Unified approach for modelling of wind turbine power train using bond graph

André Laß, Arjün Kancharia, Jändra Kumar, Frank-Heinrich Wurm
Institute of Turbomachinery | Faculty of Mechanical Engineering and Marine Technology | University of Rostock, Germany

Abstract

A Wind turbine is a nonlinear and multidisciplinary system (mechanics, aeronautics, electrical and magnetics) which deals with various energy domain to extract electricity from wind. A unified approach based on bond graph for robust multi-physics modelling and reliable simulation is used for understanding, design and simulation of wind turbine system. NREL 5MW reference turbine is modelled and eigenfrequencies as well as blade deformations are verified. Results are showing good agreement with published values. Effect of gravity and eccentricity is considered in transient rotordynamic analysis in order to show chosen approach capability.

Objectives

Development of parametric wind turbine model using bond graph approach for multiphysics domain modeling is a main objective. Rotordynamic system simulation and analysis of wind turbine power train under steady-state loading conditions is performed using electrical, magnetic and structural domain at once. Eigenfrequencies of the complex system have to be determined properly to avoid resonance in all points of operation. Torsional, translational and bending vibrations of shaft considering structural damping need to be calculated for further damage and fatigue prediction. The transient orbital displacement behavior of the power train due to eccentricity and gravity load on hub has to be observed for advanced bearing design. For optimization purposes electric and magnetic domain of induction motor is modelled to analyze starting behavior and power output.

Methods

Bond graph methodology is used to model complete wind turbine system where every element is attached to next element by half arrows called as power bond considering causality of system. Wind turbines having several important components like the blades, hub, shaft, planetary gearbox, bearings and generator and they exchange power between them as shown in Fig.1. To model Blade, it is divided in seven flexible beam elements having six degrees of freedom. Steady state or unsteady state fluid forces can be mapped from CFD or any other source to blade nodes. Complete shaft is divided into number of small elements and each element is modelled as Raleigh beam (acc. to [1]). Every element is having five degree of freedom including gyroscopic effect, spinning and gravity. Main bearing is considered as ball bearing where stiffness and damping is considered in term of geometrical description like number of ball, diameter of ball, diameter of inner race and outer race and many more. Gear box is modelled as transfer function including moment of inertia of gear and translational bearing stiffness. Squirrel cage generator is modelled considering sinusoidal distribution of stator winding voltage from electrical network. Magnetic losses, air gap loss and core losses are considered while modeling [2]. NREL 5MW Reference turbine is used for determination of input parameters and validation of results [3].

Phase I - system modelling and parametric model creation

Phase II - system analysis and load determination

Phase III - initialization of rotary movement due to electrical grid connection of induction machine and CFD – loads on blades sections

Phase IV - complex system dynamic analysis considering gravitation, eccentricity and gyroscopic effects

Results

Conclusions

Bond graph methodology can be used to achieve robust and reliable tool, which is capable of describing the dynamic behavior of rotating components in diverse energy domains for industry applications. Parametric and generic model of wind turbine can be used for any size of wind turbine to estimate system eigenfrequencies and predict real time behavior of different component for various boundary conditions. This method empowers the engineer to observe losses in different power domains, which allows optimization and pre-design of all components. Level of detail can easily be adjusted to fit engineering needs.

References

1. A. Mukherjee, R. Karmakar, A. K. Samantaray, Bond Graph in Modeling, Simulation and Fault Identification, CRC Press, 2006

EWEA Offshore 2015 – Copenhagen – 10-12 March 2015