TEFUGEN
Technologies for Future Generation

# Design and CFD analysis of Horizontal Axis Wind Turbine (HAWT)

## Objective

Design and analysis of 1 kW Horizontal Axis Wind Turbine (HAWT) for low power generation application. Wind turbine blade profile generation through analytical approach and assessment of the aerodynamic characteristics of wind turbine using Computational Fluid Dynamics (CFD).

## Challenges

- To select suitable axial induction factors for higher angular velocity of wind turbine blades.
- To achieve uniform load distribution along the blade.
- Matching of generator characteristics with WT performance.

## CAD Model

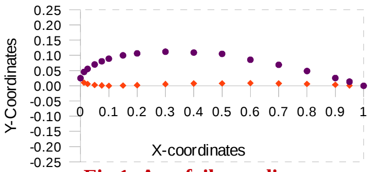



**Fig 1: Aerofoil coordinates**

**Fig 2: Aerofoil CAD model**

## CFD Model

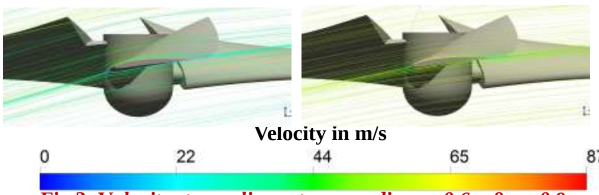



**Fig 3: *Velocity stream lines at span radius r =0.6m & r =0.9m***

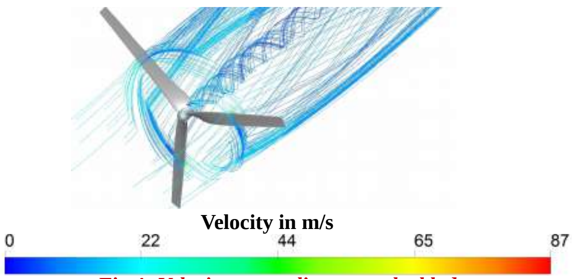
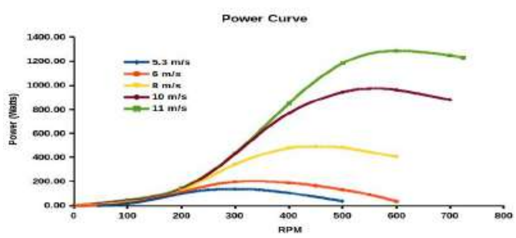



**Fig 4: *Velocity stream lines over the blade***




**Graph 1: Performance characteristics prediction of 1 kW HAWT**

## Analytical Approach:

In this case study, based on the wind speed (wind power) available at the installation location appropriate Tip Speed Ratio (TSR) and wind turbine blade diameter was chosen (TSR 6.9 and Dia 2m). The axial induction factor was determined through iterative process and based on that the relative approaching axial wind velocity was determined through standard analytical approach. Blade settling angle (β°) was determined from relative wind velocity and angle of attack,suitable aerofoil profile (GOE 682) was chosen for the case study. Performance characteristics (Drag and Lift) of the chosen aerofoil profile, for various angle of attack was assessed using X-Foil (2-D) and CFD model (3D).

## Computational Approach:

Steady state, RANS based K-ω turbulence model was used to resolve the flow field of air over the wind turbine blades. Fluid was considered to be incompressible. Near wall turbulence and flow separation at blade walls were resolved using boundary layer cells with y+ value of ~50. Rotary motion (RPM) was imparted on blades and rotor of wind turbine through moving reference frame (MRF) methodology. Turbulent parameters such as Turbulent intensity and length scale were determined for the respective wind velocity assigned at inlet. Performance characteristics of the wind turbine namely drag and lift were assessed for various inlet wind velocity and resultant power generated were also predicted **(Graph 1)**. Based on predicted shaft power the power coefficient $C_p$ was found to be 0.48. Analytical and computational results are summarized in **Table 1.**

| S. No | Parameters | Analytical | CFD – Prediction |
|---|---|---|---|
| 1 | Pressure Torque in N-m | 19.48 | 19.07 |
| 2 | Power (shaft) in W | 1478.29 | 1227.24 |
| 3 | Power Coefficient | 0.589* | 0.48 |

**Table 1: Comparison of Theoretical Calculation with CFD**

** Analytical formulation doesn't include viscous force on wind turbine blade. [Zero drag]*

## Conclusion

Results obtained from CFD analysis were in close match with the analytical values, **deviation between analytical and simulation results were noted to be less than 3%.** Choosing the right type of aerofoil profile with appropriate axial induction factor for the blades of an HAWT is of paramount importance for maximum energy conversion from the available wind power. Use of CFD analysis at the design stage could be a valuable tool to obtain detailed understanding of the working and power generation potential of a chosen wind turbine blade for any installation location. Efficient design of smaller capacity HAWT for domestic power generation applications could reduce the dependency on fossil fuel based power generating sources and significantly reduce carbon emission.

## Applications

- Low power generation application, in urban and rural areas.
- Supplementary power supply to grid.
- Small scale industry power generation application.

## Benefits

- Renewable energy resource.
- Zero carbon emission power generation.
- Very low installation & maintenance cost.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