introduction

Wind power devices are used to produce electricity, and commonly termed wind turbines.

The orientation of the shaft and rotational axis determines the classification of the wind turbines. A turbine with a shaft mounted horizontally parallel to the ground is known as a horizontal axis wind turbine or (HAWT). A vertical axis wind turbine (VAWT) has its shaft normal to the ground.

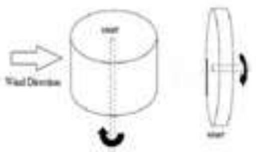


Figure 1: Configurations for shaft and rotor orientation

The two configurations have instantly distinguishable rotor designs, each with its own favorable characteristics. Vertical-axis wind turbines (VAWT) can be divided into two major groups: those that use aerodynamic drag to extract power from the wind and those that use lift. The advantages of the VAWTs are that they can accept the wind from any direction. This simplifies their design and eliminates the problem imposed by gyroscopic forces on the rotor of a convectional machine as the turbine tracks the wind. The vertical axis of rotation also permits mounting the generator and drive train at ground level. The disadvantages of this type of rotors is that it is quite difficult to control power output by pitching the rotor blades, they are not self – starting and they have low tip-speed ratio. Horizontal – axis wind turbines (HAWT) are convectional wind turbines and unlikely the VAWT are not unidirectional. As the wind changes direction, HAWTs must change direction with it. They must have some means for orienting the rotor with respect to the wind.

2. Literature Survey

2.1 Theoretical Maximum Efficiency

High rotor efficiency is desirable for increased wind energy extraction and should be maximized within the limits of affordable production. Energy (*P*) carried by moving air is expressed as a sum of its kinetic energy [Equation (1)]:

$K\,E = \frac{1}{2}\rho A V^3$
Where,
V - Air Velocity
A – Turbine Swept area
ρ- Air Density

A physical limit exists to the quantity of energy that can be extracted, which is independent of design. The energy extraction is maintained in a flow process through the reduction of kinetic energy and subsequent velocity of the wind. The magnitude of energy harnessed is a function of the reduction in air speed over the turbine. 100% extraction would imply zero final velocity and therefore zero flow. The zero flow scenario cannot be achieved hence all the winds kinetic energy may not be utilized. This principle is widely accepted and indicates that wind turbine efficiency cannot exceed59.3%. This parameter is commonly known as the power coefficient *Cp*, where max *Cp* = 0.593 referred to as the Betz limit.

2.2 Practical Efficiency

In practice rotor designs suffer from the accumulation of minor losses resulting from:
1) Tip losses
2) Wake effects
3) Drive train efficiency losses
4) Blade shape simplification losses

Comparison of Different Wind Turbines

Table 1: Comparison of wind turbines

Ref No	Design	Orientation	Use	Propulsion	* Peak Efficiency	Diagram
1	Savonius rotor	VAWT	Historic Persian windmill to modern day ventilators	Drag	16%	
2	Cup	VAWT	Modern day cup anemometer	Drag	8%	
3	American farm windmill	HAWT	18th century to present day, farm use for Pumping water, grinding wheat, generating electricity	Lift	31%	
4	Dutch Windmill	HAWT	16th Century, used for grinding wheat.	Lift	27%	
5	Darrieus Rotor (egg beater)	VAWT	20th century, electricity generation	Lift	40%	
6	Modern Wind Turbine	HAWT	20th century, electricity generation	Lift	Blade Qty / efficiency: 1 – 43%; 2 – 47%; 3 – 50%	

2.3 Wind Turbine Design Parameters:

1) Swept area
2) Power and power coefficient
3) Tip speed ratio
4) Blade chord
5) Number of blades
6) Solidity

3. Design Calculations

3.1 Power calculations

The wind turbine works on the principle of converting 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,

$$K.E ==½mv^2 \text{-----------------} (1)$$

Where,
K.E = kinetic energy
m = mass
v = velocity,
M is equal to its Volume multiplied by its density ρ of air

$$M = \rho AV \text{-----------------} (2)$$

Substituting eq. (2) in eq. (1)

We get, K E=1/2 ρAV^3
Where,
A= swept area of turbine.
ρ= density of air (1.225 kg/m^3)
V= wind velocity.

For 30 Watt power, calculate design parameters of turbine,
P=30 watts.
Considering turbine efficiency as 30% and generator efficiency 70%, %, P = 30/ (0.30*0.70)

P= 143 watts.

For wind velocity 6.67 m/s (18mph)
Density of air (1.225 kg/m3)
143 = ½*1.125*A*$(6.67)^3$

A= 0.9 Sq.m (approx taking A=1 m^2)
A = D*H (Sq.m)
D= diameter of the blade
Taking diameter as 1 meter, height of turbine can be calculated as
H=A/D =1/1
H =1m.
Diameter and height of wind turbine are 1m and $1m^2$.
Design of Turbine Blades
Wing width= diameter*0.14
=1*0.14
=0.140m = 140 mm
Wing chord = circumference*.09
= π*1*.09
=0.282m = 282mm

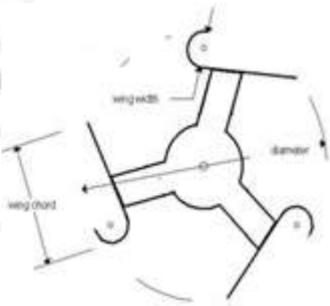
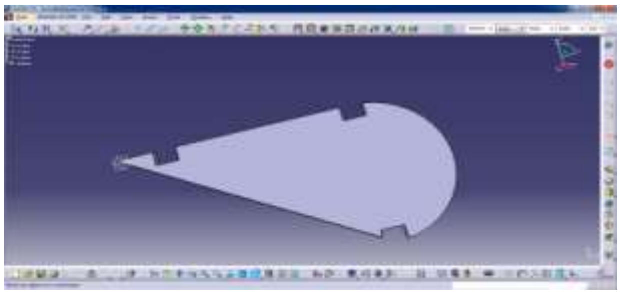


Figure 2: Blade parameters

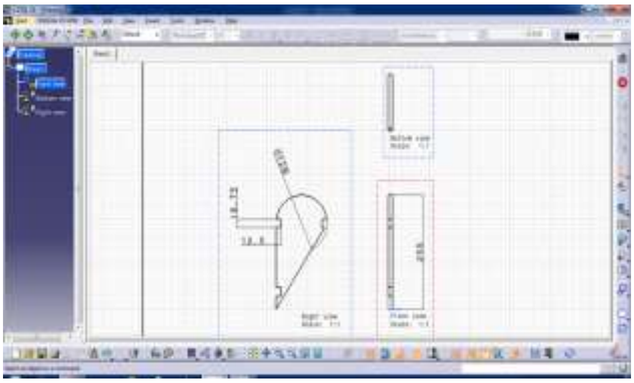
Figure 3: Block Diagram

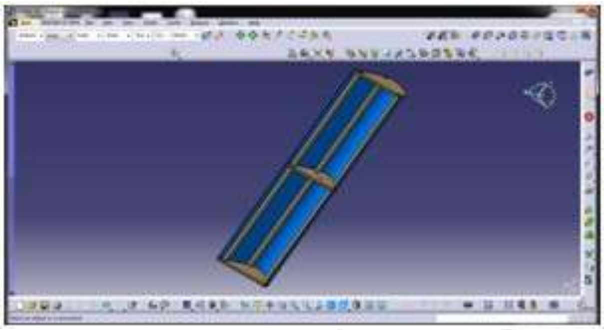
4. CAD Design

Wooden frame

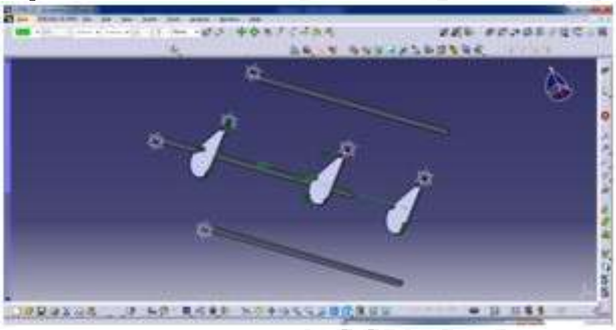


Blades

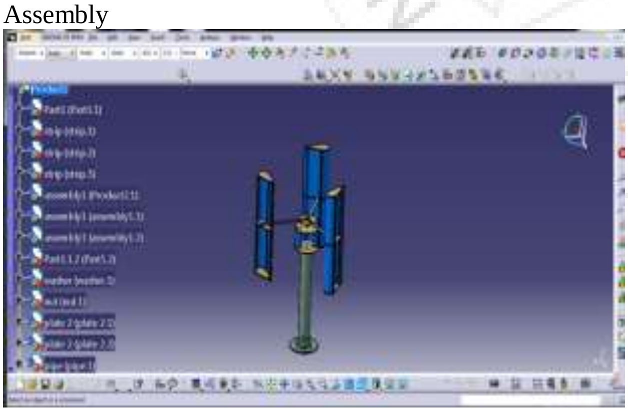




Exploded view



Assembly



5. Design Specifications

Turbine specifications

Wind rotor	Rated power	30W
	Cut in speed	3 m/s
	Rated speed	6.67 m/s
	Rotor diameter	1 m
	Swept area	1 m^2(1 m*1 m)
	Gear box type	None gear box, direct given to generator given to generator
	Brake	Not required
Generator	Generator type	DC generator
	Electric Transmission	Brushless
Turbine blade	Blade type	J-type(drag)
	Blade number	3
	Blade material	GI sheet with Wooden frame
	Hub material	MS
Blade dimension	Length	1m
	Cup radius	0.126 m
Controller	PC156511A	

6. Observation Table

Sr.no	Speed (rpm)	Voltage (Volts)	Current (Ampere)	Power (Watts)
1	30	4.39	1.86	8.16
2	38	4.74	2.28	10.82
3	48	5.83	2.38	13.87
4	70	5.84	2.98	17.48
5	98	7.26	3.74	27.15

7. Result Discussion

The results obtain were up to expectations. While in theoretical design we considered the efficiency of turbine to be 30%, but we got efficiency as 26.3%. The efficiency was decreased due various manufacturing errors and friction losses

8. Conclusion

Our work and the results obtained so far are very encouraging and reinforce the conviction that vertical axis wind energy conversion systems are practical and potentially very contributive to the production of clean renewable electricity from the wind even under less than ideal sitting conditions this project will be helpful in rural areas where the electricity supply is scarce. Also in most cities, bridges are a faster route for everyday commute and in need of constant lighting makes this an efficient way to produce energy

9. Future Scope

The efficiency can be increased by precise fabrication of prototype and also by designing the blades of the turbine more aerodynamically and use simulation software like CFD. 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.

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