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Design and Analysis of Vertical Axis Wind Turbine for Optimum Generation

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***Abstract* – Wind Energy is clean and renewable source of energy and is also the world's fastest growing energy resource. Keeping in view power shortages and growing cost of energy, the low cost wind energy has become a primary solution. It is imperative that economies and individuals begin to conserve energy and focus on the production of energy from renewable sources. Present study describes a wind turbine blade designed with enhanced aerodynamic properties. Vertical axis turbine is chosen because of its easy installment, less noisy and having environmental friendly characteristics. Vertical axis wind turbines are thought to be ideal for installations where wind conditions are not consistent. The presented wind mill is best suitable for roadsides where the rated speed due to vehicles is most often 6 ms-1.**

***Keywords* – Vertical Axis Wind Turbine (VAWT), Symmetricity, Drag Coefficient, Aerodynamic Angle, Cut in Speed.**

***Nomenclature* – Cp = Coefficient of performance, g = efficiency of the generator, = air density, b = bearings efficiency, tsr =tip speed ratio, a= Axial Flow Induction factor, R=Rotor radius ,v=Free stream air velocity, B =Number of Blades , N=Revolutions per minute , vr= Rated speed, Vf = fluttering speed, μ = absolute viscosity of air, Re = Reynold number and υ= kinematics' viscosity.**

I. Introduction

Renewable energy is energy from natural resources such as sunlight, wind, rain, tides and geothermal. Renewability means it is not depleted when used. Renewable energy is of various forms such as solar, hydro, biomass, bio-fuel, geothermal and wind. Major advantages of renewable energy include the following; it is more environmental friendly than conventional forms of power and is inexhaustible, and is appropriate for remote areas where electricity from national grid is expensive to provide. Renewable energy facilities generally require less maintenance. Wind power systems are a capital intensive technology. It requires a considerable initial investment, however, the high initial costs are offset by the lower operating and maintenance cost of the plants. One time the system builds it provides energy free of cost. The focus of this research work was laid on wind energy as wind power is the most productive among the renewable energy resources. Wind energy can be captured by the use of wind turbine. Wind turbines are used to convert wind energy into electric power with the use of electric generator. There are two types of wind turbines namely horizontal axis and vertical axis wind turbines. Vertical axis turbines are powered by wind coming from all 360 degrees, and even some turbines are powered when the wind blows from top to bottom. Because of this versatility, vertical axis wind turbines are thought to be ideal for installations where wind conditions are not consistent, or due to public ordinances the turbine cannot be placed high enough to benefit from steady wind. Because of this, VAWT preferred over horizontal axis turbines in areas where a tall tower is not feasible. Vertical wind turbines were specifically designed to resolve the unique issue associated with electricity production in urban or suburban settings where horizontal winds become vertical when encountering the face of a building. The V shaped blades of the vertical wind turbine can make use of horizontal or vertical wind bursts blowing in from any direction. Vertical axis wind turbines are different from traditional wind turbines in that their main axis is perpendicular to the ground. Their arrangement makes them suitable for both rural and urban settings and offers the owner an opportunity to offset the rising cost of electricity.

II. Designing of Blade and Analysis

The blade profile selection is done as V shape. The symmetrical air foil performs better performance under those alternating conditions. Other benefits are lower cost and easy fabrication as compared to the non-symmetrical air foil. The thicker blades show a better performance of self- start and is closer to a self-start capacity nature. Thicker the blade, higher the pressure coefficient contribution to the forward movement of the wind turbine blades. The first type of design as shown in Figure (a) is a straight blade Giromill design. Through this type of design less lift can be attainable whereas due to its shape high drag is there. Low lift coefficient and high drag coefficient make it a less efficient design with minimum capability of capturing air. The turbine could not mostly start by itself and some starting mechanism is necessary to be imparted. Another type of design which is mostly used in home application is semicircular Savonius type design as shown in Figure(b). This shape has also a less efficient design with low lift and high drag coefficient. Its self starting and air capturing capability is better than Giromill design but it also needs a starting mechanism, its air capturing capability is higher but high drag make it very less efficient. The above designs are easily manufacturable from the construction point of view. Both of the above designs could not be used for commercial purposes and less efficiency makes their use restricted. The type of designs which may be used for commercial purposes are the solid Lenz type design as shown in Figure(c) and symmetrical V shaped design as shown Figure (d) There are some advantage associated with V-shape type design. This high lift coefficient and low drag coefficient make their efficiency reasonably high compared to the other designs. As the shape corresponds the design has capability of capturing air in both clockwise and anti clockwise directions. Also the Lenz type design due to its construction is more heavy can give high torque but adds in lower starting capability. Thus the design requires a starting mechanism. Through all the analysis we come across a conclusion that the V shaped blade design is the most efficient design. The design has higher air capturing capability. The design is self starting thus no starting mechanism is required. We can harvest a greater amount of energy from the manufacturing point of both Lenz and symmetrical types require high precision and more developed construction site.

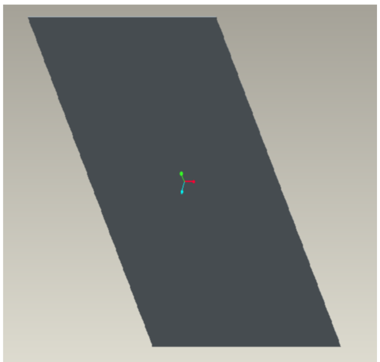


Fig.(a)

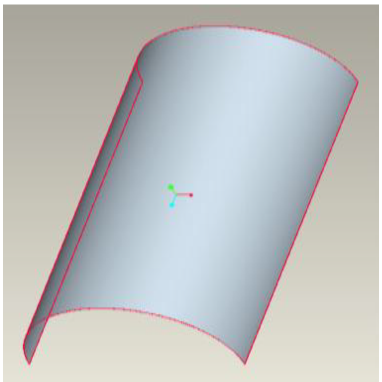


Fig.(b)

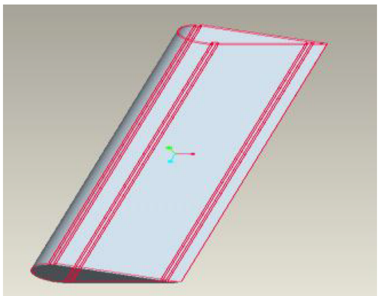


Fig.(c)

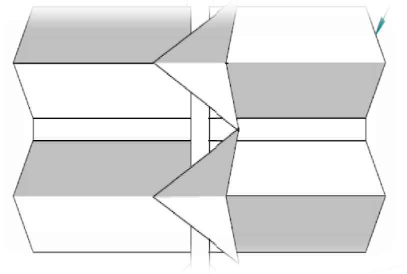


Fig. (d)

III. V- Shape Blade Design

In the wind mill design the blades rotate horizontally. It has two steps of leafs. The leafs are in V shape design each leaf faces four different directions to make rotating the mill continuously. In this wind mill design we fix the leafs faces same anticlockwise direction to make the leaf rotate only in clockwise direction and there is small gap in between the leafs. The leafs are constructed of weight less steel sheets which are connected by frame. It has an center ventilating frame which connects the two steps of triangular sheet metal construction its one side is open end and other is an closed end it divert the wind direction the whole setup is connected to a circular plate with circular shaft at the center of the wind mill.

IV. Design Calculations

Power from wind turbine is calculated as follows:

P = 0.5 x x A x Cp x V3 x g x b

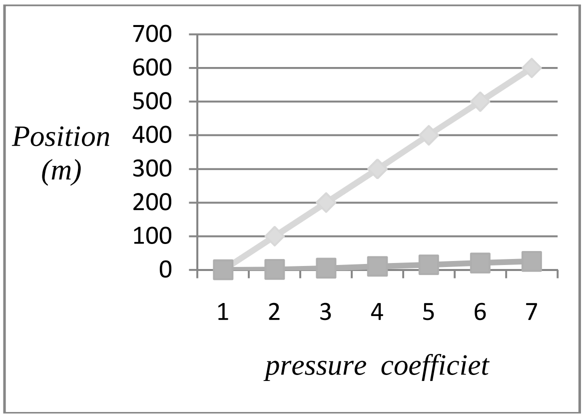
Table 1

Air velocity (m/s)	Power from wind(W)
1.5	4.15125
2 .0	9.84000
2.5	19.2187
3.0	33.2100
3.5	52.7362
4.0	78.72 00
4.5	112.083
5.0	153.75 0
5.5	204.641
6.0	265.680
6.5	337.788
7.0	421.890
7.5	518.906
8.0	629.760
8.5	755.3738

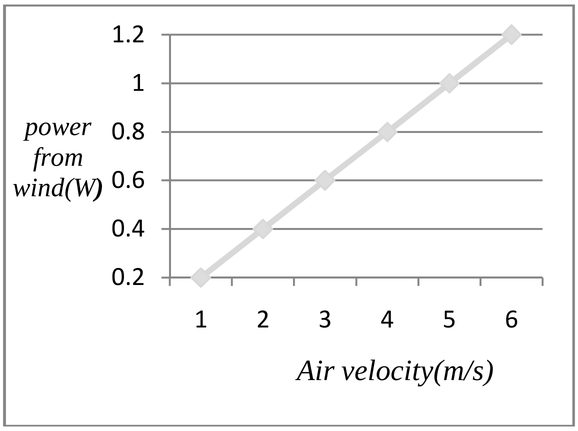
a = 0.55 (assumed), **R** = 800mm , **v** = 5m/s, **B** = 3, **ρ** = 1.23 kg/m3
Using Equation, we have
CP = 4a (1-a) 2 or CP = 4*0.55(1-0.55)2 or CP = 0.45
To calculate the power generated by the rotor, we use Equation:
3 P AU C21 P
Putting all the values, we get at normal operating velocity
P available = 70 watts

As cut in speed =1.5 m/s, Speed at which charging should start= vc =3m/s,Normal operating speed=5m/s, vr =10m/s, Cut out speed= fluttering speed= Vf = 25m/s.
Reynold number calculated is
Re = ρvL/μ
L is the plate length=8 feet, υ =1.4065e-5 m2/s and μ =1.73e-5kg/ms
υ=μ/ρ
Re = vL/υ =248844.65≈250000

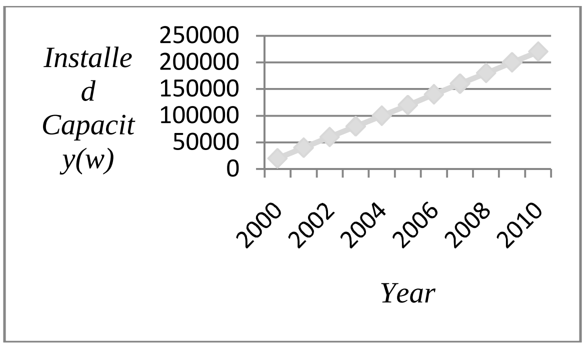
Thus from above table we can see that at normal Power at operating speed of 5m/s =70 W and Rated power at 10 m/s is ≈550W



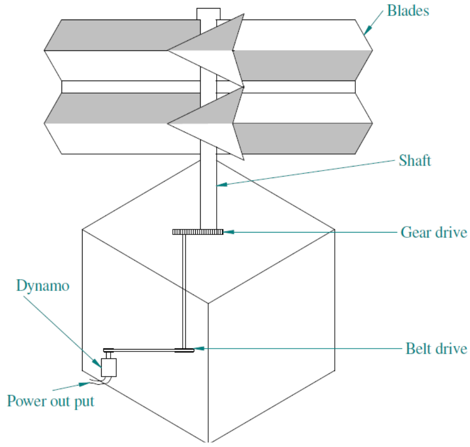
Graph I



Graph II



Graph III



V. Construction of Full Assembly

The vertical axis wind mill has V shaped blade design which is made up of weightless aluminum design. The blades are connected to the central shaft which is connected to the frame as shown in figure. The whole frame assembly has been mounted on a circular shaft with help of circular steel plate. The circular shaft is fixed on a base frame with an supporting ball bearing. At bottom end of the circular shaft a gear wheel is fixed to rotate with the circular shaft. A small pinion gear is meshed with the gear wheel with more number of teeth. The pinion with small number of teeth is fixed in a alternator which produce an alternating current. Then AC is converted into dc by means of rectifier and it can be stored in battery.

VI. Working

In the vertical wind mill design construction, it works only in clockwise or anticlockwise direction. According to the design, if the leafs faces anticlock side it will rotates in clockwise direction .The wind flows in any direction or in any side will definitely contact with the leafs and make to rotate the blades in any one of our fixed direction. All the leafs move in a particular direction will make the center shaft to rotate. That rotation is used to rotate the gear wheel and a pinion mounted on a dynomo. The dynamo is meshed with the gear wheel it gets the rotational power from center shaft and from the gear wheel. The wind mill rotates continuously till the rotation of the wind mill stops.

VII. COMPARISION

PARAMETER	VAWT	HAWT
Cost	85,000/- (approximately)	1,00,000/- (approximately)
Installation	Easy	Complex
Wind Velocity	6 km/hr	3 km/hr
Pollution	No/Less	High Noise pollution
Safety	Does not Harm birds	Harmful to birds
Construction	Simple	Complex
Fault Identification	Easy	Difficult

VIII. CONCLUSION

Optimized blade design by using most suitable and simple design. Changing its characteristics according to the turbine leads to the development of optimized turbine .The main objective behind this idea was to develop a turbine which can generate electrical energy, focusing on objective we come across a conclusion that VAWT is most suited for commercially manufacturing for urban areas due to the various advantages like less noisy, less dangerous to human beings and birds for areas where the air speeds are not constant and turbulence of air as in such circumstances horizontal axis can't work which is the case of many urban areas. Symmetrical design is selected because it has good lift-drag properties and also it is relatively easy to fabricate as compared with other airfoils. As with vertical axis wind turbine, we see that one of the drawbacks of vertical axis wind turbine is that it do not start easily and sometimes a starter motor is used to start it by changing the profile somewhat and a V type structure is made. This structure provides it starting characteristics to it enhancing starting characteristics of turbine blade by capturing air the blade pitch controlled so as to optimize the aerodynamic angle of attack on the blade on both the upwind and downwind blade passes. The graph I is between the pressure coefficient and position of the wind mill blades. The graph II is drawn for air velocity versus power using the details from the table I and graph III is for varying installed capacity of wind mill in different years.

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