1 INTRODUCTION

At present world is moving towards renewable energy sources like wind, solar, biomass tidal etc. and focus of researchers also shifted on these sources of energy to make them more efficient, easy to handle/operate and suitable to use by people. Renewable Energy Sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological. Amongst the above mentioned sources of energy there has been a lot of development in the technology for harnessing energy from the wind.

Wind is the motion of air masses produced by the irregular heating of the earth's surface by sun. These differences consequently create forces that push air masses around for balancing the global temperature or, on a much smaller scale, the temperature between land and sea or between mountains.

1.1 Wind Turbine

A wind turbine is a rotating machine which converts the kinetic energy in wind into mechanical energy. If the mechanical energy is then converted to electricity, the machine is called a wind generator, wind turbine, wind power unit (WPU), wind energy converter (WEC), or aero-generator.
Wind turbines can be separated into two types based by the axis in which the turbine rotates. Turbines that rotate around a horizontal axis are more common. Vertical-axis turbines are less frequently used.

1.1.1 HORIZONTAL AXIS WIND TURBINES

Fig.1.1 Horizontal axis wind turbine

Horizontal axis wind turbine is define as the wind turbine in which rotor shaft is parallel to the base. Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.
Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower

by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount.
Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds the 3 blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since cyclic (that is repetitive) turbulence may lead to fatigue failures most HAWTs are upwind machines.

1.1.2 VERTICAL AXIS WIND TURBINES

Fig.1.2 Vertical axis wind turbine

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable. VAWTs can utilize winds from varying directions.
With a vertical axis, the generator and gearbox can be placed near the ground, so the tower doesn't need to support it, and it is more accessible for maintenance. Drawbacks are that some designs produce pulsating torque. Drag may be created when the blade rotates into the wind.

1.2 Wind Turbine Glossary

Anemometer: Measures the wind speed and transmits wind speed data to the controller.

Blades: Most turbines have either two or three blades. Wind blowing over the blades causes the blades to "lift" and rotate.

Brake: A disc brake which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies.

Controller: The controller starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 65 mph. Turbines cannot operate at wind speeds above about 65 mph because their generators could overheat.

Gear box: Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1200 to 1500 rpm, the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes.

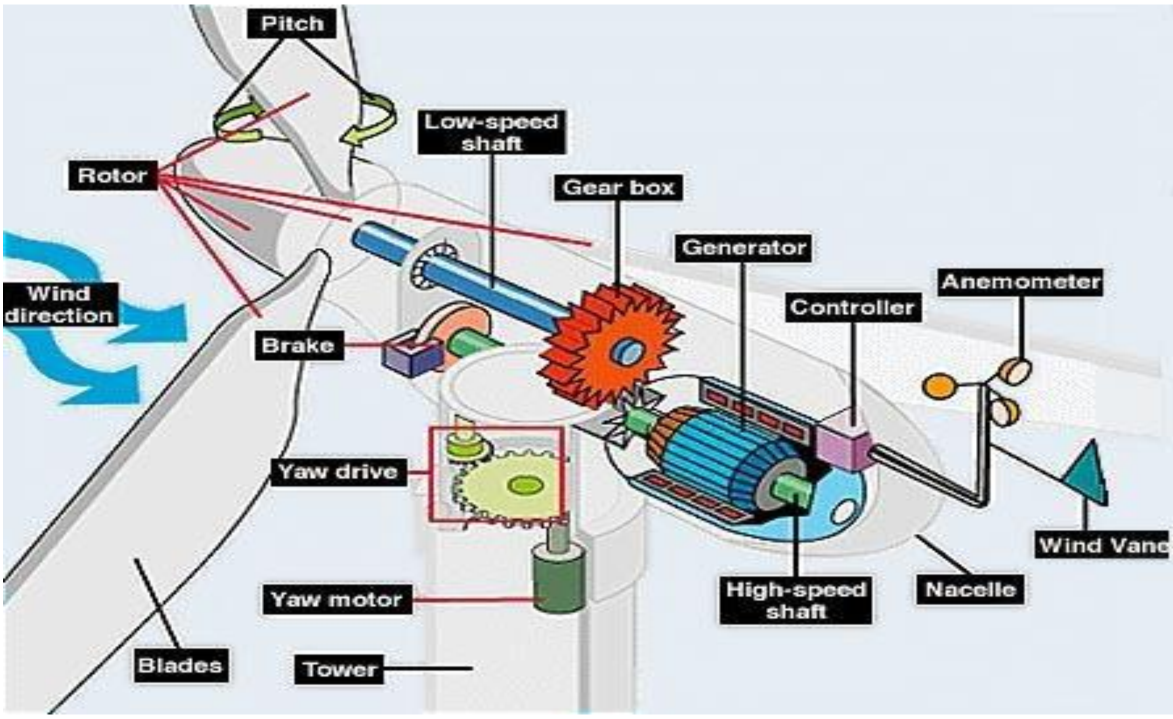


Fig.1.3 Parts of wind turbine

Generator: Usually an off-the-shelf induction generator that produces 60-cycle AC electricity.

High-speed shaft: Drives the generator. Low-speed shaft: The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.

Nacelle: The rotor attaches to the nacelle, which sits atop the tower and includes the gear box, low- and high-speed shafts, generator, controller, and brake. A cover protects the components inside the nacelle. Some nacelles are large enough for a technician to stand inside while working.

Pitch: Blades are turned, or pitched, out of the wind to keep the rotor from turning in winds that are too high or too low to produce electricity.

Rotor: The blades and hub together are called the rotor.

Tower: Towers are made from tubular steel (shown here) or steel lattice. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.

Wind vane: Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.

Yaw drive: Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines don't require a yaw drive, the wind blows the rotor downwind.

Yaw motor: Powers the yaw drive.

1.3 Wind turbine blade Airfoil Nomenclature

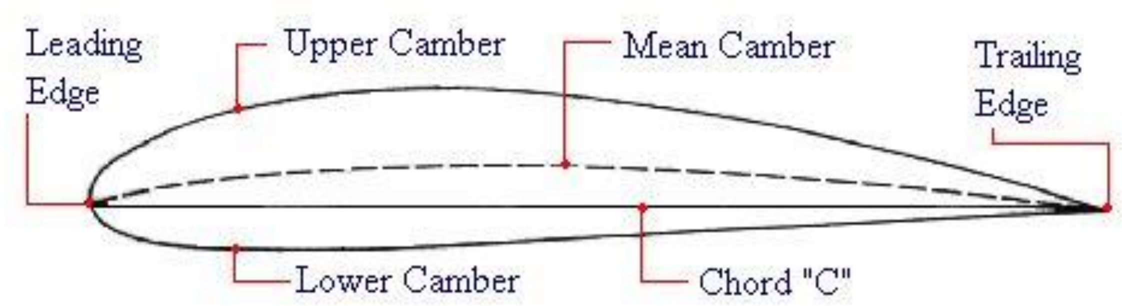


Fig. 1.4 Airfoil Nomenclature

Chord length: Length from Leading edge to the Trailing edge of a wing cross section that is parallel to vertical axis symmetry.

Mean camber line: line halfway between the upper and lower surfaces.

Leading edge: It is the front most point on the mean camber line.

Trailing edge: It is the most rearward point on mean camber line.

Camber**:** Maximum distance between the mean camber line and the chord line measured perpendicular to the chord line

2 LITERATURE REVIEW

1 Anshuman Yadav, Akshay Bhateja, Vivek Kumar Mishra concluded that the output power of a Horizontal axis wind turbine is directly proportional to the third power of wind velocity coming on the blade. In this paper they also compare the power output of NACA4412 and NACA0012 and conclude that power output of NACA4412 is slightly higher than NACA012.

2 Mr. Monir Chadrala, Abhishek Choubey, Bharat Gupta observed that Upper surface on the aerofoil experiences a higher velocity compare to the lower surface. It means that lift force must be higher than drag force. for higher value of lift force, coefficient of lift must be higher and coefficient of drag must be lower. They also observed that as the angle of attack increases, coefficient of lift also increases but beyond certain limit it will decreses.so optimum angle of attack must be selected.

3 Nugroho Agung Pambudi, Danur Lambang Pristiandaru, Husin Bugis, Karno M.W. concluded that Nozzle lances can improve the effectiveness of wind turbines by increasing wind speed and power. At low speed of wind, by nozzle lens power obtained is higher and as wind speed increases output power also increases.

4 POP E.S., Campean E., Dragan T. concluded that NACA4418, for which the best aerodynamic lift drag ratio is obtained on a big range of attack angles. it was observed that with the increase of the chamber, the aerodynamic coefficients increase as well, while the attack angle decreases. The drag coefficient increases with relative thickness, and the lift coefficient is maximum for profiles with relatively middle thickness.

5 P.Giuere, M.S.Selig concluded that The airfoils designed during this work form a unique airfoil family for small speed variable speed HAWTs. the airfoil SG6043 provides excellent lift-to-drag ratios over a broad range of lift conditions and are well suited for small variable-speed wind turbines.

6 Rohit Kumar Gupta, Vilas Warudkar, Rajesh Purohit and Sauradh Singh Rajpurohit calculated the coefficient of Lift (CL) & drag (CD) for selected airfoil NACA 63-415 from 0° to 16° angles of attack(AOA) and the maximum L/D ratio is achieved at 2° AOA. Cl increases with increase in AOA, up to 8°. After 8°, the CL decreases and stall begins to occur. The drag forces begin of dominate beyond this AOA. The rate of increase in lift is more for AOA from 0° to 8° & then it starts to decrease. The drag increase gradually up to 5° AOA and & rapidly increases and concluded that SG6043 gives the best performance for low wind speed horizontal axis wind turbine.

Conclusion:
By analysing above research paper we have selected SG6043 aerofoil for our wind turbine blade and reason behind selecting this profile is that it gives best performance for low wind speed and l/d ratio also higher for wide range of angle of attack. Profile and Properties of SG6043 are given below

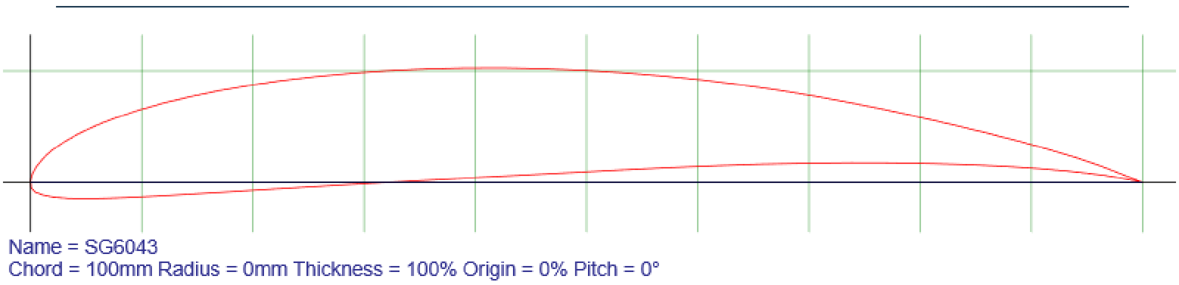


Fig. 2.1 Profile of SG6043

Selig / giguere SG6043 wind turbine airfoil (high L/D)
Max. thickness 10% at 32.1% Chord.
Max. camber 5.1% at 53.3% Chord.

3 AIM AND OBJECTIVES

AIM:
The aim of this project is to obtaining the particular combination of varying parameters for our particular design of horizontal axis wind turbine.

OBJECTIVES:

- Changing the number of blade of wind turbine.
- Changing the input speed of wind by external fan.
- Varying the pitch angle of the blade.

4 DESIGN OF ROTOR BLADE

4.1 Step to design rotor blade

- Step-1: Design procedure begins with deciding power requirement.
- $P = C_p \eta \frac{1}{2} \rho \pi R^2 V^3$

  Where, P is power, C_p is power coefficient, η is efficiency (mechanical & electrical).Here power is calculated.

- Step-2: Choose a tip speed ratio (λ) for the machine. For water pumping pick $1 < \lambda < 3$ (which gives a high torque) and for electrical power generation pick $4 < \lambda < 10$. Normally 6 or 7 TSR used for low wind speed region.

- Step-3: Choose the number of blades (B), which is based on practical experience. Generally, 3 number of blades used due to structural and performance measure. Up to 3 blades power developed is good but after this power increase is not significant and expenditure increased too much. B=3 chosen for designing rotor blade.

- Step-4: Select airfoil. Here we have selected SG6043.

- Step-5: Obtain and examine lift & drag coefficient curves for the airfoil.

5 ANALYTICAL SOLUTION

Decide the length of rotor blade and from this calculate power output from equation which are as given below.

5.1 Power Output of wind turbine

$$P = C_p \eta \frac{1}{2} \rho \pi R^2 V^3$$

Where, C_p = Coefficient of power
ρ = Density of free Air (kg/m^3)
R = Radius of Blade (m)
V = Velocity of free wind (m/s)

5.1.1 sample calculation

- Take the, Radius of Blade (R) = 0.375 m
  Velocity of air (V) = 4 m/s
  Density of air = 1.22 kg/m^3
  Coefficient of power = 0.4
  Efficiency of electric motor = 0.85

$$P = C_p \eta \frac{1}{2} \rho \pi R^2 V^3$$

P=0.4*0.85*0.5*1.22*3.14*0.375*0.375*4*4*4

P=5.86 watt

- For R = 0.375 m, Density of air = 1.22 kg/m^3 and efficiency of electric motor =0.85

Velocity of free air (V) in m/s	Coefficient of power (C_p)	Power (P) in watt
3	0.3	1.85
3	0.4	2.50
4	0.3	4.39
4	0.4	5.86
5	0.3	8.59
5	0.4	11.45

Table 5.1 Power output for different parameter

By above calculation we get to know about capacity of our wind turbine and selection of motor such that it’s capacity range is up to 15 watt.

5.2 Chord length Distribution

For designing the Chord length distribution consider the chord distribution as given in below figure. It calculated for SG6043 aerofoil and for radius of 1.2 m. For this Reynolds number taken as 100000, tip speed ratio 7 and wind speed 6 m/s.

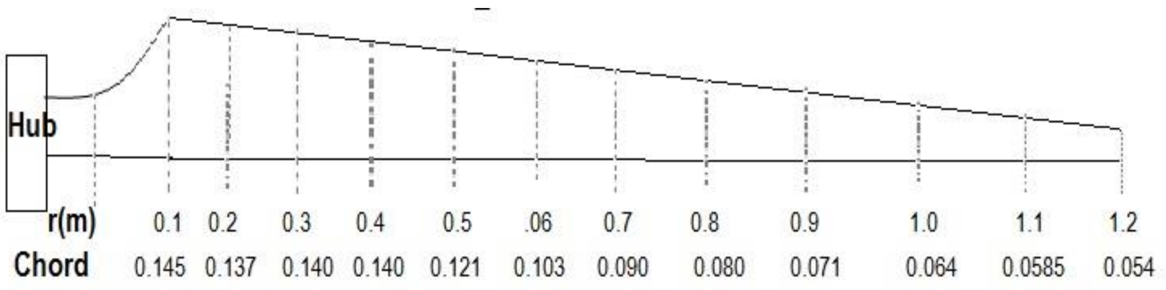
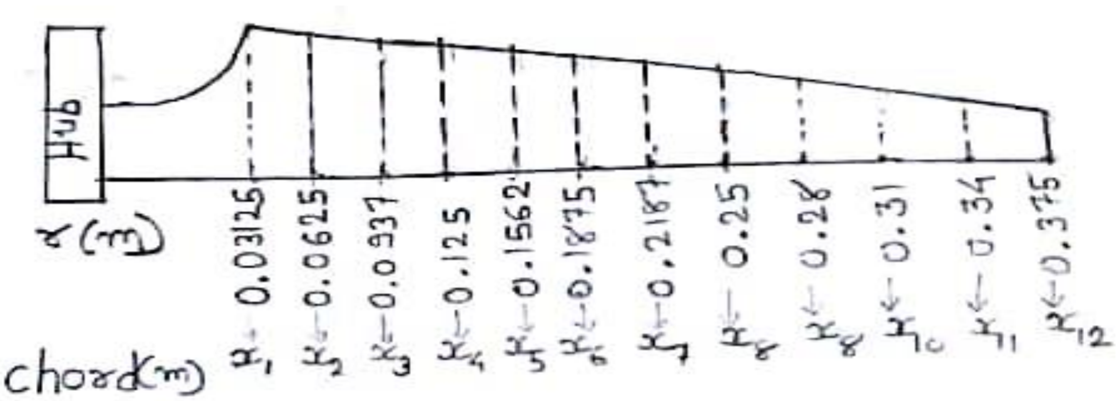


Fig.5.1 Chord distribution for SG6043

For calculating the chord thickness for our blade which having 0.375 meter radius. Divide this radius in 12 part same as above.



Find out the value of x1,

$$\frac{0.1}{0.145} = \frac{0.03125}{x1}$$

x1 = 0.0453 meter

Same as x1 find out x2, x3, x4….x12,

Distance from hub in meter	Value of x in meter
0.03125	x1=0.0453
0.0625	x2=0.0428
0.0937	x3=0.0437
0.125	x4=0.0437
0.1562	x5=0.0378
0.1875	x6=0.0321
0.2187	x7=0.0281

0.25	x8=0.025
0.28	x9=0.022
0.31	x10=0.0198
0.34	x11=0.018
0.375	x12=0.016

Table 5.2 Chord length Distribution

By above calculation we get to know above our wind turbine blade chord distribution.

Result and Discussion

For purpose of design analysis the horizontal axis wind turbine needs to be chosen for a given task. In which designer should know the parameter which affect the wind turbine blade such number of blade, pitch angle, wind speed drag and lift forces etc. However efficiency of low wind speed turbine is greatly depends on aerofoil of blade and lift to drag ratio. So we choose the SG6043 profile which gives the best performance in low wind speed for wide range of angle of attack.
And we also calculated the power output mathematically and we get the power range up to 15 watt for different condition of coefficient of power and input wind speed.

FUTURE WORKS

We completed theory portion which include understanding of horizontal axis wind turbine principle and design of blade. We designed blade on basis of standard values and select the aerofoil for blade. Experiment will be conduct and by taking the reading we will select the best combination of number of blade for optimum value of pitch angle.

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