Keywords: harsh conditions, gearbox failure, complex terrain, aero elastic simulation, atmospheric turbulence

Analysis of wind turbines under harsh operation conditions

A. Wickström[a], H. Johansson[b], H. Abedi[c], V. Berbyuk[b], S: Fogelström[e] and O.Carlson[d]

This project focuses on the harsh operational conditions that sometimes lead to gearbox and bearing failures before their expected lifespan have been reached. Individual wind turbines that are subjected to extreme wind conditions and other severe operational conditions have been identified in close cooperation with wind turbine operators. Methods for determining the operational severity from data acquired during operation have been developed. Raw measured data have been processed and compared to the assumed data that were used in the wind turbine design process. Feedbacks from maintenance reports have been used to strengthen the relevance of these indices. A generic V90 turbine model has been created for the simulations using both FAST and VIDYN aero elastic simulation codes. The wind turbine dynamical behaviour has been analysed in arbitrary wind conditions and grid dynamics.

The assessment has been made using 17 wind turbines of same design but with different operational conditions. The data from these turbines have been compared and comparison has also been made using simulated data for complex and flat terrains. The results show that the complex terrain increases the fatigue on the gearbox shaft and the fluctuation of wind direction in the complex terrain is much higher than for the flat terrain, resulting in more destructive fatigue loads. Simulation also shows that de-rating of the turbine has a significant impact on the loads in the drive train but no significant impact on the fatigue loads on the nacelle.

There are different systems running for capturing operational data during operation. Normally the system stores only one measurement data point at each 20 seconds, i.e. 0.05 Hz. Then it is difficult to observe any details related to loads based on turbulence or other environment or technical conditions. For that reason, the project has managed to get higher resolution measurement data, 1 Hz sample rate, for specific turbines in the available fleets.

The complex topography of a specific wind farm was extracted from LASer data and it was imported into the Computational Fluid Dynamics (CFD) software, STAR-CCM+, to generate the computational wind grid for the numerical simulations. The on-site meteorology mast data, provided by project partners, were used to determine the dominant mean wind speed/direction and turbulence intensity.

A system simulation model in FAST or VIDYN can reasonably well predict the hub forces and mechanical torque of a Vestas V90 turbine under different kind of wind load in operation. A turbine designer is allowed to use any specific wind conditions as input for the load calculations. It might be outside the wind classes specified in IEC-61400-1 and therefore denoted class S, where the specific input conditions are stated. Using the calculated data for the complex terrain, a class 3S turbine has been defined with turbulence intensity, TI=0.17, shear $\alpha = 0.34$ in comparison with standard wind turbine class 3A with TI=0.16 and $\alpha = 0.20$. When using these input conditions, a fatigue load comparison and evaluation has been done. It shows that both drive torque and tower top bending moment increase with about 6 percent when class3S is used.

[a] RISE, Research Institutes of Sweden
[b] Division of Dynamics, Chalmers University of Technology
[c] Division of Fluid Dynamics, Chalmers University of Technology
[d] Division of Electric Power Engineering, Chalmers University of Technology
[e] Swedish Wind Power Technology Centre, Chalmers University of Technology