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Global Sensitivity Analysis of Offshore Wind Turbine Foundation Fatigue Loads

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1 Introduction

The design and analysis of offshore wind turbine foundations are traditionally based on deterministic design approaches, where partial safety factors are applied to account for the uncertainties in the design parameters. Environmental inputs, in particular, are site-specific and some general code-based design can either be unsafe or over conservative. The main objective of this study is to understand the sensitivity of fatigue loads with respect to primary structural, geotechnical and metocean parameters used in wind turbine simulations. As opposed to one-factor-at-a-time (OAT) approach, global sensitivity analysis (SA) techniques are more appropriate for highly nonlinear models, such as integrated wind turbine models represented by large number of parameters.

2 Methods

The sensitivity analysis is performed using the NREL 5 MW reference wind turbine [1] installed on a gravity based foundation. Aero-hydro-servo-elastic simulations are carried out using HAWC2 [2] for three modified IEC [3] design load cases (DLC) summarized in **Table 1**. Loads are calculated in terms of damage equivalent loads (DEL) at the interface and foundation base. Linear regression of Monte Carlo simulations is performed to evaluate sensitivity of the loads to the input parameters.

Table 1 Description of design load cases

Case No.	Design Load Case	Uw [m/s]	Hs [m]	Tp [s]	Turb. Model
1	Power production (FLS)	12.0	1.55	5.2	Normal
2	Parked (FLS)	12.0	1.55	5.2	Normal
3	Parked (ULS)	42.0	6.10	11.0	Extreme

3 Findings

Results showed that parameter significance rankings vary depending on both (1) location and (2) DLC considered. **Figure 1** illustrates the parameter sensitivity in terms of variance decomposition. In general, uncertainties in the fatigue loads are highly influenced by turbulence intensity at the interface and wave load uncertainties at foundation base. Uncertainties in soil property suggest significant

nonlinear or interactive effects, particularly during Case 2 where aerodynamic damping is significantly reduced. Comparison of sensitivity indices with Morris method indicates good agreement [4].

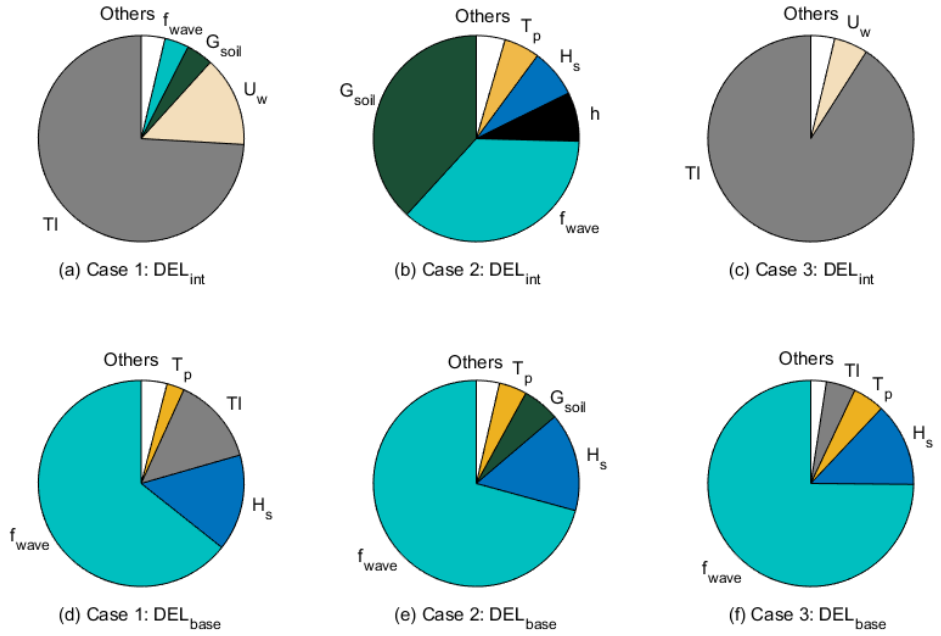

Figure 1 Variance decomposition for DEL at base and interface [4]

4 Conclusions

This study demonstrates application of Monte Carlo method for global sensitivity analysis of offshore wind turbine loads. Parameters with main and nonlinear effects were identified, and it was found that the set of influential parameters vary according to location and design load case considered. This work provides insights to foundation designers and wind turbine manufacturers on which parameters must be assessed in more detail in order to reduce uncertainties in load prediction.

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