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A simulation concept for the azimuth system of horizontal axis wind turbines

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Abstract

The global challenge of limited fossil resources causes a growing significance of renewable energies. Due to their comparatively high energy efficiency wind turbines play an important role to accomplish the switch to sustainable energy sources. A robust design of these systems in terms of fatigue behaviour is a prior target in the dimensioning process. In general, this requires experimental analyses, which in practice, are not feasible over the entire product life cycle. Therefore, reliable simulation models have become indispensable for both analysing the system dynamics in the design phase on the one hand, and identifying specific causes of failure in existing constructions on the other hand. At the same time constantly rising computer capacity allows an increasing depth in detail for simulations.

This contribution provides an approach to display the dynamic effects occurring in the azimuth drive, also called yaw system, of a 2 MW wind turbine designed by W2E Wind to Energy (W2E), see Figure 1. The azimuth unit primarily ensures the correct orientation of the nacelle relative to the respective wind direction. The analysed system in particular consists of four electrical drive units followed by multistage planetary gears and integrated brake assemblies. Additionally, four hydraulic brake units keep the nacelle in position after a succeeded yaw procedure. The drive units are installed in the nacelle and mesh with a gear ring mounted on the tower head. Therefore, the azimuth system is redundantly actuated. However, due to their high transmission ratio the drive units possess specific flexibilities in the gear stages. Associated with this is a number of practical challenges, that must be considered for yaw procedures. For example not all of the drive units will usually start simultaneously, once the control command to yaw is given. Among other issues, this may cause interlocking between the drive units, which can subsequently lead to significant peaks in the drive train loads.

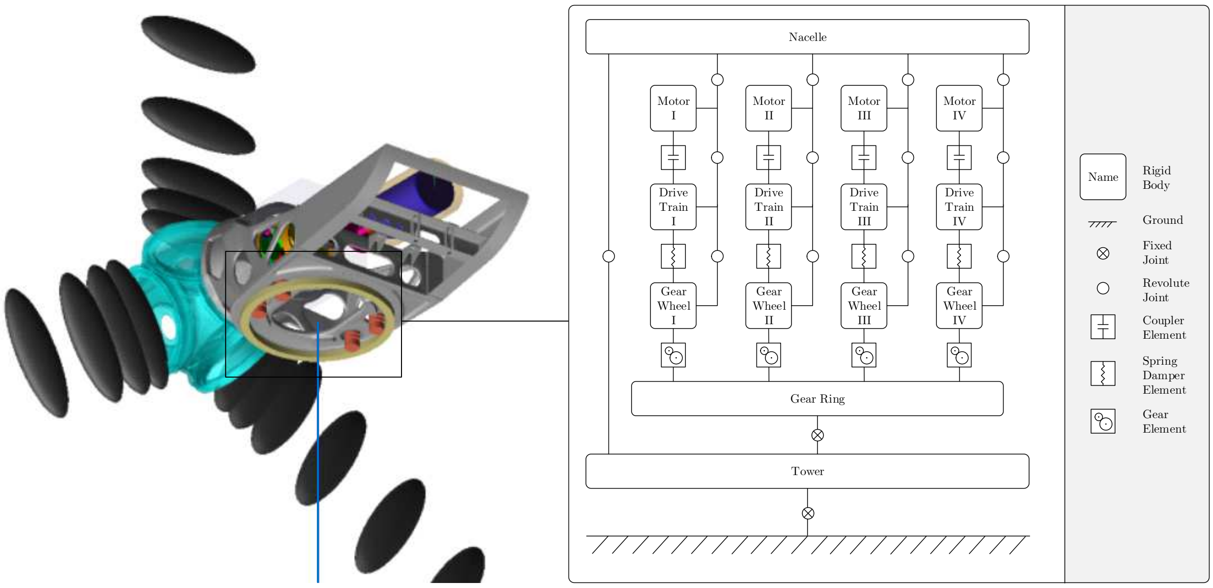

Figure 1: Mounting position and multibody topology of the azimuth system

In the context of this contribution a multibody simulation model of the azimuth drive is built up as an extension to an already existing flexible model of the entire 2 MW turbine including components, such as the main drive train with gear pair contact or a lattice tower [2]. Further theoretical background

information on multibody systems is provided by [1]. As simulation environment the general purpose multibody package MSC.Adams® is used. A major requirement to the model is the ability of reproducing the dynamic properties of the real system. Therefore, the dynamic behaviour of the azimuth drive units is assumed to be represented by a two-mass oscillator including respective inertia properties as a first approximation. Frictional losses of the gear pair contacts are not considered, and thus the planetary gear stages can be reduced to a total transmission ratio. Both drive train flexibility and internal clearance are represented by a torsional spring, based on nonlinear spring characteristics recorded by W2E. The brake units are modelled under the assumption of Coulomb friction. Appropriate parameters are available from the manufacturers. For forward dynamics simulation of the two-mass oscillator a torque controller is implemented for each drive motor. After all, the entire simulation model is fully parametrised using MATLAB®. The validation process is based on measured data provided by W2E, which were recorded on an existing prototype of the 2 MW wind turbine.
In the present contribution a number of important load cases is investigated. Exemplary the major effects of one drive unit starting delayed is depicted in Figure 2. The simulation is performed with due regard to wind loads on the turbine that have to be compensated by the azimuth system. A user defined turbulent wind field is generated by TurbSim, developed by the National Renewable Energy Laboratories (NREL), before the respective aerodynamic loads on the rotor blades are computed by the aerodynamic code AeroDyn, also provided by NREL. The resulting load input on the azimuth system is shown in Figure 2a. In a next step the nacelle orientation is to be changed by 20° about the vertical axis, see Figure 2b. The respective speed characteristics of the drive units with motor I starting delayed by 1 s are depicted in Figure 2c. As shown in Figure 2d this results in interlocking between the drive units and thus leads to different load levels in the corresponding drive trains. These additional loads should be considered in the design process in order to prevent premature fault of the drive units.

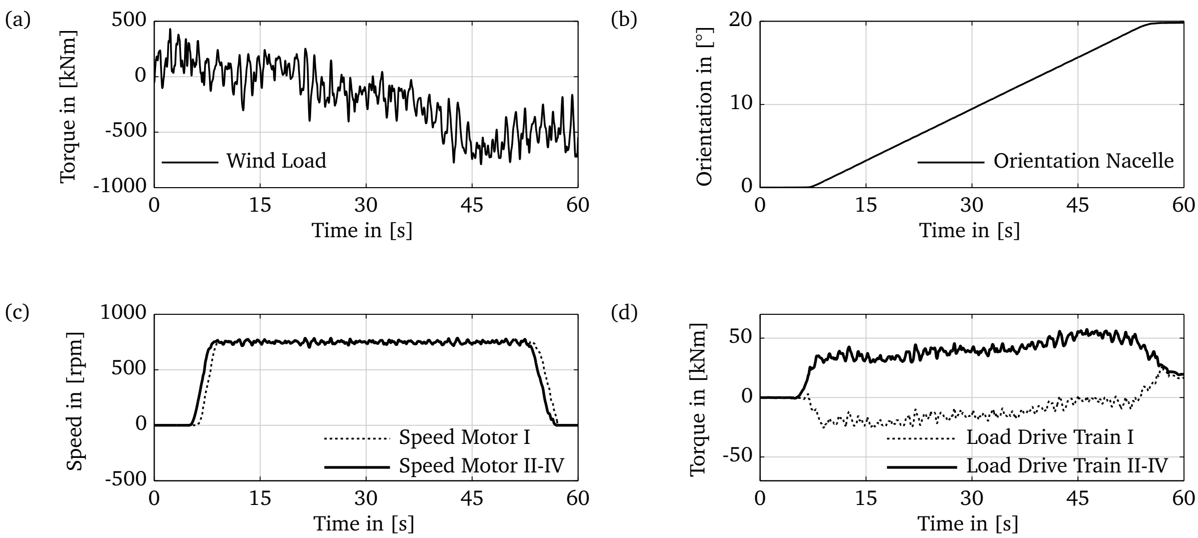

Figure 2: Load case of motor I starting delayed by 1 s

References

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[2] J. Zierath, R. Rachholz, C. Woernle. Comparison of various Multibody Codes for Wind Turbine Modelling and their Experimental Validation by means of Prototype Testing. Multibody Dynamics: Computational Methods and Applications (Computational Methods in Applied Sciences). Zdravko Terze (Ed.), pp. 545-557, Springer, Amsterdam, 2014.