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Walk-to-work accessibility assessment for floating offshore wind turbines

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ABSTRACT

This paper presents a methodology to assess the walk-to-work accessibility of a floating wind turbine. The system composed by the vessel and the platform is modelled in the frequency domain as a rigid, possibly constrained multibody system. Non-linear actions, such mooring and viscous forces are linearised. Extreme maxima for the response variables are calculated assuming that crests are Rayleigh distributed. Two vessels are studied: a catamaran equipped with fender, and a supply vessel mounting a motion-compensated gangway. For the catamaran, accessibility is possible when no-slip conditions between the vessel fender and the ladder landing platform are ensured. For the supply vessel, accessibility is possible when the gangway motions are below the hydraulic system compensation limits. The catamaran is able to handle wave heights up to 2 m, provided that it can work under head sea conditions and take advantage of the shielding effect of the platform. The supply vessel allows personnel transfer with wave heights up to 5 m, but it is important that roll motions are not excited. The proposed methodology and the calculated maps are a valuable source of information for decision-making during personnel transfer to and from offshore floating platforms.

1. Introduction

1.1. Offshore wind market

At the end of 2014 the global offshore wind capacity reached almost 9 GW, most of it (91%) distributed across Northern European waters (Global Wind Energy Council, 2014). Though the cumulative power represents a small share of the current renewables market, the growth of offshore wind industry has been remarkable in the last years and is foreseen to consolidate in the next decades. Currently, the vast majority of the offshore grid-connected wind turbines are installed on structures fixed to the seabed, which are usually economical up to water depths of 40–50 m (European Wind Energy Association, 2015a, 2015b, 2014). At the same time, the limited availability of shallow water locations is driving the focus of industry towards floating technologies, which would allow harnessing energy in deeper waters and opens a huge potential market worldwide.

Floating wind turbines are quite recent technologies. Two 2 MW full-scale prototypes have been successfully deployed few years ago (Hywind by Statoil and WindFloat by Principle Power) and led the respective developers to planning the first floating farms (Statoil, 2015) (Principle Power, 2015). Several countries are approaching the sector with demonstration projects, and among them Japan is making giant steps. The Fukushima FORWARD project achieved the installation of a 2 MW floating turbine and the first worldwide floating substation and is going ahead with the deployment of two more turbines (7 MW and 5 MW) (Mitsubishy Heavy Industries, 2015). The successful operation of these prototypes represents a good premise for further development of the sector.

1.2. Accessibility for inspection and maintenance: costs and risks

Running floating wind turbines in a long-term perspective still presents large uncertainties, due to the exposure of such systems to severe metocean conditions and the short experience with full-scale prototypes. Nowadays, operation and maintenance of fixed offshore turbines may account for 25% of the final cost of energy (GL Garrad Hassan, 2013); this might be even higher for floating systems, since platform motions may increase the difficulty of access and the probability of faults (Butterfield et al., 2007). With no doubt, all the operations related to access, inspection and maintenance of offshore systems must be performed within rigorous safety limits to prevent any accident which would endanger the health of the personnel involved. The experience of the oil and gas industry, where several fatalities have occurred during personnel transfer (International Association of Oil & Gas Producers,

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2010) (Spouge et al., 2014), and a series of *near misses* in the offshore wind industry (International Marine Contractors Association, 2015), impose to use caution with the topic.

The growing offshore wind industry needs to combine both cost-effective and safe strategies to ensure effective access of installations. Offshore wind turbines can be accessed either by helicopter or by boat. This work will focus on the latter access type. Generally speaking, boats can ensure personnel transfer in two ways: either landing on the wind turbine transition piece through a fender (see Fig. 1) and allowing technicians to jump on a structure-mounted ladder, or using gangways through which people can walk to the tower, without any contact between the vessel and the turbine structure (see Fig. 2).

Several guidelines exist in order to ensure that the transfer would occur in the safest way (G9 Offshore Wind Health and Safety, 2014; International Marine Contractors Association, 2010; Det Norske Veritas, 2013; Sgurr Energy Ltd., 2014). The green light for starting any operation is usually given by the metocean conditions and the associated vessel motions.

However, appropriate tools are necessary in order to predict the response of a service vessel during the transfer of technicians to and from a floating wind turbine. In literature, it was possible to find only studies related to fixed wind turbines, both in the time domain (González et al., 2015) and the frequency domain (Wu, 2014), which however neglect the hydrodynamic interaction between the turbine structure and the vessel. Furthermore, for floating turbines there are no studies yet, to the authors' knowledge.

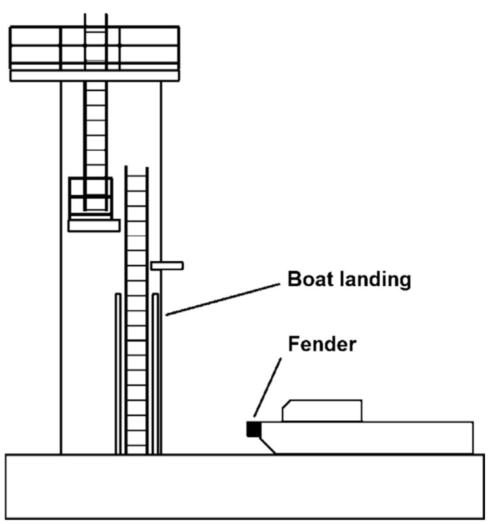

Fig. 1. Service vessel with fender, adapted from (G9 Offshore Wind Health and Safety, 2014).

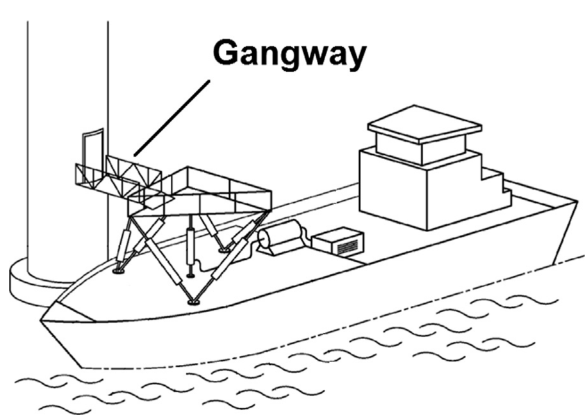

Fig. 2. Service vessel with gangway, adapted from (Van Der Tempel et al., 2013).

1.3. Objective and motivation

This work aims at developing a methodology for the calculation of the combined motions of a floating wind turbine and a service vessel in a personnel transfer configuration, to define safe accessibility levels for inspection and maintenance. This will include the modelling of multi-body hydrodynamics in waves, mooring forces and possible contact forces.

The study is mainly motivated by

- The high cost of operation and maintenance for offshore wind turbines.
- The risk associated to transfer of personnel to and from offshore structures.
- The lack of modelling tools in case of floating wind turbines.

2. Methodology

2.1. Overview

The system composed by a floating platform and a service vessel is modelled in this work as a rigid, possibly constrained, multi-body system in the frequency domain. A frequency domain approach implies the assumption of linear force–displacements relationships; therefore, potential non-linear phenomena have to be linearised accordingly. Once the system transfer functions are known, it is possible to calculate short-term response extremes based on given wave conditions and statistical assumptions. The methodology proposed is thus based on the following points:

- Definition of relevant coordinate systems.
- Equation of motion for the vessel-platform system.
- Linearization of the mooring forces.
- Linearization of the viscous damping forces.
- Calculation of limiting significant wave height.

2.2. Definition of relevant coordinate systems

As a first step, it is essential to clearly define the coordinate systems used in this work (see Fig. 3); all of them are inertial:

- *Global coordinate system (CSYS-g)*. The x_g–y_g plane lies on the still water plane (SWP), while the z_g-axis points upwards opposite to gravity. Its origin is the point *G*.

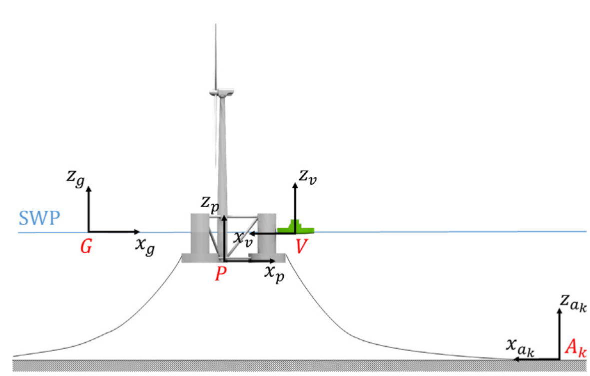

Fig. 3. Coordinate systems used in this work.