Title of Diploma Thesis

Investigation of the Effect of Different p-y Formulations on the Dynamic Response of Offshore Wind Turbines with Monopile Support Structures

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ABSTRACT

An important structural component of an Offshore Wind Turbine (OWT) is its support structure (including the foundation), in terms of both integrity and cost. With the monopile being the predominant solution nowadays, it is crucial to model accurately its dynamic behavior, taking into account the soil – pile interaction. A well-known method for analyzing the soil – pile interaction is the Subgrade Reaction Method, where the soil is replaced by distributed nonlinear springs, which behave according to specific p-y curves (with p being the soil resistance and y the displacement). However, due to the continuous increase of the energy demands and, hence, the increase of the wind turbines' size and of the pile's diameter, existing p-y curves of modern regulations (API, DNVGL) have been proven inadequate. This fact has in turn triggered the development of new p-y curves in order to model more accurately the soil – pile interaction.

The objective of the present diploma thesis is to investigate the effect of different p-y formulations on the dynamic behavior of a 5 MW OWT with monopile support structure. More specifically, 3 different p-y formulations are taken into account corresponding to the well-known and widely used p-y curves of API and DNVGL to recently (2010) developed p-y curves that are characterized by their accuracy and the absence of application constraints. The numerical modeling of the dynamic behavior of the examined OWT is implemented through the application of FAST. The soil stiffness values required for the analysis in FAST are obtained from LPILE. However, considering the non-linear behavior of the springs, the stiffness values finally applied in FAST are calculated through an appropriate iterative procedure, which is developed in this thesis. The investigation is carried out assuming foundation on clay, while three different undrained shear strengths and two different load cases (wave - wind) are taken into account. Initially, the effect of the examined p-y formulations on the Power Spectral Densities (PSDs) and statistical quantities of appropriately selected variables describing the dynamic response of the OWT is investigated. Finally, for the case of the recently (2010) developed p-y curves, the effect of the soil undrained shear strength and of the different load cases is examined on the above-mentioned variables as well as on the Damage Equivalent Loads (DELs).

The results of the present thesis clearly demonstrate the drawbacks of the p-y curves of the regulations. Moreover, they illustrate the important effect of the pile-soil interaction, and more specifically, of the soil's stiffness, on the dynamic behavior of the OWT's tower and of the monopile. A stiffer clay soil, due to either its high undrained shear strength or the use of more accurate p-y curves, avoiding its underestimation, leads to smaller displacement of the aforementioned components as well as to smaller internal loads. This, in turn, can contribute to a more efficient, in terms of cost reduction, design of the tower and of the monopile.

Keywords: Offshore wind turbines, Pile-soil interaction, P-y curves, Clay soil, Dynamic response.