Generic Hurricane Extreme Seas State: An Engineering Approach

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ABSTRACT

Extreme sea states, which the IEC 61400-3 (2008) standard requires for the ultimate limit state (ULS) analysis of offshore wind turbines are derived to establish the design basis for the conceptual layout of deep water floating offshore wind turbine foundations in hurricane affected areas. Especially in the initial phase of floating foundation concept development, site specific metocean data are usually not available. As the areas of interest are furthermore not covered by any design standard, in terms of design sea states, generic and in engineering terms applicable environmental background data is required for a type specific conceptual design. ULS conditions for different return periods are developed, which can subsequently be applied in site-independent analysis and conceptual design. Recordings provided by National Oceanic and Atmospheric Administration (NOAA), of hurricanes along the US east coast and the Gulf of Mexico (1851 - 2009) and Japanese east coast (1951 -2009) form the basis for Weibull extreme value analyses to determine return period respective maximum wind speeds. Unidirectional generic sea state spectra are obtained by application of the empirical models for hurricane generates seas by Young (1998, 2003, and 2006), requiring maximum wind speeds, forward velocity and radius to maximum wind speed. An averaged radius to maximum sustained wind speeds, according to Hsu et al. (1998) and averaged forward speed of cyclonic storms are applied in the initial state. In a second step the influence of the forward velocity is investigated and related to the assumption of an extended fetch.

KEY WORDS: Hurricane Waves, Extreme Sea State, Ultimate Limit State

INTRODUCTION

Not all industrialized countries, in fact only a minority, are blessed with shallow coast areas, i.e. shelf seas, like the traditional offshore wind nations, e.g. UK, Denmark and recently Germany. The majority of the 2.3GW of installed offshore wind capacity is based on bottom fixed structures in water depth up to 30 meters, Musial (2010). Countries like Norway, Japan, Portugal, and the US having vast potential of offshore wind energy face the challenge of deeper waters when exploiting such resources. The Japanese waters alone are anticipated to hold a deep water wind resource potential of 275GW, Henderson (2010). According to the study from Musial (2010) the US has wind resources in the order of 2451GW in water depth beyond 60 meter. Considering the above named regions it becomes evident that hurricane, tropical cyclone or typhoons need to be considered in the design. All storm types characterize basically the same kind of storm, though are only geographically different named phenomena. The term Hurricane will be used in the following.

DESIGN BACKGROUND

For development and research on deep water foundations, site specific environmental data is by nature seldom available in a pre detailed design stage. Consequently generic environmental boundary conditions need to be applied and a development of such is presented in the following. It is focused on the ultimate limit state analysis and hence it seems sensible to develop extreme design events towards the background of hurricane like environmental conditions. The Saffir Simpson scale, see Table 1, e.g. Marks (2003), categorizes hurricane force storms from 1