Superelement Approach in Fully Coupled Offshore Wind Turbine Simulation: Influence of the Detailed Support Structure Modelling on Simulation Results for a 5-MW Turbine on a Tripod Substructure

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ABSTRACT

Fatigue design and certification of offshore wind turbines (OWT) is performed using aero-servo-hydro-elastic time domain simulations. So far, the local flexibility of the joints in branched OWT support structures has been neglected in those simulations. In this work, a superelement approach, allowing for detailed modeling of local joint flexibility in the OWT design tool ADCoS-Offshore, is presented. The influence of this simulation approach, taking into account joint stiffnesses with the same level of accuracy as detailed finite element models, is described and interpreted using the example of a realistic 5 MW OWT on a tripod in 45 m of water. Further, recommendations for modeling of turbines on this type of structure are given.

KEYWORDS

Offshore wind turbine; ADCoS-Offshore; fully coupled simulation; offshore structure; steel support structures; joint flexibility; substructuring; superelement

INTRODUCTION

Growing turbine size and steps towards deeper waters and serial production of support structures are key parameters describing the current offshore wind energy development. Branched bottom mounted support structures such as tripiles¹, tripods or jackets² ³ are currently used as prototypes and accepted as promising solution for large scale future projects. To allow for cost effective and reliable design, accurate and confidable simulation of the system offshore wind turbine (OWT) is inevitable. Especially for fatigue simulation and certification, aero-hydro-servo-elastic tools are used. A selection of the tools that are currently available is shown by Nichols et al. (2009).

For the purpose of this study, a 5-MW OWT on a tripod support structure was implemented in ADCoS-Offshore. This is the aero-servo-hydro-elastic tool used at Fraunhofer IWES. ADCoS-Offshore is a nonlinear finite element (FE) based tool applying a direct implicit time domain integration scheme. Details on ADCoS-Offshore are provided in Kleinhansl et al. (2004) and Vorpahl et al. (2007).

The model in ADCoS-Offshore incorporates deterministic or stochastic wind fields and modified blade-element momentum (BEM) theory for aerodynamic description of the turbine. Hydrodynamics are described using linear or nonlinear regular waves as well as irregular linear waves combined with Morison’s equation. More details about ADCoS-Offshore are published in Vorpahl et al. (2009b).

So far, ADCoS-Offshore uses beam elements for support structure modeling. This approach neglects local joint flexibilities, that were found to be a critical issue for the following reasons: Joint models implemented with beams and neglecting local flexibilities do not lead to accurate results and the joints are often design driver for the support structures due to fatigue loads (cf. De Vries (2008), Vorpahl (2009) and Vemula et al. (2010)). Therefore, a superelement approach was implemented in ADCoS-Offshore as described by Vorpahl et al. (2009a). With this approach, joint models with the same stiffness properties as detailed FE models but dramatically reduced number of Degrees of Freedom (DOF) are included in the fully coupled OWT simulation. The superelement or substructuring approaches using Guyan (cf. Guyan (1965)) or Craig-Bampton (cf. Craig and Bampton (1968)) methods are widely used and described for example in NASTRAN (2004) or ANSYS (2007).

MODEL DEVELOPMENT

In this work, an OWT with a rated power of 5 MW on a tripod support structure in 45 m of water is simulated. Three different tripod models, including joint models with different levels of detail, are used.

²http://www.alpha-ventus.de/index.php?id=80; November 19, 2009
³http://www.beatricewind.co.uk/home/default.asp; November 19, 2009