Mechatronics 21 (2011) 737–752

Contents lists available at ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

Insights in wind turbine drive train dynamics gathered by validating advanced models on a newly developed 13.2 MW dynamically controlled test-rig

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ARTICLE INFO

Article history:
Available online 10 December 2010

Keywords:
Gear dynamics
Drive train
Wind turbine
Flexible multibody

ABSTRACT

Guaranteeing reliable and cost-effective wind turbine drive trains requires expert insights in dynamics during operation. A combination of advanced modeling techniques and detailed measurements are suggested to realize this goal. The flexible multibody modeling technique enables the simulation of dynamic loads on all drive train components. Moreover it facilitates estimation of structural component deformation caused by dynamic loading. This paper gives a detailed overview of the assumptions made in this modeling approach. Furthermore the influence of the different structural component flexibilities is investigated in detail. To gain confidence in the models created, model validation by means of a comparison with measurements is necessary. To overcome issues concerning test repeatability experienced in field testing, test-rig testing is suggested as a valid alternative. In order to be representative, dedicated dynamic load cases, which represent specific dynamic behavior of the gearbox in a wind turbine need to be realized on the test-rig. However a highly dynamic test-rig complying with the specifications was not commercially available. Therefore Hansen developed a high dynamic test-rig with a nominal power of 13.2 MW and a peak power capacity of 16.8 MW. A back-to-back gearbox configuration was used. The complexity of controlling dynamics of the test-rig was solved by identifying dedicated load cases which represent specific wind turbine behavior. This paper describes the development process of the project consisting of four phases. During two phases a scaled set-up was used, which enabled iterative optimization of the complex interaction between the mechanical dynamics and the electrical controller of the test-rig. In the final part of the paper the two previously discussed approaches are combined, as it discusses results from the validation of simulation models using measurements performed on the 13.2 MW test-rig.

1. Introduction

Wind energy industry has experienced quick growth during the last decade. In the same period, there has been similar growth in wind turbine power output, with new and always bigger designs. Maintaining high product reliability during the evolution towards mature technology in such booming conditions, makes the design of reliable and cost-effective subsystems, such as the gearbox, of great importance. A requirement for reliable gearbox design is accurate load data and sufficient insight in the dynamics of the entire wind turbine drive train. To ensure this, research focuses on advanced modeling and simulation techniques supported by fundamental and elaborate experimental validation.

The operating circumstances of a wind turbine are largely determined by wind field turbulence, electricity grid disturbance and, in the case of an offshore turbine, sea wave excitation. From a simulation point of view, aero-elastic design codes are currently used to model the wind turbine. These codes represent most relevant environmental conditions at the site, including aerodynamic loads [1,2], gravitational loads, inertial loads and operational loads. The latter consist of generator torque, loads induced by certain control actions such as blade pitching, starting up, braking or yawing. As described by Peeters [3], these turbine codes output time series describing load variations. All external conditions are modeled in detail for operational and fault conditions. Expertise of dedicated specialists and research groups in the domains of wind loads, electricity grid, rotor dynamics, generator and control systems greatly contributed to the high quality of these modeling techniques. However the wind turbine drive train is reduced to just a few degrees of freedom in these models, yielding restricted detail in describing the dynamic behavior. In general, the simulated outputs of the traditional wind turbine codes represent mechanical loads at the rotor hub, i.e. at the interface between rotor and gearbox. These loads include load variations at the global level, but lack

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doi:10.1016/j.mechatronics.2010.11.005