

Distributed Control and Data-Driven Optimization of Robust Wind Turbines and Wind Farms

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The proposed project aims to develop AI-driven and distributed optimization and control strategies to enhance wind turbine operation and wind farm performance, optimizing turbine coordination, wake mitigation, and energy capture.

Building on prior work in model-based robust control for single turbines, this project extends the focus to multi-turbine optimization using machine learning-based controllers, distributed optimization algorithms, and federated learning frameworks for scalable wind farm coordination.

A key component is the investigation of neural network controllers for blade pitch, yaw, and generator torque optimization, alongside consensus-based control strategies to dynamically adjust turbine yaw angles in real time. The project also explores privacy-aware federated learning techniques to improve turbine collaboration without centralized data dependencies. The various proposed approaches will be validated through high-fidelity Monte Carlo simulations, ensuring robustness to wind variability and operational uncertainties.

As a complementary outreach initiative, the project includes a micro-wind turbine showcase on campus, designed to engage students, raise public awareness, and stimulate discussion on wind energy and AI applications. This educational component will feature interactive learning materials and hands-on experiential learning opportunities through design, prototyping, and data logging/collection and processing.

Expected outcomes include improved wind farm efficiency, reduced operational uncertainty, and extended turbine lifespan, with long-term extensions toward digital twins, LIDAR-enhanced predictive control, and offshore wind platforms (the current scope focuses on onshore wind turbines). By integrating AI, distributed control, and real-time optimization, this project complements our previous efforts on robust control design via advanced mathematical frameworks and robustness guarantees through systematic analysis.

Together, our projects lay the groundwork for the next generation of scalable, adaptive wind energy control systems.