Wind turbine simulation in flat and complex terrain using generic wind fields based on Lidar and sonic measurement data

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1. Introduction

The fatigue loads on a wind turbine which is operated in complex terrain vary in general from those occurring in flat terrain. This is due to the fact that the inflow conditions, especially regarding turbulence intensity and wind shear, show a different behaviour for different terrain and wind conditions. The simulation of wind turbines in complex terrain is difficult as the inflow conditions are seldom well known or are not represented by the used wind fields. This work presents approaches for a simulation environment that reflects the behaviour of wind turbines in complex terrain by implementing and using measurement data for an improved simulation of the inflow wind field and also of the turbines itself.

2. Approach

Within the research project “Lidar complex”, funded by the German Federal Ministry for the Environment, a wind field generator based on the Mann uniform shear model [1], which is recommended for design load calculations [2], has been developed with the purpose to use real measurement data as input parameters for wind turbine simulations. Consequently different types of generic wind turbine models have been simulated based on measurement data gathered in flat and complex terrain. The fatigue loads are compared with results based on simulations with standard wind field parameters given in [1]. The special feature of this approach is the application of different data sources such as measurement data from sonic anemometers as well as from ground- and nacelle-based Lidar devices as input data for the wind field generator.

3. Main body of abstract

The Mann turbulence model includes the wind shear which is why it was expected that, especially for complex terrain, it will allow a better simulation environment of the inflow conditions than the Kaimal spectral and exponential coherence model. The Mann model uses linearized Navier-Stokes equations to estimate the wind components u, v, w whereas the Kaimal model calculates the wind components indepently. The model is included in the wind field generator consisting of a pre-processing unit and a post-processing unit. The u, v, w components of the wind field in discrete points are needed to calculate the three necessary Mann parameters i.e. the shear distortion parameter γ, the unsheared isotropic variance σ_{iso}

and the scale parameter l. These wind vector components can be provided by ultra sonic measurements as well as Lidar measurements under certain assumptions and test configurations. Both input data formats have been used to create wind fields which can be exported as rectangular or tubular wind fields with a flexible number of grid points and positions required by different simulation tools for wind turbines.

The necessary measurements were taken at two test sites [3,4] both suited with IEC compliant met masts of 95m and 100m top height and equipped with sonic anemometers on several measurement heights. Furthermore measurements have been taken with ground- and/or nacelle-based Lidar systems including a wind scanner system [5] developed at the University of Stuttgart capable to scan the wind field with flexible trajectories. The terrain type of the first test site in the north of Germany can be categorized as very flat whereas the second test site situated on the Swabian Alb in the south of Germany is very hilly and possesses a more complex character with a steep increase of the terrain in flow direction. (see Fig 1.)

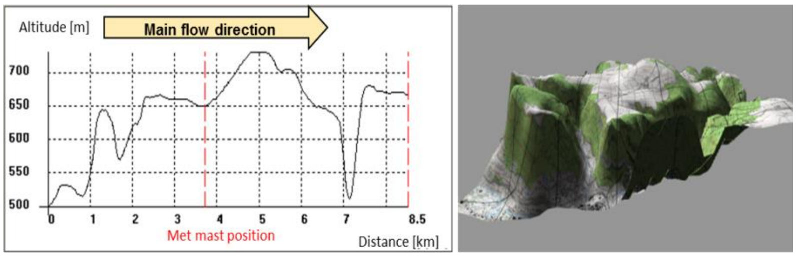

Figure 1: Visualization of complex terrain site

Different generic wind turbines of varying turbine sizes have subsequently been simulated with the aeroelastic simulation tool Flex5. The simulations were carried out for both test sites. The necessary wind fields have been generated with the respective Mann parameters calculated for each site based on measurement data as well as the standard Mann parameters [1]. The whole simulation process is visualized in Fig 2.

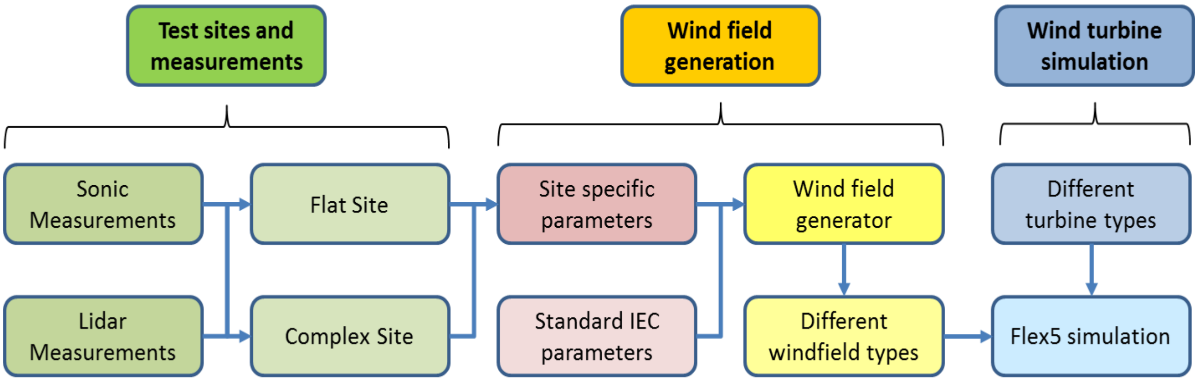

Figure 2: Flow chart of the wind condtions and wind turbine simulation process

Subsequently the resulting fatigue loads for the fundamental wind turbine load quantities [6] like the blade loads, the rotor loads and tower loads have been compared for the different inflow conditions resulting from terrain types and measurement procedures.

4. Conclusion

In this study it is shown how measurement data of different data sources can be used to understand and simulate the wind conditions and consecutively the turbine behaviour in complex terrain with higher accuracy. However further validation of the results and of the actual benefit of this simulation chain regarding load assessment is necessary. Next steps will include also the comparison of real turbine data i.e. damage equivalent loads with simulation results for these specific turbines.

5. Learning objectives

Principles of wind field generation based on measurement data including Lidar data will be shown. The delegate will learn how such measurements can improve the process of wind turbine simulation and load evaluation in complex terrain. Also an overview about wind measurement techniques in complex terrain will be given.

Bibliography

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