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DESIGN OPTIMIZATION OF GORLOV TURBINE WITH CFF ANALYSIS FOR A SKYSCRAPPER SCENARIO

Chanduri Sai Ram [1], Dr. K. Kishore [2]

[1]B.E, Department of Mechanical, Vasavi College of Engineering
[2]Professor, Department of Mechanical, Vasavi College of Engineering

ABSTRACT:

Wind power is one of the most abundant resources around us, available around the world regardless of geography. This is especially true in urban environments, and it offers many advantages, such as the fact that it can be used to produce energy throughout the day. Urban areas containing skyscrapers, have high wind speeds close to the walls of the skyscraper, but they cannot be captured using tradition horizontal axis wind turbine, as they cannot withstand fatigue loads caused due to rapid change in angles of attack, and do not offer high efficiency. Traditional rooftop horizontal axis involute blade designs are suitable for low speeds, and have a small adoption rate, as they spoil aesthetics of buildings.

Development of wind energy use in urban environments is of growing interest to industries and local governments, as an alternative to utility-based and non-renewable forms of electric production. Although most performance testing for small-scale wind turbines is conducted in outdoors wind testing sites, wind tunnel testing can provide a good reference for maximum possible performance under ideal flow conditions.

This project concerns the design of vertical axis wind turbines along with CFD analysis for a skyscraper scenario, involving high wind speed, and a large variance of angles of attack. A detailed review of current state of art for wind turbine blade design is presented which includes aerodynamic design principles for a modern wind turbine, blade plan shape/quantity, aero foil selection and optimal attack angles and also deals with the terrain selection, annual energy production etc.

INTRODUCTION

In recent years, wind energy has become one of the most economical renewable energy. Today, electricity generating wind turbines employ proven and tested technology, and provide a secure and sustainable energy supply. At typical sites, wind energy can already successfully compete with conventional energy production in both magnitudes of energy generated, and cost. Many countries have considerable wind resources, which are still untapped. The technological advancements of the past decade have brought us more efficient and more reliable wind turbines, and have made wind power more cost-effective. In general, the specific energy costs per annual kWh decrease with the size of the turbine notwithstanding existing supply difficulties.

Many countries expect to see electricity demand expand rapidly in coming decades. At the same time, finite natural resources are becoming depleted, and the environmental impact of energy use and energy conversion has been generally accepted as a threat to the global society at large. Many developing countries and emerging economies, such as India, have substantial unexploited wind energy potential. In many locations, generating electricity from wind energy offers a cost-effective, and environmentally friendly alternative to thermal power stations. It has advantages such as lower impact on the environment and climate, reduces dependence on fossil fuel imports and increases security of energy supply.

Because the geometrical conditions gives us the opportunity to work in this field, due to the availability of development of particular energy resource so that it can be further.

GORLOV HELICAL TURBINE:

- Lift type of VAWT model.
- They have curved aerofoil blades and effective distribution of foil sections throughout the cycle.

- Said to be more efficient compared to other VAWT models.
- Less stresses act upon the turbine due to light weighed blades and specific design.
- Self-starting at low airflows.

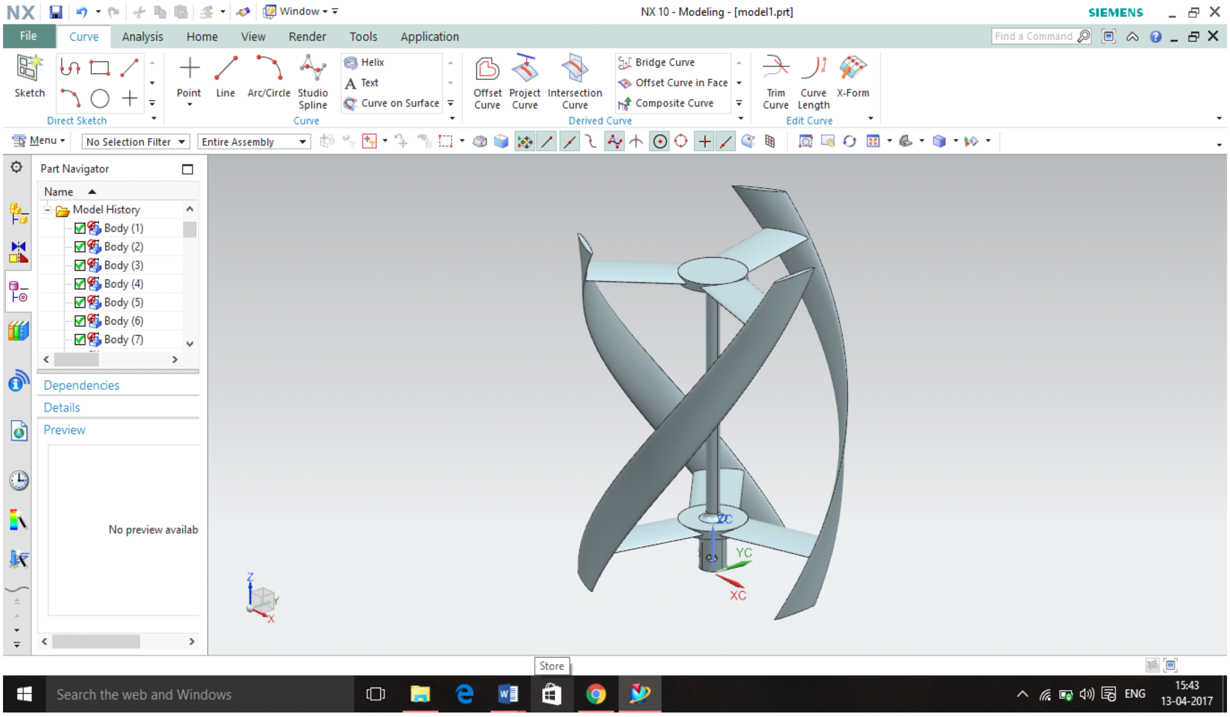


Fig represents the Designed model of Gorlov turbine in Siemens NX 10

Q-BLADE SOFTWARE:

For an efficient conversion of the wind energy into mechanical energy with wind turbines is the optimal design of the rotor blades. Methods for rapid development, reliable and robust predictions of the aerodynamic characteristics and simulation of the flow conditions around a rotor blade are essential for this design task.

THE Q-BLADE VAWT MODULE:

Q Blade includes a module for the simulation of those wind turbines. The implemented algorithm is applicable for the performance analysis of lift based VAWT's such as the classical "Eggbeater" Darrieus rotor. Based on the calculated aerofoils, polars and 360 polars, the blade shape is defined in the blade design sub module. This part of the program provides a range of scaling and optimization functions as well. In the following, the user can choose between rotor simulation and turbine simulation. The former one is a dimensionless calculation for a range of tip speed ratios whereas the latter one requires the definition of concrete turbine parameters such as rpm and is executed for a range of wind speeds. In either module, simulation parameters and corrections can be selected for the calculation. For visualization purposes, three different graph types are available to plot the simulation data: the blade graph for vertical plots, the azimuthal graph for circumferential plots and the rotor graph for plots of global variables, such as the power coefficient.

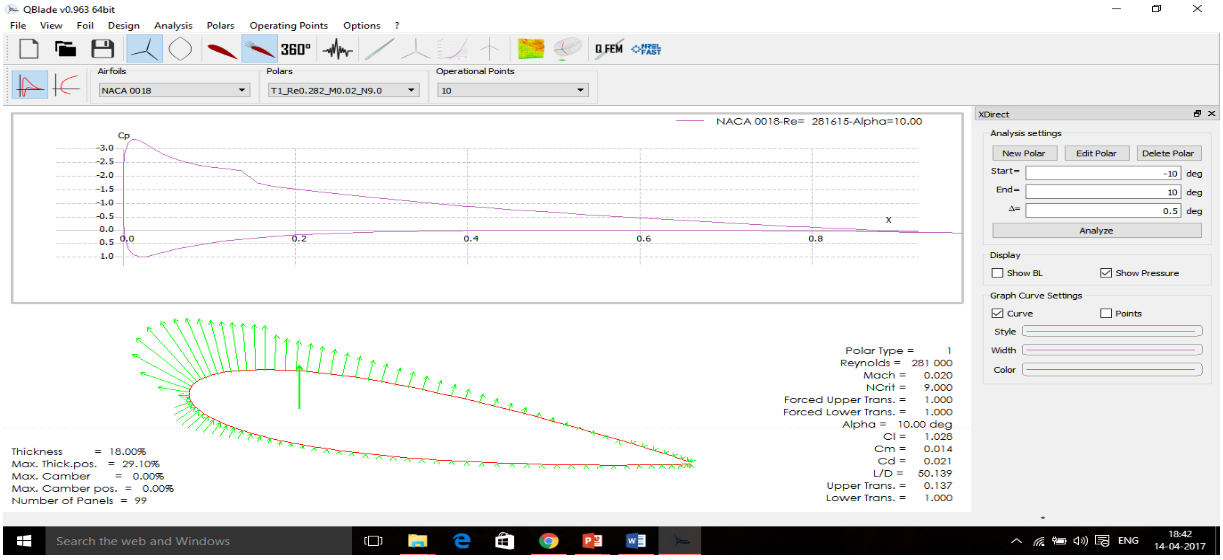


Fig: coefficient of power for NACA 0018 at AOA 10 at Reynolds no: 281615

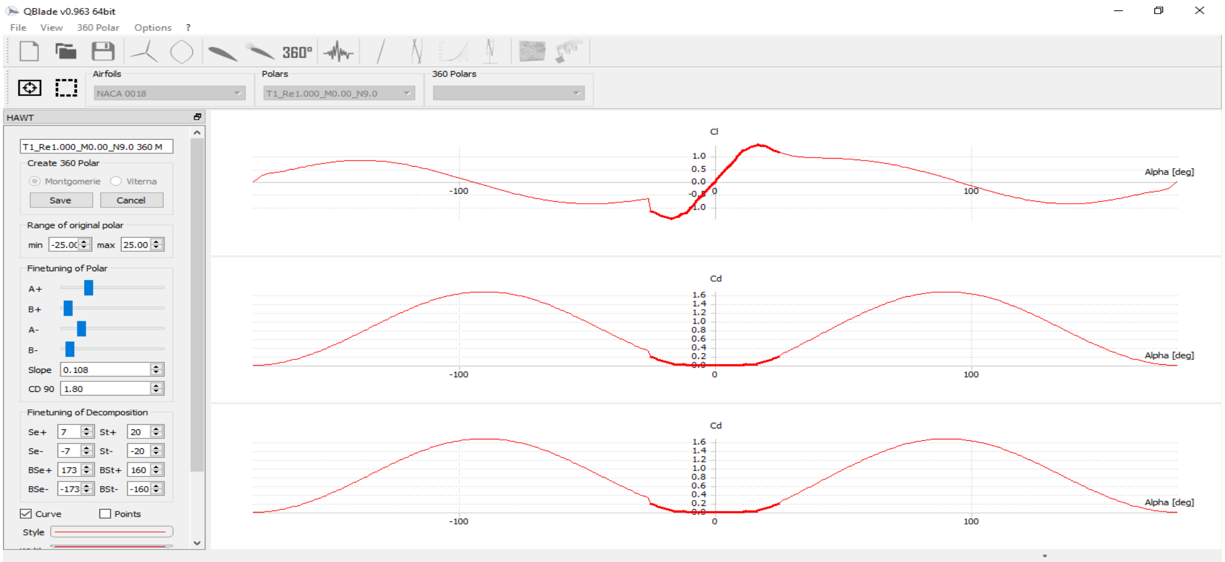
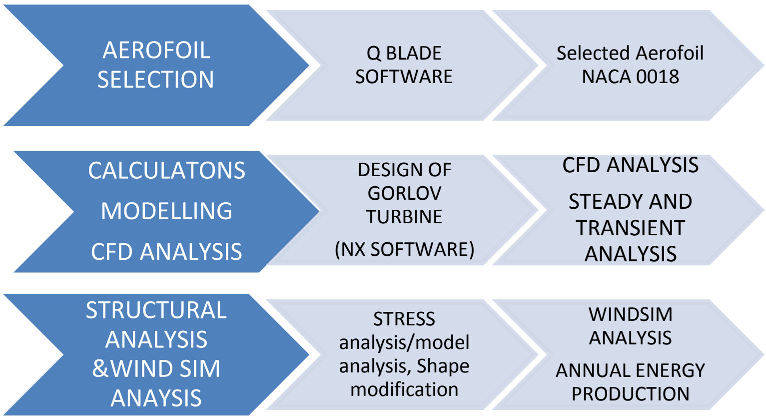


Fig: coefficient of lift and drag values extrapolated 360 AOA (Q blade software)

DESIGN PROCEDURE:



MATERIAL CONSIDERATIONS:

Material selection is a process which is performed to select the best material which may have the potential to perform well both industrially and commercially. In the selection of materials, a systematic approach is necessary to select the best materials for a particular model. If a proper technique is followed, first it is required to carefully define the application requirements in terms of mechanical, thermal, environmental, electrical, and chemical properties. Production techniques also have a major importance in selecting the best material. Material property data sheets never should be used for the ultimate selection of materials. The actual performance of a material under different conditions may differ from what is expected.

Material (1): Aluminum 6061:

Material (2): (CFRP) Carbon Fiber Reinforced Plastic:

DESIGN PARAMETERS:
1) Swept area S=2RL; R is the rotor radius; L is blade length
2) Power and power coefficient: $\frac{1}{2}\rho sV^3$ V0 is the wind velocity (m/s) ρ is air density (kg/m3); Cp = captured mechanical power by blades Wind power
3) Tip speed ratio: TSR= ω*R/Vo; ω is angular speed (rad/sec); R is rotor radius
4) Solidity: σ =NC/D = 3*0.189/0.974 = 0.58
5) Mechanical power $\frac{1}{2} s\rho cpVo^3$
6) Blade profile (NACA 0018)
7) Aspect ratio A.R = H/R; H = Blade length; R=Rotor radius •
8) No: of blades (B) = 3
9) Helix angle φ = BH/D
10) Chord length (C)
11) Reynolds no: (Re) = Cω/ν

CALCULATION OF LIFT AND DRAG FORCES ON A SINGLE BLADE

1) Fl,h =Fl[(90π/180)-(αactual π/180)] =115.2N Fl.h is force in direction of travel(N)
2) Fl,circ is Flsin[(90π/180)-(αactual π/180)] =2.028N Fl,circ is force contributing to centrifugal force (N)
3) Fd,h =Fdcos(αactual π/180) =55.997N Fd,h is force opposing motion of blade travel (N)
4) Fd,circ =Fd((αactual π/180) =0.54 Fd,circ is force contributing to centrifugal force (N)
5) Finally perpendicular and parallel forces are added to obtain F1 and F2 values F1 = Fl.h - Fd = 59.203 N F2 = Fl,circ + Fd,circ = 2.568 N

DESIGN AND ANALYSIS OF GORLOV TURBINE BY USING SIEMENS NX 10 AND AUTODESK INVENTOR.
• Power = 1kW
• Aerofoil = NACA 0018
• Wind speed = 10 m/s
• Air density =1.225 kg/m3

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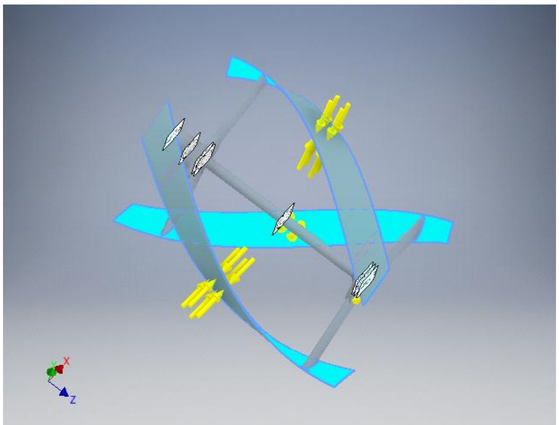
- Kinematic viscosity = 1.817*10-5
- Aspect ratio = 2
- Reynolds no: = 218615
- Rotor Diameter = 0.974m
- Chord length =0.189m
- Rotational speed = 299 rpm

STRESS ANALYSIS

Load Type	Pressure external
Magnitude	18.190 psi

Load Type	Pressure internal
Magnitude	5.570 psi



The above fig represents the stress acting on turbine (i.e 183.2 Mpa) and displacement due to forces (1.705 mm)

CFD ANALYSIS (TRANSIENT STATE)

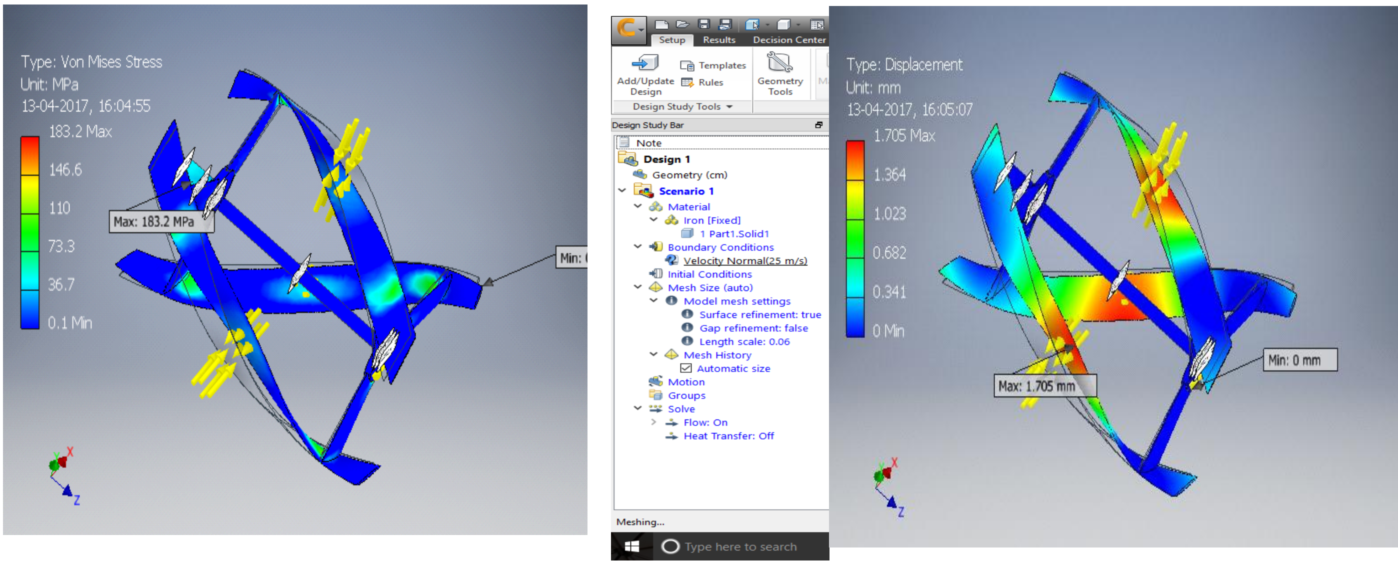


Fig represents the meshing of the Gorlov turbine in CFD Autodesk Inventor

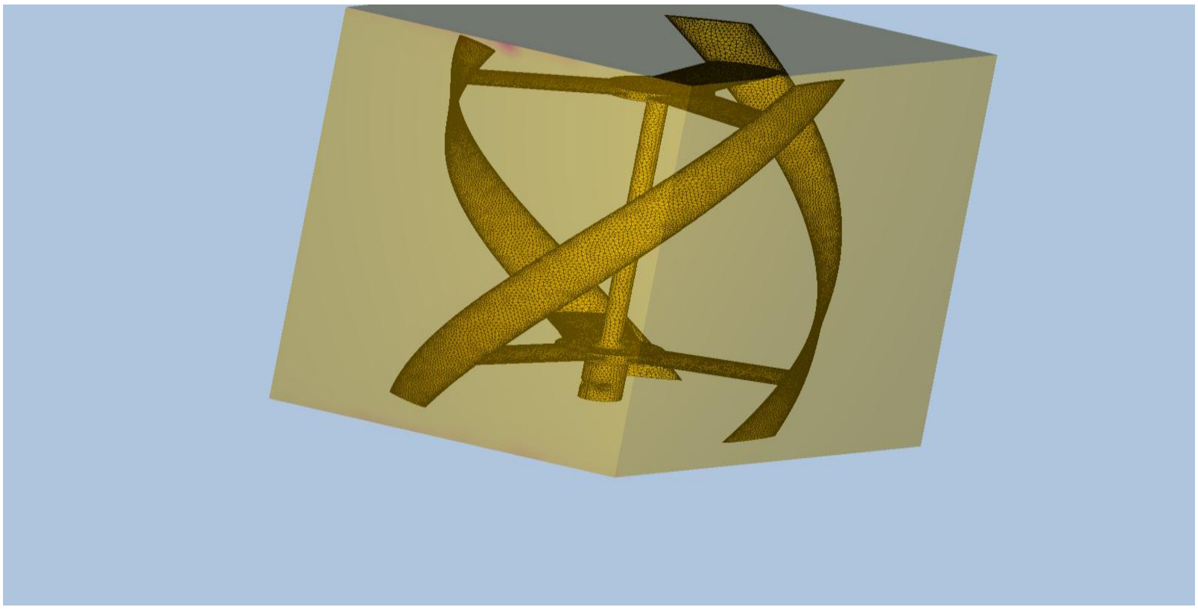


Fig shows the meshed model of gorlov turbine for CFD analysis

Results:

Results	Resulting values obtained in CFD analysis
inlet 1	
inlet bulk pressure	1254156.4 dyne/cm^2
inlet bulk temperature	0.0 C
inlet Mach number	0.0190562
inlet residence time	-3.06214e-05 sec
mass flow in	3737.81 g/s
minimum x,y,z of opening	0.0
node near minimum x,y,z of opening	62954.0
Reynolds number	281615.0
surface id	76.0
total mass flow in	3737.81 g/s
total vol. flow in	3231260.0 cm^3/s
volume flow in	3231260.0 cm^3/s

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WIND SIM ANALYSIS (WIND SIM SOFTWARE):

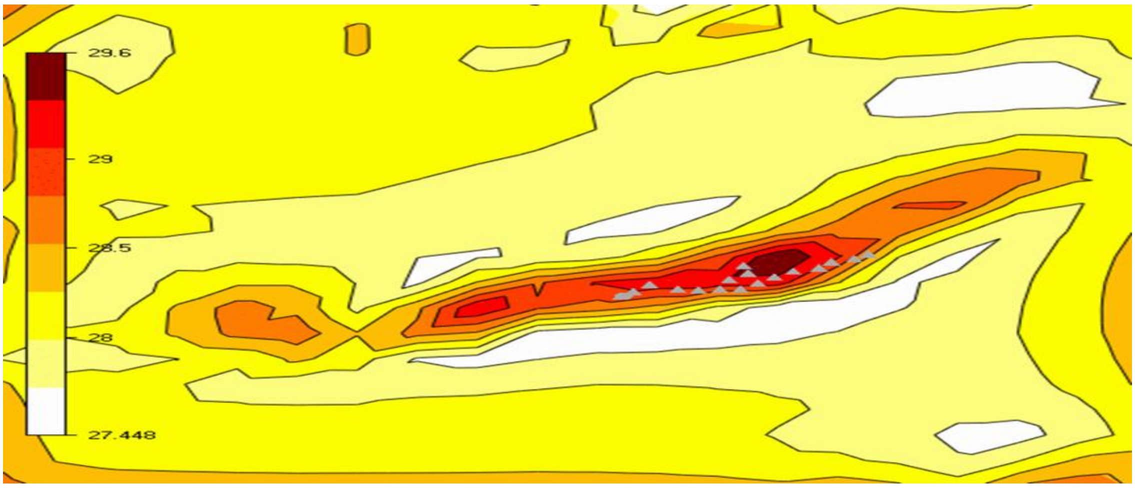

Fig represents the wind resource map and triangles representing the turbines

Roughness read for Terrain File
Co-ordinate system read from terrain file
Bi-Linear smoothing done

INPUT VARIABLES

Climatology name	File name	Representative period	Measurement height (m)	Average wind speed (m/s)
Hyderabad-Draught	HYD_WWS	18.03.99 - 18.02.00	30.00	23.44

Turbine Type	Hub Height (m)	No. of turbines	Capacity (MW)	Gross AEP (GWh/y)	Average wind speed (m/s)	Wake losses (%)	AEP with wake losses (GWh/y)	Full load hours (hours)	Capacity factor(%)
VAWT Vasavi Type	160.0	34	0.0	0.3	29.3	n.a.	n.a.	7664.7	87.5

OUTPUT (ENERGY PRODUCTION RATE):

Turbine Type	Hub Height (m)	No. of turbines	Capacity (MW)	Gross AEP (GWh/y)	Average wind speed (m/s)	Wake losses (%)	AEP with wake losses (GWh/y)	Full load hours (hours)	Capacity factor(%)
VAWT Vasavi Type	160.0	17	0.0	0.3	29.3	n.a.	n.a.	7664.7	87.5

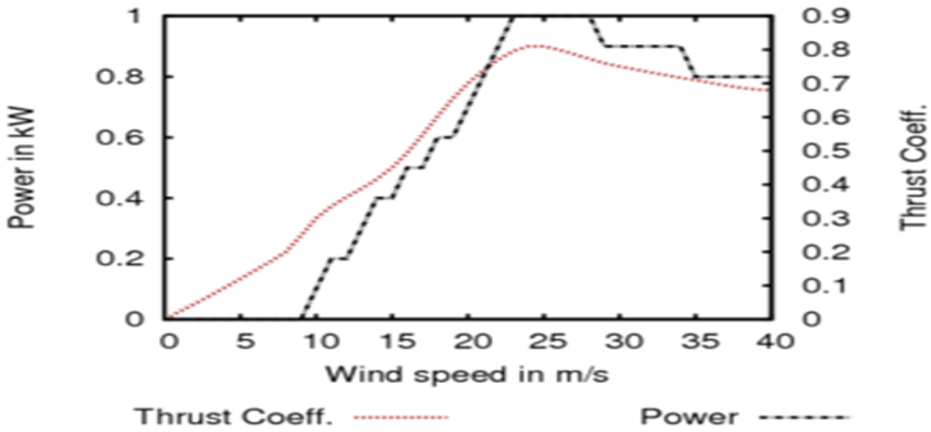

Fig. Estimation of Power generated w.r.t. wind speed

Results and Discussions:

1. According to the problem statement we have developed a small scale Vertical Axis Wind Turbine which can be used in urban scenario this solution is expected to supplement other renewable resources and not to substitute them. We have successively completed the subjective.
2. A single VAWT mounted on a skyscraper would be able to produce 276MWhr per year and a peak power generation capacity of 1 Kw. The power generated from this VAWT can be used reduce energy consumption by the building. 8.823MWhr/yr energy is generated by each VAWT which saves 88,235/- per year by each turbine.
3. The designed VAWT model satisfies the Von-mises criteria for which the obtained factor of safety for our model is 1.5.
4. The design is optimized for performance per unit volume.

REFERENCES

1. Jha, A.R. (2010). Wind turbine technology. Boca Raton, FL: CRC Press

2. Raciti Castelli, Marco; Englaro, Alessandro; Benini, Ernesto (2011). "The Darrieus wind turbine: Proposal for a new performance prediction model based on CFD". Energy. 36 (8): 4919–34. 10.1016/j.energy.2011.05.036.

3. Islam, M; Ting, D; Fartaj, (2008). "Aerodynamic models for Darrieus-type straight-bladed vertical axis wind turbines". Renewable and Sustainable Energy Reviews. 12 (4): 1087–109. 10.1016/j.rser.2006.10.023. https://fenix.tecnico.ulisboa.pt/downloadFile/395143097660/Extended%20abstract.pdf

4. El Ksmi, Amina; Masson, Christian (2008). "An extended k–ε model for turbulent flow through horizontal-axis wind turbines". Journal of Wind Engineering and Industrial Aerodynamics. 96: 103–22. 10.1016/j.jweia.2007.03.007.

5. Eriksson, S; Bernhoff, H; Leijon, M (2008). "Evaluation of different turbine concepts for wind power". Renewable and Sustainable Energy Reviews. 12 (5): 1419–34. 10.1016/j.rser.2006.05.017.

6. Peace, Steven (June 1, 2004). "Another Approach to Wind". Mechanical Engineering.

7. Svitil, Kathy (July 13, 2011). "Wind-turbine placement produces tenfold power increase, researchers say". PhysOrg.

8. Buchner, A-J.; Lohry, M.W.; Martinelli, L.; Soria, J.; Smits, A.J. (2015). "Dynamic stall in vertical axis wind turbines: Comparing experiments and computations". Journal of Wind Engineering and Industrial Aerodynamics. 146: 163–71. 10.1016/j.jweia.2015.09.001.