Project title	Fatigue Loads in Forest Regions
Project number	TG2-2
Organisation	Chalmers University of Technology, Applied Mechanics
Project leader	Lars Davidson
Other participants	Bastian Nebenführ (PhD student)
Report for	2013-10-01 – 2014-09-30
Participating companies	SKF, Teknikgruppen, WindVector AB, Vattenfall, DIAB

Project description

As a consequence of the development of wind turbines with hub heights above 100m, wind turbines can operate efficiently, even in the relatively low wind speeds above forests. Placement of wind turbines in forest regions has hence become an appealing option. Moreover, permits are usually granted more easily than for wind parks close to residential areas. However, the flow above forests is characterized by strong wind shear and strong turbulence, which induce high aerodynamic loads on the wind turbines. In turn, the increased loads lead to shorter maintenance intervals and shorten the wind turbines fatigue life.

The present project aims at using CFD for the prediction of the atmospheric boundary layer (ABL) under the direct influence of a forest. Both wind shear and turbulence are inherent in the flow solution and can be stored in a database for subsequent use as input in load calculations. We are able to perform these load calculations in-house, using the state-of-the-art structural wind turbine simulation tool FAST. Additionally, load calculations can be performed by our project partner, Teknikgruppen, using their tool, ViDyn.

In order to validate the CFD results, measurement data from the Ryningsnäs test site are available.

Results

Numerous Large-Eddy Simulations (LES) of the wind flow over forests have been performed. Even from the rather coarse simulations, good agreement with measurement data is obtained.

Large-Eddy Simulations (LES) were used to predict the neutral atmospheric boundary layer over a sparse and a dense forest, explicitly represented in the computational domain through momentum sink terms. An additional simulation was carried out for flat terrain with a low aerodynamic surface roughness. From these simulations, consecutive cut planes of the fluctuating velocity field were extracted in order to serve as inflow turbulence for simulating the dynamic structural response of the NREL 5MW reference wind turbine using FAST. In this way, the influence of a forest and its density on the fatigue loads could be studied. We chose to analyze the tower-base bending moment (TBBM), the blade-root bending moment (BRBM) and the low-speed shaft bending moment (LSSBM). The results show that, while the mean values of TBBM and BRBM were reduced in the presence of a forest, the standard deviation was increased significantly, due to the increased turbulence intensity, leading to considerably increased equivalent fatigue loads. However, the density of the forest appeared to be of less importance. In contrast, for the LSSBM, both the mean value and standard deviation were found to increase in the flow above the forest. The effect of the spatial resolution of the inflow plane was also investigated and results showed that a spatial resolution of \$16\$ m is sufficient only to a limited extent as input to FAST. Moreover, the fatigue loads obtained by FAST simulations based on LES inflow turbulence and traditional synthetic turbulence, generated by the Mann model, were compared and showed good agreement in terms of spectral content. The resolved turbulence in the LES had sufficient energy to excite the first natural frequency of the wind turbine tower, which had proven difficult in previous studies. In general, we found that the inflow turbulence from LES lead to higher wind turbine loads than the synthetically generated turbulence.

Cooperation with the project “TG2-1: Aerodynamic loads on rotor blades” has been on-going. Atmospheric turbulence from Large-Eddy simulations has been supplied for the use in that project

Bastian defended his PhD thesis 25 September. The projected was terminated 30 September.

Fulfilment of SWPTC's goals

In the project, methods for more accurate prediction methods of aerodynamic loads in forest are developed. This will lead to:

- lighter wind turbines
- increased lifetime of wind turbines
- reduced maintenance costs

Deviations from project plan

No deviations.

Publications

- B. Nebenführ, L. Davidson, Large-Eddy Simulation Study of Thermally Stratified Canopy Flow", Boundary-Layer Meteorology, Vol. 156, number 2 , pp. 253-276, 2015
- B. Nebenführ, L. Davidson, Prediction of wind-turbine fatigue loads in forest regions based on turbulent LES inflow fields (under review), J. Of Wind Energy.
- Nebenführ, B. "Turbulence-resolving simulations for engineering applications", PhD thesis, Division of Fluid Dynamics, Dept. of Applied Mechanics, Chalmers University of Technology, Göteborg, Sweden, 2015.

External activities