Numerical Investigation of Vortex-induced Motion of a Semi-submersible Floating Offshore Wind Turbine

Yuanchuan Liu¹, Tao Wang²,³, Fushun Liu*¹

¹College of Engineering, Ocean University of China, Qingdao, Shandong, China
²POWERCHINA Huadong Engineering Corporation Limited, Hangzhou, Zhejiang, China
³Key Laboratory for Far-shore Wind Power Technology of Zhejiang Province, Hangzhou, Zhejiang, China
*Corresponding author

ABSTRACT

In this paper, 2DoF VIM of a semi-submersible FOWT subjected to current flow is investigated numerically, which could influence its aerodynamic performance but has been rarely studied. Simulation results for a number of flow speeds show that lock-in occurs across a wide range of reduced velocity from 6 to 30. The maximum transverse response amplitude of the platform reaches 0.94 times the column diameter. Drag force increases significantly at high reduced velocity of 30, possibly due to an increase in transverse response frequency. Interactions between vortices shed from upstream and downstream columns are also observed via flow field visualisation.

KEY WORDS: Vortex-induced motion; lock-in; floating offshore wind turbine; CFD.

INTRODUCTION

A recent trend in the offshore wind industry is to install wind turbines farther offshore in deeper water sites in order to exploit more abundant wind resource (Liu et al., 2019b). However, when the water depth of installation sites increases further to over 50 metres, fixed-bottom wind turbines widely adopted nowadays will be too costly to build and install while floating offshore wind turbines (FOWT) can be a more economical alternative. Meanwhile, installing a wind turbine on a floating platform brings about many engineering challenges. Most notably, the aerodynamic performance of an FOWT, e.g. thrust and power, is greatly affected by the six-degree-of-freedom motions of its floating platform, which are induced by environmental loads from wind, wave and current (Liu et al., 2019a; Tian et al., 2020). The majority of existing researches on FOWTs focused on the analysis of coupling effects between the wind turbine and the floating platform under various wind and wave conditions either experimentally (Coulling et al., 2013; Duan et al., 2016) or numerically (Tran and Kim, 2016; Liu et al., 2017b). However, there have been few studies on the motion responses of FOWTs subjected to current flow. Previous researches (Waals et al., 2007; Liang and Tao, 2017) on floating oil and gas platforms show that when placed in current flow, these structures will experience inline and transverse motions induced by periodic vortex shedding, a phenomenon commonly referred to as vortex-induced motion (VIM). As floating platforms of FOWTs mostly inherit the mono- or multi-column design from the offshore oil and gas industry, it is thus reasonable to expect that VIM will also occur for FOWTs subjected to current flow.

Many efforts have been made to investigate the VIM of floating oil and gas platforms under free stream conditions. A number of experimental tests were performed for scaled platform models in towing tanks. Waals et al. (2007) studied the VIM of a multi-column floater and found that a lower mass ratio led to a wider response range and that the largest motions of the floater occurred at a towing direction of 45 degrees. Gonçalves et al. (2012) discovered from their experiment that the hull appendages on the columns of a semi-submersible platform greatly influenced its VIM responses. Gonçalves et al. (2013) further pointed out that the transverse motion amplitude of the platform in waves was much lower than that in current. By carrying out experiment for a semi-submersible platform with four square columns, Liu et al. (2017a) concluded that a decrease in the aspect ratio of the columns resulted in a smaller peak transverse amplitude.

In recent years, numerical investigations of VIM of floating platforms have also been carried out by some researchers using Computational Fluid Dynamics (CFD) methods, which are able to provide detailed visualisation of flow field and thus help improve the understanding of the interaction between fluid flow and floating structures. Kim et al. (2011) numerically studied the VIM of a four-column TLP and results from their CFD simulations agreed well with model test data. Chen and Chen (2016) compared the VIM responses of a semi-submersible platform with three corner geometries and found that VIM was sensitive to corner rounding. Liang and Tao (2017) examined the vortex shedding and formation of a deep-draft semi-submersible (DDS) platform in current flow and observed the interaction between vortices and the DDS. Zhao et al. (2018) analysed the VIM of a paired-column semi-submersible platform and pointed out that the pontoons of the platform had damping effects on its VIM responses.