Controlling loads in a wind turbine drivetrain

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Introduction

Wind turbine drivetrains are subjected to large dynamic loads, coupling two high inertia components with rapidly changing aerodynamic and generator loads. Events including emergency stop, gust, and grid changes cause torque overload, torque reversal and non-torque gearbox loads.

This presentation will demonstrate the importance of understanding these transient events, and changing designs to avoid them. This is crucial in improving drivetrain reliability while avoiding the overdesign that leads to very high tower top mass.

Driveline reliability continues as an issue, with evidence from insurers showing that claims remain high for gearbox failures in offshore wind turbines[1].

Approach

We use aeroelastic simulation of conventional wind turbine drivetrains to identify how transient events result in high drivetrain loads. We then show how innovative generator control strategies can affect theses loads, and show the implication of these control strategies on other turbine parameters.

We review the underlying material physics of failure relevant to wind turbine gearbox bearings, and identify that conventional fatigue calculations are not suitable, as the loading conditions are significantly outside the area where standard fatigue theory is valid.

We propose an innovative mechanical and hydraulic load control device to decouple the gearbox from off-axis loads, and to limit torque overload and mitigate torque reversals in the drivetrain. We show multibody simulation results, demonstrating the behaviour of the load limiting device. We show results from a scale prototype, validating the simulation results.

We then use a combined mechanical and aeroelastic simulation model to demonstrate the integration of the load control device within the overall turbine system.

Main body

The current solution to wind turbine drivetrain reliability is overdesign, using a very high safety factors in the design process, via the design load cases and design safety factors [2]. This may itself be causing problems as lightly loaded bearings are actually more at risk for skid type failure mechanisms [3], as well as the obvious cost of high tower top mass. The need for this overdesign shows that the loads are not properly understood, or are not at a level where the conventional damage models used in the certification standards are valid.

We will present an alternative approach, were we use measurement and simulation, coupled with an understanding of the underlying failure mechanisms to review why wind turbine gearboxes have had such severe durability problems, and using this knowledge to propose solutions to avoid the conditions that cause this damage.

We show how through the application of these solutions, drivetrain loads could be controlled into regions where conventional and well known damage models apply, therefore allowing the design of a drivetrain with reduced mass, and high and well understood reliability. The reduction in levelised cost of energy will be shown, in the range of 5 to 13%.

Conclusions

Through the application of simulation, fundamental research into damage mechanisms, and understanding the coupling between aerodynamic, mechanical and controller behaviour, we can understand and propose solutions to wind turbine driveline damage, and avoid the current approach of overdesign.

Learning Objectives

- Show the link between control strategy and mechanical loading in wind turbine drivetrains.
- Show why conventional fatigue methods should not be applied outside their area of applicability, and why this can have a significant result on design decisions.
- Show how control and mechanical solutions can be implemented to improve drivetrain load conditions, into regions where conventional and well known damage models apply.

References:

1. Sam Millard & Jonas Dalsgaard, Poster presentation: *Reducing the cost of offshore wind by sharing risk improvement measures: an insurer's approach*, Codan Forsikring A/S, EWEA Offshore, 2015
2. *Guideline for the certification of Offshore Wind Turbines*, Germanischer Lloyd, 2012
3. Sharad Jain & Hugh Hunt, *A dynamic model to predict the occurrence of skidding in wind-turbine bearings*, 2011, Journal of Physics, 305(1).