Multibody Modelling of Floating Offshore Wind Turbine Foundation for Global Loads Analysis

Lucie Guignier, Adrien Courbois, Riccardo Mariani, Thomas Choisnet
Ideol, La Ciotat, France.

ABSTRACT

This paper presents a methodology for the calculation of internal loads, induced by wind and waves, on a floating offshore wind turbine. The ring shaped hull is divided in separated compartments on which diffraction radiation is calculated and then used in a time-domain dynamic analysis of the floater, also including wind turbine and mooring system. In addition to reproducing the dynamic behavior of a rigid body, the multibody modelling provides information of loads transmission inside the hull.

KEY WORDS: Floating offshore wind turbine, time-domain hydrodynamics, global loads analysis.

INTRODUCTION

Several ways of modelling floating wind turbines and accessing loads exerted in the hull can be considered. The most suitable model is usually chosen on the basis of the hydrodynamic and aeroelastic properties of the wind turbine. Several techniques were presented whereby the floating foundation was modelled on the basis of simple hydrodynamic models like in Utsunomiya et al. (2013) for a spar platform or Le Cunff et al. (2013) for a three floater semi-submersible platform, or where the full 3D pressure field of the waves was directly calculated at each time-step in time domain simulations and then mapped to finite element models as proposed by Cermelli et al. (2010). The floating foundation considered in the present paper is a large volume structure for which it is necessary to account for diffraction and radiation, but for which part of the wave loads are caused by viscous vortex-shedding effects. Both techniques mentioned above have been tried, but the technique proposed by Utsunomiya et al. (2013) and Le Cunff et al. (2013) could not effectively be used due to the limited accuracy of Morison’s equation for the ring floater, while the latter technique used by Cermelli et al. (2010) is more adapted when most of the loads come from perfect fluid phenomena. In addition, the computation time of the structural analysis using direct pressure field application made the latter method difficult to handle in the detailed design of a floating foundation where a large number of load cases need to be considered.

This made the authors search for an alternative method described here, which would provide accurate hydrodynamic modelling of the foundation and direct information on the loads governing the structural design of the hull: tower loads, accelerations, but also bending, shears and torque of the caissons constituting the hull.

FLOATING WIND TURBINE CHARACTERISTICS

The wind turbine is a 130m rotor diameter wind turbine weighing 450 tons. It is a regular variable speed, pitch-regulated wind turbine. The floater is a square ring fitted with a large opening at centre. The hull is 45m in breadth with a depth of 11m and an opening 27 m x 27 m wide. The skirt placed all around the hull increases floater wave frequency damping. The floating turbine draft is 7 m. The hull is composed of 16 compartments, some of them are filled with sea water ballast in order to equilibrate the floating wind turbine. The floating foundation also includes a transition piece which connects the tower to the hull and ensure a smooth transition of wind and inertial loads within the hull. Its mooring lines are grouped in three clusters of two catenary mooring lines, each spurring at 120° from each other. More information on the concept is provided in Choisnet et al. (2014).

ENVIRONMENT DATA

For this design, the offshore site has a 55 m depth and the following waves and wind conditions.

Waves

Waves are modelled by irregular waves without directional spreading. The wave spectrum is the Pierson Moskowitz / ISSC spectrum. It is a two-parameter spectrum mostly relevant for locally-generated sea-states. The power spectrum density as a function of wave frequency is given by the Eq. 1.

\[ S_{\eta}(f) = \frac{0.3125 \cdot H_s^2 \cdot f_p^4}{f^5} e^{-1.25(f_p/f)^4} \]

where: