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DESIGN AND ANALYSIS OF VERTICAL AXIS WIND TURBINE (VAWT)

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***Abstract*--Increasing demand for energy in recent years has been in development of alternative energy sources. Wind being one of the most abundant and easily available sources is an excellent alternative to conventional energy sources. With the recent search in demands of cleaner energy sources wind turbines are becoming a more valid for electric power generation. This project aims in simulation of a vertical axis wind turbine (VAWT) using helical blades with a blade angle of 120 degree using NACA 0018 airfoil which is capable of generating power of 790W at the wind speed of 5m/s. The simulation of VAWT is done using Q-blade software and blade geometry is designed using solid works, flow analysis using CFD & structural analysis using FEA.**

***Keywords*---VAWT, Q-Blade, Helical blade, Airfoil, Darrieus.**

I.INTRODUCTION

Wind power is one of the fastest developing and low-cost Industry which is a renewable energy utilization way. The average wind speed is varying as high and low temperature. Therefore, the worldwide concern about environmental pollution and possible energy shortage has led to increasing interest in generation of renewable electrical energy. Wind turbine can be divided into Horizontal Axis Wind Turbines (HAWTs) and Vertical Axis Wind Turbine (VAWTs) of two categories by different rotor shaft which are used mainly for electricity generation, VAWTs have inherent advantages, the principal advantages of the vertical axis format are their ability to accept wind from any direction without yawing and the ability to provide direct rotary drive to a fixed load. Compare with HAWTs, VAWTs have strong resisting wind ability. In addition, the noise of VAWTs is much smaller. This study aims to develop a VAWTs rotor using the helical shape blades which is adopted to provide energy with the condition that the wind turbine can work properly to produce electric power. At the same time, the structure should be light weight, small volume with high efficiency for power generation. Therefore, the **Q-blade software** is used for optimization and to determine maximum power. Then by **Solid works** software the single helical blade of 2m with angle of 120° is designed using the NACA0018 airfoil, on importing this blade on **CFD Ansys Fluent** for determining lift and drag force and on **Ansys FEA** for structural analysis.

II.LITERATURE SURVEY

Aravind S[1]et.al.published a journal on **"Trembling Analysis of Helical Blade Vertical Axis Wind Turbine (VAWT)"**. This paper tells about the trembling analysis of vertical axis wind turbine with helical blades. The essential intent is to define the behavior of the turbine in order to select the most preferable material, and avoid problems, such as frequent maintenance and misalignment of the turbine. For modeling and vibration analysis of the wind turbine, SOLIDWORKS 2010 software package is used.

Aditya Kumar[2]et.al. published an international journal on topic **"Design and Calculation of Coefficient of Lift and Drag for Helix Wind Turbine using Solid works and Ansys Fluent"** .This paper is about the Helix Wind Turbine which focuses on its design and calculation of its coefficient of lift and drag. The Helix Wind Turbine is designed in the Solid works 2014 with NACA airfoil. The aerodynamic characteristics like coefficient of lift and drag is calculated in Ansys Fluent 15.0. The overall objective of this paper is to select the best NACA airfoil out of the airfoils over Which analysis is performed. The paper also discusses about the design parameters.

MD. Saddam Hussen[3]et.al. Have presented a journal on **"Design and Analysis of Vertical Axis Wind Turbine Rotors"**. With the shortage of fossil fuels, alternative energy has required for the increasing energy demands of the world. A wind turbine is a rotary device that extracts energy from the wind and converts wind energy into mechanical energy. For efficient utilization of the available wind energy, it is imperative to study the behavior and performance of the wind turbines subjected to aerodynamic and ambient conditions. In the present work NACA 0018 airfoil wind turbine blade is used to modeling the vertical axis wind turbine rotors. The straight three bladed vertical axis wind turbine rotor is twisted to 45degrees and 90 degrees in order to improve the performance of rotor. By twisting the rotor by maintain the height and diameter of rotors the weight of rotor are significantly increased To decrease the weight without compromising the performance of the rotor the fiber reinforced composite materials are used. Which were fabricated from carbon, glass fibers, and epoxy resin have been used to increase the strength to weight ratio. For this purpose, the CFD analysis in ANSYS-FLUENT and structural analysis in ANSYS of a straight and twisted three bladed vertical axis wind turbine rotor has been undertaken. Due to limitations on experimentation, the computational fluid approach has been used to quantify the wind loads on the blades. On further application of these loads, the structural behavior of the rotor is obtained for a predetermined set of operating conditions. The results from the analysis are compared with pre-existing ones for the purpose of validation.

Ritesh Sharma[4]et.al. Published a journal of **"Design and Simulation of Darrieus (Eggbeater) Type Vertical Axis Wind Turbine using Open Source Software Q Blade"**. This work concentrates on review of Design and Simulation of Vertical Axis Wind Turbine rotor blades through General Public Licensed Software Q blade.

S.S.Suprajha[5]et.al. published a journal on helical blade with a title as **"Design and Analysis of Helical Blade Wind Turbine"**. This report describes about the wind power and its potential that can be harnessed in the future to meet the current energy demand. The shape of the blades is changed to helical so that it can rotate continuously at any direction of wind. Hence the efficiency of the turbine is improved and also the stresses are minimized. Conclusions were made about the behavior of the wind in urban location. Thereafter, the helix angle of the blade is changed and the best angle of operation is analyzed.

III.COMPONENTS OF VAWT ROTOR

The portion of the wind turbine that collects energy from the wind is called the rotor. The rotor is the heart of a wind turbine and consists of multiple rotor blades. It is the turbine component responsible for collecting the energy present in the wind and transforming this energy into mechanical motion.

***Shaft*:** The shaft is the part that gets turned by the turbine blades. It in turn is connected to the generator within the main housing.

***Generator*:** The generator converts mechanical power from the rotating wind blades to electrical power.

IV.JUSTIFICATION

- **Electricity:** Helical turbine generates at 3 m/s.
- **Safer Operation:**Helical turbine decreases the risk of injuring birds.
- **Installation:** Helical is easy to mount on roof tops.
- **Cost:** VAWT is inherently simple, less expensive to build and more aesthetically pleasant.
- **Direction:** VAWT rotates about a vertical axis and are always facing the wind therefore does not need to turn into the wind.

V.METHODOLOGY

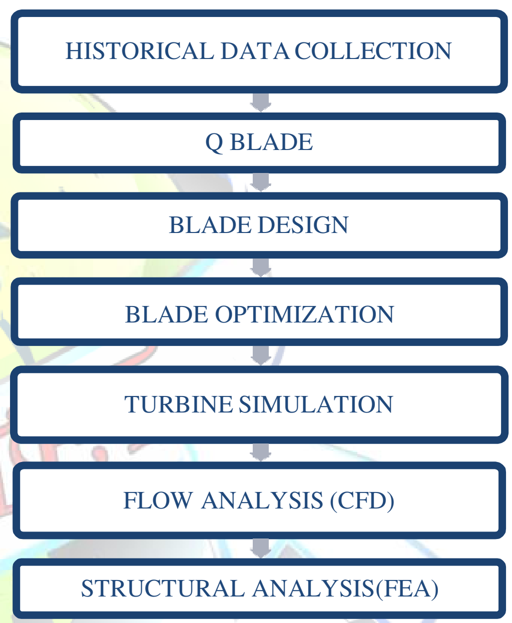

Fig.1 Methodology for VAWT

A. Q-Blade

The Q-Blade module allows an extrapolation of the angle of attack to a range of 360˚.The required power out can be obtained. There are two different methods available.

The Q-Blade HAWT and VAWT modules. Both consists of sub-modules,

- Blade design and optimization.
- Turbine simulation.

B. Blade Design

Thus, the helix blade has been designed using Q-Blade and the input data is given as shown in table I for the optimization of NACA 0015, 0018, 0021 airfoils, the power output for these are validated and we choose the airfoil which gives highest power output.

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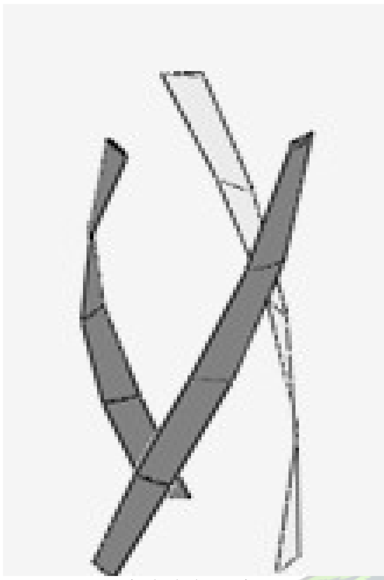

Fig.2Blade Design

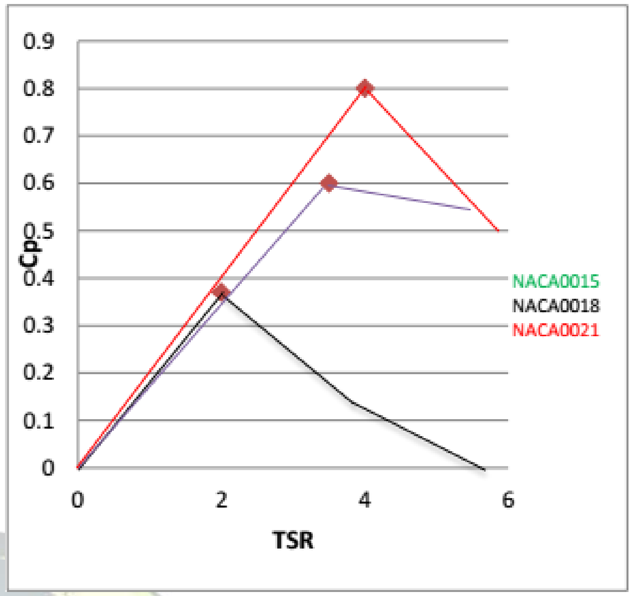

Fig.3 TSR vs. C_p

C. Optimization of Airfoil

Generally increasing on tip speed ratio (TSR) increases co-efficient of power (C_p).For small VAWT the C_p ranges from 0.35-0.45 at low TSR.On optimization and plotting the graph for three airfoil we select the airfoil.

TABLE I
INPUT DATA FOR Q BLADE

DESIGN PARAMETERS	**GIVEN DATAS**
No.of blades	3
Blade Angle	120 deg
Length of blade	2 m
Chord	0.2 m
Tip speed ratio	3-7
Cut-in wind speed	3 m/s
Cut-out wind speed	25 m/s
Reynolds number	300000
Chord length	0.2 m
Rotational speed range	200-600 rpm
Rated wind speed	5-25 m/s

By graph we found that C_p for NACA 0018 is 0.36 at TSR of 2 is best compared to NACA 0015, 0021.

D. Turbine Simulation

In turbine simulation the power output will be generated by giving the input data such as,

- ✓ Cut in wind speed
- ✓ Cut out wind speed
- ✓ Rotor blade

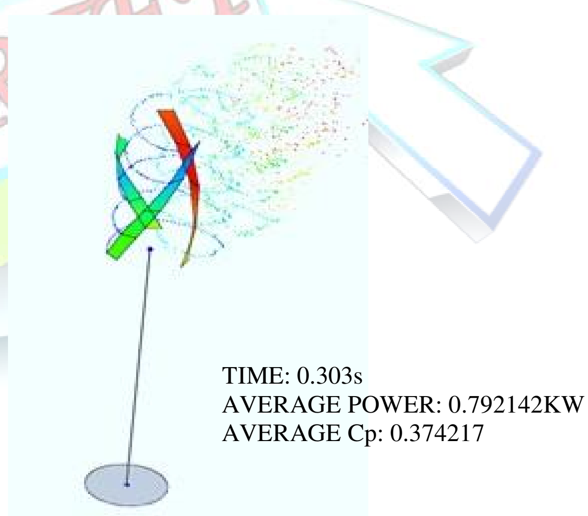

Fig.4 Turbine Simulation

E. CFD Flow Analysis

The single blade geometry is designed using solid works as shown in fig.5

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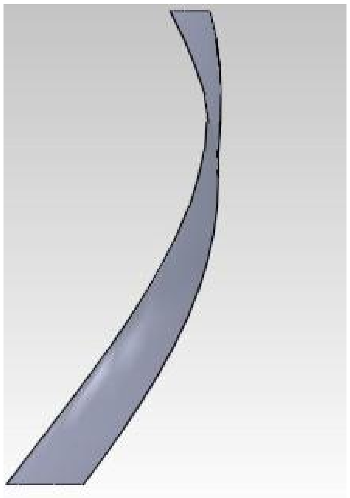

Fig.5 Single Blade Design

And this blade is imported on CFD to calculate,

1. Lift force
2. Drag force

The above terms are determined by using the **single helical blade design** which is designed using the **solid works.**

From analysis we obtained the value for

$C_l = 0.36$

$C_d = 0.001$

By using above values, we calculate lift and drag force by the formula,

$F_l =$ ρ_{air}

$\mathbf{F_l = 2.205N}$

$_d=$

$\mathbf{_d = 0.006N}$

F. Structural Analysis in FEM

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. Using this we determine,

- Stress
- Strain
- Deformation

The above terms are determined by using the **single helical blade design** which is designed using the solid works .For structural analysis the material is selected as aluminium, the most used material for wind turbines. The following are the characteristics of aluminium,

- Weight less when compare to other metals.
- Corrosion resistance
- Electrical and thermal conductivity
- Ductility
- Recyclability

The structural analysis of single blade is shown in fig.6, 7, and 8.

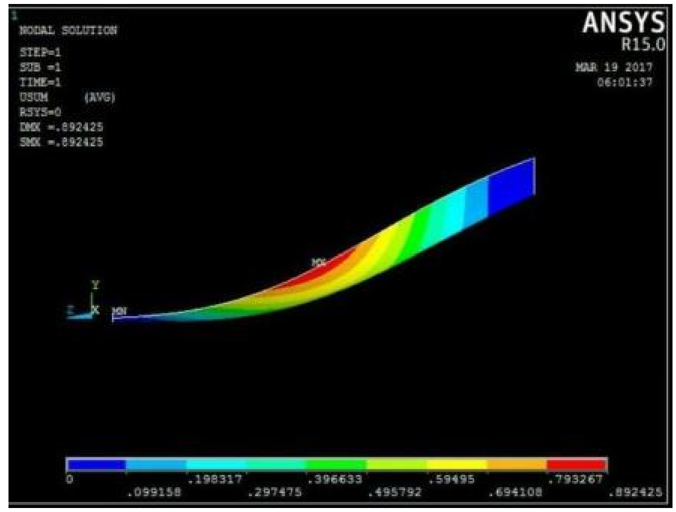

Fig.6 Stress Analysis

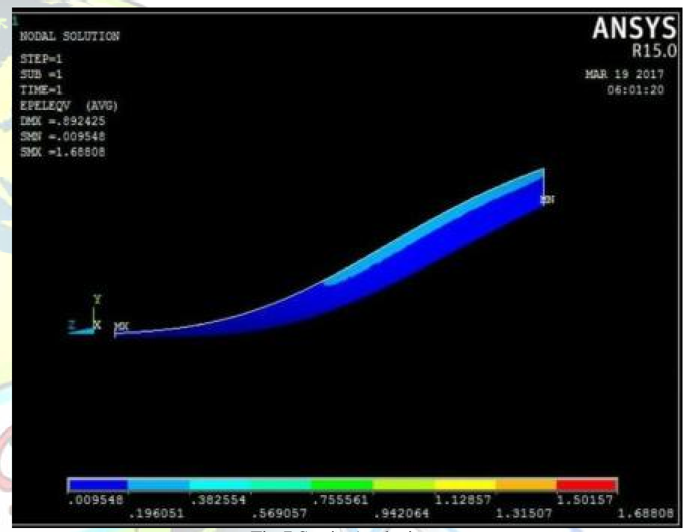

Fig.7 Strain Analysis

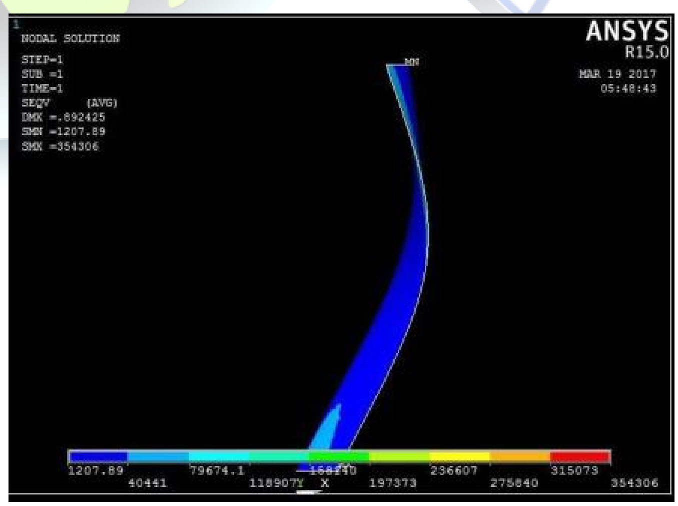

Fig.8 Deformation

Results from FEA

Maximum Stress	- 0.793267 N/m
Maximum Strain	- 1.50157
Maximum Deformation	- 0.79694 m

VI. CONCLUSION

In this paper for design and analysis of VAWT, the NACA airfoil of 0015, 0018, and 0021 is chosen from literature survey and compared. The airfoil selection is done by optimization of these airfoils in Q-blade software, based on TSR vs. C_P curve and maximum output power of 790 watts for NACA 0018 is obtained. Thus by using single blade geometry using solid works, CFD Ansys Fluent analysis is done and co-efficient of lift and drag are obtained as 0.36N and 0.001N. Using these values we obtain lift and drag force as 2.205N and 0.006N.Finally by Ansys FEA the structural analysis for single helical blade, we obtain maximum stress of 0.793267N/m, Maximum Strain of 1.50157 and Maximum Deformation of 0.79694m.

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