Aerodynamic Inflow Conditions on Floating Offshore Wind Turbine Blades for Airfoil Design Purposes

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ABSTRACT

Combined aerodynamic, hydrodynamic and mooring line forces on floating offshore wind turbines (FOWT) create unique operating, failure and design conditions. These conditions influence the aerodynamics of the rotor and of the airfoil sections along the blade. This paper presents the identification and analysis of the aerodynamic inflow conditions on a representative catenary moored FOWT and discusses differences and design implications with respect to the bottom-mounted and onshore wind turbines.

The results show the influence of wave induced motions on inflow conditions, e.g. a decrease in mean and increase in variance of inflow velocity probability density functions. These influences and interdependencies are described and evaluated.

KEY WORDS: Offshore; inflow conditions; floating wind turbine; airfoil design; aerodynamics; computational fluid dynamics; CFD; multibody simulation; MBS.

INTRODUCTION

Modern Onshore wind turbines have achieved a high aerodynamic development status and show optimized performance and low noise emission. Offshore, large (5MW-class) and very large offshore (6-10+MW-class) wind turbines, especially on floating structures, due to the platform motions, the different (far) offshore atmospheric boundary layer, higher average wind speeds, lower turbulence levels and increased blade roughness (sea salt, erosion) have clearly different flow conditions and other design priorities as onshore turbines. Optimization on these inputs and criteria will have an important potential for improvements.

In work package 3 (WP 3) of the EIT (European Institute for Innovation and Technology) KIC (Knowledge & Innovation Communities) Offshore Wind Enabling Technologies (OFFWINDTECH) project, tools and airfoils aimed especially on these wind turbines are developed, focusing on:

- Special inflow conditions on large floating offshore wind turbines
- Other design parameters (thickness, trailing edge thickness, surface conditions, higher tip speed and others)
- Offshore wind farm wake effects and the impact of the floating platform design on WT operation

This paper defines the inflow design conditions and constraints for the new airfoils based on advanced multibody simulation (MBS) for large horizontal axis catenary moored floating offshore wind turbines (LFOWT). In particular, a definition of the inflow conditions for each reference blade section is given in terms of the airfoil design relevant parameters effective inflow velocity (c) and Mach (Ma) number, Reynolds number (Re), angle of attack (AoA), and lift coefficient (c).

The results of this study serve as input for the improved airfoil design. Advanced modelling methods are required to effectively identify these inflow conditions. In this study a high-fidelity multibody simulation tool is applied. Based on the IEC61400-3 Offshore Standard (IEC 61400-1, Ed.3, 2005) a selection of stochastic load cases relevant for the airfoil design around and below rated wind speed is performed and simulated to ensure that statistical variations are accounted for. In addition, deterministic load cases are simulated to obtain airfoil design points.

The calculated inflow conditions are analyzed in terms of variations of the design parameters, applying statistical methods. With this data a comparison is made between the parameters of the FOWT and the equivalent turbine on a rigid onshore foundation.

BASELINE MODEL

For the baseline LFOWT, a 5 MW wind turbine on a spar buoy floating support structure has been chosen. The spar buoy concept represents a public version (OC3 Hywind) of the first commercial utility scale LFOWT Hywind, installed off the coast of Norway by Statoil in 2009. The wind turbine is a modified version of the UpWind reference wind turbine (Jonkman, et al., 2007), based on the NREL 5MW Baseline turbine (Jonkman, Butterfield, Musial, & Scott, 2009). The metocean parameters are representative for a location at 61° 20’ N latitude, 0° 0’ E longitude northeast of Scotland (Jonkman J., 2007).

Major changes for the UpWind reference turbine blade and airfoil definition were introduced for the OFFWINDTECH baseline turbine, in