

Wind Turbine design and fabrication to power street lights

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Abstract. The objective of this work was to design and build a wind turbine which can be used to power small street lights. Considering the typical wind speeds in Abu Dhabi, UAE and ease of construction, the design of the wind turbine was chosen to be Sea Hawk design from vertical axis wind turbine category. A three phase AC generator was used for its availability over the DC motors within the region. A 12V battery was used for storage and a charge controller was used for controlling the charge flow into the battery and for controlling the turbine rotation when the battery is fully charged. The blades used in the turbine were made of foam board according to the NACA 0018 airfoil shape with a chord length of 15cm. The connecting shaft was made of stainless steel. Structural analysis and CFD analysis were performed along with other calculations. Testing was executed to calculate the voltage output from the turbine at different wind speeds. The maximum voltage the turbine produced at 6.4 m/s wind speed was 2.4V and the rotational speed of the turbine was 60.3 rpm.

1 Introduction

Wind turbines typically are divided into two types based on their axis of rotation with respect to the wind flow direction; Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). HAWT has blades that are similar to propellers that spin on horizontal axis. The position of main rotor shaft and electrical generators in horizontal axis turbine is at the top of a tower provided that this must be pointed in the direction of wind. Typically, the gearbox combined with the high-speed shaft increases the rotation of about 30-60 rpm to almost 1200-1500rpm. This is the typical rotation speed required for generators used in HAWT [1]. The offshore wind turbines have the advantage in case of noise pollution as it is far from shore without affecting the people and are less affected by turbulence whereas the onshore turbines create noise pollution and are affected more by turbulence [2]. In a VAWT, the main rotor shaft is fixed vertically. Vertical axis wind turbines can be subdivided into two kinds: Darrieus and Savonius [1]. Typical Darrieus wind turbine (different types shown in Fig. 1) contains 2 or 3 blades [3].

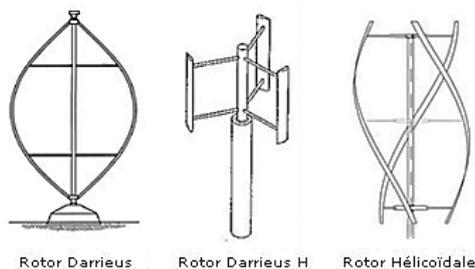


Figure 1. Types of Darrieus VAWT [3].

Savonius drag-based VAWT works similar to the paddle propelling in a boat. The drag is the pressure or thrust developed when wind passes through the blade. The blade is S shaped cross section; this is to implement the drag technique and also to provide certain lift [4]. UAE is currently in the process of determining the viability in wind farm projects within the country. UAE Ministry of Energy is carrying out various research projects for further understanding the variability of wind from year to year [6].

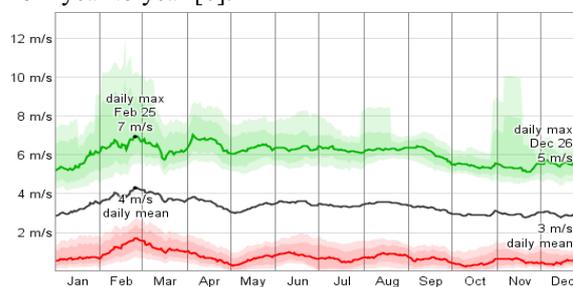


Figure 2. Red is average daily minimum, Green is maximum, and black is average wind speed with percentile bands [7].

Figure 2 shows the wind speed data over a year in Abu Dhabi. Daily maximum wind speed ranges from lowest 5m/s to highest 7m/s. The lowest daily wind speed can go to a maximum of 2m/s. In an average curve, the maximum wind speed is found to be 5m/s and minimum is 3m/s. Hence the design constraint was selected to be a wind speed of around 5m/s [7]. The average wind speed in Abu Dhabi is less than 5m/s and VAWT can be utilized at such wind speeds. The start-up wind speed generally is 2m/s for the same. Sea hawk design as shown

in Fig. 3 satisfies the regional conditions and is appropriate for Abu Dhabi weather conditions [5].



Figure 3. Sea Hawk turbine [5].

The objective of the present work is to design and construct a wind turbine to power small street lights of typically 30 W lamps. The wind turbine is to be designed for wind conditions encountered in Abu Dhabi UAE. The turbine should run effectively with an average wind speed of 5-6 m/s. A battery will be used to store energy while the wind turbine is running during the day. The same can power the street light after sunset. In addition, the whole turbine should be modular and easily manufactured with inexpensive material requirements. Considering the use for street lighting, the typical wind velocities available in Abu Dhabi, and the ease of manufacturing Sea Hawk VAWT was selected as a good candidate to serve the purpose.

2 Design of the Wind Turbine

Swept area of the wind turbine is the area of the wind turbine which captures the wind. The power available from the wind turbine increases with an increase in the swept area. Another parameter that greatly affects the power available from the wind turbine is the wind speed [8]. Kinetic energy can be calculated as:

$KE = 0.5mV_{\infty}^2$; where V_{∞} is the free stream velocity and m is the mass of air trans versing such that $m = \rho AV_{\infty}$ in which A = swept area and ρ = density of air

Therefore,

$$KE = 0.5\rho AV_{\infty}^3 \quad (1)$$

Including coefficient of performance in equation (1), the power output can be determined as:

$$P_w = \frac{1}{2} C_p \rho AV_{\infty}^3 \quad (2)$$

Power density is the terminology used to define the available power per unit area swept by the blade/airfoil [9]. Power density can be calculated as:

$$p = \frac{1}{2} C_p \rho V_{\infty}^3 \quad (3)$$

Symmetrical shape is easier to manufacture than curved shapes. NACA 0018, 0012, 0015 are all symmetric in shape. NACA four series is recommended since symmetrical airfoils work better for higher Reynolds number; particularly NACA 0012, 0015, 0018. These are more appropriate for smaller angle of attack [8].

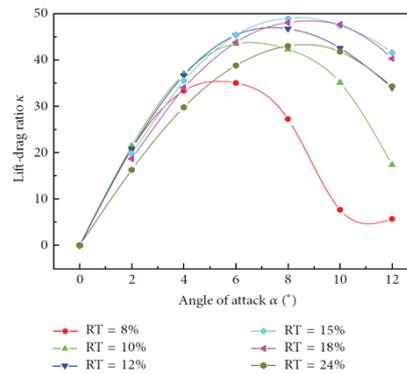


Figure 4. Lift-drag ratio of symmetric airfoils at various relative thickness [9].

Figure 4 represents comparison between six different NACA airfoil thicknesses which include 8, 10, 12, 15, 18, and 24 percentages. The relative thickness ‘RT’ represents thickness / chord ratio (t/c ratio) and is the maximum thickness of the airfoil expressed as a percentage of the chord. Considering symmetric airfoil shapes, the airfoils with 15% thickness has the highest lift drag ratio. This means 15% thickness can provide the maximum lift and least drag. The second highest lift drag ratio is for 18% thickness NACA airfoil. It is evident in the graph that when angle of attack increases after a specific value, the drag element increases and the ratio decreases. When thickness increases beyond a limit, the drag also increases accordingly. Thus airfoil with thickness 15% or 18% is preferred. It should also be considered that 18% is thicker than 15% and is more robust than 15%. Another important finding is that thicker airfoil increases the startup torque. It was found that 19% thickness showed good start-up and traverse characteristics. Theoretically it is proven that 18% has better performance at low Reynolds number and highest power coefficient was achieved at 18% [9]. Studies [8] prove that a larger leading edge radius is preferred to be less sensitive to roughness. Thick blunt trailing edge is preferred for increasing lift [9]. Choosing an appropriate number of blades for the turbine is a balance between blade stiffness and aerodynamic efficiency. Increasing the blade number for a specific radius and thickness leads to sacrificing blades stiffness for a very slight increase in aerodynamic efficiency. Single bladed turbines suffer from a parasitic drag. Two bladed rotors are more sensitive towards mass imbalance vibrations and causes higher operating cost and maintenance compared to three blades. Minimum three blades are required to decrease vibrations due to mass imbalance issues [9]. In the sea hawk type of vertical axis wind turbines, the blades are not cambered and are symmetric. The diameter of the turbine is 0.80m and 1.2m tall. All the blades positions are distributed evenly. Blades can be made from light and inexpensive materials. Sea Hawk design was chosen as the prototype design. This decision was made after comparing the score in efficiency, cost, ease of manufacturing, and ease of maintenance. The blades in this type of turbine can be designed in straight, symmetric, and anti-symmetric airfoil shapes.

Initial optimized parameters have been chosen to set the initial design of the turbine. Table 1 summarizes the

initial dimensions of the turbine which were obtained based on best dimensions of the airfoil.

Table 1. Starting parameters.

Symbol	Parameter	Value
V_{∞}	Wind speed	5m/s
TSR	Tip speed ratio	0.625
R	Rotor Radius	0.385m
C	Blade Chord	0.07m
L	Blade length	1.22m
N	Blade numbers	6, 8, 15, 16

Once the initial dimensions and TSR are specified the next step is to find the solidity which is a dimensionless parameter which will help to find the geometry of the VAWT. The blade solidity ' σ ' can be calculated as:

$$\sigma = \frac{B C}{R} \quad (4)$$

where 'B' is the number of blades; 'R' is the radius of the rotor; 'C' is the chord length

An increase in solidity increases the production of the higher torque at the low tip speed ratios. Table 2 shows properties of different materials considered for the blade. The wind turbine structure is the main source of the stresses as well as the change of input forces [11].

Table 2. Material properties.

Material	Stiffness (GPa)	Tensile Strength (MPa)	Density (g/cm ³)	Elongation at break (%)	Max temp (°C)
Steel	30	190	7.5	15	550
Aluminum	10	90	2.7	12	400
Glass-E	73	3500	2.54	3	350
Carbon	350	4000	1.75	1.8	500
Aramid	120	3600	1.45	11	250
Foam T90	0.5	1.5	0.065	0.2	70

The shaft of the turbine (1.05m long) is made up of stainless steel for its advantages such as durability and resistance to corrosion and rust. At some point the flow of charge from the generator to the battery should be regulated. According to the generator rated power output of 30W and voltage of 12V FW03-12A waterproof charge controller was chosen. The specifications of the controller are mentioned in Table 3.

Table 3. Controller specifications.

Specifications	
Rated power	300W
Battery Voltage	12V
Brake voltage	13.5V
Level of protection	IP67

3 Design Parameters

The main design objective of the turbine is to produce an output power of 30W or above to power LED street lights. The design constraints of the turbine are the turbine diameter, airfoil type, chord length, number of blades, and pitch angle. The input parameters of the design are the rotor radius, blade length, blade chord length, and number of blades. The input parameters of the wind are the free stream wind speed, and air density. The parameters such as swept area, power available from the wind, angular velocity, rated blade velocity, tip speed ratio, lift force, drag force, tangential force, normal force, torque and expected power output is calculated.

Using the equation for Swept Area,

$$\text{Swept Area (A)} = H \times D \quad (5)$$

$$A = 0.832\text{m}^2$$

Using equation (2),

$$\text{Power available from wind (P}_w) = 63.7\text{W}$$

From the literature review and based on the wind data, the cut in speed (V_d) was assumed to be $3.13 \frac{m}{s}$

To find the Angular velocity(ω),

$$\omega = \frac{V_d}{R} = 7.825 \frac{rad}{sec} \quad (6)$$

Using the equation for Blade velocity,

$$\text{Blade velocity (V}_b) = R \times \omega = 3.13 \frac{m}{s} \quad (7)$$

Using equation, the magnitude of relative velocity is

$$|\vec{W}| = V_{\infty} \sqrt{\left(\frac{\omega R}{V_{\infty}} + \cos\theta\right)^2 + (\sin\theta)^2} \quad (8)$$

Finding the relative velocity, lift force, drag force, tangential force, torque, expected power output and coefficient of performance when the blade position is at 30 degrees and the pitch angle is at 10 degrees. Fig. 5 shows the velocity vector when the blade is at positioned at 30 degrees.

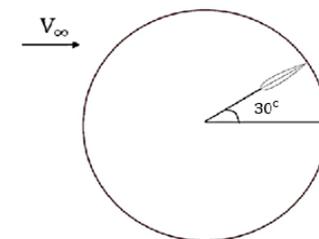


Figure 5. Velocity vector when blade is positioned at 30 Degree When the blade is in position which is the azimuth angle (θ) is at an angle of 30° , $|\vec{W}| = 6.29 \frac{m}{s}$

The angle of relative velocity can be found using equation,

$$\phi = \tan^{-1} \left(\frac{\sin \theta}{\frac{\omega R}{V_d} + \cos \theta} \right) - \frac{\omega x_0 C}{W} - \frac{\omega C}{4W} \quad (9)$$

Where x_0 is the blade attachment at the middle of chord length, thus $x_0 = 0$. Therefore, $\phi = 12.36^\circ$

Using the equation for tip speed ratio,

$$\lambda = \frac{R\omega}{V_{\infty}} = 0.624 \quad (10)$$

Angle of attack and pitching angle is related to each other and this can be mathematically modeled. By fixing the azimuth angle as 30° and varying the pitch angle -10° to 60° Fig. 6 was generated.

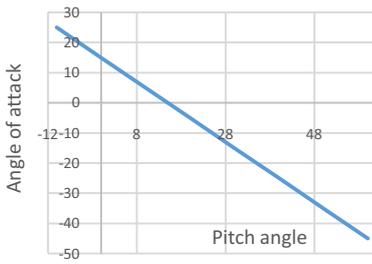


Figure 6. Angle of attack vs Pitch angle.

For the calculation, the pitch angle was assumed to be 10° . From the graph plotted in Fig. 6, the angle attack was found to be 5.025° .

RPM of the turbine

$$N = 7.825 \times \frac{60}{2\pi} = 74.72 \text{ RPM} \quad (11)$$

Using equation for Reynolds number,

$$Re = \frac{\rho WC}{\mu} = 58284.79 \quad (12)$$

The values for C_L and C_D are found to be 0.7352 and 0.03446 from the table for NACA 0018. Using the angle of attack (α) which is equal to 5.025° .

Using the equation for lift force,

$$\text{Lift Force } (F_L) = \frac{1}{2} \times C_L \times \rho \times W^2 \times A_p = 2.779 \text{ N} \quad (13)$$

Using the equation for Drag Force,

$$\text{Drag Force } (F_D) = \frac{1}{2} \times C_D \times \rho \times W^2 \times A_p = 0.13 \text{ N} \quad (14)$$

Using the equation for Tangential Force,

$$F_T = F_L \sin \phi - F_D \cos \phi = 0.64 \text{ N} \quad (15)$$

Chord length for the turbine blade was determined after comparing and analyzing existing VAWT turbine designs. It was found that most of the turbine blade chord length

was somewhere between $\frac{1}{15}^{\text{th}}$ to $\frac{1}{10}^{\text{th}}$ of the turbine diameter. But based on the preliminary design and sketches performed it was found that the gap between the turbine blades was huge so the chord length was increased to 15cm from 7cm. According to the chosen NACA0018 blade, the thickness should be 18% of the chord length. The thickness of the blade was computed using equation (16) to be,

$$T = C \times 0.18 = 15 \times 0.18 = 3 \text{ cm} \quad (16)$$

The effect of coefficient of lift as well as coefficient of drag will affect the overall performance of the turbine. C_L and C_D are functions of Re and the particular airfoil section. The values of coefficient of lift and drag for the prototype blade with 15cm chord length was taken from the table for NACA 0018. Using the equation for the coefficient of performance,

$$C_p = \frac{\text{Expected power output}}{\text{Power available from the wind}} = \frac{P}{P_w} \quad (17)$$

$$C_p = \frac{C_T \times C \times W^2 \times B \times \lambda}{D \times V_\infty^2}$$

$$C_T = C_L \sin \alpha - C_D \cos \alpha = 0.03$$

$$C_p = \frac{0.03 \times 0.15 \times 6.29^2 \times 0.624}{0.8 \times 5^2} \times B$$

The graph shown in Fig. 7 was generated by fixing the wind speed, diameter of the turbine, tip speed ratio, and

the only variation used was the blade number. This was performed in order to choose the best number of blades for the turbine. However, 16 blades were rejected as it had almost same value of C_p as 15 blades and also to reduce the added weight on the turbine.

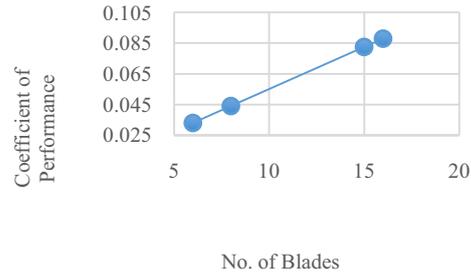


Figure 7. Graph of Coefficient of performance vs No. of blades. The torque of the turbine was found using the equation for torque

$$Q = B \times F_T \times R = 15 \times 0.64 \times 0.4 = 3.84 \text{ Nm} \quad (18)$$

Using the equation for the power output,

$$P = \text{Torque} \times \text{Angular Velocity} = Q \times \omega = 30 \text{ W} \quad (19)$$

Using the equation for power,

$$C_p = \frac{\text{Expected power output}}{\text{Power available from the wind}} = \frac{P}{P_w} \quad (20)$$

$$C_p = 0.474$$

The above calculations for torque, expected power output, and power coefficient were calculated by assuming the blade position at 30 degrees from the reference and the pitch angle at 10 degrees.

4 Structural Analysis of the Turbine

Structural analysis of the turbine is one of the important parameters that need to be considered in terms of design. The factors considered in the structural analysis are maximum bending moment, normal and shear loads on the blades, allowable stresses, and moment of inertia on the blades.

The normal stress is calculated using equation

$$\sigma_N = \frac{\text{Normal force}}{\text{Area perpendicular to force}} \quad (21)$$

Normal force (F_N) is calculated using equation

$$F_N = \frac{1}{2} \times \rho \times C \times L \times W^2 \times C_N \quad (22)$$

Where C_N the coefficient of normal force, C is the chord length, ρ is the density of air, and W is the relative velocity of the blade.

The coefficient of normal force is calculated to be

$$C_N = C_L \sin \alpha + C_D \cos \alpha = 0.09844 \quad (23)$$

Therefore, the normal force from (22) is 0.372N

The perpendicular area is found by assuming the blade as cuboid. Thus, the perpendicular area is found using equation

$$A_d = \text{thickness of blade} \times \text{length of blade} \quad (24)$$

$$A_d = 0.0312 \text{ m}^2$$

Therefore, from (21), $\sigma_N = 11.923 \text{ Pa}$

Shear stress occurs due to tangential force. The tangential force was found to be, $F_T = 0.64 \text{ N}$ which is same as the shear force F_s . The shear stress is calculated using equation (25) as

$$\tau = \frac{F_s}{\text{Blade area}} = 4.1 \text{ Pa} \quad (25)$$

The bending moment is proportional to the centripetal acceleration. The centripetal acceleration is given by equation (26)

$$a_n = \frac{v_b^2}{R} = 24.5 \text{ m/s}^2 \quad (26)$$

Where, a_n is the centripetal acceleration, v_b is the blade velocity and R is the radius of the turbine.

$$\text{Bending moment} = F_N \times \text{Distance} = 0.558 \text{ Nm} \quad (27)$$

5 Structural Design of the Rotor

The material selection was done comparing stiffness, tensile strength, density, elongation at break, temperature up to which it can hold, cost and ease of manufacturing.

Table 4. Material Comparison [13].

Material	Stiffness (GPa)	Tensile Strength (MPa)	Density (g/cm ³)	Elongation at break (%)	Max temp (°C)
Steel	30	190	7.5	15	550
Al	10	90	2.7	12	400
Glass-E	73	3500	2.54	3	350
Carbon	350	4000	1.75	1.8	500
Aramid	120	3600	1.45	11	250
FoamT90	0.5	1.5	0.24	0.2	70

Foam board was selected as the material for the blades. Figure 8 shows the schematic of NACA 0018 with 15cm chord length.

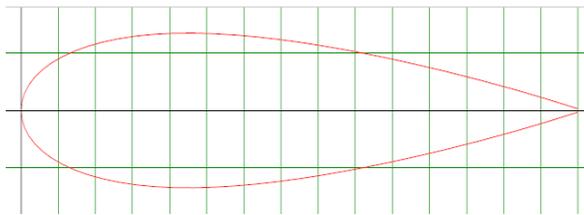


Figure 8. Schematic of NACA 0018 with 15cm chord length. The mass of the manufactured blade was found to be 0.169 kg. Acceleration analysis is done to determine theoretically that the turbine can achieve the desired RPM [14]. The inertial moments by approximating the blade shape as a cuboid; using Steiner theorem, is given using equation

$$I_{\text{blade}} = \frac{1}{12} m_{\text{blade}} [C^2 + (0.21C)^2] + m_{\text{blade}} R^2 \quad (28)$$

$$I_{\text{blade}} = 0.273 \text{ kgm}^2$$

Where m_{blade} is the mass of the blade, C blade chord is, R is rotor radius. To get an approximate value of total momentum, inertial momentum is multiplied by the number of blades. The angular acceleration (rad/s) can be calculated using equation

$$A_a = \frac{Q}{I} \quad (29)$$

Where Q is the torque and I is the rotor inertial moment.

Relative velocity, torque, tangential, normal, lift, drag force, and expected power output were calculated for one blade positioned at $\theta = 30^\circ$ and $\delta = 10^\circ$. For VAWT the torque varies according to position of the blade and angle of attack, unlike HAWT where torque remains constant. Relative velocity, torque, tangential force, normal force,

lift force, drag force, and expected power out depends on angle of attack. To achieve a constant torque and power output angle of attack has to be fixed.

Total moment of inertia (30)

$$= \text{moment of inertia of one blade} \\ \times \text{number of blades} = 0.405 \text{ kgm}^2$$

Therefore, the angular acceleration is given by:

$$A_a = \frac{Q}{I} = \frac{3.84 \text{ Nm}}{0.405 \text{ kgm}^2} \times \frac{\text{kg m/s}^2 \times \text{m}}{\text{kg m}^2} \\ = 9.5 \frac{\text{rad}}{\text{s}^2} \quad (31)$$

Load analysis for the blade dimensions can be divided into centrifugal and aerodynamic loads.

Centrifugal force is calculated by:

$$F_C = mr\omega^2 = 4.1128 \text{ N} \quad (32)$$

The aerodynamic load is normal force (F_N) and using equation (22) F_N was found to be 0.372N.

The resultant force for one blade in rotation can be calculated. The assumption made for this is that both centrifugal and normal force are in the same direction.

$$F_R = F_C + F_N = 4 \quad (33)$$

$$\text{Allowable stress} = \frac{\text{Yield Strength}}{\text{Tensile strength} \times \text{FS}} \quad (34)$$

Assuming factor of safety as 3, the allowable strength of the Styrofoam board was found to be 0.5MPa.

For 74.72 rpm, the angular velocity on the shaft can be calculated by:

$$\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 74.72}{60} = 7.8 \text{ rad/s} \quad (35)$$

Torque on the shaft is based on the generator output power.

$$\text{Torque} = \frac{\text{Power output from the generator}}{\omega} = 3.8 \text{ Nm} \quad (36)$$

6 Prototype and its testing

A foundation is required to hold all the blades in place in a robust and straight manner. Two sheets 80cm diameter and 2cm thick was used on top and bottom made from Styrofoam sheets to satisfy these criteria. This adds strength to the shape and reduces the slanting of the blade while operating. The prototype has 15 blades with thickness of 3cm, height of 1m, and the material used was Styrofoam. The 3 phase AC PMA generator can produce 30watt. It is 20cm in diameter. The steel shaft was 1 meter long and with a diameter 1.2cm. The shaft goes through the Styrofoam sheets and covers almost all of the turbine height. The generator is fixed to the flange which is then fixed to the base. Flange acts as a mediator to the generator and base. The diameter of the flange is 9cm and height is 25cm. Turbine base helps to avoid turbine from tipping due to the force from the wind. The base was made from marine plywood. The dimensions of base were 60cm long, 54cm wide and 14cm. The turbine is bolted to base to ensure stability. Table 5 shows the specification of the generator.

Table 5. Generator Specification

Generator type	3 phase AC PMG
Rated voltage	DC 12V
Rated speed	300 rpm
Power output	30 W @10 m/s
Weight	4.5 kg

Start-up wind speed	2 m/s
Torque	9.74 Nm

Figure 9 shows a 3D isometric view of the turbine respectively. A 15 blade model shown below was developed using Solid works. This model was later used to perform structural analysis.

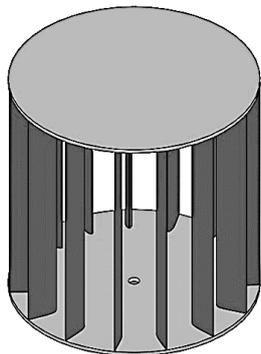


Figure 9. Engineering 3D isometric drawing of the turbine.

Wind turbine testing was done to ensure that it performs well at different wind speeds. Subjecting to various wind speeds the turbine voltage outputs were recorded and analyzed. Bending test was carried out in the lab using the method of three-point bending experiment. The strength and deformation capability of the blade was found out using this. Before performing the test, the blade was weighed and was found to be 0.169 kilogram. The stress loaded on the blade was determined using the equation (37)

$$\sigma_b = \frac{3F_{Load_ed} S}{2CT^2} \quad (37) \text{ where}$$

σ_b stands for the stress on the blade, F_{Loaded} is force loaded on blade, S means span, b is the width of the blade and T is the thickness of the blade. The blade broke at a load of 89.76N. Span was taken to be 50 cm and 'C' the chord length was 15cm and thickness of the blade was 3cm. Therefore, the stress load came out to be 49.8 Pa. The turbine was subjected to different wind speeds by the help of wind tunnel facility. Fig.10 compares the different wind speeds and voltages as output while the turbine rotates.

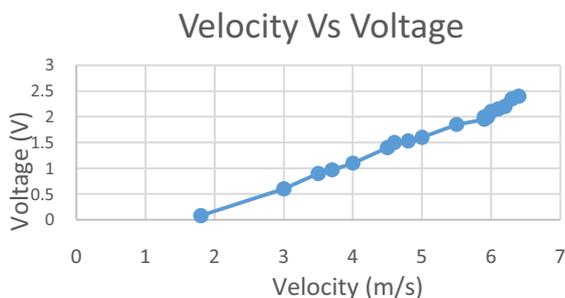


Figure10. Wind speed vs Voltage

As expected, when wind speed increases the voltage value increases. With the current facilities in wind tunnel the maximum voltage achieved was 2.4 volts with a wind speed of 6.4 m/s. The least voltage achieved was during 1.8 m/s wind with a voltage value of 0.08 volts. RPM of the turbine was calculated using tachometer counter and was found to be 60.3.

7 Conclusion

In conclusion, the project’s initial intention was to design, create, and simulate a wind turbine which can be used to power LED street lights. The necessary approaches starting from literature review to find all the necessary background details required, collecting the wind data, selecting the appropriate turbine, blade type, determining the components required, calculating the power density, structural analysis, CFD analysis, building the prototype, till the testing of the turbine were performed. From the literature review it was found that VAWT works better due to the facts that the efficiency is better, works with lower wind speeds, cheaper, smaller, cheaper, and easier to manufacture. Operational parameters such as cut-in, cut-out speed, rated wind speed, rated power output, power coefficient, rpm and pitching of blade were analyzed for performing calculations. From wind data it was established that the average wind speed is 5m/s and relative humidity typically varies from the lowest value of 16% to the highest 85%. From detailed design, it was found that the power density increases as wind velocity increases. All the required design parameters such as the swept area, expected power output, turbine diameter, airfoil type, chord length, number of blades, angular velocity, rated blade velocity, tip speed ratio, lift force, drag force, tangential force, normal force, torque and expected power output were calculated by using the input parameters of the design such as the rotor radius, pitch angle, blade length, blade chord length and number of blades. In the structural analysis of the turbine normal stress, normal force, coefficient of normal force, perpendicular area, shear stress, and bending moment were determined. The maximum voltage the turbine achieved at 6.4 m/s wind speed was 2.4 volts and the rotational speed of the turbine was 60.3 RPM. Future development would be to build a mechanism to prevent the wind turbine from rotating at high wind speeds that may damage the blades.

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