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Application of Design Standards to the Design of Offshore Wind Turbines in the U.S.

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Abstract

This paper concerns the application of design standards to the design of offshore wind turbines, focusing on the United States. Offshore wind turbines (OWTs) are those wind turbines whose support structures are subject to hydrodynamic loading. A considerable number of OWTs have been installed in Europe, but so far none in the United States. Interest in offshore wind energy is growing in the U.S., and it is expected that projects will reach the design stage in the near future. This paper will facilitate development in the U.S.

The paper consists in three highly related parts. The first part gives the background for the development of offshore wind in the U.S. in terms of external conditions and expected design standard requirements.

The paper's second part provides a summary of the method and recommendations of the committee draft of the OWT design standard IEC 61400-3 [1] that is believed to represent state-of-the-art. It is placed within the context of other relevant standards. Of particular note are both wind turbine specific standards and standards that are presently used to design offshore structures in the U.S. and internationally. This summary is crucial for the appreciation of the principal differences between designing OWTs, where dynamic response to wind loads is most often dominant, and typical bottom fixed offshore structures.

The last part of the paper discusses the level of structural reliability implied by the design rules of IEC 61400-3. There is a long tradition in design of wind turbines to use 50-yr return period values for extreme environmental conditions with associated load safety factors. The tradition in design of offshore structures is to use 100-yr return period values, with or without load factors depending on code format. When developing design standards for OWTs this difference has to be addressed. The paper explains how this has been done in the IEC 61400-3 CD and what the philosophy behind it is been in terms of choice of reliability level. This includes an estimation of the structural reliability under extreme North European environmental conditions. Especially the uncertainty model assumptions are presented in some detail. For hurricanes the uncertainty model will be different possibly implying different load factors if return period is maintained. The paper discusses what should be considered in this regard, e.g. if it is feasible to aim at the same reliability as for U.S. offshore structures. Some simple tools are provided that can be of use for initial assessments structural reliability acceptance criterion.

Introduction

The initial European work on offshore wind systems were concerned with the scaling and structural and economic optimization of bottom-mounted offshore wind farm systems. Two early examples of this type of design work include the Opti-OWECS (Optimization of Bottom-Mounted Offshore Wind Energy Converters) study [2] and the Dutch Offshore Wind Energy Converter (DOWEC) project [3]. In more recent times, more detailed offshore wind system studies have been carried out that incorporate both system design and design standards development (i.e., the European Community project RECOFF (Recommendations for the Design of Offshore Wind Turbines) [4]).

The design process so far has been based on the experience of both wind turbine designers and offshore structure designers. The first attempt to merge these disciplines was made in the Danish Recommendation for technical approval of offshore wind turbines [5] which points out issues that require special attention rather than it provides detailed guidance. Since then more mature guidelines have been provided in the standards by Det Norske Veritas [6] and Germanischer Lloyd [7]. Finally an effort has been underway over the past five years by the International Electrotechnical Commission (IEC) to develop an internationally accepted set of design standards to guide design of future projects. This effort has recently resulted in the release of a committee draft of IEC 61400-3 [1]. For the wind related parts of the design load cases in [1], [6], and [7] one recognizes many or the entire load cases from IEC 61400-1 [8] which is the current international standard for design requirements for land-based (horizontal axis) wind turbine generators. The differences between [1], [6], and [7] is mainly in the way combination of wind generated and wave generated loads is made. It is outside the scope of the current paper to dig into details about these differences that are in some aspects minor and in others significant. People responsible for [5], [6], and [7] have been deeply involved in the drafting of IEC 61400-3, which in the authors opinion is to be considered the-state-of-the-art. Therefore, in the rest of this paper only the IEC 61400-3 committee draft will be considered.