Numerical and experimental validation of wind farm active power control

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Summary
Active power control (APC) enables wind turbines to contribute to frequency control on the power grid, which is needed to allow even higher wind energy penetration levels. This work focuses on the development and validation of the closed loop APC in waked wind farms. Validation of the developed controller is performed in large-eddy simulations and wind tunnel experiments, demonstrating a high level of power tracking, and a possibility to influence the structural loading on the individual turbines.

1. Introduction

Future wind farms should be able to respond to grid requirements through control of their power production to balance power supply with demand, the so-called active power control (APC). Control of turbines in a wind farm is challenging because of the wake interactions among wind turbines [1]. This is even more emphasized for offshore wind farms, which typically have a higher number of turbines and are characterized by slower wake recoveries.

2. Active power control concept

We propose an APC structure based on the power and loads feedback signals [2], as shown in Fig. 1, which can track a wind farm power reference and achieve a fairer distribution of wind turbines loads simultaneously. The validation is performed in wind tunnel experiments using two fully controllable Ø 58 cm wind turbine models [3], and in large-eddy simulations using the code PALM coupled with actuator disc models [2].

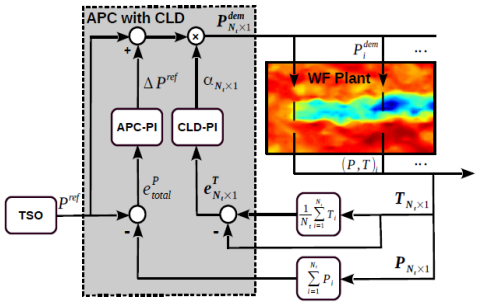

Fig. 1: Schematic illustration of the proposed APC of wind farms with coordinated load distribution (CLD).

3. Study and validation

Both numerical and experimental results (see Fig. 2 and Fig. 3) show good power tracking possibilities of the proposed control concepts. Detailed comparisons with the open-loop approach are performed, including situations with insufficient available power, wind turbine failure and turbulent conditions.

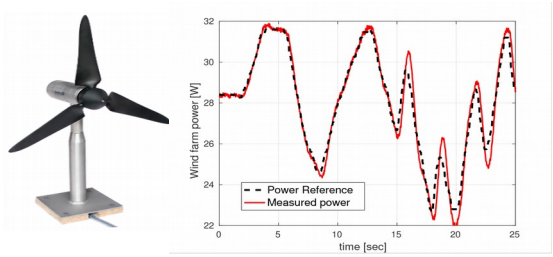

Fig. 2: A model wind turbine (left) and model wind farm following the power reference in wind tunnel experiments (right).

Simulation results (see Fig. 3) show that there is a possibility to level the dynamic loadings on the individual turbines through actively adjusting the power demand distribution law. The standard deviation of the applied thrust forces on each turbine is studied.

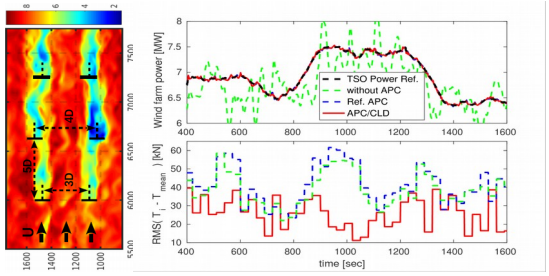

Fig. 3: A 2x3 wind farm layout in LES (left) and total power and root mean square of errors between 30-sec averaged applied thrusts and their mean value (right).

4. References

[1] van Wingerden JW, Pao LY, Aho J, Fleming P, Active power control of waked wind farms, IFAC-PaperOnLine 2017; 50:4484-4491.
[2] Vali M, Petrović V, Steinfeld G, Pao LY, Kühn M, Large-eddy simulation study of wind farm active power control with coordinated load distribution, TORQUE 2018; in press.
[3] Petrović V, Schottler J, Neunaber I, Hölling M, Kühn M, Wind tunnel validation of a closed loop active power control for wind farms, TORQUE 2018; in press.