

CFD Modeling of the Neutral Atmospheric Boundary layer above and inside Forest Regions

Background: Wind resource assessment is the core concept of the economical feasibility of a wind turbine farm project. Because of the legal constraints to build wind farms in the vicinity of urban areas, nowadays most of the wind farms are located in countryside. Around 53.1% of Sweden's total land area is covered by forests [1]. Therefore, onshore wind power in Sweden will get into contact with forests.

The previous studies [2-3] show that the forest canopies make higher vertical wind shear and turbulence intensity, compared to the plain areas, which in turn reduce the generated power of a wind turbine. Moreover, the strong vertical wind shear and turbulence give rise to the large fluctuating forces acting on rotor blades which consequently results in higher fatigue loads, higher maintenance costs and shorter lifetime.

Turbulent inflow may be generated in several ways. Traditionally, it was generated from simple spectral models. Although these models are generally computationally efficient, they may suffer from their simplicity. To overcome these shortcomings and to provide more realistic turbulence fields, Computational Fluid Dynamics (CFD) have become more common in recent years to perform wind resource assessment [2-4].

To model the atmospheric boundary layer (ABL), different disciplines such as boundary-layer meteorology, geology and climatology must be taken into consideration. In addition to various number of meteorological phenomena such as the Coriolis force, buoyancy forces and heat transport, the impact of the *Forest Canopies*, where the ABL flow encounters with a wide range of different turbulent motions and a wind-speed profile with large vertical wind shear, must be carefully taken into consideration.

Objective: The aim of the project is to assess the effect of the forest canopies on energy production (power curve) and dynamic response of the wind turbine.

The commercial CFD software **STAR-CCM+** will be used to model the airflow. The forest canopies model may be done as either porous media or drag force. Either Large-Eddy Simulation (LES) or Detached-Eddy Simulation (DES) model may be used to predict the atmospheric turbulence and wind profile over the forest.

The computed velocity field by STAR-CCM+ will then be supplied to the aeroelastic solver called **FAST** [5] (Fatigue, Aerodynamics, Structures and Turbulence). FAST is an open-source CAE tool for simulating the structural and system response of wind turbines developed by NREL. It includes various modules for aero-hydro-servo-elastic simulation predicting motions, loads and performance of the wind turbine (<https://nwtc.nrel.gov/FAST>).

Project description: In this project, student(s) will simulate the neutral ABL using STAR-CCM+ over a horizontally homogeneous forest and over a flat terrain with low aerodynamic roughness (referred to the forest and non-forest regions). Next, they will run FAST using the computed turbulent inflows. Finally, the power production and dynamic response of the wind turbine exposed to these wind fields will be compared.

Prerequisites: STARCCM+, MATLAB programming language, Fluid Mechanics.

No. of student: one/two.

No. of Credits: 30/60 hp.

Supervisor: Dr. Hamidreza Abedi, Div. of Fluid Dynamics, abedih@chalmers.se

Examiner: Prof. Lars Davidson, Div. of Fluid Dynamics, lada@chalmers

References: [1] Statistics Sweden. p. 42. Retrieved 14 June 2011.

[2] Deardorff, J.W., “Numerical investigation of neutral and unstable planetary boundary layers”, Journal of the Atmospheric Sciences, Vol. 29, No. 1, pp. 91-115, 1972.

[3] Bengtsson, J., “Turbulence Wind Flow Modeling in Complex Terrain; A Comparison Between a Linear Model, a CFD Model and a NWP Model”, Master’s thesis in Applied Mechanics, Department of Applied Mechanics, Chalmers University of Technology, Göteborg, Sweden. 2015.

[4] Nebenführ, B. and Davidson, L., “Influence of a Forest Canopy on the Neutral Atmospheric Boundary Layer-a LES Study”, ETMM10: International ERCOFTAC Symposium on Turbulence Modelling and Measurements, Marbella, Spain, 2014.

[5] <https://nwtc.nrel.gov/FAST>.

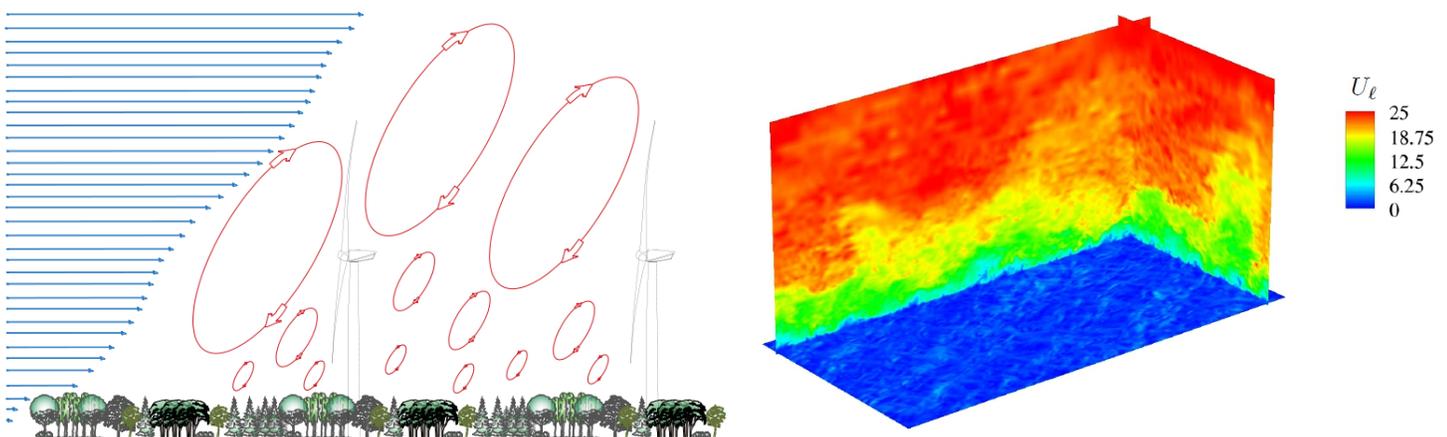


Figure 1: Schematic and simulated flow field inside and above a forest [4].