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Fixed Bottom Tripod Type Offshore Wind Turbines under Extreme and Operating Conditions

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ABSTRACT

The focus of this article is a complete analysis of a fixed bottom offshore wind turbine tripod type for both operating and extreme conditions. Time histories of the rotor load and the resulting forces at various levels of the structure are presented. The percentages of the rotor load contribution to the stresses of the structure components during power production are investigated and shown. The percentages of the structure components' stress for Operating conditions in comparison with these for Extreme conditions reveal the regions where the loadings of the power production state dominate and, thus, determine the design.

KEY WORDS: Wind energy; Wind turbine; Offshore; Rotor load; Time series; Tripod; Operating; Storm.

INTRODUCTION

On a planet under severe environmental crisis, the limitless exploitation of the limited, and expensive nowadays, underground fossil fuel is not a way of covering humanity's vast and fast growing needs for energy. A very promising alternative to the Nations for security, independency and economy comes from the wind. After the wind energy industry increased its experience and capacities, and gained people's and governments' trust, the efforts for optimization of the productivity and elimination of the drawbacks of the wind parks led to the sea. Above the sea area, the wind has higher velocity due to smaller wind shear. An Offshore Wind Turbine (OWT) can have larger size, because it is away from the society and does not have any visual impact or noise effect. An offshore wind park can include a very big number of turbines due to reduced restrictions of property issues. For these reasons, the potential for the construction of offshore wind parks is growing every year. According to EWEA, in the first six months of 2010, 118 offshore wind turbines were fully grid connected producing a total of 333 MW. Overall 16 offshore wind farms with total capacity of 3,972 MW were under construction. This takes the total installed offshore wind power capacity to 2,396 MW as of 30 June 2010. (European Wind Energy Association, 2010)

The fixed bottom OWTs are offshore structures with special design requirements, due to the dynamic interaction between the supporting structure and the wind turbine at the top of the tower. Few attempts for performing integrated load analysis of Wind Turbines under combined wind and wave loads in time domain have been made so far (Klose, Dalhoff and Argyriadis, 2007; Vorpahl, Strobel, Busmann and Kleinhansl, 2010), while static and dynamic analysis of OWT foundations have been made for monopile types (Zhang, Sun, Wang and Hao, 2010).

As ordinary software for structural analysis do not have the capacity of including the rotor load, a software coupling is usually necessary. An attempt of coupling has been made by Kaufer, Cosack, Boker, Seidel and Kuhn (2009); another attempt was made by Seidel, Mutius, Rix and Steudel (2005).

This paper shows and discusses numerical data of a rotor load through Time Domain and Frequency Domain presentations, as well as of the resulting dynamic forces at various levels of the structure.

The analysis takes care of all the elements of nature that can interact with the structure in reality, such as the rotor, the marine growth, the buoyancy, the sea current, the wind and the wave. The added mass of the structure due to the submerged members of the tripod is also taken care of. The inelastic behavior of the soil was simulated by using non-linear lateral and vertical springs. The connection of the structure with the foundation in the model, accurately represents reality since grouted tubular members were assigned in the tripod legs (Pile sleeves). The Pile sleeves in offshore structures effectively reduce excessive vibration (Wang, Li and Bao, 2007). The rotation of the system nacelle-rotor that causes a modification of the structure's geometry for every wind direction is simulated in the modeling approach that is presented.

Two kinds of comparisons are presented using the member stresses' results. The first was the comparison between the stresses that are caused during operation and those that are caused under extreme conditions. The purpose of this comparison is to reveal the regions of the structure where the design is driven by the operating state, and those where the design is driven by the idle state (extreme conditions), where the wind velocity and the wave height are much higher (50 years return period), but the rotor is not working and the turbine is parked. The second was the comparison between the stresses that are caused by the rotor load only, and those that are caused by all the other loads except the rotor under operating conditions. The purpose of this comparison is the investigation of the level of the contribution of the rotor load to the member stresses. The authors' aim is to highlight the significance of the use of an accurate rotor load to the design of a wind turbine and the level of the difference in the nature of an offshore wind