Design and Development of Compact Size Wind Turbine for Remote Villages

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***Abstract* – India is a land of villages: out of which most are situated in remote hilly areas. In such areas electricity cannot be supplied easily due to geographical limitations. In order to overcome these difficulties, wind energy can be effectively utilized. In hilly areas wind energy is readily available with greater velocity compared to ground level velocity. Hence compact sized horizontal axis wind turbine has been proposed as per environmental condition available at such areas. The same can be customized as per the requirement. Design and development of compact size horizontal axis wind turbine has been further demonstrated and explained in this paper.**
Keywords – Green Energy, Horizontal Axis Wind Turbine, Renewable Energy, Wind Energy

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I. INTRODUCTION

A wind turbine is a rotating machine which converts the kinetic energy of wind into mechanical energy. The first electricity generating wind turbine was battery charging machine installed in July 1887 by Scottish academic James Blyth to light his holiday home in Marykirk, Scotland. In India there are lots of villages still having no supply of electricity. Some of them are situated in hill areas where it is not possible to supply electricity. In hill areas the velocity of wind is more comparing to ground level. So we can use this wind to generate electricity with the help of wind turbine. In some villages it is not possible to install large size wind turbine so for such villages we can design small size wind turbine than can produce enough electricity for small equipment li CFL Bulbs. Some of the unelectrified villages in Maharashtra are “Dhak” village (Tal. Karjat, Dist. Raigarh), “Atwan area” (Tal. Mawal, Dist. Pune), “Adare” village (Tal. Chiplun, Dist. Raigarh). The Turbine Components for Horizontal Axis Wind Turbine are: Blade which converts the energy in the wind to rotational shaft energy, The Tower that supports the blade and generator assembly, other equipment including generator, electrical cable and ground support equipment. Coefficient of performance Cp is called the power coefficient. Cp is the percentage of power in the wind that is converted into mechanical energy. The maximum achievable coefficient of performance Cp max is 0.59 given by Betz limit. Efficiency is the actual amount of energy that can be extracted from the wind is less than the theoretical amount of energy available with the theoretical limit being about 60%. A typical efficiency for wind turbine is about 40% which is about 40% of the power available in the area swept by the wind turbine blades.

Power Output

$$P = \frac{C_p \varrho V^3 \pi R^2}{2}$$

Where

Cp is the power coefficient

ϱ is the density of air ($1.2 kg/m^3$)

R is the radius of the blade

V is wind velocity

II. DESIGN CALCULATION

A. Design of Blade

Modern Wind Turbine Deign has been selected from literature because it has more efficiency. The 3 bladed configuration has been selected because 3 blades has a much smoother power output, more efficient, higher energy yield and balance gyroscopic force compared to single and two bladed turbines.

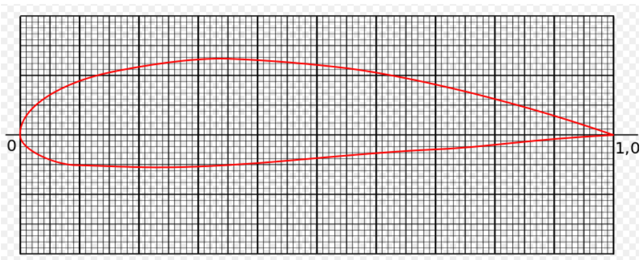

Fig 1 Airfoil NACA 4418

The NACA 4418 Airfoil Section has been used for Blade design because it has maximum Lift to drag ratio.

The characteristic of NACA 4418:

- Maximum lift coefficient $C_L$max of 1.797 which corresponds to critical angle of attack of 15^0
- Lift coefficient for angle of attach of 9^0 is 1.405

For 3 bladed configurations λ should be greater than 4 for electrical power generation. The Tip speed ratio λ of 4.5 has been selected based on literature review. The angle of attack of 9^0 has been selected for blade configuration. The blade was divided into ten elements as shown in Fig 2. The angle of attack is same at all section.
The Chord (C) and the angle of relative wind (ϕ_r) of the blade at every section has been found from equations (Manwell 2009)

$$\phi = \frac{2}{3}\tan^{-1}\frac{1}{\lambda_r}$$

$$C = \frac{8\pi r(1-\cos\phi_r)}{BC_L}$$

Where, $\lambda_r = \lambda\,(r/R)$, r is the radial length of element, R is the rotor radius and B is the number of Blades

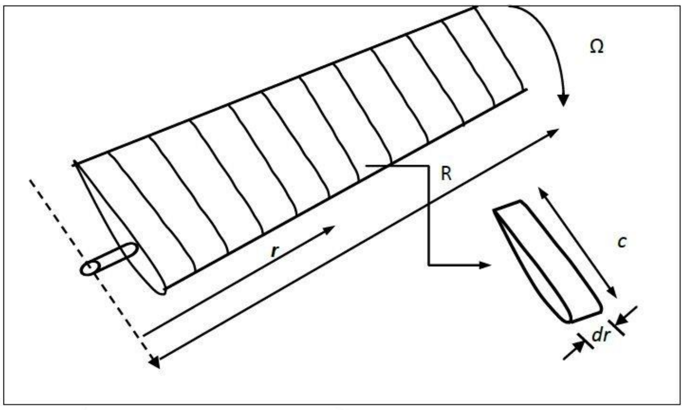

Fig 2 Schematic representation of blade elements

S No.	Radius r (mm)	Chord (mm)
1	125	140
2	189	131
3	253	115
4	317	100
5	381	88
6	445	78
7	509	69
8	573	62
9	637	57
10	701	52
11	765	48

Table I Geometry of Blade

B. Design Blade Airfoil

NACA 4418 Four-Digit Series: The first family of airfoils designed using this approach became known as the NACA Four-Digit Series. The first digit specifies the maximum camber (m) in percentage of the chord (airfoil length), the second indicates the position of the maximum camber (p) in tenths of chord, and the last two numbers provide the maximum thickness (t) of the airfoil in percentage of chord. NACA 4418 airfoil has a maximum thickness of 18% with a camber of 4% located 40% back from the airfoil leading edge (or 0.4c). Utilizing these m, p, and t values, we can compute the coordinates for an entire airfoil using the following relationships: 1. Pick values of x from 0 to the maximum chord c.
2. Compute the mean camber line coordinates by plugging the values of m and p into the following equations for each of the x coordinates.

$$y_c = \frac{m(2px - x^2)}{p} \qquad \text{from } x=0 \text{ to } x=p$$

$$= \frac{m((1-2p)+2px-x^2}{(1-p)^2} \qquad \text{from } x=p \text{ to } x=c$$

Where,
x = coordinates along the length of the airfoil, from 0 to c (which stands for chord, or length)

y = coordinates above and below the line extending along the length of the airfoil, these are either y_t for thickness coordinates or yc for camber coordinates
t = maximum airfoil thickness in tenths of chord (i.e. a 18% thick airfoil would be 0.18)
m = maximum camber in tenths of the chord
p =position of the maximum camber along the chord in tenths of chord

Sr no	x (mm)	y_c (mm)
1	10	1.8214
2	20	3.2857
3	30	4.3928
4	40	5.1428
5	50	5.5357
6	56	5.6
7	60	5.5700
8	70	5.2371
9	80	4.5336
10	90	3.4599
11	100	2.016
12	110	0.2017
13	120	0.162
14	130	0.125
15	140	0

Table II Camber Line Calculation

Calculating the thickness distribution above (+) and below (-) the mean line by plugging the value of t into the following equation for each of the x coordinates.

$$y=5t(0.2060(\frac{x}{c})^{0.5}-0.1260(\frac{x}{c})-0.3516(\frac{x}{c})^{2}+0.2843(\frac{x}{c})^{3}-0.1015(\frac{x}{c})^{4}$$

Sr no	x (mm)	y (mm)
1	10	8.6500
2	20	11.0664
3	30	12.2064
4	40	12.5939
5	50	12.4594
6	56	12.1863
7	60	11.9375
8	70	11.1174
9	80	10.0613
10	90	8.8125
11	100	7.3993
12	110	5.8379
13	120	4.1334

14	130	2.2805
15	140	0

Table III - Thickness Distribution

Determining the final coordinates for the airfoil upper surface (x_U, y_U) and lower surface (x_L, y_L) using the following relationships.
$x_U = x - y_t \sin\Theta$, $y_u = y_c + y_t \cos\Theta$, $x_L = x + y_t \sin\Theta$, $y_L = y_c - y_t \cos\Theta$

$\Theta = \tan^{-1} \frac{dy_c}{dx}$

Sr no	x	Θ	x_U	y_U	x_L	y_L
1	10	9.329	8.597	10.39	11.402	-6.719
2	20	7.326	18.588	14.299	21.411	-7.690
3	30	5.305	28.871	16.546	31.128	-7.7613
4	40	3.270	39.281	17.716	40.718	-7.430
5	50	1.227	49.733	17.992	50.266	-6.920
6	56	0	56	17.786	56	-6.586
7	60	-0.848	60.176	17.506	59.823	-6.366
8	70	-2.967	70.575	16.339	69.424	-5.865
9	80	-5.077	80.890	14.555	79.109	-5.488
10	90	-7.174	91.100	12.203	88.899	-5.287
11	100	-9.252	101.189	9.319	99.075	-5.283
12	110	-11.306	111.143	5.920	108.856	-5.280
13	120	-13.330	120.952	4.184	119.047	-3.860
14	130	-15.322	130.602	2.324	129.397	-2.074
15	140	-17.276	140	0	140	0

Table IV Coordinates for Airfoil

The material E glass fiber has been used for manufacturing of blades because of light weight, high strength and low cost property.

C. Other parts

The Hub is made from aluminum plates for reducing the weight. For Tower simple MS pipe has been used. The readily available wind alternator has been used for generating electricity. The vane is made from MS sheet for guiding the wind turbine in wind direction.


Fig 3 actual model of wind turbine

III. RESULTS

Experiment wore performed on fabricated set up and the results obtained for various air velocities are listed in table.

S No.	Wind velocity (m/sec)	Power (watt)
1	3	3.2
2	4	7.5
3	5	15
4	6	27
5	7	46
6	8	62

Table V Results

IV. CONCLUSION

- The wind turbine that we developed is efficient to produce power for small electrical uses like 10watt CFL bulbs
- The size of the wind turbine is small so it can be easily transported to remote villages.
- We can use this power to charge batteries and batteries can be used for any purpose.
- The 3 bladed configurations have much smoother power output, more efficient and balance gyroscope force.

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