Target sensitivity informed reliability analysis for offshore wind turbine fatigue assessment

E. Fekhari[†,1,2], V. Chabridon[‡,1], J. Muré[‡,1], B. Iooss[§,1,2]

[†] PhD student (presenting author) [‡] PhD industrial advisors [§] PhD supervisor

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[1] EDF R&D, 6 Quai Watier, 78401 Chatou, France
elias.fekhari@edf.fr

[2] Université Nice Côte d'Azur, 28 Avenue de Valrose, 06103 Nice, France

Abstract

Offshore wind turbines are a rapidly growing technology in energy production. The design, installation, and exploitation of these industrial assets are regulated by international standards, providing generic guidelines. However, offshore wind turbines are more and more subject to uncertainties, making long-term investment decisions riskier. Usually, uncertainty sources are divided into two parts: those arising from environmental factors (e.g., wind and wave conditions) and those related to the system itself (e.g., geometry, material, and soil properties). These two sources are often assumed to be mutually independent and propagated through a costly-to-evaluate computer model simulating the various physics involved in the turbines' behavior [5]. As an output, a possible variable of interest can be, for instance, the distribution of the material fatigue at a specific spot of the structure [2]. To ensure that this output respects the standard resistance limit, one needs to conduct a reliability analysis to estimate a corresponding failure probability (e.g., around 10^{-4} according to IEC 61400-1 standard).

The present work falls within a specific framework: due to some common engineering practice, a finite batch of Monte Carlo simulations, previously realized, is already available. Unfortunately, this batch is insufficient to solve the reliability assessment problem but could help us to get a better understanding of the underlying behavior of the system regarding its failure.

Under such a limited amount of simulations, the first step consists in performing a preliminary target sensitivity analysis based on the use of dedicated indices derived from the so-called Hilbert-Schmidt Independence Criterion (HSIC) [3]. Then, a metamodel-based strategy, coupled with efficient sampling techniques (such as, e.g., subset sampling) is used [4]. During this phase, iterative results of target sensitivity analysis are used together with non-parametric copula fitting techniques (based on the empirical Bernstein copula, see [1]) to estimate the joint density conditional to the failure event. By reusing this relevant information together with the knowledge of the most influential parameters through the iterative process, one can minimize the extra number of simulations required to estimate the target failure probability.

Short biography (PhD student)

After graduating from the French Institute for Advanced Mechanics (now SIGMA Clermont) with an Engineer's degree, I joined the R&D lab of the French electric utility company EDF. I worked for three years as a research engineer in applied Mathematics for industrial risk management before starting a Ph.D. on the treatment of uncertainties in simulation models for wind turbine asset management.

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