Integration of an Aerodynamic Wind Turbine Module

In the last years wind turbines have increased dramatically in size so that their structural-dynamic behaviour is becoming progressively more important. Industrial simulation codes for wind-turbine-specific problems have some shortcomings in structure modelling, especially for drive trains. This leads to new approaches to wind turbine simulation. The Endowed Chair of Wind Energy at the Institute of Aircraft Design (University of Stuttgart) initiates the usage of SIMPACK for the simulation of wind turbine models. This requires some add-ons to SIMPACK. The most important of these consists of an aerodynamic module to consider rotor aerodynamics and turbulent wind field input.

STATE OF THE ART

The structural dynamics of wind turbines are nowadays simulated with special software codes, developed solely for this application. The majority of these simulation codes use a modal approach that considers only a rather limited number of natural modes. A few other tools apply finite element methods which are more powerful in principle but computationally inefficient due to the kinematical and material non-linearity of the system and the overall long calculation times. Recently it became obvious that all codes so far have deficits in modelling the drive train dynamics and its interaction with the other main components like blades, tower, etc. This leads to a poor significance of component coupling.

AERODYNAMIC MODULE “AERODYN”

AeroDyn is a module for the simulation of wind turbine rotor aerodynamics developed by the US National Renewable Energy Laboratory (NREL). AeroDyn is already used in conjunction with other wind turbine simulation software. As all other industrial wind turbine rotor aerodynamics design tools, AeroDyn calculates aerodynamic loads using a combination of blade element and momentum theory, i.e. Blade-Element-Momentum-Theory (BEM). The global flow field is described by Froude’s actuator disk theory originating from 1889 which was later adapted to wind turbine applications by Betz. In order to overcome the shortcomings of this rather crude method, several engineering rules are applied as corrections. AeroDyn considers most of these corrections, like Blade Tip Loss and Hub Loss. These corrections are necessary because of the 3-dimensional flow. The stream tube
Simulation Results: Structural Response on Turbulent Wind in Time and Frequency Domain

3-dimensional Turbulent Wind Field Possibly Used by AeroDyn [Fig. GE Wind Energy]

Simulation Results: Structural Response on Turbulent Wind in Time and Frequency Domain

INTERFACE AERODYN & SIMPACK

The interface that integrates AeroDyn into SIMPACK is written in a SIMPACK user routine. User routines provide a powerful capability for SIMPACK. They allow additional functionality to be imported into SIMPACK. Moreover, they are open for modelling features from other engineering disciplines to be included in a MBS model. It is possible to define user routines for different MBS elements such as force elements, joints, constrains, etc. The programming language can be either FORTRAN or C. The user routines can read in data during simulation via the SIMPACK Access Functions. Such Access Functions also allow the measurement of kinematical dependencies in the MBS model. Since AeroDyn calculates aerodynamic forces, the interface is realised as a SIMPACK User Force. Aerodynamic forces depend on structural velocities of the blade elements. SIMPACK Access Functions are used to gain these velocities during simulation when the SIMPACK solver calls the interface code which conducts the aerodynamic calculation in AeroDyn. The interface code collects the relevant kinematic information of each blade element and transfers it to AeroDyn. By the time AeroDyn finishes the calculation, the interface affects the blade elements in the MBS model with the calculated forces.

SIMULATION EXAMPLE

A typical wind turbine model with 1.5 MW power and 70 m rotor diameter was used to demonstrate the SIMPACK coupling and to analyse mass and aerodynamic imbalances in the presence of a turbulent wind field. It would have been possible to use a detailed structural model of the drive train, but the focus was on aero-elastic coupling. The interpretation was performed in both the time and frequency domains. It could be seen that the transient and stochastic effects of turbulent wind in particular have a major influence on the results.

CONCLUSION

The multibody approach of the simulation software package SIMPACK is a sophisticated tool to simulate the complex structural dynamics of modern wind turbines. SIMPACK’s User Routines offer an easy way to implement external user-defined modules for specific problems like rotor aerodynamics, control, etc. These promising results encourage the further development of the wind turbine simulation capabilities of SIMPACK to serve the needs of the fast-growing energy industry.