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An ongoing research activity on the effects of wind farm controls on the design of wind turbines

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At present, one of the most important fields of research within the wind energy community is related to ''wind farm control'', i.e. the synergistic control of all turbines in a wind farm, with the aim of maximizing the total power [1]. In fact, the interference among turbines and wakes is typically detrimental in terms of produced energy and reducing such effect with ad hoc controllers entails increasing the power.

Many control techniques have been presently considered by both academia and industry as means to maximize wind farm power. Among all, the two most promising solutions are the ones based on the wake redirection (WR) and active wake mixing (AWM). The WR approach consists in yawing intentionally the upstream machine to redirect the wake out of downstream machines [2]. The AWM is based on a dynamical change of the turbine thrust obtained by a periodic collective motion (PCM) of blade pitch, with the effect of reducing the in-wake speed deficit thanks to an improved energization of the flow [3].

When it comes to synthesizing a wind farm control law, the power is considered as the main driver for control development, whereas turbine loading, usually analysed only through fatigue, takes on a less prominent role. In the current scenario, such an analysis does not appear complete enough to evaluate the eventual impact of the controls on the cost of the energy. In fact, any wind turbine is designed according to several drivers and constraints, which comprise also ultimate loads, actuator duty cycle and blade tip displacements.

The goal of this work is to provide a thorough analysis on the impact of different wind farm control strategies on turbine level. The analysis considers the entire set of Design Load Cases (DLCs) prescribed by the certification guidelines. Moreover, in order to assess the impact on the cost of the energy, a multidisciplinary optimal turbine design [4] is performed taking into account the presence of the wind farm controls.

In this abstract, an excerpt of the results related to the INNWIND.EU 10MW reference wind turbine is presented. Specifically, in Fig. 1, the impact of AWM control on the blade root flap-wise fatigue (left) and ultimate (right) loads are displayed, as functions of different amplitudes and frequencies of the periodic pitch motion. The fatigue may increase up to 7%, while the ultimate loads, coming from DLC 1.3 at 15 m/s to 6%.

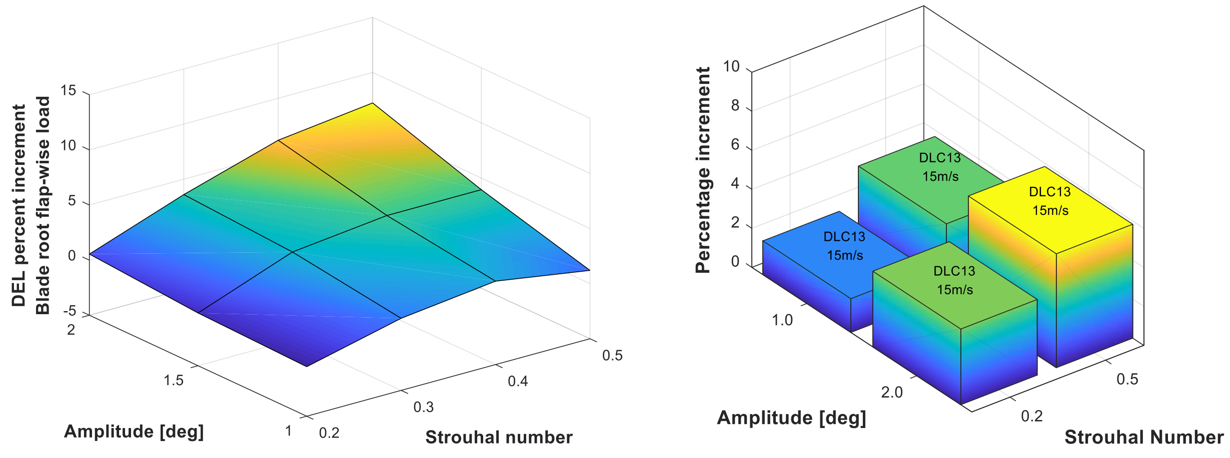

Figure 1: Percentage increment induced by Active Wake Mixing control on blade root flap-wise fatigue (left) and ultimate (right) load, as functions of amplitude and frequency. The frequency is expressed as the related dimension less Strouhal number, $S_t = fD/V$, being f the frequency, D the rotor diameter and V the wind speed.

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