Dynamic Analysis of Fixed Bottom Offshore Wind Turbines

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ABSTRACT

In the present paper, by using and comparing two simulation approaches, analysis of the dynamic behavior of a fixed-bottom Offshore Wind Turbine (OWT) with a monopile support structure is implemented in order to: (a) assess and demonstrate the effect of the dynamic coupling between the support structure and the superstructure on the calculation of dynamic performance quantities and (b) investigate the effect of the foundation on the dynamic response and the structural assessment of an OWT.

KEY WORDS: Offshore Wind Turbines; Monopile; Dynamic Analysis; Integrated; Semi-coupled; Stress analysis.

INTRODUCTION

Wind energy represents a very important renewable energy type, which is utilized to a great extent mainly through the construction and the operation of onshore wind turbines. Nevertheless, the advantage of the wind energy in offshore areas, where the wind speed is higher, along with the existence of some difficulties/problems of the onshore wind turbines have stimulated the development of Offshore Wind Turbines (OWTs). The design and operation of this kind of structures is characterized by intense complexity due to the existence of: (1) the complex marine environment and (2) the significant interactions between components of the structure which affect its response (Fig. 1). As a result, several simulation approaches have been and are still being developed and applied for the effective analysis and assessment of the performance of an OWT. These approaches can be divided into two main categories: (1) the “single software fully integrated” approaches and (2) the “multiple software fully integrated (fully coupled)” approaches. Category 1 approaches use only one software and ensure: (a) the dynamic coupling between the support structure and the superstructure in the dynamic analysis and (b) the simultaneous wind and wave action on the whole system. Category 2 approaches use more than one software coupled together to ensure the dynamic coupling and the simultaneous loading action. Examples of Category 2 approaches are included in Klose et al. (2007), Passon et al. (2007) and Vorpahl et al. (2010) while Seidel et al. (2005), Vorpahl et al. (2007) and Kaufer et al. (2009) developed Category 2 approaches.

In the present paper, the dynamic behaviour of a fixed-bottom OWT with a monopile support structure is analyzed by applying and comparing two simulation approaches: (1) a “single software fully integrated” simulation approach and (2) a different than Category 1 and Category 2 approaches named here as a “semi coupled” approach. The latter one has been presented by Farmakis and Angelides (2011) and is further investigated here. With the first approach (Category 1 approach), using the open source code FAST (Jonkman and Buhl, 2005), the dynamic analysis of the whole structure is implemented under the simultaneous wind and wave action; furthermore, the dynamic coupling between the two sub-systems, i.e. the support structure and the superstructure is taken into account through the coupling of the Degrees of Freedom (DOF) of these sub-systems; this coupling is materialized through the existence of non-zero off-diagonal terms in the matrices of the combined aero-hydro-servo-elastic equation of motion. The second approach (“semi-coupled”) includes the application of FAST along with MicroSAS, a structural software used in the oil industry. In this approach, FAST is applied in order to obtain the dynamic loads at the top of the tower. These loads are then inserted in MicroSAS and the dynamic analysis of the tower and the support structure is implemented considering additionally the wave action and the static wind force on the tower. In both approaches, rigid