VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Francisco Jara Avila**

The public defense will take place on **Friday 26th June 2026 at 5pm** in room **I.2.02** (Building I, VUB Main Campus)

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PREDICTION AND UNCERTAINTY ESTIMATION OF PERFORMANCE INDICATORS IN HIGH FREQUENCY SYSTEMS FOR WIND PARKS

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Abstract of the PhD research

Wind is a renewable energy that has become more important in recent years. Wind turbines are equipped with a SCADA system, which allows for remote supervision of the wind farm. The most studied relationship between the source, wind speed, and the output from the turbine has traditionally been active power. The most studied relationship is usually portrayed by the Power Curve which transforms the wind speed into active power. There exist several methodological attempts to provide estimations from wind speed and wind direction to certain SCADA indicators for each turbine in a system. Given the non-linear nature of the functional relationships inside the turbine machine learning and deep learning techniques have been adopted to predict SCADA performance indicators. The use of the prediction of these SCADA indicators could help for normal behavior modelling, by studying the distribution of the expected value at each timestep.

Subsequently, uncertainty estimations are either based on the distribution of the residuals and making gaussian assumptions. These estimations, also, tend to not consider the fact that the turbine in the offshore setting is usually part of a system. The usual data-driven techniques found in literature, apart from the known engineering curves, tend to not be transparent about how the prediction process or the underlying function works. A study on transparent methods is presented, starting by two algorithms that study the similarity between turbines in a wind farm based on environmental conditions. The algorithms study this not only on a turbine level but also on a farm-wide level, mapping similarities or correlations inside the wind farm.

Wind farm performance monitoring has traditionally relied on the deterministic models mentioned, which often also fail to account for farm-wide behavior and uncertainty quantifications. A methodology for farm-wide estimation is proposed. This methodology can work despite of which function is thought for the prediction and calculates the associated variance of the prediction. It is thought that this associated variance is a both an epistemic uncertainty and aleatoric uncertainty. The inclusion of the inferential framework does not inherently provide better predictions, but provides overall an uncertainty estimation calculated on farm-wide behavior.