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Development of Software for Coupled Aero-Elastic Dynamic Analysis of Wind Turbine System

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ABSTRACT

A fully coupled aero-elastic simulation technology is developed with enough sophistication to have the features required to perform loads analyses for a variety of wind turbine configurations. Blade and tower are modeled multiple rigid bodies which are connected beam elements to represent a flexibility for their bending and torsional behaviors. AeroDyn which is developed by NREL are chosen for aerodynamic analysis. This is a popular and open code and needs hub-height wind data, full field turbulent wind data and airfoil data to calculate an aerodynamic force. DAFUL, which is a commercial multi-body and structure dynamics analysis tool, is used for multi-body dynamics analysis considering a flexibility of the blade and tower. The interface to perform coupled analysis between these two softwares is developed with a user-subroutine of vector force in DAFUL. Analysis results of a sample model to verify This proposed simulation technology is applied to the analysis of a sample model for verification of the developed program.

KEY WORDS: Wind turbine, aerodynamic force, multi-body dynamics, coupled analysis, blade element

INTRODUCTION

When there are no obstacles, the wind has fast and consistent speed. That wind is very useful for wind turbine. A sea provides the good wind and proper environment. A wind power generation can be classified into two groups, onshore wind turbines and offshore wind turbines, and offshore wind turbines can be sorted by the fixed type and the floating type wind turbines. Fixed type wind turbine systems are set up at relatively low depth of water near shore but floating type wind turbines are to be set up at more deep sea. The tower of the fixed type wind turbine is fixed on the ocean floor like onshore type, but the tower of a floating offshore wind turbine is to be fixed on the float and the movement of the float is to be controlled by a mooring system. Several choices are possible for the platforms of floating wind turbines with various kinds of float type and mooring systems (for example, see Chung, Moon, Rim and Nam, 2008). When designing a floating type of wind turbine, most important thing is how to estimate and control movement of the float, because its movement directly influences the motions of tower and nacelle.

This paper introduces the software under development for the dynamic analysis of a land based wind turbine using AeroDyn of NREL and DAFUL which is multi-body dynamics analysis program (Laino and Hansen, 2002; DAFUL, 2010). This program will be extended for the dynamic analysis of a floating wind turbine system by integrating a fluid dynamics code in near future.

DYNAMICS MODEL OF WIND TURBINES

A multi-body dynamics model of a wind turbine system is developed as shown in Fig. 1. The system consists of nacelle, hub, low speed shaft, high speed shaft, generator, tower and blade. A platform and the bottom of tower are connected with a fixed constraint (Haug, 1989). The tower and blade are divided some rigid bodies which have mass and moment of inertia and a beam elements are modeled between the segments. The beam force can be calculated from following equation.

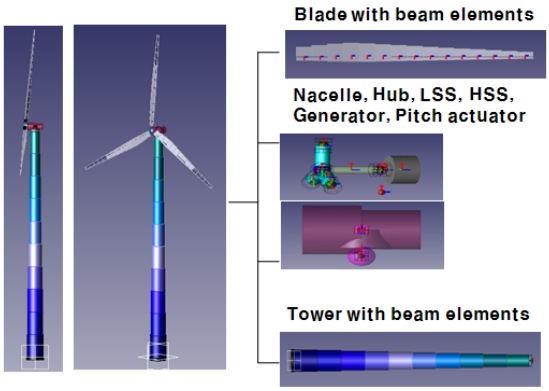

Fig.1 Wind turbine system

$$\mathbf{f}_{\text{beam}} = [\mathbf{K}]\mathbf{u} + [\mathbf{C}]\dot{\mathbf{u}}$$