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DOCTOR OF ENGINEERING SCIENCES

of **Ayoub Talamalek**

The public defense will take place on **Monday 18th November 2024 at 4pm** in room **D.2.01** (Building D, VUB Main Campus)

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TURBULENCE EFFECTS AND WAKE REPLENISHMENT IN PAIRED VERTICAL-AXIS WIND TURBINES

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Abstract of the PhD research

In recent years, lift-based Darrieus vertical-axis wind turbines (VAWTs) have attracted growing attention as a promising renewable energy solution, thanks to their potential advantages and suitability for floating offshore applications. This dissertation investigates the performance and wakes of vertical-axis wind turbines in a wind farm context, with special attention given to the benefits of grouping VAWTs in closely spaced, counter-rotating pairs. The modified aerodynamics resulting from this pairing increases the power production and affects the development of the wake. Both effects are sensitive to inflow turbulence. The goal of this research is to further our understanding of paired VAWTs and how this knowledge can be used to optimise the use of paired VAWTs in wind farms.

We investigate the wake replenishment mechanisms of paired counter-rotating VAWTs through dedicated wind tunnel experiments. We find that, compared to isolated VAWTs, paired VAWTs promote vertical wake replenishment at the expense of lateral replenishment. Also, the wakes of paired VAWTs are significantly affected by their rotational direction. Experimental measurements are compared with an actuator-line model (ALM) integrated within an unsteady Reynolds-averaged Navier-Stokes (uRANS) solver. The ALM captures the overall wake characteristics but underestimates the magnitude of the wake replenishment mechanisms. In particular, vertical and lateral advection mechanisms are underestimated.

Experiments are performed under different turbulence levels of the inflow, to investigate the effect on power and wake. We find that both isolated and paired VAWTs have higher power coefficients under turbulent inflow. The ALM simulations confirm this and show that the higher power coefficients are mainly due to enhanced blade lift. Higher turbulence increases the turbulent wake replenishment, as expected, but leaves the vertical and lateral momentum advection largely unaffected.

The outcomes of this dissertation contribute to the knowledge on the wake dynamics of counter-rotating paired VAWTs and offer a deeper understanding of how inflow turbulence affects both power performance and wake. Additionally, this work provides useful insights for developing a strategy to better integrate paired-VAWTs in wind-farms.