SCIENCES & BIOENGINEERING SCIENCES

The research group
Artificial Intelligence Lab

has the honor to invite you to the public defence of the PhD thesis of

Simon Daenens

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

Power Prediction and Health-Aware Control for Offshore Wind Farms - A Graph-Based Learning Approach

Supervisor:
Prof. dr. Ann Nowé (VUB)
Co-supervisor:
Prof. dr. Jan Helsen (VUB)

The defence will take place on
Friday, November 13, 2026 at 2 p.m.

VUB Etterbeek campus, Pleinlaan 2, Elsene, Auditorium K.2.56

Members of the jury

Prof. dr. Wolfgang De Meuter (VUB, chair)
Prof. dr. Abdellah Touhafi (VUB)
Prof. dr. Peter Vrancx (VUB)
Prof. dr. Michael Howland (Massachusetts Institute of Technology, USA)
Dr. Julian Quick (Danmarks Tekniske Universitet, DK)

Curriculum vitae

Simon Daenens obtained his Bachelor's and Master's degrees in Aerospace Engineering at Delft University of Technology, including an exchange semester at the University of British Columbia in Canada. His Master's thesis focused on condition-based maintenance for airline operations. Before starting his PhD, he gained industry experience as a data scientist at TUI. In November 2022, he started his PhD at the Vrije Universiteit Brussel under the supervision of Prof. Ann Nowé and Prof. Jan Helsen, at the Artificial Intelligence Lab and OWI-Lab. His research focuses on graph-based machine learning for power prediction and health-aware control in offshore wind farms.

Abstract of the PhD research

Offshore wind is expanding rapidly, and two operational realities are reshaping how farms are run. First, transmission system operators increasingly require farms to track a mandated power reference rather than generate at maximum capacity, making curtailment routine rather than exceptional. Second, as fleets age, the uneven accumulation of fatigue across turbines—driven by wake interactions—increasingly determines a project's economic viability. This dissertation addresses both with data-driven methods that represent the wind farm as a graph of turbines coupled by their wakes, developed and validated on real SCADA and field data from Belgian North Sea farms.

Part I develops methods to predict the *potential power* of every turbine—the power it could produce under the prevailing wind, independent of control actions. Starting from a farm-wide deep neural network combining convolutional (spatial) and recurrent (temporal) representations of high-resolution SCADA, the work progresses to a spatio-temporal Graph Neural Network (GNN) aggregating information along wake-aware edges, and finally to a transferable, multi-task GNN that generalizes across farm layouts and turbine types, predicting accurately on farms never seen during training. Because these models learn local features from the SCADA data every farm already records, one trained model can serve an operator's entire fleet; embedded in a Normal Behavior Model framework, they cut undetected power-loss events from roughly one in eight to near zero and quantify the energy lost to curtailment.

Part II turns from prediction to control: given a curtailed farm's surplus capacity, *how* should power set-points be distributed across turbines? Coupling a field-calibrated Gauss-Curl Hybrid wake model (FLORIS) with fatigue estimates from calibrated OpenFAST simulations, and using a coordination graph to keep the problem tractable, the work first introduces a health-aware Set-Point Thompson Sampling controller that reduces farm-wide damage equivalent loads by up to 5.6 % versus a discrete proportional heuristic while honoring the grid reference—an advantage that persists under stochastic wind. It then generalizes to a Health-Aware Control (HAC) framework targeting lifetime directly: over a 35-year lifecycle simulation of a 44-turbine farm, with the main bearing as the life-limiting component, it equalizes fatigue across the fleet, delaying the first fatigue-driven component failure by roughly 208 days and synchronizing end-of-life at no cost to efficiency—so that decommissioning can be planned as a single coordinated event.