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Integrated Modelling Platform for Dynamic Performance Assessment of Floating Wind Turbines

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Abstract

The paper presents an integrated modelling platform that can be used to assess the dynamic performance of an offshore wind turbine mounted on a spar-buoy type floater. Sub-models of generator and converter controllers and the power network are combined with a state-of-the-art numerical simulation of the hydro-, aero- and structural dynamic behavior of the floating wind turbine, using FEDEM Windpower software. The aim is to provide a tool that allows analyzing response of floating turbines to grid faults, interactions and potential conflicts between controllers. A study case of grid disturbance was conducted to illustrate the applicability of an integrated model. A grid fault that lasted 100ms and resulted in 50% residual voltage at the grid connection point was applied, and wind turbine operation both in still water and in large sea wave conditions were analyzed. The results show that the turbine was capable of riding through voltage-dips without severe effects on the electrical or mechanical systems. A significant, but not critical, dip in the tower bending moment was observed. The most affected component of the bending moment is around the axis of the rotor, which is directly related to the loss of generator torque due to the grid disturbance event.

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Keywords: Floating turbine; Integrated modelling; Wind turbine modeling; Fault ride through; Motion response; Offshore Wind Introduction

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Offshore sites are very promising for the further, large-scale deployment of wind power generation. The reasons are better and more stable wind conditions, more access to new sites, less political controversies, possibilities for larger turbines and improved logistics [1]. Due to the enormous potential, there is substantial political and economic support for offshore wind power around the world. There are already several large offshore wind farms in operation around the world. The turbines in these wind farms are installed in shallow waters with support structures fixed to the seabed. However, a large portion of the potential for harvesting wind energy is found farther offshore, in deeper waters than existing offshore wind farms, and current bottom-fixed technologies are not practical and economical at these sites.

For wind turbines mounted on floating platforms to emerge as viable options, these structures must be reliable in the offshore environment. Additionally, the response to both mechanical and electrical disturbances must be robust. There are many studies focusing on the motion response of floating wind turbines due to environmental loads, such as turbulent wind and waves [2-4]. Regarding the control of floating wind turbines, current research has focused on identifying new control strategies with large emphasis on reduction of platform motions and structural loads [5, 6]. Most proposed controllers have been implemented assuming normal power production and operating conditions, and there has been little mention on how electrical faults in the grid may impact the control performance and overall wind turbine behavior. In [7, 8], a simulation tool dedicated to aero-elastic and structural studies (HAWC2 [9]) has been coupled with a simulation tool dedicated to power system analysis and control design in order to study different electrical and mechanical dynamic phenomena of wind turbines. The impact of grid faults on the mechanical structure of a bottom-fixed DFIG wind turbine was covered.

In this paper, the performance of a floating wind turbine during grid faults is evaluated. The motion response of a floating turbine due to an electrical fault that has occurred in the grid is studied. The simulated wind turbine is a 5 MW synchronous generator with full converter wind turbine mounted on a spar-buoy floater. The generator, converter and the electric power grid are implemented as sub models. These sub-models are combined with a detailed state-of-the-art numerical simulation of the hydro-, aero- and structural dynamic behavior of the floating wind turbine. The study case presented aims to illustrate the applicability of an integrated model to assess the behavior of floating wind turbines and control performance in the event of grid disturbances. The existence of such a tool is essential bearing in mind that advanced controllers concerned with stabilizing the platform fore-and-aft motion rely on the integrity of the torque demand signal (torque control loop), which is highly impacted on during a grid disturbance.

1. Floating wind turbine configuration

At deeper water sites, it might be economical to use floating substructures for wind turbines. However, the technology is at a nascent stage of its development. The consequence of moving towards floating structures is a new set of wind turbine design specifications. These design specifications emerge due to a need to handle the coupled hydrodynamic/aerodynamic forces, as well as the added weight and buoyancy stability requirements. A vast number of permutations of offshore wind turbine platform configurations are possible, considering the variety of available anchors, mooring, floater geometry, and ballast options [10].

In this study, the floating wind turbine is based on the benchmark model developed by the Offshore Code Comparison Collaboration (OC3) [11]. OC3 is an international collaboration established to verify the accuracy and correctness of aero-hydro-servo-elastic codes used for offshore wind turbine simulations. The model used here is a wind turbine installed on a floating spar-buoy support structure, which is an adapted version of the Hywind demo. Hywind is a full scale deep-water floating wind turbine that has been in operation since 2009 [12].

1.1. Wind turbine specification

The wind turbine used is based on the NREL 5MW reference turbine [13] placed on top of the floating spar platform. Key parameters of the wind turbine used in the simulation study are presented in Table 1.