Simulation of a small wind turbine with a bolted lattice tower under consideration of mass distribution and damping

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Abstract

This research describes investigations on a multibody model of a prototype small wind turbine under consideration of damping and mass distribution effects at the tower structure. The prototype is a horizontal axis, stall-controlled wind turbine characterised by a rated power of 50 kW and a hub height less than 50 meters. The multibody model is developed in SIMPACK and applies aerodynamic forces by means of interfaces for aerodyn and turbsim [3,4]. The prototype wind turbine is equipped with a lattice tower with bolted joints. The overall multibody model will be used for design load case simulations due to regulations of classification societies like IEC or the Germanischer Lloyd (GL) [2,6]. The multibody model is validated by comparisons with measurements during operation of the wind turbine.

The model of the lattice tower of the wind turbine in SIMPACK is based on a finite element model built up in Ansys that consists of beam elements. To incorporate it into the multibody environment it is modally reduced by means of Craig Bampton method. The Ansys model is generated by an APDL (Ansys Parametric Design Language) text file defined by a MatLab Script in order to enable immediately design modifications like the overall height, the kind of bracing and dimensions of profile cross sections. The first two bending modes and a torsion mode of the lattice tower of the prototype are shown in Fig. 1.

Moreover, it is possible to apply lumped masses at different positions on the tower structure representing additional installations like ladders, maintenance platforms and cables. Due to the low mass of the lattice tower structure itself, the effects of these installations cannot be neglected. Their typically unsymmetrical distribution leads to the dynamic behavior of the wind turbine that depends on the actual wind direction that has to be taken into account in the certification process.



Figure 1: Bending and torsional modes of the elastic lattice tower model.

The damping of lattice towers with bolted joints is mainly governed by local joint patch damping effects, in contrast to steel tube or concrete towers showing equally distributed material damping. The

finite element formulation of the overall lattice structure defined in Ansys only takes into account the material damping and does not include joint patch damping. In order to include joint patch damping effects into the multibody model a resonance test stand of a single bolted joint equipped with measurement appliances was built up [5]. The overall setup consists of two cylindrical bodies suspended by wires at the center of gravities and connected to each other by the bolted lap joint as shown in Fig. 2a and is based on [1]. The setup is excited by an electrodynamic shaker in axial direction. The design was defined in such manner that axial deformations are excited only. Moreover we developed the multibody model of the experimental assembly shown in Fig. 2b. To reproduce the measured damping behaviour the setup was modeled in SIMPACK. In the multibody environment the measured damping behaviour was modeled by meas of an adequate force element. The validation is performed by comparing the displacement-force hysteresis between model and measurement. The goal is finally to develop a SIMPACK model of the overall lattice tower consisting of separate beam elements connected by joints and constraints and additionally taking into account material and joint patch damping. This leads to improved estimations of operational loads enabling optimised lattice tower designs.



Figure 2: a Arrangement for resonance test stand. b SIMPACK simulation model

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