Load-constrained wind farm control based on wake redirection and derating

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Power derating and wake redirection are two wind farm control techniques proposed in the last decade as means for increasing the overall farm power. Wake redirection showed a marked potential to increase farm production, both in silico and in experiments [1, 2]. However, according to this strategy, the upstream wind turbines may operate at large misalignment angles with a possible increase in rotor loads, which represents a source of concern especially when it comes to testing controls on existing farms that were not designed explicitly for prolonged misaligned operations [2, 3]. In fact, in order to keep the wind turbines within a safe load envelope, in the experimental campaign performed in [2] a “one-side” wake steering was employed, limiting the misalignment between 0 and 20 deg. Additionally, according to the findings of Croce et al. [3], also ultimate loads and maximum blade deflections could increase if gusts or failures occur during misaligned operations. On the other side, power derating is associated with a limited impact on farm power increase but also with a significant decrease in turbine loading levels [4].

The research presented in this work eventually aims at combining these two farm control strategies in a single constrained optimal algorithm that maximizes the overall output, while maintaining unaltered the turbine load envelope.

The main idea is to derate the turbines any time they intentionally yaw to redirect their wake out of downstream machines, to compensate for the possible increase in fatigue, ultimate loads and deflections.

To do so, firstly, one should compute the derating level, function of the misalignment angles, that can compensate for the expected increases in rotor loading. This task can be accomplished through a simple parametric analysis based on single turbine aeroelastic simulations, where design loads and displacements are computed for different derating levels and misalignment angles, hence, it does not require farm-specific analysis, nor expensive CFD simulations. The so-obtained derating level, function of misalignment angles, can be then used as a constraint in a wind farm power optimization.

Initial results on a simple two-turbine farm implemented in FLORIS [5] demonstrate that the proposed load-constrained farm control is effective in increasing the overall farm power while keeping the turbines working within the safe envelope. The proposed control does not require one-sided limitations to the range of admissible misalignment angles and features a mildly lower farm power increase with respect to the classical wake redirection strategy.

References

[1] Gebraad PMO, Teeuwisse FW, van Wingerden JW, Fleming PA, Ruben SD, Marden JR, Pao LY. Wind plant power optimization through yaw control using a parametric model for wake effects CFD simulation study. Wind Energy 2016;19(1):95-114.

[2] Fleming P, King J, Dykes K, et al. Initial results from a field campaign of wake steering applied at a commercial wind farm – part 1. Wind Energy Science 2019; 4(2):273-285.

[3] Croce A, Cacciola S, Sartori L. Evaluation of the impact of active wake control techniques on ultimate loads for a 10 mw wind turbine. Wind Energy Science 2022; 7:1-17.

[4] Astrain Juangarcia D., Eguinoa I., Knudsen T. Derating a single wind farm turbine for reducing its wake and fatigue. Journal of Physics: Conference Series 2018; 1037(3): 032039.

[5] Fleming P. FLORIS: FLOw Redirection and Induction in Steady State. https://www.nrel.gov/wind/floris.html.