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Simulation and Parameter Evaluation of Wind Turbine Blade

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ABSTRACT:- *A wind turbine is a device that converts kinetic energy from the wind into electrical power. Wind is exerted on blades and produced lift force to rotate the blade. The concentrated parameter for simulation and evaluation are generator power, pitch angle, twisting angle, power coefficient, tip speed ratio and wind speed. 2-D drawing of NACA 4424 cross section and 3-D three blade model of wind turbine developed in creo parametric software. Whole simulation work done in MATLAB software .it conclude that 12 m/s is the optimum wind velocity for obtain best output performance of wind turbine.*

Keywords:- *Blades; Sandwich Structure; setting angle; mean wind speed; pitch angle.*

I. INTRODUCTION

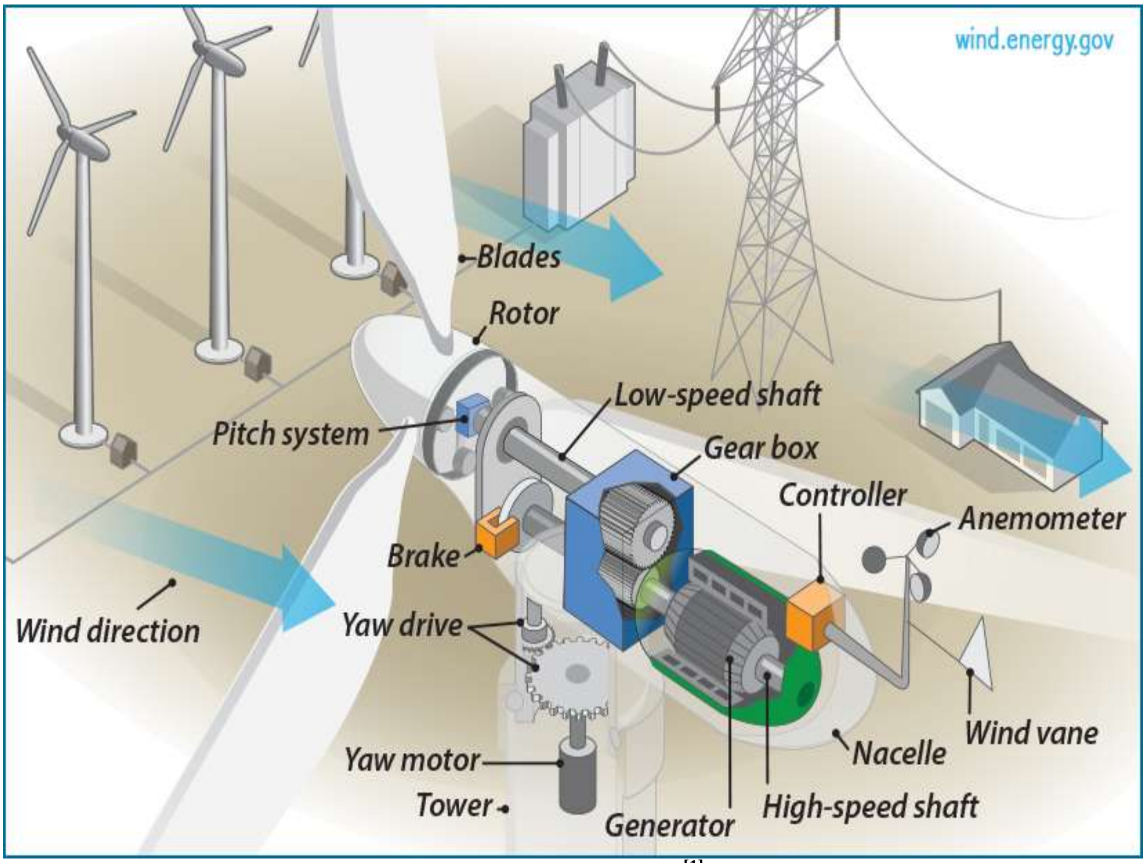

Fig. 1 Wind Turbine [1]

Wind turbine is a tall structure that has large blades attached to the rotor which is coupled with generator through gear box for produce electricity. In this turbine wind force is used for rotate the turbine. Wind turbines harness the wind to produce electrical power. A turbine consists of generator that is equipped with fan blades and placed at the top of a tall tower. The tower must be tall enough to harness the wind at a greater velocity while avoiding obstacles such as trees, hills, and buildings. As the turbine rotates in the wind, the generator produces electrical power. A single wind turbine can range in size from a few KW. [1]

1.1CURRENT SCENARIO

Wind power installed generating capacity in India is increasing year by year from 2006 to 2016. Expected capacity in 2016 is 27030 MW. As of 31 Dec 2015 the installed capacity of wind power in India was 25,088 MW, mainly spread across South, West and North regions. East and North east regions have no grid connected wind power plant as of March, 2015 end. No offshore wind power farm utilizing traditional fixed-bottom wind turbine technologies in shallow sea areas or floating wind turbine technologies in deep sea areas is under implementation.

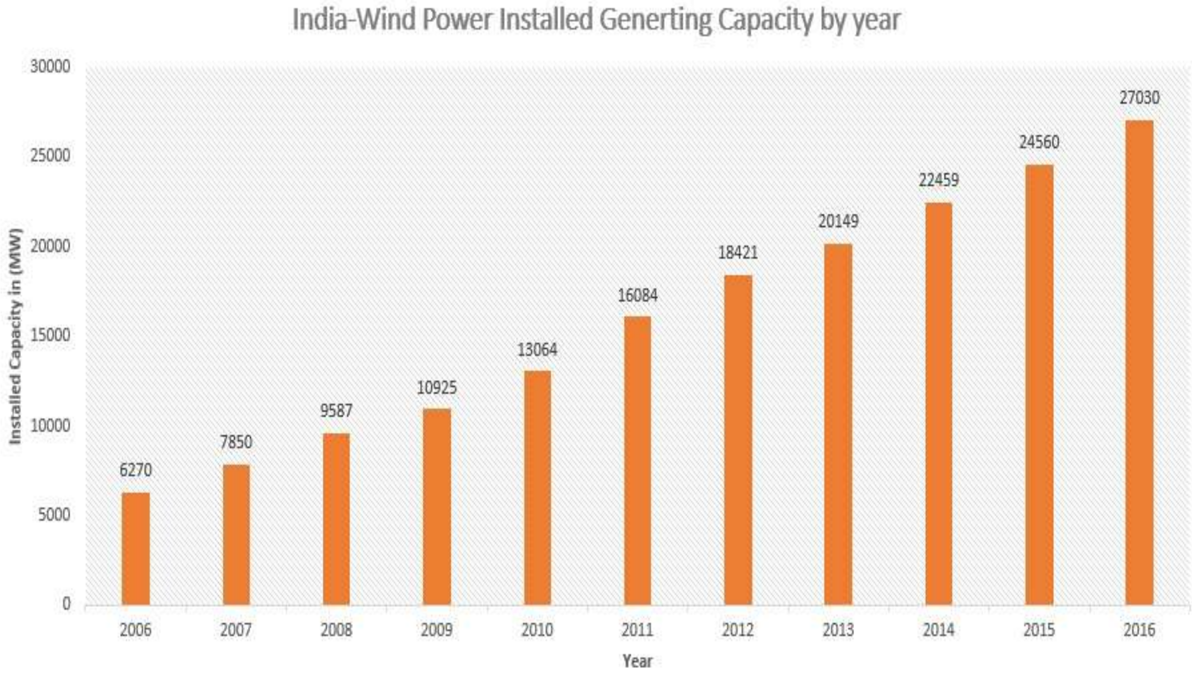

Fig. 2 wind power capacity in India by year[2]

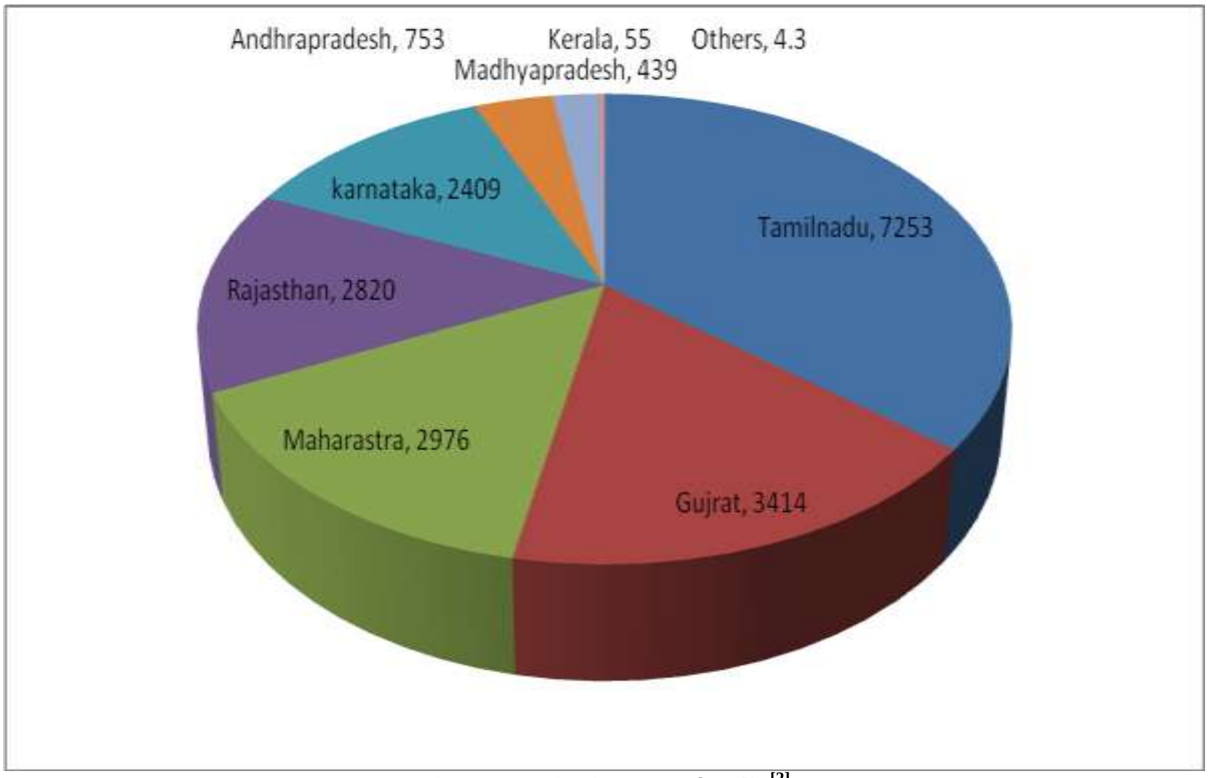

Fig 3.Capacity in state of India[2]

Table 2 Manufacturers in india[3]

Sr No.	Manufacturer Name & Address	Capacity (Kw)	Sr No.	Manufacturer Name & Address	Capacity (Kw)
1	Elecon Engineering Ltd, V.V Nagar, Gujrat, India.	600	2	Southern Wind Farm Ltd, Chennai, India.	225
3	Enercon India Ltd, Mumbai, India.	800	12	Suzlon Energy Ltd, Pune, India.	750
4	Global Wind Power Ltd, Mumbai, India.	750	13	Vestas Wind Technologist Pvt Ltd, Chennai, India.	1650
5	Leitner Shriram Ltd, Chennai, India.	1350	14	Wiinwind Power Energy Pvt Ltd, Chennai, India.	1000
6	India Wind Power Ltd, Ahmadabad, India.	250	15	Inox Wind Ltd, Noida, India.	2000
7	Kenersys India Pvt Ltd, Pune, India.	2000	16	Ge India Pvt Ltd, Bangalore, India.	1500
8	Pioneer Wincon Pvt Ltd, Chennai, India.	250	17	Gamesa Wind Power Pvt Ltd, Chennai, India.	850
9	Regen Powertech Pvt Ltd, Chennai, India.	1500	18	Essar Wind Power Pvt Ltd, Mumbai, India.	1500
10	Rrb Energy Ltd, Chennai, India.	600	19	Chiranjjeevi Wind Energy Ltd, Pollachi, India.	250
11	Siva Wind Turbine Erode, India.	250			

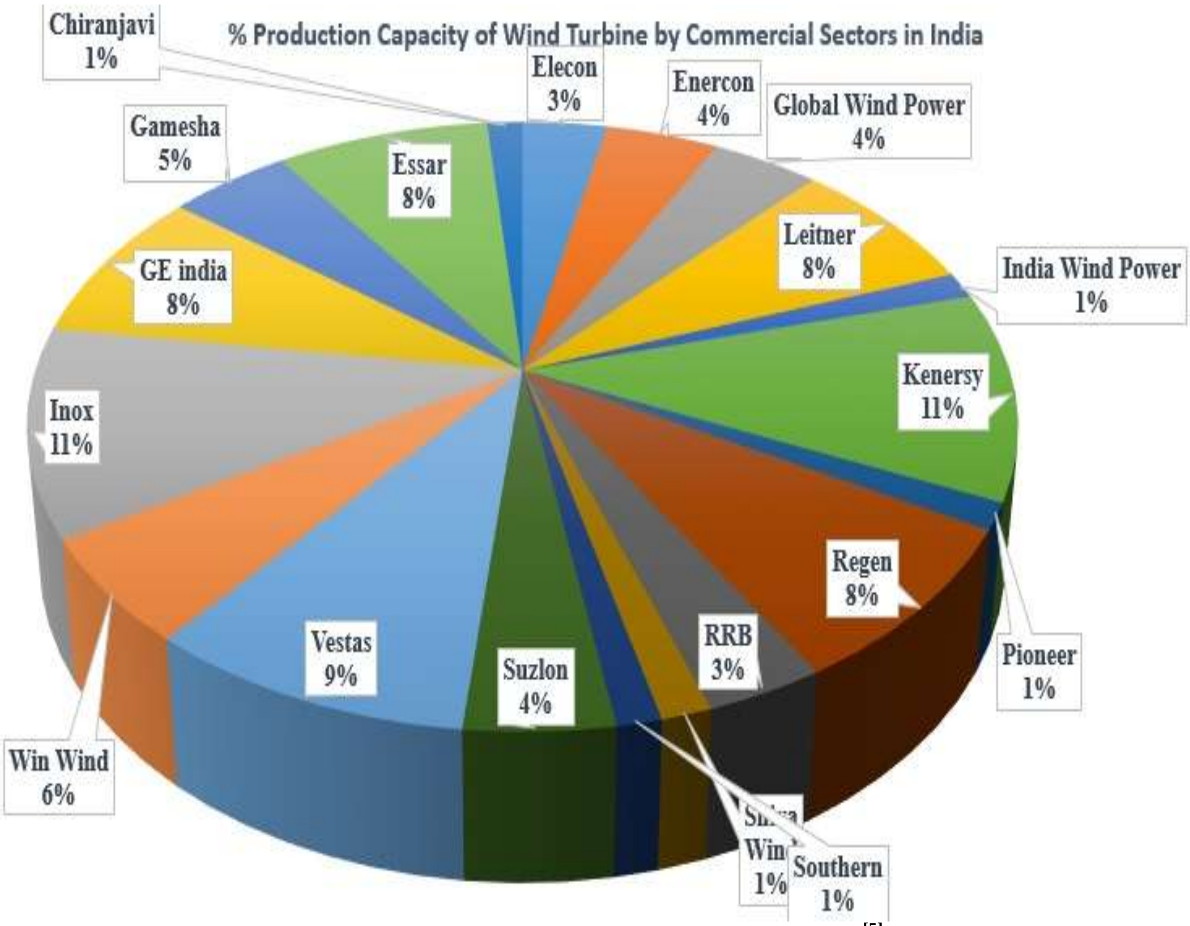

Fig.3 production capacity chart of manufacturers [5]

II. METHODS AND MATERIALS

Use Computational Fluid Dynamics (CFD) in 3-D analysis of aerodynamic forces of a Horizontal Axis Wind Turbine (HAWT) blade and compare the 3-D results with the 2-D experimental results. The results are compared with the experimental data obtained by NREL at NASA Ames Research Center for the NREL Phase VI wind turbine blade. The aerodynamic forces are evaluated using 3-D Computational Fluid Dynamics (CFD) simulation. For the case study seven varying wind speeds (5 m/s, 7 m/s, 10 m/s, 13 m/s, 15 m/s, 20 m/s, 25 m/s) with constant blade rotational speed (72 rpm) are considered. [6]
Based on the momentum-element theory, mathematical model of numerical simulation of the output characteristics is set up for resemble models of MW-scale wind turbine blades, which is under a test system with three different setting angles of 10.5°, 30.5°and 50.5°. [7]
several wind turbine designs have been analyzed and optimized designs have been proposed for low wind speed areas around the world mainly for domestic energy consumption. The wind speed range of 4-12 mph is considered, which is selected based on the average wind speeds in the Atlanta, GA and surrounding areas. These areas have relatively low average wind speeds compared to various other parts of the United States. Traditionally wind energy utilization is limited to areas with higher wind speeds. In reality a lot of areas in the world have low average wind speeds and demand high energy consumption. wind turbines are installed in remote offshore or away from habitat high wind locations, causing heavy investment in installation and maintenance, and loss of energy transfer over long distance. [8]

The proposed investigation aims at evaluating concepts for modularizing horizontal axis wind turbine blades and also evaluate for their load carrying capability. This work begins with evaluation of a non-modularized blade to serve as a reference and for comparison with modularized blade. Static bending test is simulated as per IEC61400-23 standard.[9]

Emergency shutdown is always a challenge for an operating vertical axis wind turbine. A 5-MW vertical axis wind turbine with a Darrieus rotor mounted on a semi-submersible support structure was examined in this study when generator failure happens, a brake should be applied to stop the acceleration of the rotor to prevent the rotor from over speeding and subsequent disaster. In addition to the traditional mechanical brake, a novel hydrodynamic brake was presented to apply to the shutdown case. The effects of the hydrodynamic brake on the platform motions and structural loads under normal operating conditions and during the emergency shutdown events were evaluated. The use of both the hydrodynamic brake and mechanical brake was also investigated. [10]

2.1 Equations of wind turbine parameters [12]

Generator power P,

$$P = \frac{1}{2}\rho A u^3 C_p \quad (1)$$

Rotor power P_{rotor},

$$P_{rotor} = \rho R^2 u^3 Cp \quad (2)$$

Wind power P_{wind},.

$$P_{wind} = \rho A u^3 \quad (3)$$

Power coefficient C_p,

$$C_p = P/P_{WIND} \quad (4)$$

Tip speed ratio λ,

$$\lambda = R_m/u \quad (5)$$

The shear stress T_S,

$$T_S = F/A \quad (6)$$

The bending stress T_B,

$$T_B = My/I_x \quad (7)$$

2.2 2D Drawing (NACA 4424)

- **Specification of NACA 4424[11]**
  Maximum thickness 24% at 29.4% chord.
  Maximum camber 4% at 40 % chord.

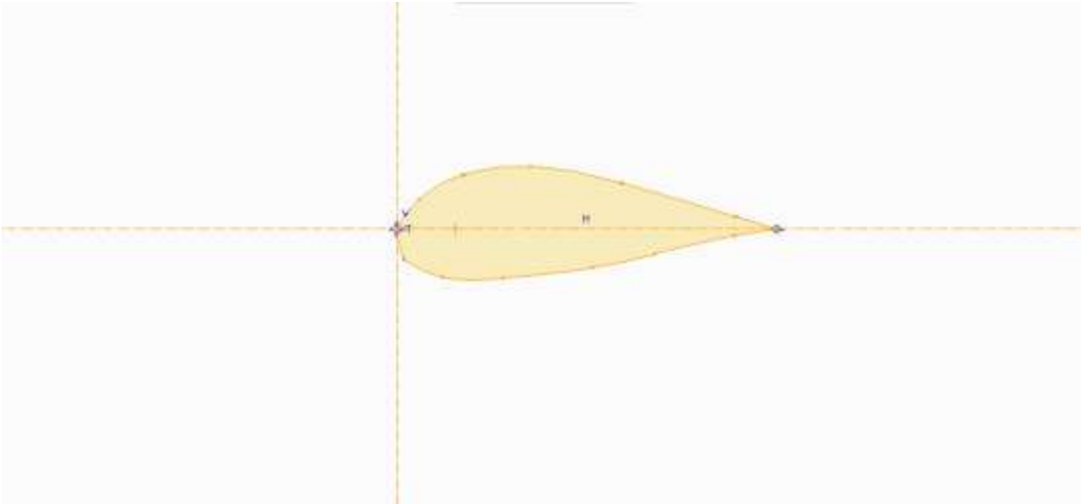

Fig.5 cross section of aerofoil blade

Cross section of NACA 4424 aerofoil developed in creo parametric 2.0 than it is used for three blade 3D model.

2.3 3D Drawing (Three blade model)

Fig.6 3D model of wind turbine blade

Take four different datum plane along same distance than put naca 4424 at all plane at different size and at different angle 60, 70, 80 and 85. Than four datum plane made blend and 3D drawing developed as shown in above figure 6.

III. RESULTS AND DISCUSSION

3.1 Graphs

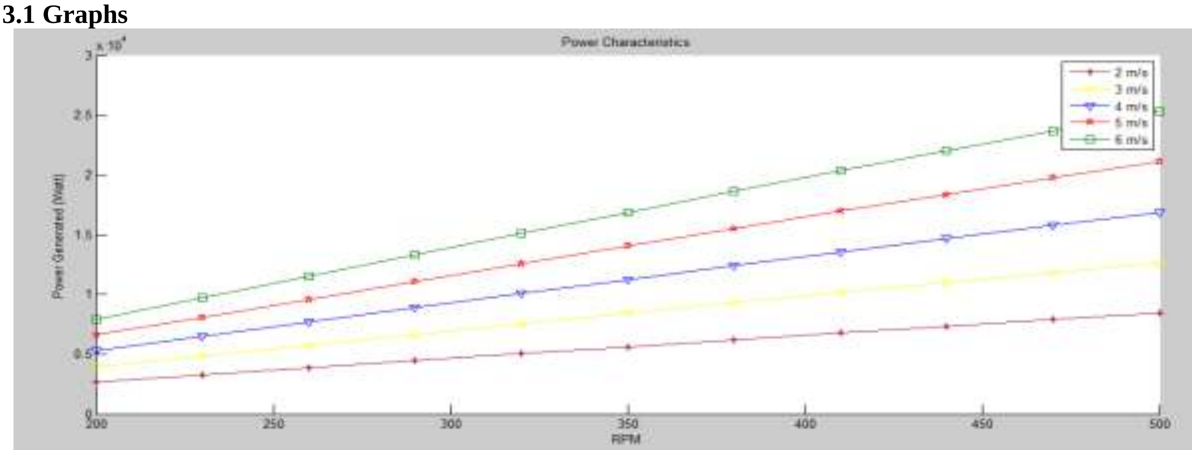

Fig.7 power generated vs turbine speed

For different wind velocity 2 m/s , 3 m/s, 4 m/s, 5 m/s, 6 m/s graph is developed for power generated vs turbine speed. Where power generated increases with increase in turbine speed and wind velocity. Therefore we can get maximum power output in high wind speed area.

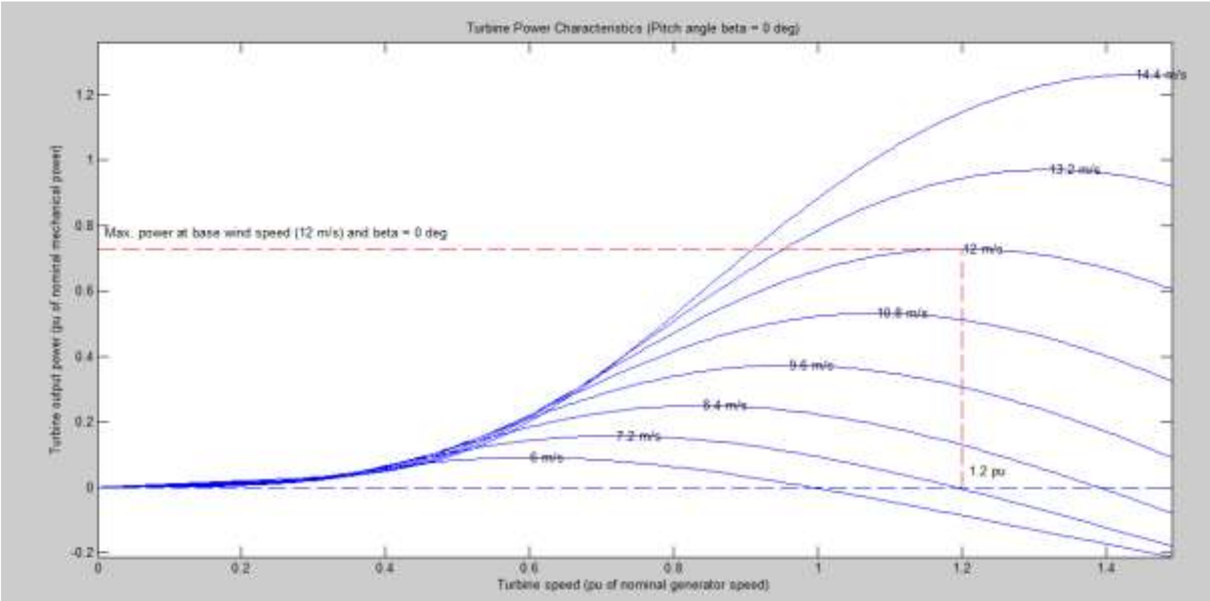

Fig.8 Output power vs turbine speed

Graph between turbine output power and turbine speed is developed above at different wind speed , power is increases with increase in wind speed up to some limit than its start decreasing ,max power at base wind speed is 12 m/s and 1.2 pu of nominal generator speed. Above 12 m/s bending losses and load on blade increases therefore 12 m/s is the optimum wind speed for obtain max output performance.

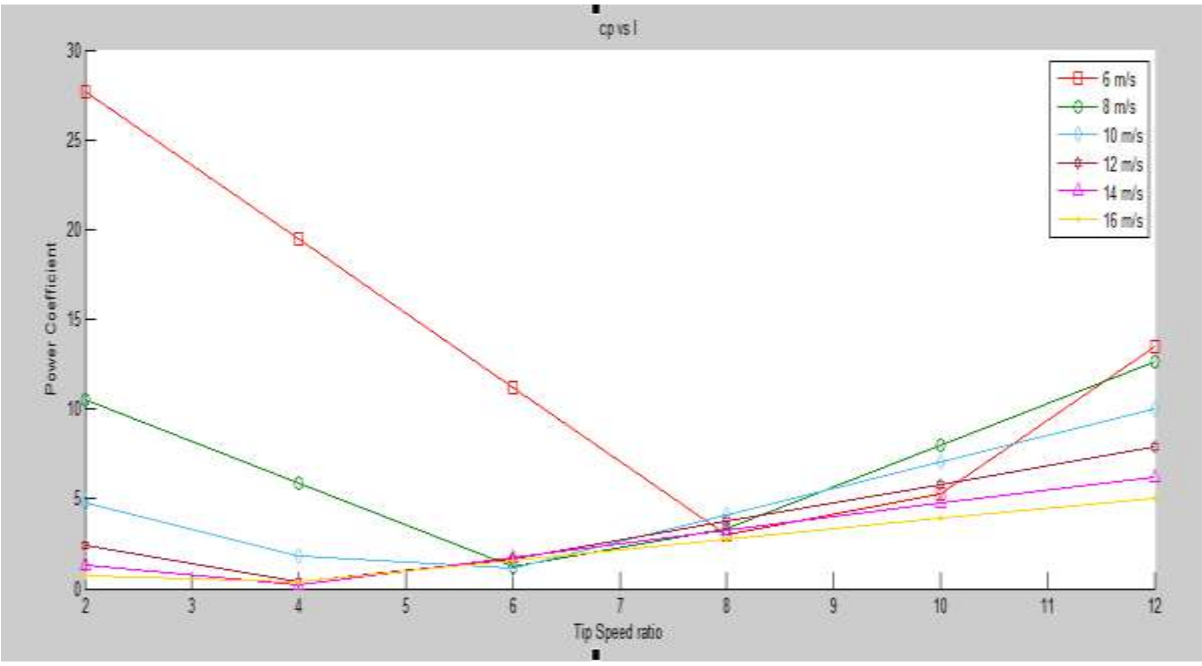

Fig.9 Power coefficient vs tip speed ratio

For different wind velocity up to some limit power coefficient decreases with tip speed ratio increases than its start increasing with increase in tip speed ratio. Lower wind speed give highest power coefficient after tip speed ration is 10.

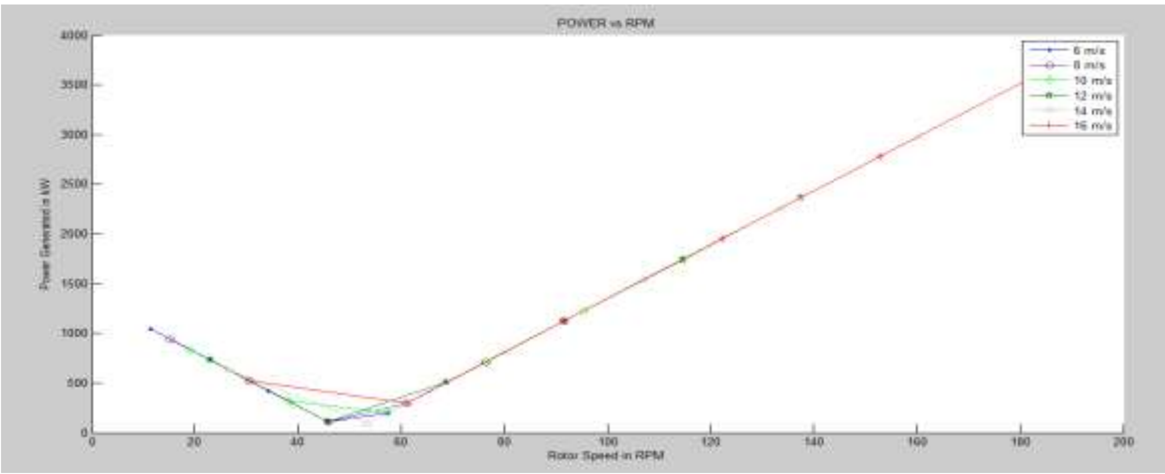

Fig.10 Power generated vs rotor speed

Graph is developed between Power generated and rotor speed. In this graph generated power is decreases with increases in rotor speed up to some limit, than its started increasing with increase in rotor speed. Optimum velocity is 12 m/s for obtain max generated power with minimum losses.

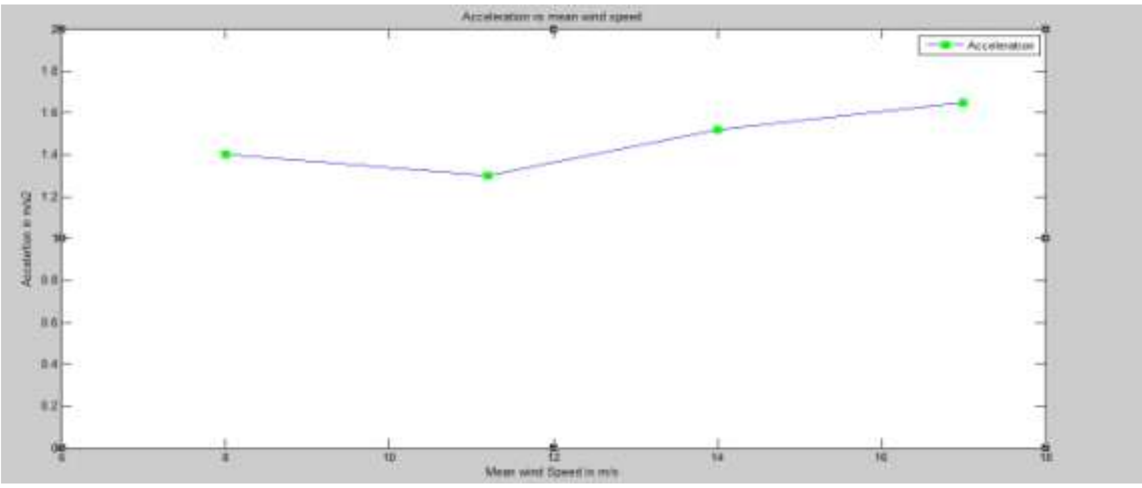

Fig.11 Acceleration vs mean wind speed

For offshore wind turbine acceleration slight decreases with increase in mean wind speed up to 11.2 m/s. than its start increases with increases in mean wind speed.

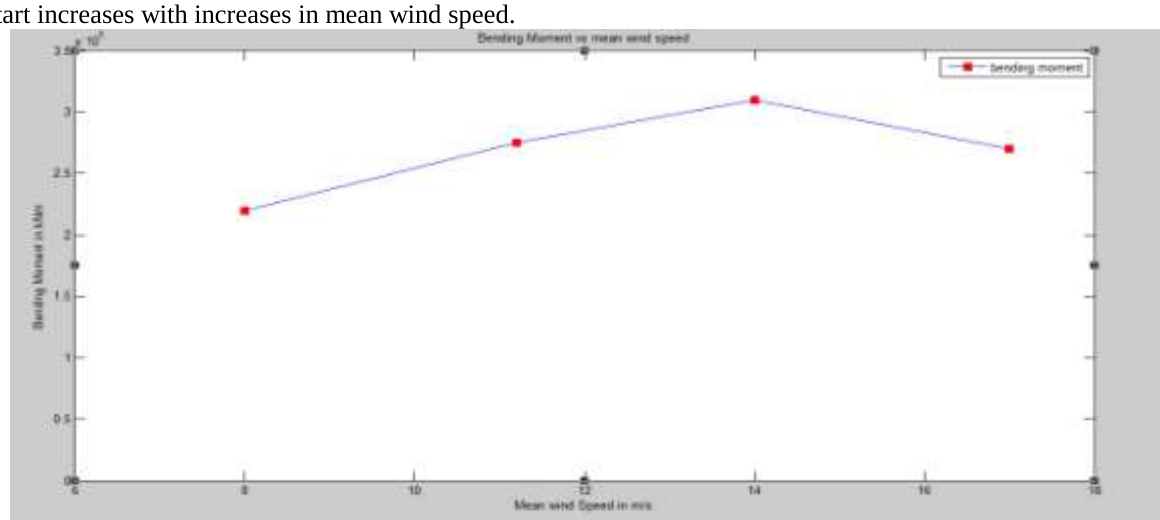

Fig.12 Bending moment vs mean wind speed

In this graph bending moment increases with increase in mean wind speed up to certain limit after that it will decreases with increase in mean wind speed. Bending moment is increases after wind velocity 12 m/s.

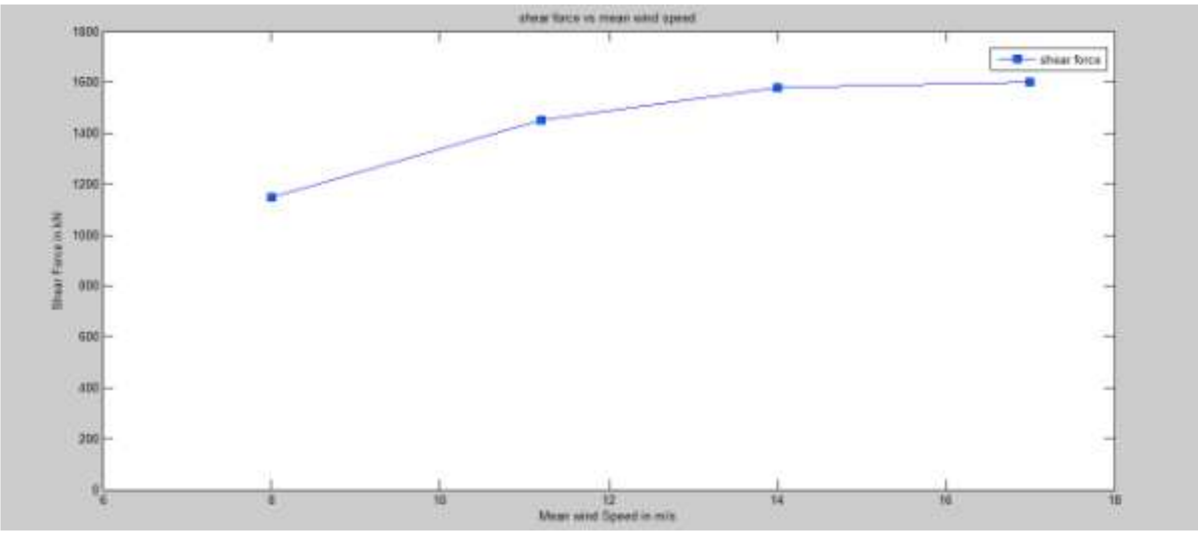

Fig.12 Shear force vs mean wind speed

In this graph Shear force is gradually increase with increase in mean wind speed. Shear force also increases after wind velocity 12 m/s.

IV. CONCLUSION

- For that reason 3-D CFD simulation has been used to determine the aerodynamic of a HAWT and the obtained results are compared with the NREL 3-D experimental results. The 3-D values of lift and drag coefficient is also compared with the both the NREL 3-D and 2-D experimental values. The Shear Stress Transport (SST) Gamma-Theta turbulence model and 0-degree yaw angle condition are adopted for CFD analysis. From the above discussion it can be concluded that all the results of current analysis such as sectional pressure coefficient, torque, thrust, tangential force co-efficient and normal force co-efficient values show good agreement with the NREL experimental values. So we can say that in case of an unknown situation CFD can predict the accurate result.
- Simulation and test results show that, for the same set of blades, among the setting angles of 10.5 °, 30.5 ° and 50.5 °, the system with smaller angle has better output performance.
- First a HAWT with airfoil blades is undertaken for optimization. The max rotor diameter for this turbine is only two meters, which classifies it as a micro wind turbine. There are, however, only a limited number of wind turbine airfoils that have been developed exclusively for small blades and low wind speeds between 4 - 12 mph. The SG604x airfoil family is designed specifically for low speed wind turbines and these airfoils provide enhanced lift-to-drag ratios for small variable-speed wind turbines as compared to previously existing airfoils.
- The load carrying capability of the modularized and non-modularized blades are less different (Max is 3% with respect to slope). The design and analysis of the joint is critical to the load carrying capability of the blade. The location of the joint is very important activity for which the rate of change of deflection is an important input.
- The application of the hydrodynamic brake is expected to be efficient for rotor shutdown and for reducing the platform motions and structural loads.

NOMENCLETURES

- P = power output from wind machine in kw,
- Pwind= power available in wind in kw,
- η = drive train efficiency,
- ρ = air density in kg/m3,
- R = rotor radius in m,
- U = wind speed m/s,
- Cp =power coefficient,
- Protor = Rotor power in kw,

- λ = tip speed ratio,
- Rm = turbine rotor radius in m ,
- = rotor rotational speed in rad/s,
- n =turbine rotor speed in RPM,
- = the shear stress in N/m2,
- F = the force applied in N,
- A = the cross-sectional area of material with area parallel to the applied force vector in m2,
- =the bending stress in N/m2,
- *M*= the moment about the neutral axis in N.m
- y= the perpendicular distance to the neutral axis in m.
- IX = the second moment of area about the neutral axis *x* in m2.

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