Modified Constitutive Relation Error for Multi-Physics Wind Turbine Calibration

A. Roussel[1,2,*], L. Chamoin[1], J.-P. Argaud[2], P. Bousseau[2]

[1] Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS
LMPS - Laboratoire de Mécanique de Paris-Saclay
4 avenue des Sciences 91190 Gif-sur-Yvette France
e-mail:{antoine.roussel, ludovic.chamoin}@ens-paris-saclay.fr
Web page: https://lmps.ens-paris-saclay.fr

[2] EDF R&D
Boulevard Gaspard Monge 91120 Palaiseau France
e-mail: {pierre.bousseau, jean-philippe.argaud}@edf.fr
Web page: https://www.edf.fr

[*] presenting author

ABSTRACT

To make offshore wind turbine (OWT) technology more efficient, attention needs to be given to the damage seen by the sub-structure. As can be seen in Figure 1, the sub-structure is installed on the sea bed, support the tower and the turbine.

Figure 1: A OWT Overall Architecture

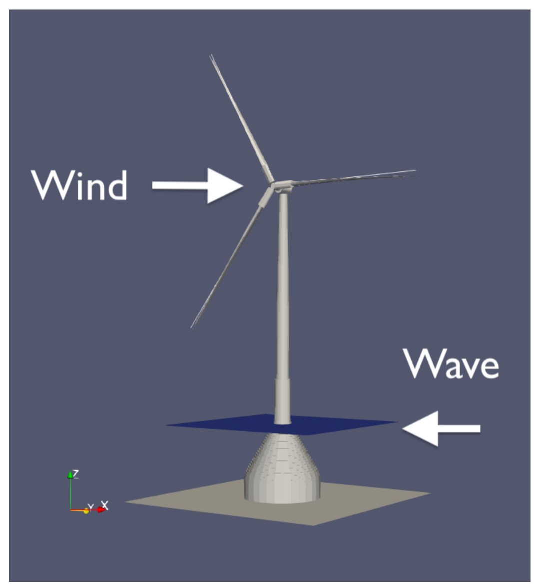

Figure 2: OWT Dedicated Modeling (DIEGO)

Sub-structures designs, design margins, and remaining lifetime assessment can be optimized by the calibration of numerical models [1] (Fig. 2). Data-based modeling is relevant since simulations involve numerous uncertain and empiric parameters (drag and inertia fluidic coefficient, structural damping, soil stiffness), and wind turbines are closely monitored. Also, despite data being used for calibration, there is a gap in the knowledge of adapting monitoring campaigns to simulation needs.

There are two means of calibrating existing wind turbine models: 1) reducing the gap between the early-stage modeled structure and the operating structure *responses* and 2) improving the accuracy of hydrodynamics and aerodynamics *loadings*.

In the case of noisy data and multi-fidelity laws, the modified Constitutive Relation Error (mCRE) method has proven useful since it considers data and low-fidelity laws uncertainties through dedicated errors [2,3]. High-fidelity laws are assumed perfect and are thus strongly enforced in the inversion process. The delimitation between high and low fidelity laws is called the *physical a priori* and depends on the simulation underlying physics. Model adaptation is obtained by minimizing the calibration gap $\Delta_{calibration}$ split into data fitting (E^2_{data}) and low-fidelity laws fitting (E^2_{laws}):

$$\Delta_{calibration} = E^2_{data} + E^2_{laws} \tag{1}$$

Previous works only feature regularization errors for *response* laws such as elasticity or inertia [4,5]. The uncertainty held by hydrodynamic and aerodynamic laws involved in wind turbine *loadings* modeling led us to extend the mCRE concept by proposing a functional of the form:

$$E^2_{laws} = E^2_{elasticity} + E^2_{inertia} \underline{+ E^2_{hydro} + E^2_{aero}} \tag{2}$$

In this session, we will first propose a definition for the hydrodynamic and aerodynamic constitutive relation errors (E^2_{hydro}, E^2_{aero}) that follow the mCRE concept and the requirements of wind turbines mechanical simulations and instrumentations. Secondly, we will focus on multi-physics vibratory dynamics equations to adapt the calibration process to the finite element computational framework. Finally, the errors optimization strategy and the on-site data analysis will be presented.

Based on this method, we have processed EDF Blyth on-site data for model calibration. The mCRE calibration showed promising results for parameter estimation and law fidelity comparison. The optimized errors also indicated local discrepancies between laws and data that suggested sensor position improvements for future monitoring campaigns.

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