

## **ROTOR-FLOATER-TETHER COUPLED DYNAMIC ANALYSIS OF OFFSHORE FLOATING WIND TURBINES**

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### **ABSTRACT**

In the present study, a numerical time-domain model has been developed for the fully coupled dynamic analysis of an offshore floating wind turbine system including blade-rotor dynamics, mooring dynamics, and platform motions. The performance of the National Renewable Energy Laboratory (NREL) mini-TLP-type system in a typical wind-wave condition has been simulated and analyzed. In the present case, the dynamic coupling between the rotating blades and the floater is also considered in addition to the mooring-floater dynamic coupling. It is seen that the rotor-floater coupling effects increase with blade size. The increased coupling effects tend to increase the dynamic tension on tethers especially in the high-frequency region. The significantly increased dynamic tension not only increases the maximum tension but also reduces its fatigue life by increasing both stress level and number of cycles. The developed technology and numerical tool are readily applicable to the design of new offshore floating wind farms planned in the future.

**KEY WORDS:** Renewable energy; Wind Energy; Offshore floating wind turbine; Rotor-floater-tether coupled dynamics; Blade size; Fatigue failure.

### **INTRODUCTION**

As the world population continuously increases and our society is more and more industrialized, the demand for energy is also growing fast. During the past century, people have been depending on fossil fuels as their major source of energy. However, fossil fuels continue to be depleted and its negative environmental impact is very alarming. Therefore, the importance of finding new clean renewable energy cannot be too much emphasized for the promising future of all human being.

Wind is the fastest growing clean and renewable energy source. Its installed capacity is 74 GW in 2007 and current annual growth rate worldwide is about 25% (World Renewable Energy Congress, 2003). The on-land wind farms can be limited by the lack of available space, noise, shade, visual pollution, community opposition, and regulatory problems. Therefore, many countries in Europe started to build wind

farms in coastal waters and so far, most offshore wind farms are located in relatively shallow water (<30 m) using bottom-fixed-type wind turbines. Recently, several countries like Norway have been the frontiers in the development of more innovative offshore floating wind farms. Large sea areas in deeper waters are in general less sensitive to space, noise, visual pollution, and regulation problems and exposed to stronger and steadier wind field. In designing those floating wind farms, the existing technology and experience of offshore industry used for petroleum production is directly applicable. If technology and infrastructure is fully developed, offshore wind farms are expected to produce huge amount of clean electricity at a competitive price compared to other energy sources.

In deeper (>30m) offshore areas, floating-type wind farms are expected to be more economical than the fixed ones (Tong 1998; Henderson et al. 2002,2004; Musial et al. 2003; and Wayman et al. 2006). One disadvantage of floating type wind farms is possibly large inertia loading on tall tower caused by floater accelerations. In the development of the offshore wind-turbine technology, the high-frequency excitation caused by rotating blades may greatly increases the fatigue damage, which has rarely been studied in the open literature especially for floating-type wind farms (e.g. Withee 2004, Jonkman et al 2006). The major goal of this research is to develop a fully-coupled dynamic analysis among rotating blades, floater, and mooring lines for the reliable design of offshore floating wind turbines. The analysis method integrates rotor dynamics, floater dynamics, and mooring-line dynamics and the full dynamic coupling among them. Using the developed computer program, fully coupled time-domain simulations are carried out in a realistic design sea state with quality wind.

The rotor-floater-mooring coupled dynamic analysis computer program is developed by combining several modules. For the floater hydrodynamics, 3D diffraction/radiation panel program WAMIT (Lee et al. 1991) was used as a pre-processor. For the dynamic analysis of wind turbine system, the primary design code of wind turbines FAST promoted by National Renewable Energy Laboratory (NREL), is employed (Jonkman et al., 2004). The FAST is implemented into the floater-mooring coupled dynamic analysis program, CHARM3D, which has been developed by authors' group during the past decade (Kim et al., 1999).