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DESIGN AND FABRICATION OF VERTICAL AXIS WIND MILL

* Vignesh J[1], Simon Christopher A[2], Pravin Tamil Selvan C[3] and Jegan R[4]

[1, 2, 3 and 4] Department of Mechanical Engineering, V. V College of Engineering, V.V.Nagar, Tisaiyanvilai (Via), Tirunelveli (Dist.), Tamilnadu, India.

ABSTRACT

It is well known that we rely on the nonrenewable resources such as fossil fuels, oils, natural gas, etc which will certainly get exhausted some day. So keeping these things into consideration we thought of generating power using non-conventional sources which is abundantly available naturally and has zero threat for extinction. Among the various non-convention methods for generation of electric power, wind has found its place to be efficient. Wind Energy being renewable resource of energy has got much attention for power generation, now a day. Having a nature of abundance unlike employment of resources in conventional methods satisfies the growing needs. Wind energy depends upon natural terrains which have wind potential, though these terrains are not found even in nature everywhere, but those which have, are the places that can be harnessed for high potential power generation. Taking into consideration the geographical attributes of our region, the vertical axis windmill will be efficient for power generation. The basic reason for using VAWT is that, it does not consider the wind direction and it can be operated at low wind speed. The main objective of this paper is to design and fabricate a vertical axis wind mill. Vertical axis wind mill (VAWT) is a type of wind mill where the main rotor shaft is set vertically. VAWT offer a number of advantages over traditional horizontal axis wind mill (HAWT). In the vertical axis wind mill, the blade is fabricated with the help of PVC and the blades are arranged in cylindrical shape with the help of rim. The advantages of this arrangement are that the generator and the gearboxes can be placed close to the ground.

Keywords: *Design of vertical axis wind mill, Vertical Column, Rotary blades, Gear, Journal bearing, Shaft and Power generation.*

1. Introduction

Wind energy is the conversion of wind energy into more useful forms using wind turbines. Most modern wind power is generated in the form of electricity by converting the rotation of turbine blades into electrical current by means of an electrical generator. In windmills (a much older technology) wind energy is used to turn mechanical machinery to do physical work, like crushing grain or pumping water. Wind power is used in large scale wind farms for national electrical grids as well as in small individual turbines for providing electricity to rural residences or grid-isolated locations. Wind energy is ample, renewable, widely distributed, cleans, and works against the greenhouse effect if used to replace fossil fuel.

Wind turbines are the evolution of the classic windmills that can be seen in more rural areas of the world. They operate by using the kinetic energy of the wind, which pushes the blades of the turbine and spins a motor that converts the kinetic energy into electrical energy for consumer use. Wind turbines are used to produce electricity from the kinetic power of wind.

Although integrating a large amount of wind power is technically possible, higher integration costs might be incurred when the penetration level of this intermittent power increases. This paper reviews wind power variability and its different impacts on power systems. In addition, an up-to-date overview of wind power balancing costs is presented [1].

Vertical axis wind turbines (VAWT) have a great potential to contribute to growing worldwide reliance on Green energy. For these machines to be efficient, they must be applied outside of their traditional farm environment. This paper aims to improve the applications of design aspects of VAWT. Here, the

**Corresponding Author - E- mail: vigneshjay86@gmail.com*

natural wind flow is free to move unobstructed by trees or buildings down a highway and would be ample enough to turn the blades of the turbines. The relative wind velocities produced by passing traffic would act in conjunction with the natural wind to increase the angular velocity of the blades.

The target for this paper is to better understand the effects of three design considerations: airfoils, airfoil arm supports, and bearings that will contribute to a more efficient turbine. It is hoped that this research and experimentation will make a small contribution to the evolving field of "green" energy and reduce dependence on fossil fuels. This paper will test three different airfoils, two different support arm configurations and produce a comprehensive bearing analysis. These components were tested both experimentally and theoretically.

It was discovered that the most commonly used airfoil for VAWT applications, NACA 0018 was indeed the most efficient airfoil for the scaled down version that was constructed. The longer moment arms allowed for greater space between the airfoils and therefore it has the greater ability of air to enter the turbine and increase its rotational speed. The pricing goals for the wind energy produced were not achieved, but the price is within the range of imminent improvement. The bearing chosen for the theoretical model which was the basis for the final cost analysis was an enclosed ball bearing. The experimentation and research that led to this summary is as follows [2].

It is well known that we rely on the nonrenewable resources such as fossil fuels, oils, natural gas, etc which will certainly get exhausted some day. So keeping these things into consideration we thought of generating power using non-conventional sources which is abundantly available naturally and has zero threat for extinction. Among the various non-convention methods for generation of electric power, wind has found its place to be efficient. Wind Energy is the renewable resource of energy which has got much attention for power generation, now a days. Taking into consideration the geographical attributes of our region, the vertical axis windmill will be efficient for power generation. The basic reason for using VAWT is that, it does not consider the wind direction and operates at low wind speed [3].

Consequently, VAWT blades generally use symmetrical aerofoils with a lower lift-to-drag ratio than cambered aerofoils tailored to maximize horizontal axis wind turbine rotor performance [6].

This paper considers the feasibility of circulation controlled (CC) VAWT blades, using a tangential air jet to provide lift and therefore power augmentation. However, CC blade sections require a higher trailing-edge thickness than conventional sections giving rise to additional base drag. The choice of design parameters is a compromise between lift augmentation, additional base drag as well as the power required to pump the air jet. Although CC technology has been investigated for many years, particularly for aerospace applications, few researchers have considered VAWT applications. This paper also considered the feasibility of the technology, using Computational Fluid Dynamics to evaluate a baseline CC aerofoil with different trailing-edge ellipse shapes. Lift and drag increments due to CC are considered within a momentum based turbine model to determine net power production. The study found that for the modest momentum coefficients significant net power augmentation can be achieved with relatively simple aerofoil geometry if blowing is controlled through the blades rotation [4].

This project studied the potential for installing roof-mounted vertical axis wind turbine (VAWT) systems on house roofs. The project designed several types of VAWT blades with the goal of maximizing the efficiency of a shrouded turbine. The project also used a wind simulation software program, WASP, to analyze existing wind data measured on the roofs of various WPI buildings. Scale-model tests were performed in the WPI closed-circuit wind tunnel. An RPM meter and a 12 volt step generator were used to measure turbine rotation speeds and power output at different wind speeds. The project also studied roof mounting systems for turbines that are meant to dissipate vibrations to the roof structure. Turbine vibrations were measured during the wind tunnel tests and in impact tests on a scale-model house. Recommendations were made for future designs of roof-mounted VAWT [5].

In this work the rotor blades, shafts; bearings are designed in analytical method. The prototype of vertical axis wind turbine was constructed and the output power of vertical axis wind turbine was calculated.

2. Design Calculations

2.1 Design of rotor blades

The optimum tip speed ratio depends on the number of blades in the wind turbine rotor. The fewer number of blades, the faster the wind turbine rotor needs to rotates to extract maximum power from the wind. A two-bladed rotor has an optimum tip speed ratio of around 6 to 7, a three-bladed rotor around 5 to 6, and a four-bladed rotor around 3 to 4 [7].

Table 1 Tip Speed Ratio for different number of blades

Number of blades	Tip Speed Ratio (TSR)
2	6 to 7
3	5 to 6
4	4 to 5
5	3 to 4
6	2 to 3

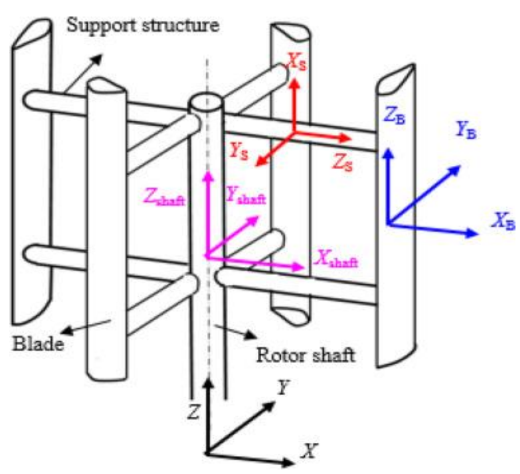

Figure 1 View of blades arrangement.

2.1.1 Betz Limit

Albert Betz was a German physicist who in 1919 concluded that no wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy by turning a rotor. This is known as the Betz limit or Betz Law. This limit has nothing to do with the inefficiencies in the generator, but in the very nature of wind turbines themselves.

The theoretical maximum efficiency of a wind turbine is given by the Betz limit around 59 percent. Practically, wind turbines can be operated below the Betz limit [8].

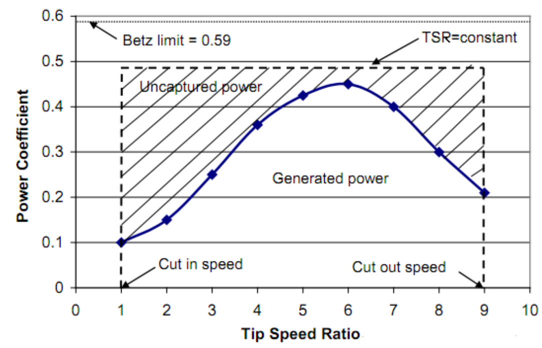

Figure 2 Power Coefficient Vs Tip Speed ratio

2.2 Calculation of Wind Power

Height of the blade R= 20 cm = 200 mm = 0.2m
Radius of the rotor blade r = 45 mm = 0.045 m
Average wind Speed V = 30 Km/hr = 8.33 m/s
Tip Speed Ratio i = Tip Speed of Blade / Wind Speed

i = v / V

Tip speed ratio for 6 blade rotor = 3
Kinetic Energy, E= 0.5 * mass * Velocity ^{2}
Mass per Second (Kg/s) m = Velocity * Area * Density of air

Swept Area A $= \pi * R^2 = \pi * 0.2^2$
A $= 0.126\ m^2$
Density of air ρ $= 1.23\ Kg/m^3$
Mass/Second m = 8.33 * 0.126 * 1.23
m = 1.29 Kg/s
Kinetic Energy E $= 0.5 * 1.29 * 8.33^2$
E = 44.75 Joules
The power generated by the kinetic energy
Wind Power (Available Power)
P $= 0.5*\rho*A* C_p * V^3$
Power Coefficient C_p (from graph) = 0.25 (for TSR = 3)
Wind Power
$P = 0.5 * 1.23 * 0.126 * 0.25 * 8.33^3$
P= 11.19 Watts

The power coefficient is defined as the power extracted by the turbine relative to that available in the wind stream.
Power Coefficient $C_p = P_t / P$
Output Power of Turbine $P_t = C_p * P$
= 0.25 * 11.19

P_t = 2.8 Watts

2.3 Design of Hollow Shaft

Outer diameter of hollow shaft D_o = 25 mm
Inner diameter of hollow shaft D_i = 20mm
Length of hollow shaft L = 350mm
Speed N = 200 rpm (Assume)
Shear stress τ = 50 N/mm^2
Torque $T = (\pi/16) * \tau * [(D_o^4 - D_i^4)/(D_o)]$
$T = (\pi/16) * 50 * [(25^4 - 20^4)/(25)]$
T= 90566.22 N.mm

Solid Shaft

Diameter of solid shaft d = 12 mm
Length of solid shaft L = 250 mm
Torque T $= (\pi/16) * \tau * d^3$
T $= (\pi/16) * 50 * 12^3$
T = 16964.6 N.mm
Angle of twist $(\tau/r) = (T/J) = (G\theta/L)$
Polar moment of Inertia $J = (\pi/32) * d^4$
$= (\pi/32) * 12^4$
J = 2035.75 mm^4
Modulus of rigidity G $= 0.84*10^5$ N/mm^2
Angle of twist $(\tau/r) = (G\theta/L)$
$\theta = \tau L / rG$
$= 50*250 / (6 * 0.84*10^5)$
Angle of twist $\theta = 0.0248$ radian $= 1.42^o$

2.4 Design of Journal Bearing

Diameter of Journal D = 25mm
L/D ratio 3 for shafting (PSG Data Book 7.31)
Bearing Pressure = 11 kgf/cm^2
(Zn/P) min = 426.7
Length of Journal L= L/D = 3
= L/25 = 3 ; L = 75 mm

Load on Bearing W

Bearing Pressure p = W/LD = 11 kgf/cm^2
= 1.1 N/mm^2
1.1= W/75*25

W= 2062.5 N = 2.0625 KN
Diametrical Clearance C = 50 microns
Clearance ratio C/D = 0.05 / 25 = 0.002
Selection of Lubricating Oil
(Zn/p) min = 426.7
Z = (426.7* 11)/200 Assume (n =200 rpm)
Z = 23.46 = 24 Centipoises
Assume Operating Temperature = 60^o
From Graph (PSG Data Book 7.41) SAE 20Oil is Selected
Coefficient of Friction $\mu = (33.25/10^{10}) * (Zn/p) * (D/C) + k$

K = 0.003 (PSG Data Book 7.34)
$= (33.25/10^{10}) * 426.7 * (1/0.002)$
Coefficient of Friction μ = 0.0037
Heat Generated Hg $= \mu * W * V$
$= 0.0037 * 2062.5 * (\pi * 0.025 * 200/60)$
= 2 W
Heat Dissipated Hd $= (\Delta t + 18)^2 * L*D / K$
(Assume K =0.484 for medium duty)
$\Delta t = \frac{1}{2}(T_o - T_a) = \frac{1}{2}(60-30) = 15^oC$
Hd $= (15 + 18)^2 * 0.075 * 0.025/0.484$
= 4.22 W
Heat Dissipated is more than Heat Generated, therefore artificial cooling arrangement is provided
Diameter of Bearing D_b = D + C = 25 + 0.05
D_b = 25.05 mm

3. Consturction

A vertical column of the length 250mm and breadth 200mm is fabricated by joining the mild steel bars with the help of manual arc welding. A vertical column acts as a base and all the components of vertical axis wind turbine are mounted on it. A mild steel hollow shaft of outer diameter 25mm and inner diameter 2 mm is fitted with the vertical column and a disc of diameter 400mm welded at the top of the hollow shaft.

The rotor blades (six blades) are connected with the disc at an angle of 60^o each by using bolted joints. This arrangement allows the generator and gearbox to be located close to the ground, facilitating service and repair. VAWT do not need to be pointed into the wind, which removes the need for wind-sensing and orientation mechanisms. A steel bush is used to connect the hollow shaft and the solid shaft of diameter 12 mm.


Figure 3 Construction of VAWT

A journal bearing is connected with the hollow shaft for avoiding unwanted friction and allow to rotate the shaft freely. The gear is welded at the bottom of the solid shaft, and a dynamo is inversely connected with a vertical column, then the knurled portion of dynamo is connected with the gear. The output of dynamo is connected with LED Bulb

4. Working Principle

In VAWT the airfoils are arranged as they are symmetrical and having an angle that the airfoils are set corresponding to the structure. This setup is equally efficient on any directional wind. When the VAWT rotor rotates, the airfoils move forward through the air in a round path. Relative to the blade, the resultant airflow makes a varying small positive angle of attack to the blade. This creates a overall force pointing diagonally forward along a definite line of action. This force can be projected inwards past the turbine axis at a certain distance, giving a positive torque to the shaft. As the airfoil rotates around the back of the apparatus, the angle of attack changes to the opposite sign but the generated force is still obliquely in the direction of rotation, because the wings are symmetrical. The rotor spins at a rate irrelevant to the winds speed. The energy producing from the torque and speed can be extracted and converted into useful power. Lift and drag forces along the approaching net relative airflow respectively. When the rotor is stationary and if the wind velocity rises quite high then the rotor must already be spinning to generate torque. Thus the design is not generally self-starting.

In VAWT when wind turns the blades, the disc is rotated by using the velocity of wind and the shaft also rotated at the same speed then the power is transferred from a disc to the gear arrangement which is welded at the bottom of the shaft. A dynamo get the power from the gear by the engagement of gear and a knurled portion of a dynamo and the output power is given to the LED bulb.

ADVANTAGES OF VAWT

They can produce electricity in any wind direction

- Strong supporting tower in not needed because generator, gearbox and other components are placed on the ground
- Low production cost as compared to horizontal axis wind turbine
- As there is no need of pointing turbine in wind direction to be efficient so yaw drive and pitch mechanism is not needed
- Easy installation as compared to other wind turbine
- Easy to transport from one place to other
- Low maintenance cost
- They can be install in urban area
- Low risk for human and birds because blades moves at relatively low speed
- They are particularly suitable for areas with extreme weather conditions, like in the mountains where they can supply electricity to mountain huts.

5. Conclusion

Today, wind power is economically competitive compared to traditional energy because the cost of wind turbines is getting cheaper because of technological advancement and government incentives. Wind energy is also a renewable and pollution-free energy which can help us reduce the emissions of greenhouse gases. I believe that wind energy can become an important asset to solve climate change and global warming issues in the future. In the recent era of rapidly developing technology the design of this vertical axis wind mill generator can to fulfil certain amount of energy requirements

The design and fabrication of power generation and irrigation by windmill has been successfully introduced. By doing this project, the sole aim of producing optimum energy from the wind is fulfilled.

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