Development of a Multibody Dynamics Kernel for Motion Analysis of a Floating Wind Turbine

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ABSTRACT

In this paper, a dynamics kernel for a multibody system with wave and wind loads was developed and applied to the dynamic response analysis of an offshore wind turbine on a floating platform. The floating offshore wind turbine was modeled as a multibody system consisting of several bodies constrained with mechanical joints.

To carry out dynamic response analysis of the multibody system, a dynamics kernel was developed. In this kernel, the inertial reference frame and the body-fixed reference frames were defined, and the kinematic relations between the rigid bodies were imposed by defining various types of joints. The kernel was used to solve the equations of motion of the multibody system, derived by using recursive formulation. For the dynamic response analysis of the offshore wind turbine, an external force calculation module was developed. The developed module calculates the hydrostatic force considering the nonlinear effects and the linearized hydrodynamic force by using the 3D Rankine panel method, and the mooring force for the forces exerted on the floating platform. Additionally, the aerodynamic force was calculated based on the blade element momentum theory for the blades.

The kernel can also be used for the dynamic response analysis of a general multibody system operating in ocean waves. With the use of the dynamics kernel developed in this paper, a dynamic response simulation of a 5-MW wind turbine was carried out. The motion of the floating wind turbine was analyzed based on the simulation results.

KEYWORDS: multibody dynamics, floating offshore wind turbine, dynamic analysis, wave loads, wind loads

INTRODUCTION

Due to the limitation of supply and harmfulness of fossil fuel, the interest in renewable resources such as wind power is growing. Land-based wind power has been the world’s fastest growing renewable energy source for more than a decade now. On-land turbines, however, are limited in size to about 3 MW due to transportation constraints. Also, it is advantageous for offshore wind turbines to develop very large multi-megawatt turbines to make it worth the cost because the offshore support structure becomes a large factor in the overall cost equation. These are the reasons why 5-MW wind turbines are installed at locations that are farther away from the coastline. The floating-type platform is used for the installation of a land-based wind turbine on the vast deep waters instead of the fixed type as shown in Fig. 1.

The floating-type platform offers flexibility in terms of site selection for the installation of a wind turbine. In contrast with the fixed type, however, stability and safety during operation are significant issues for the floating-type platform because of its wave-induced motion.

In this study, a dynamics kernel for a multibody system with wave loads was developed to address the stability and safety issues of the floating offshore wind turbine. The equations of motion of the floating offshore wind turbine were derived by using recursive formulation. The hydrostatic force considering nonlinear effects with wave elevation, the linearized hydrodynamic force, the mooring force, and the aerodynamic forces were calculated.

Figure 1. Progression of the platform designs from shallow to deep water for the floating wind turbine.