Validation of an Aero-Acoustic Wind Turbine Noise Model Using Advanced Noise Source Measurements of a 500 kW Turbine

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In this contribution, the validation of an aero-acoustic wind turbine model including the three dominating noise sources, namely trailing edge (TE), turbulent inflow(TI) and stall noise, will be presented. This study will be based on comparisons with measurements of a 41 m rotor diameter 500 kW wind turbine that will be conducted within the next few months (∼ August-October 2015).

During this experiment, a technique involving surface pressure microphones glued on the airfoil blade near the leading and trailing edges will be tested. In addition, 8 classical shielded microphones for outdoor noise measurements will be located on the ground evenly spaced around the wind turbine. Concerning the turbine itself, the existing SCADA system will be used to monitor rotational speed, blade azimuth, yaw, etc. A nearby met mast will provide information about the atmospheric inflow conditions such as wind shear and direction, as well as turbulence intensity. Finally, the acquisition system is designed so that all measurement devices are synchronized in time.

It is well-known that outdoor noise measurements can be challenging, in particular due to background noise. The far-field acoustic measurements will be analyzed using classical techniques, e.g. as recommended by the IEC-61400-11 standard. Background noise will be simply evaluated by shutting down the wind turbine. However, it is intended to develop more advanced post-processing techniques, such as those used in speech recognition, e.g. Blind Source Separation, Independent Component Analysis, Direction of Arrival estimation, etc, for which different speakers (the different blades in our case) can be separated and background noise can be filtered out.

On the modelling side, since a few years a continuous effort toward the modelling of wind turbine aeroacoustics has been undertaken at DTU Wind Energy. A number of engineering models have been implemented and improved. These studies have concentrated on the main aeroacoustic noise contributions from a wind turbine. More precisely, the TI noise has been modelled using Amiet's theory. It is well known that atmospheric turbulence is not isotropic and the model has been modified to include anisotropy using the so-called Mann's model [1] but this approach could not yet be confronted to actual wind turbine noise measurements (mostly because of the lack of knowledge of the actual atmospheric inflow conditions simultaneously with the acquisition of far-field acoustic data). Concomitantly, the

TE noise also appears to be a dominating noise source. Several studies have been conducted [2, 3] to improve the so-called TNO model which original version suffered from deficiencies, in particular for high angles of attack. Furthermore, there exist evidences that stall noise can under certain conditions produce Amplitude Modulation noise [4] and is certainly a major noise source in the case of stall-regulated wind turbines. Recently, a stand-alone stall noise model has been developed [5] and this will be the opportunity to test and validate the model in real conditions. It is noteworthy that these models are all based on the surface pressure spectra which will be measured during the measurement campaign.

In order to study and model an actual wind turbine, the above models have been implemented within an aeroelastic tool for wind turbine simulations which uses Blade Element Momentum as a basis for the modelisation of the aerodynamic flow impacting the turbine. Therefore, together with the detailed input data from the measurement campaign, this combined aeroelastic and aero-acoustic simulation tool should be able to reproduce the wind turbine noise with good accuracy. It should be noted here that the authors have access to all the data relative to the geometry of the wind turbine since the test wind turbine is owned by DTU Wind Energy.

It is expected that it will be possible to identify the different noise source mechanisms by cross-correlating the measurement data from the surface pressure and field microphones. In addition, these results will be correlated with the wind turbine operating conditions which should shed light on the driving parameters for the different noise mechanisms.

The main axis of research concerning the analysis of the results and the modelling part will be the following:

1. Comparison of measurements with model results - Model validation
2. Identification of noise sources from combined analysis of surface pressure and far-field noise measurements
3. Correlation between source generation and atmospheric conditions (wind speed, turbulence intensity, shear...)
4. Correlation between source generation and wind turbine operation (rpm, stall, yaw, wake operation...)
5. Noise directivity issues in conjunction with dominating noise source
6. Possibility to monitor far-field noise from surface pressure microphones only

References

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