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 **Pieter-Jan Daems**

The public defense will take place on **Thursday 9th February 2023 at 4:00pm** in room **D.0.08** (Building **D**, Brussels Humanities, Sciences & Engineering Campus)

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AUTOMATED ASSESSMENT OF WIND TURBINE LOADING AND DYNAMICS USING SCADA AND VIBRATION DATA

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Abstract of the PhD research

The effects of climate change are widely acknowledged within the scientific community. To limit these, the Paris Accords were signed in 2015. A core prospect of these accords is to limit CO2 emissions, for which it is needed to transition towards renewable energy sources. To enable their market penetration, they must be economically competitive with gray energy sources. Many renewable energy sources, such as wind, have known drastic reductions in their operational costs throughout the last decade. To further reduce the operating costs of wind farms, industry strives towards more optimized designs. These require detailed design insights in the behavior of wind turbines with respect to loading and dynamics. Such opportunities are presented through Industry 4.0, which has already pushed wind manufacturers towards more heavily instrumented turbines. Several challenges nevertheless still remain with respect to automated data processing, which this dissertation tackles.

First off, wind turbines are subject to variable and complex loading conditions, which are highly dependent on the farm location. A proper understanding in these is required to ensure that design lifetime requirements are met. Therefore, this dissertation develops a framework to automatically annotate different load cases based on SCADA data of the wind turbine. This is a widely available data source for modern wind turbines. Based on this method, occurrence rates are obtained for different load cases. These are then compared with the ones used during the design, such that insights are gained in the validity of the different hypotheses. Detailed annotation moreover allows to gain insights between different events which are interlinked with one another, allowing to mitigate their impact.

Second off, the dynamic behavior of the machine is to be assessed by the manufacturer, as this influences both the fatigue lifetime of the structure, and the noise emission of the turbine. The latter is especially important for onshore turbines, where it has been shown that noise emissions are still one of the most important factors limiting the social acceptance of wind. Operational Modal Analysis (OMA) presents a power methodology in civil applications to assess the dynamic behavior of structures in their real environment. The wide-spread use of this technique is nevertheless limited in the domain of rotating machinery due to the presence of frequency and amplitude modulated harmonics in the acquired vibration signals. The presence of these harmonics results in erroneous results in case no pre-processing is done. The required steps might be dependent on the operating condition of the turbine. To automate this aspect, the aforementioned annotation framework is combined with novel pre-processing methods to remove the harmonic content. Afterwards, classical OMA methods can be used to estimate the modal model. These are in turn used by industry to update complex simulation models.