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Wind Tunnel Wake Measurements of Floating Offshore Wind Turbines

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Abstract

This paper reports the results of a wake measurement campaign carried out at Politecnico di Milano wind tunnel to support current studies of the authors about unsteady aerodynamics of floating offshore wind turbines (FOWT) as well as evaluating experimental evidence for wind farm applications of FOWT. The wind turbine scale model adopted for these tests is the 1/75 DTU 10 MW wind turbine developed for the LIFES50+ project. In this study, imposed surge motions, at different frequencies and amplitudes, were provided at the base of the turbine's tower, to investigate the influence of motion on the wake. Results reported show good agreement with the state-of-the-art of wind turbines wake aerodynamics in steady conditions; concerning the unsteady conditions (imposed motion) interesting data are reported and collected with respect to a "wake reduced frequency" parameter which is, according to the authors, a straightforward value to estimate the "level" of unsteadiness connected to a specific dynamic condition due to floating motion. Interesting and consistent phenomena are observed and commented, although opening to the need of further experimental and numerical investigations.

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Keywords: Floating Offshore Wind Turbines, FOWT, Wake, Unsteady Aerodynamics, Wind Farm

1. Introduction

As Floating Offshore Wind Turbines (FOWT) are currently attracting great interest from scientific and industrial sectors, the importance of investigating thoroughly the aerodynamics of such system, which is made more complex due to the motion of the platform, is evident. The unsteady aerodynamics, which is a characteristic of FOWTs, is still far from being extensively understood, and this has an impact on the optimization of their design and power production. Furthermore, the comprehension of the wake behaviour downstream of a FOWT, is fundamental in wind farm application (e.g. optimal layout and control), and literature of this topic is still scarce, compared to onshore application ([1],[2]). This paper aims at reporting a first set of wake measurements, carried out downstream of a

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1/75 wind turbine scale model ([3], [4]), in imposed surge motion conditions, at difference amplitudes, frequencies and wind turbine operational conditions, with the goal of providing a first reference in the assessment of the wake of FOWTs. This was also performed to support the current assessment of unsteady aerodynamics of wind turbines that authors are carrying out, based on experimental evidences coming from the same experimental setup (Fig.1) imposing surge and pitch motions ([5], [6]), in the same facility (Politecnico di Milano, 14x4 m Atmospheric Boundary Layer Wind Tunnel).

Although the literature in this topic is weak, previous studies are worth mentioning, as [7], where a model floating wind turbine was assembled on a TLP structure and installed in a wind tunnel and water tank respectively: near wake measurements were carried out using single probe hot wire anemometry for both fixed and floating platform conditions, at fixed distances downstream of the rotor under floating conditions. It was found that for higher tip speed ratios (λ) greater difference in the aerodynamic performances (e.g. C_P) were evident. This was also confirmed by numerical studies in [8] and [9], which concluded that the difference between the mean power coefficient under platform surge conditions and the steady power coefficient depends either on platform surge frequency, surge amplitude and the rotor operating conditions. Furthermore, in [10] experiments were performed using two model wind turbines operated in tandem with a bottom-fixed configuration and a floating configuration with both turbines allowed to freely oscillate in the stream- wise direction. Wakes of both turbines were measured using stereoscopic Particle Image Velocimetry (PIV) concluding that the pitching motion of the turbine leads to the need of longer distances between floating turbines in a farm, to allow for a better recovery of the wake to achieve the same power production, as for bottom fixed turbines.

In the present paper a traversing system with a hot-wire anemometer was adopted for carrying out downwind air velocity measurements at a fixed distance from the turbine (2.3 times the diameter D), for different operational conditions (below-, above- and rated) as well as for different amplitudes and frequencies of the imposed surge motions, spanning a range considered significant for a floating wind turbines of such size (10 MW).

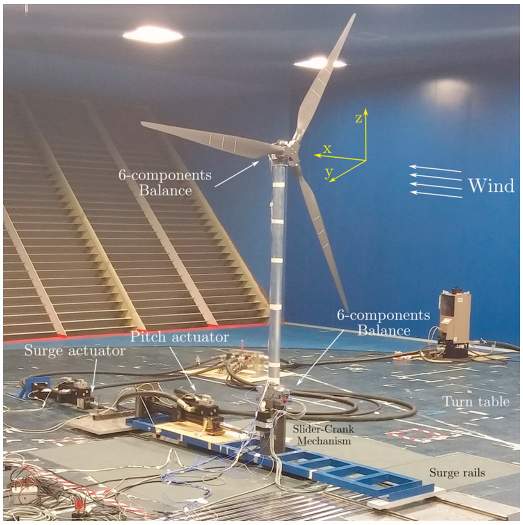

Fig. 1: Wind tunnel setup

2. Wind tunnel tests

2.1. Wind turbine model and setup

The wind turbine model used for this work is a scaled model of the DTU 10MW reference wind turbine [11]. It has been designed by the authors ([3], [12], [13]) as part of the LIFES50+ EU H2020 project [14], which aims at providing cost effective technology for floating substructures for 10 MW wind turbines through a novel approach in