CFD Modeling of the Neutral Atmospheric Boundary Layer over Complex Terrain

Background: Wind resource assessment is the core concept of the economical feasibility of a wind turbine farm project. Wind turbines always operate within the Atmospheric Boundary Layer (ABL) and are therefore subjected to atmospheric turbulence. Therefore, prediction of flow field is extremely important for design purposes which accordingly reduces operating and maintenance costs and increase turbine's life.

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 [1-4].

To model the atmospheric boundary layer (ABL), different disciplines such as boundary-layer meteorology, geology and climatology must be taken into consideration. Apart from various number of meteorological phenomena such as the Coriolis force, buoyancy forces and heat transport, the effect of ***Complex Terrain***, where the ABL flow is highly variable depending on the location, must be carefully taken into consideration.

Objective: The aim of this project is to assess the effect of the complex terrain on both wind field and dynamic response of the wind turbine.

The commercial CFD software **STAR-CCM+** will be used to model the airflow. Either Large-Eddy Simulation (LES) or Detached-Eddy Simulation (DES) model may be used to predict the atmospheric turbulence and wind profile over the complex terrain.

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).

Moreover, in FAST, the wind field may be computed using **Turbsim**, which is a numerical tool to simulate a full field inflow turbulence. However, in Turbsim, the effect of the complex terrain would not be taken into account.

Project description: In this project, student(s) will simulate the turbulent wind field using STAR-CCM+ over the complex terrain and supply it to FAST. Next, they will run the FAST while generating stochastic inflow turbulence using Turbsim. Finally, to assess the effect of the complex terrain, the dynamic response of the wind turbine by using two different generated wind fields will be compared.

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

No. of student: one/two.

No. of Credits: 30/60 hp.

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[2] Walmsley JL, Troen I, Lalas DP, Mason PJ. “Surface-layer flow in complex terrain: comparison of models and full-scale observations”. Boundary-Layer Meteorology 1990; 52: 259-281.

[3] Jimmy Bengtsson, “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.

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

[6] http://www.twd-wind.com/en/riam.html

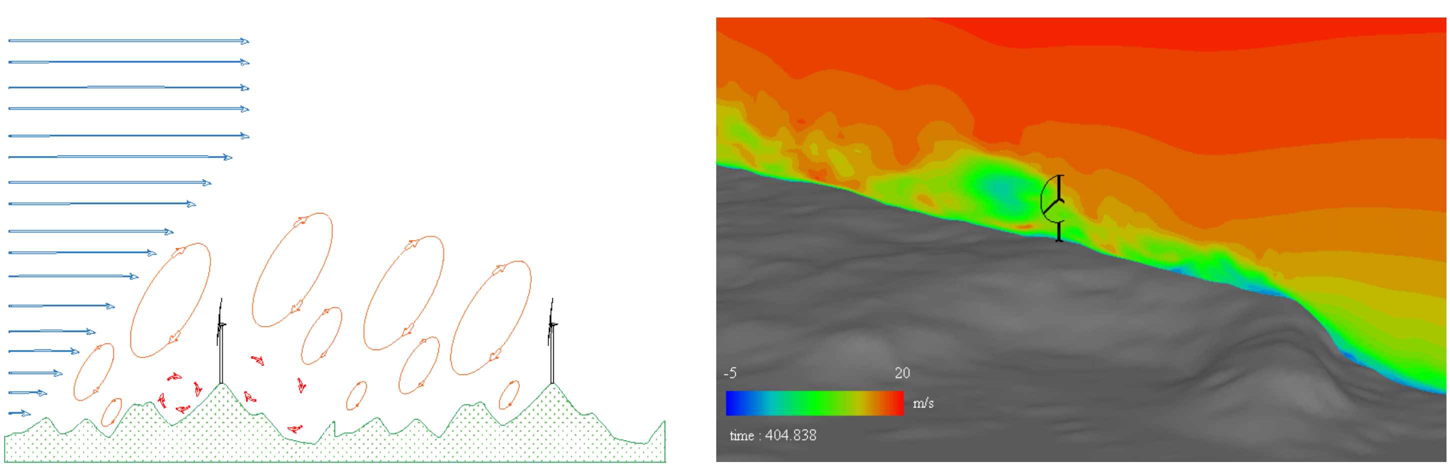

Figure 1: Schematic of the flow over complex terrains and CFD Simulation [6].