A Comparative Study of the API and NORSOK Standards Apply to Design Analysis for an Offshore Wind Turbine with Jacket Support Structure

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ABSTRACT

This paper is to perform the Jacket support structure design analysis for a 5MW reference offshore wind turbine of IEA OC4 project using API RP 2A-WSD and NORSOK N-004 design standards. The analysis is conducted by a global-local structural analysis scheme. In global analysis, the NREL FAST code is employed to analyze the dynamic responses of entire OWT structure under severe design load cases of IEC 61400-3. The tower base forces and moments are thus calculated and then used as the input of SAP2000 to conduct the Jacket support structural analysis, and then the member and joint strength checks are performed using the API and NORSOK standards, respectively. Totally 9 severe design load cases are considered in this work. The results show that the analyzed Jacket structure is fully in compliance with the requirements of API and NORSOK standards. In addition, it reveals that the NORSOK standard provides slightly more safety margin than API.

KEY WORDS: Offshore wind turbine; Jacket support structure design; Design standard comparison.

INTRODUCTION

With the global warming and climate change, using renewable energy to replace fossil fuel or coal power has been an inevitable trend. Over years, exploiting the wind energy resource has already become a mature and feasible technology, particularly for the offshore wind turbine (OWT). An offshore wind farm is primarily with better average wind speed and lower turbulence, it can make better wind power compared with the land-based wind farm. However, OWTs has to face more severe conditions than those on land, such as typhoon, wave, current and even the earthquake (Twidell and Gaudiosi, 2009). In this regard, the BOEMRE (Bureau of Ocean Energy Management, Regulation, and Enforcement) of U.S. DOI delegated ABS (American Bureau of Shipping) to study the support structure of NREL 5MW reference turbine under hurricane conditions. Meanwhile, the fitness of IEC and API standards for the potential offshore wind farm locations under hurricane conditions was discussed. According to IEC 61400-3 and API RP 2A-WSD (API, 2002) standards, associated with the extended ABS guidance for building and classing offshore wind turbine installations (ABS, 2010), ABS completed a design standard for offshore wind farms in 2011 (ABS, 2011).

On the other hand, IEA has deployed a series of projects for code comparison (Jonkman and Musial, 2010; Jonkman et al., 2012) since 2010 to conduct a series of OWT simulation code comparison based on a fictitious 5MW OWT published by NREL (Jonkman, 2009). The specifications of the widely used reference OWT are listed in Table 1. It has been also noted that the monopole support structure is one of the main focuses in the OC3 project, and the continued OC4 dealt with the reference turbine with Jacket support structure and semi-submersible support structure, respectively.

In view of engineering practice, no matter how the support structure designed by numerical simulation or analytical approach, the OWT support structures have to pass the examination of the design codes or standards for offshore steel structures, achieving the balance of economics and safety. In general, most of OWT support structures are designed according to the design codes recommended by IEC 61400-3 and some guidelines such as those by DNV and GL (DNV, 2013; GL, 2012), where the USD (ultimate strength design) or LRFD (load resistance factored design) design standards (API, 1997; ISO-19902, 2007; Standards Norway, 2013) are recommended for the so-called ULS (ultimate limit state) design.

On the other hand, in the US, the ABS studied the OWT support structures in the potential offshore wind farm located in the northeastern Atlantic coast and the Gulf of Mexico, to study the governing load cases and load effects of bottom-founded offshore wind turbines subjected to the hurricanes on the US Outer Continental Shelf (OCS), to review and evaluate the existing methods of calculating the breaking wave slamming load exerted on an offshore wind turbine support structure, and to provide constructive recommendations to support the future enhancement to the relevant design criteria for offshore wind turbines (ABS, 2011). Their subsequent structural design analyses were based on the API RP 2A-WSD (API, 2002), which primarily follows the philosophy of allowable stress design (ASD) (AISC, 1989).

After the Fukushima nuclear accident happened in Japan 2011, the countries in the East Asia have seriously been paying attention to the exploit of offshore wind energy. In Taiwan, there are two demonstrative offshore wind farms which have been permitted to