Design and CFD Analysis of Wind Turbine for Domestic Purpose

Darshana Ishwardas Patil[1] Prof. M. Shakebuddin[2]
[1]MTech Student [2]Professor
[1,2]Department of Mechanical Engineering
[1,2]Anjuman College of Engineering & Technology, Nagpur, Maharashtra, India, India

Abstract— An energy crisis is the major problem in all over world. Almost all the energy requirement is fulfilled by thermal power plants based on coal and diesel leading to pollution in the environment. Preventing these polluting power sources it is necessary to adopt alternate energy resources like solar power, wind power, etc. But out of all these wind energy is preferred as domestic safe-economical energy resource. The proposed work focuses on design and CFD analysis of wind turbine for domestic purpose. In present work, we will be accumulating all the data relevant to wind turbines, domestic wind turbines, its components, basic working principle of wind turbine, types of blades used, etc. According to collected data CAD model of domestic wind turbine will be generated and CFD analysis will be performed .After that results will be discussed and design will be finalized.

Key words: Analysis, CFD

I. Introduction

The development of wind power in India began in the 1990s, and is significantly increasing from the last few years. India has the fifth largest installed wind power capacity in the world. As on October 31, 2009 the installed capacity of wind power in India was around 10,925 MW.

A wind turbine is a device that transforms kinetic energy from the wind energy into mechanical energy in a process known as wind power. Wind energy is one the most widely used renewable energy resources. Small and domestic wind turbines need to be affordable, reliable, and versatile and almost maintenance free for the average person to consider installing one.

Growing awareness of increasing levels of greenhouse gases, global warming and increasing prices of fossil fuels have led to a shift towards investing into low-cost domestic wind turbines.

The domestic wind turbines are vital wind power extracting devices in the rural, suburban and even in the populated city areas where installation of large scale wind turbines would not be accepted due to space constraints and generation of noise. The domestic wind turbines are Simple structured, compact in design, portable.

Domestic wind turbines have been integrated and deployed on domestic house roof tops, farms, remote communities. In poor wind sites and in applications that require a high level of reliability Domestic wind turbines produce more costly electricity than large and medium-scale wind turbines . However, when optimised properly and used at optimal working conditions, domestic wind turbines could be a reliable energy source and produce socio-economically valuable energy not only in developing countries but also in autonomous applications in locations that are far away from the grid power in developed countries. Power coefficients of domestic wind turbines is 0.25 or greater in comparison to large turbines which have values around 0.45. Domestic wind turbines are in fact becoming an increasingly promising way to supply electricity in developing countries. The domestic wind turbines have quite different aerodynamic behaviour when compared to large-scale counterparts.

II. Basic Constructional Components and the Working of Wind Turbine:

Wind energy is harnessed and transformed into electrical energy using turbines called wind turbines. The amount of electricity produced by the turbine depends on its size and the speed of the wind.

Basic parts of wind turbines: blades, a tower, and a gearbox. They work together to transform the wind's kinetic energy into mechanical energy that generates electricity.

- The moving air spins the turbine blades. The blades are connected to a low-speed shaft. When the blades spin, the shaft turns. The low-speed shaft is connected to a gearbox. Inside, a large slow-moving gear turns a small gear quickly.
- The first small gear turns another shaft at high speed. The high-speed shaft is connected to a generator. As the shaft turns the generator, it produces electricity.
- The electric current is sent through cables down the turbine tower to a transformer that changes the voltage of the current before it is sent out on transmission lines.

III. Design Calculations

A. Concept Design:

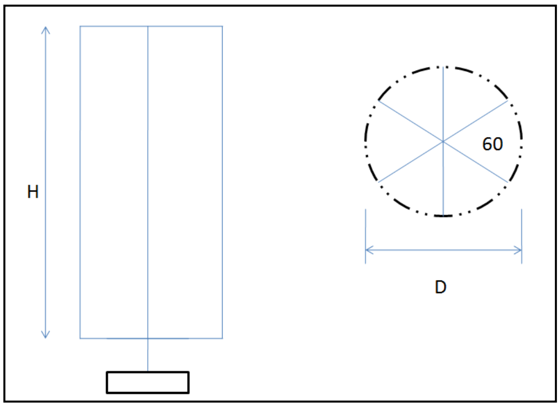


Fig. 1: Concept design

Blade thickness=12mm
Power required= 15watt
V=3.41m/s
Cp=0.245
ρ Air=1.225 kg/m3

1) Power extracted from wind by turbine

$$pt = 0.5 \times \rho \times A \times Cp \times v^3$$
$$15 = 0.5 \times 1.225 \times A \times 0.245 \times 3.41^3$$
$$A = 2.52m^2$$

If no. of blade is 6

$$\frac{2.52}{6} = 0.42\text{m}^2$$

Blade thickness=12mm
Disc Thickness=1.5mm
No. of blades=6
Shaft outer diameter=32mm
Shaft inner diameter=29mm
Length of the shaft=1500mm
Disc outer diameter=832mm
Disc inner diameter=32mm
Length of blade=300mm
Design Process of WAVT Aerofoil shaped Drag type:
Choose Turbine size
Choose a TSR
Calculate angle of attack
choose Airfoil (GIVEN)
Given Data:
Power required = 15 watt
Coefficient of performance = 0.245
Velocity of air = 3.41 m/s
Air density = 1.225 kg/m3
airfoil shape with 6 number of blades
Power generated by turbine:

$$Pav = \frac{1}{2} \times \rho \times Cp \times A \times V^3$$

$$15 = \frac{1}{2} \times 1.225 \times 0.245 \times A \times 3.41^3$$

$$A = 2.52\ m2$$

Power Available in wind:

$$Pav = \frac{1}{2} \times \rho \times A \times V^3$$

ρ = density of air
A = swept area of turbine
V = undisturbed wind velocity

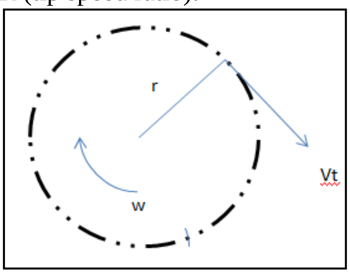
$$Pav = \frac{1}{2} \times 1.225 \times 2.52 \times 3.41^3$$

$$Pav = 61.2\ watt$$

Combination of Diameter and Height for calculated area:

Parameter	Area = 2.52 m2	Area = 2.52 m2	Area = 2.52 m2
Diameter	1.5 m	1.4 m	1.26 m
Height	1.68 m	1.8 m	2 m

Input Data:
Dia = 1.26 m
Height = 2 m
Air velocity = 3.41 m/s
Cp = 0.245
Density = 1.225 Kg/m3
Output :
Turbine area = 2.52 m2
Power available = 61.2 watt
Power generated = 15 watt
Maximum TSR (tip speed ratio):



$$Vt = \omega r$$

$$\omega = \frac{rad}{sec}$$

$$r = m$$

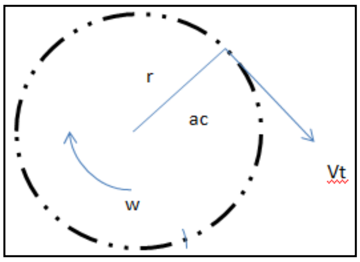
$$TSR = \frac{Vt}{Vwind}$$

$$\omega = N \times \frac{2\pi}{60}$$

$$r = \frac{d}{2}$$

$$TSR = \frac{\pi N d}{60 \times Vwind}$$

Radial Acceleration:



$$ac = \omega^2 r$$

$$ac = \left(\frac{\pi N}{30}\right)^2 \times \frac{d}{2}$$

compare with gravity,

$$G = \frac{ac}{9.81}$$

$$r = \frac{1.26}{2} = 0.63\ m$$

consider N = 120 rpm

$$\omega = 120 \times \frac{\pi}{30} = 12.56 \frac{rad}{sec}$$

$$ac = 12.56^2 \times 0.63 = 99.38\ m/s2$$

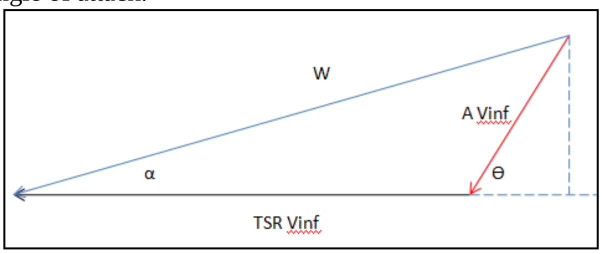
$$G = \frac{99.38}{9.81} = 10.1$$

$$TSR\ max = \frac{12.56 \times 0.63}{3.41} = 2.32$$

Input:
Dia = 1.26 m
Limits:
air velocity = 3.41 m/s
rotation = 120 rpm
w = 12.56 rad/sec
Output:
TSR = 2.32
ac = 99.38 m/s2
G = 10.1
Changing RPM,

Percentage %	G's	Accel m/s2	Speed rad/s	Speed RPM	TSR	Radius m	V wind m/s
100%	10.1	99.38	12.56	120	2.32	0.63	3.41
83	7.0	69.02	10.47	100	1.93	0.63	3.41
75	5.7	55.90	9.42	90	1.74	0.63	3.41
67	4.5	44.17	8.37	80	1.55	0.63	3.41
58	3.4	33.82	7.33	70	1.35	0.63	3.41
50	2.5	24.85	6.28	60	1.16	0.63	3.41
42	1.8	17.25	5.23	50	0.97	0.63	3.41
33	1.1	11.04	4.19	40	0.77	0.63	3.41
25	0.6	6.21	3.14	30	0.58	0.63	3.41
17	0.3	2.76	2.09	20	0.39	0.63	3.41

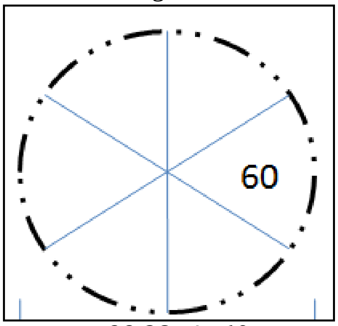
Angle of attack:



$$\tan \alpha = \frac{a\, V_{\infty} \sin \theta}{a\, V_{\infty} \cos \theta + TSRV_{\infty}}$$

$$\alpha = \tan^{-1}\left[\frac{a\ \sin \theta}{a\ \cos \theta + TSR}\right]$$

6 number of blade, Hence angle between two blades s 60



$$\alpha = \tan^{-1}\left[\frac{99.38\ \sin 60}{99.38\ \cos 60 + 2.32}\right] = 31.14$$

IV. DESIGN OF BLADE:

The blade is designed in Airfoil shape so as one blade passes another blade comes in the position of first. 6 blades are used so as to use of maximum utilization of wind

In the project six blades with vertical shaft are used, it has a height & width of 2 m & 1.26 m respectively. The angle between two blades is 60. The material used for the blade is Mild steel. This material is taken because it is low-cost and the weight is also less, due to this the project weight also decreases and due to this the rotational speed also increases so as output

V. CAD MODELING

CAD, or computer-aided design and drafting (CADD), is the use of computer technology for design and design documentation. CAD software replaces manual drafting with an automated process. If you work in the architecture, MEP, or structural engineering fields, you've probably used 2D or 3D CAD programs. These programs can help you explore design ideas, visualize concepts through photorealistic renderings, and simulate how a design will perform in the real world. AutoCAD software was the first CAD program, and it is still the most widely used CAD application. CAD depending on whether your design process involves 2D vector-based graphics or 3D modelling of solid surfaces. Most 3D CAD programs let you apply multiple light sources, rotate objects in three dimensions, and render designs from any angle.

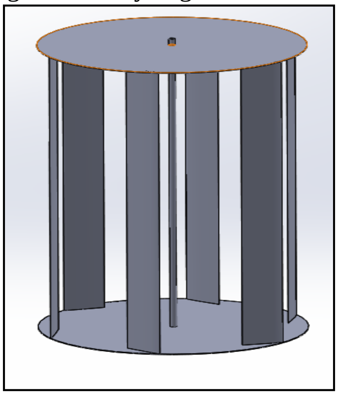


Fig. 2: Isometric View of Vertical Axis Wind Turbine

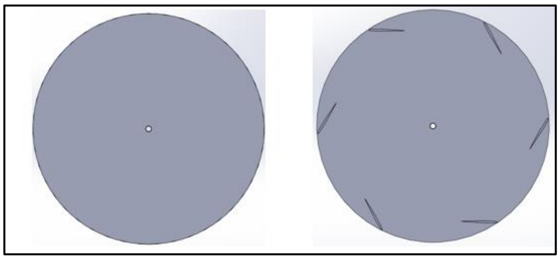


Fig. 3: Different view of Vertical Axis Wind Turbine

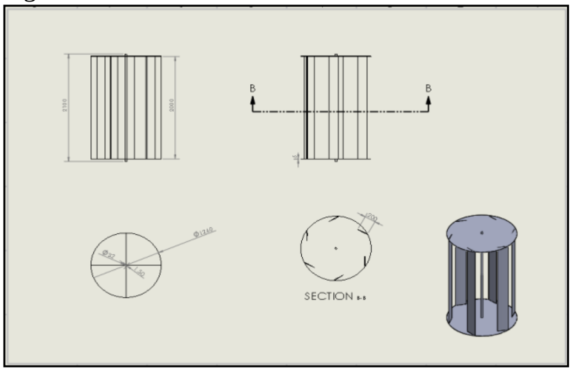


Fig. 4: Detailed view of Vertical Axis Wind Turbine

VI. CFD ANALYSIS

Computational Fluid Dynamics (CFD) is the simulation of fluids engineering systems using modeling (mathematical physical problem formulation) and numerical methods (discretization methods, solvers, numerical parameters, and grid generations, etc.). The process is as figure

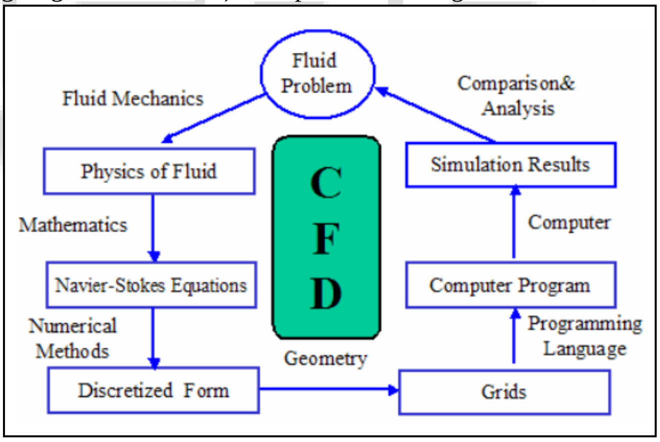


Fig. 5: Process of computational Fluid dynamics

Firstly, we have a fluid problem. To solve this problem, we should know the physical properties of fluid by using Fluid Mechanics. Then we can use mathematical equations to describe these physical properties. This is Navier-Stokes Equation and it is the governing equation of CFD. As the Navier-Stokes Equation is analytical, human can understand it and solve them on a piece of paper.

A. FE modelling:

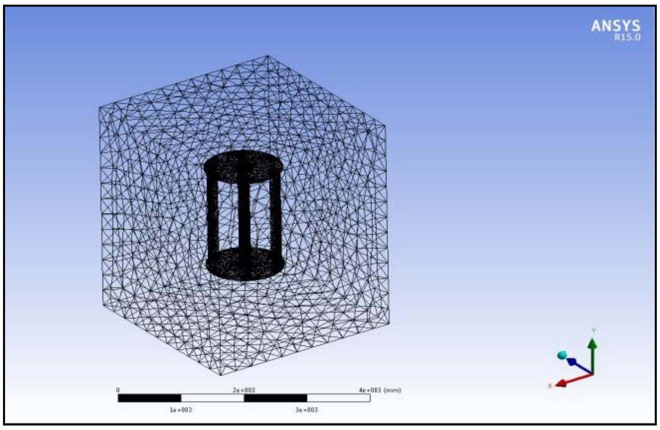


Fig. 6: Isometric View of FE model

B. Boundary Conditions:

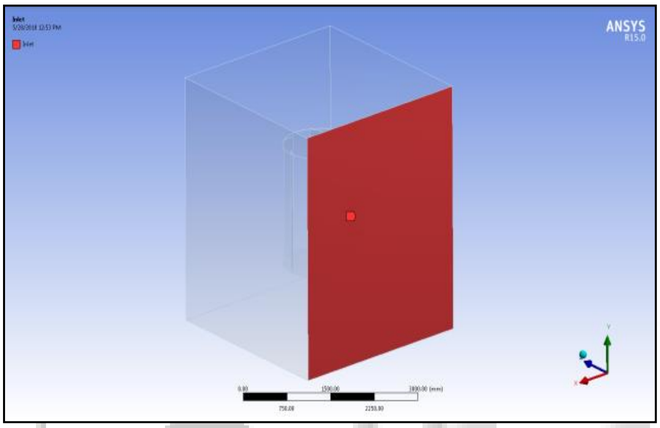


Fig. 7: Inlet

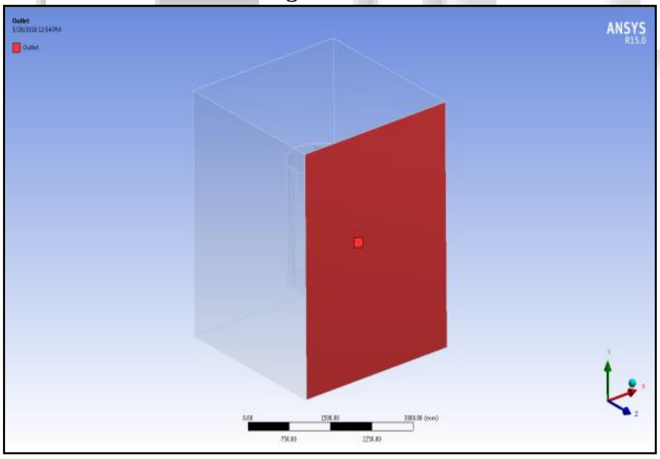


Fig. 8: Outlet

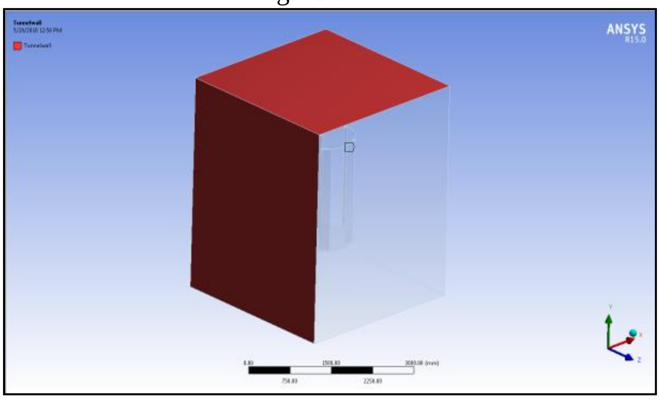


Fig. 9: Boundary wall

C. CFD ANALYSIS OF THE DRAG TYPE VAWT

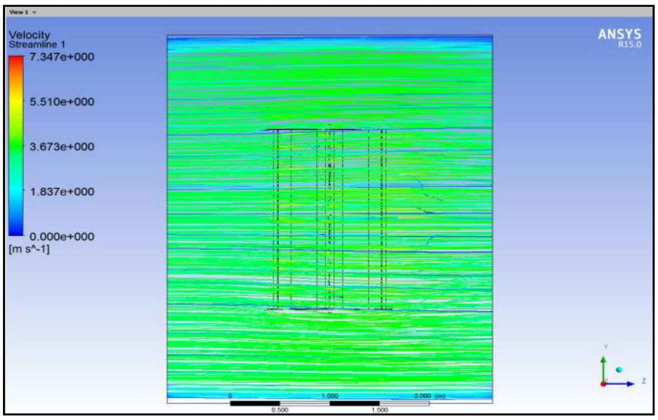


Fig. 10: Stream lines of inlet velocity 3.41 m/s and exit velocity 1 m/s over a VAWT in Wind tunnel

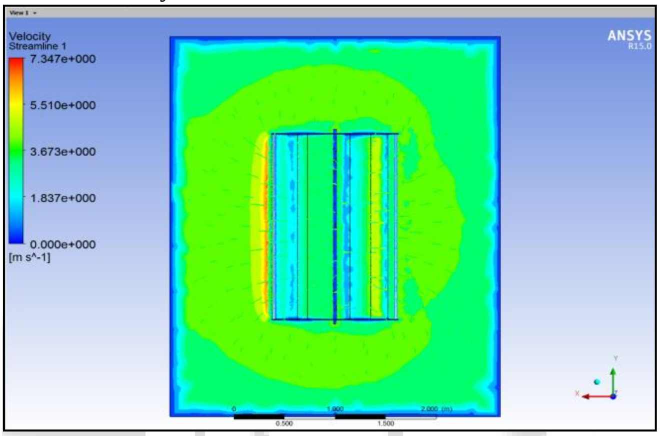


Fig. 11: Stream lines of inlet velocity 3.41 m/s and exit velocity 1 m/s over a VAWT in Wind tunnel

VII. RESULT DISCUSSION

In present study, we have designed a Vertical Axis Wind Turbine for 15 watts power output. dimensions obtained from calculation for Vertical axis wind turbine are 1.26m diameter of turbine and 2m height of the turbine. with 6 blade configuration to obtain maximum power from the wind. at inlet velocity 3.41 m/s exit velocity 1m/s is obtained at blade from computational fluid dynamics

VIII. CONCLUSIONS

In present study, we have designed a Vertical Axis Wind Turbine for 15 watts power output by performing design calculations as per the data accumulated and literature studied. By using CAD software Solidworks a CAD model of Vertical axis wind turbine is modeled as per the dimensions calculated. To study flow pattern and exit velocity over the blade of wind turbine a computational fluid Dynamic analysis is carried out. with the inlet velocity 3.41 m/s, output velocity obtained is 1 m/s.

REFERENCES

[1] DharampalYada ,HaripalDhariwaandBarun Kumar Roy"MODIFICATIONS IN DOMESTIC WIND TURBINE"Corresponding Author: DharampalYadav, dharampal_er02@yahoo.com

[2] Practical Analysis of A Small Wind Turbine for Domestic Use on Latitude 7.0670N, Longitude 6.2670E"Odia O. Osadolor, Ososomi . Sunday, Okokpujie I. Princes.Faculty of Engineering and Technology, Ambrose Alli University, Ekpoma, Nigeria;
[3] VaibhavR.Pannase,Prof.H.R.Bhagat,Prof.R.S.Sakarkar "Optimization Design, Modeling And Dynamic Analysis For Wind Turbine Blade" (Department of Mechanical Engineering, BabasahebNaik College of Engineering.,Pusad 2(H.O.D.,Department of Mechanical Enginering, Jagadambha College of Engg.& Technology,Yavatmal .
[4] Navin Prasad E, Janakiram S, Prabu T,Sivasubramaniam S Design and development of horizontal small wind turbine blade for low wind speeds PG, Department of Mechanical, PSG College of Technology, Tamil Nadu, India
[5] RakeshRoshan, PawanMirshra, Mahendra Agrawal "Analysis of Blade Design, Power Output and Efficiency of A Horizontal Axis Wind Turbine on A Working Model". M.Tech., Thermal System & Design, Research Scholars, SRCEM Banmore Gwalior, M.P, India
[6] K. Sunil Kumar and R. Palanisamy "Design and analysis of windmill blades for domestic" applications Mechanical Department, Veltech, Avadi, Chennai-India

