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Efficient time-domain ROMs for aeroelasticity and UQ in downwind turbines

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Design of aeroelastic structures such as wind turbine blades, requires characterisation of unsteady effects in order to predict instabilities and fatigue. However, most of these computations require large computational resources [1] and hence lower fidelity linear models are mostly used in the industrial design practise. But these models are unable to provide an accurate representation of the nonlinear aerodynamics, which leads to over-designed structural components since large factors of safety are considered. Further, the industrial design practise of wind turbine blade does not take into account the uncertainties in the operational parameters, which could have a detrimental effect on the performance of the turbine. In this paper, we present a methodology for computationally cheap characterisation of blade loading in an experimental wind turbine, while also considering uncertainties in the inputs.

Initially, an aeroelastic model of the wind turbine of downwind orientation is developed, considering all structural components such as nacelle, blade and tower. The fluid model is based on RANS-based Navier-Stokes, while the structure is represented in the form of a 1-D beam model considering non-uniform blade properties. The aeroelastic model is validated and an extensive aeroelastic characterisation is performed. This model is then employed to train a data-driven reduced order model (ROM), which is based on ideas of system identification. The ROM is able to accurately predict the blade loading, and also provides an accurate representation of the forcing due to the tower wake experienced in downwind turbines. Finally, uncertainties are considered, which are reduced in a Bayesian framework through experimental data. The presented method can be useful in a probabilistic design framework to predict structural fatigue in wind turbines of downwind orientation.

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