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 **Ali Ghandour**

The public defense will take place on **Monday 16th December 2024 at 3pm** in room **D.2.01** (Building D, VUB Main Campus)

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THE WIND TURBINE TOWER SHADOW EFFECT: EXPERIMENTS, MODELLING AND MITIGATION

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Abstract of the PhD research

In a horizontal-axis wind turbine (HAWT), when a blade rotates in proximity to the tower, it can experience temporary variations in wind speed and direction. The passage of each blade results in periodic fluctuations in the aerodynamic loads it experiences. This, in turn, contributes to a decrease in efficiency and a shorter operational lifespan, ultimately reducing the overall performance of the turbine. This phenomenon is commonly referred to as the 'tower shadow effect'.

In modern three-bladed HAWTs, the largest and the most common periodic power pulsations are observed at what is known as the 3p frequency. This is equivalent to three times the rotor frequency and thus the frequency at which the blades traverse the tower. While the tower shadow effect is not the sole contributor to such pulsations, it is acknowledged as a primary factor. Consequently, engineers aim to mitigate the impact to ensure reduced blade loads and a more consistent and efficient energy generation process.

This dissertation provides a comprehensive exploration of the tower shadow effect, particularly emphasizing its influence on both blade aerodynamics and overall turbine performance. It then focuses on the use of flow control to reduce the cyclic loads acting on the blades. Firstly, an in-depth investigation is conducted employing an integrated methodology that combines potential flow and blade element momentum theory. This analytical framework is complemented by wind tunnel experiments to provide a better understanding of the tower shadow effect. In this study, microtabs have been selected as a favourable flow control option due to their low cost, minimal energy requirements and ease of integration. The effectiveness of microtabs in lift force enhancement and mitigation is thoroughly examined through extensive wind tunnel studies done at varying turbulence levels.

Finally, to assess the practicality and efficacy of microtabs as a potential solution, a dedicated wind tunnel setup is devised mimicking the real-world tower shadow effect. The blade is equipped with a microtab fixed near the trailing edge. The experimental results affirm the feasibility and effectiveness of microtabs to mitigate the impact of the tower shadow effect. This research not only contributes to a deeper understanding of the tower shadow effect but also introduces microtabs as a viable and tested solution. The integrated approach of theoretical modeling, wind tunnel experimentation, and practical application opens avenues for enhanced wind turbine design and blade load alleviation in the face of the tower shadow effect.