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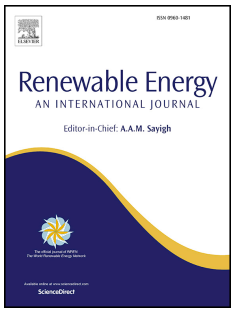

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Hierarchical Four-Step Global Sensitivity Analysis of Offshore Wind Turbines Based on Aeroelastic Time Domain Simulations

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Abstract

Although uncertainties are present in all real parameters, numerical calculations of the structural behaviour of offshore wind turbines are usually conducted with deterministic values. However, with this approach, optimisation processes can be misleading and reliability levels cannot be calculated. The reasons for deterministic calculations are high computing times of probabilistic approaches and the lack of knowledge about the scatter of data. For deterministic approaches, more complex models with higher computing times are possible, although they, are less generally valid. Therefore, it is useful to identify the most influential parameters that have to be treated in a probabilistic manner using sensitivity analyses is valuable. Contrary to rudimentary sensitivity approaches being used in offshore wind energy so far, this paper presents a new four-step sensitivity analysis reducing the probabilistic parameter subset step by step and aiming to achieve a compromise between computing time and complexity. It can be shown that for different substructures and different load cases, only a small parameter subset is influential and many other inputs can be regarded as deterministic without losing accuracy. However, attention must be paid to the slight differences among substructures. Therefore, it must be highlighted that not all results are general.

Keywords: Global sensitivity, Offshore substructures, Wind energy, FAST, Time domain simulations

1. Introduction

Over the past decades, wind energy in general and recently offshore wind energy in particular have become more and more important for global energy production. However, the costs for offshore wind energy are still too high compared with energy based on coal to be really competitive [1]. For offshore wind turbines (OWTs), substructures and foundations account for a significant part of these costs [2]. Therefore, both the probabilistic analysis and the optimisation of substructures of offshore wind turbines become necessary. Since the design of OWTs has to be based on holistic time domain simulations, as stated in current standards [3], the calculations are fairly time-consuming. Furthermore, for an optimisation or a probabilistic analysis, a high amount of calculations is necessary which leads to computing time issues. Hence, apart from the development of suitable time domain models, the identification of the most relevant input parameters is crucial to treat non-influential inputs as deterministic. In this context, non-influential inputs means that the scattering and uncertainty of these parameters do not influence the outputs significantly.

Current time domain models are based on finite elements (FE), multi-body systems (MBS) and modal approaches. Aerodynamics and hydrodynamics are coupled with the elastic behaviour of the turbine and its controller, which makes the overall system highly non-linear and quite complex. Turbulent wind fields, irregular waves as well as geometric non-linearities due to large rotations or shortening/lengthening are taken into account as well. The complexity of existing time domain codes allows only considering of a limited number of probabilistic input values. Some of the most important aero-elastic codes are GH BLADED, FAST, FLEX5 and HAWC2. An example of an even more sophisticated code with computing times of several days, and therefore not suitable for probabilistic calculations, can

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