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Real time data assimilation for the digital twinning of wind farms

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Abstract

Wind energy is the fastest-growing renewable energy and is playing a pivotal role in the journey toward decarbonization. To match this ever-growing demand, wind turbines have increased in size over than one order of magnitude in past decade and have been clustered in farms to mitigate installations and maintenance costs. These two factors severely challenge classical control and model syntheses methods, that usually rely on simplified linear time-invariant (LTI) formulations. In fact, operations in unsteady conditions, i.e. immersed in wakes, and the slenderness of modern machines, i.e. high deflections, challenge the underlying assumptions of these LTI models, increasing the gap between models and real-systems behaviors and motivating further investigations in adaptive controls, possibly via machine learning techniques [1], and adaptive models, such as digital twins [2]. The aim of this work is to develop a digital twin for real turbine models through an extensive wind tunnel experimental campaign, the setup of which is shown in Figure 1. The digital twin is designed to enable control using model-based approaches. The study focuses on predicting the aerodynamic performance of the turbines under different operating conditions, with particular attention to a configuration where two turbine models are placed one behind the other, operating in wake-induced conditions. To this end, we set an optimization problem in a set of weights $\boldsymbol{w_p} \in R^{\dim(\boldsymbol{w_p})}$ that parametrizes a parametric function using RBFs of the power coefficient which we want to identify, such that the mismatch between the real system and its virtual replica is minimized. The digital twin follows a first-order model of the turbine and relies on real-time measurements as inputs. Namely, (1) the rotational speed of the turbine ω, (2) the mechanical generator torque τ_g and (3) the wind speed v are assumed available at each sampled time t_i. We note on passing that we use a gradient-based optimization that relies on adjoint gradients, as described in [2], but other approaches are possible.

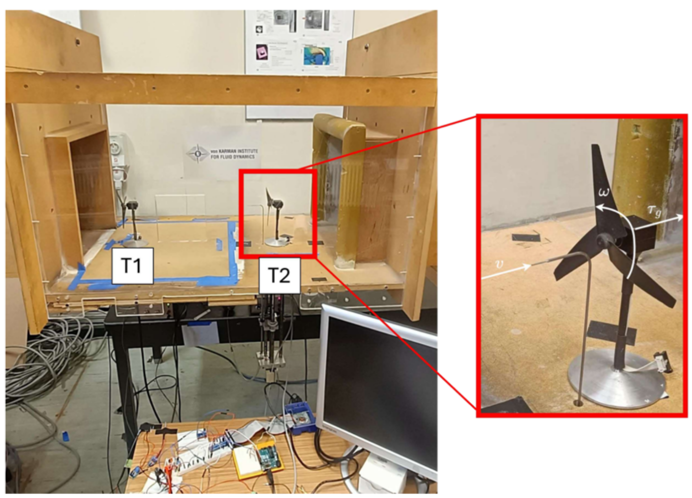

Figure 1: Experimental setup featuring two scaled wind turbine models (T1 and T2), used to develop a digital twin and subsequently test model-based controllers in a wind farm-like configuration.

Keywords: Wind energy, wind turbine aerodynamics, digital twin, adaptive modeling, model-based control.

References

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