15th EAWE PhD Seminar on Wind Energy
29-31 October 2019
Ecole Centrale de Nantes, France

Experimental analysis of the wake behaviour during yaw variation imposed through wind farm control strategies

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Keywords: Turbine modelling, wind tunnel, actuator disc concept, PIV measurements

1 Introduction

This work focuses on the analysis of dynamic wind turbine misalignment. Generally this condition is considered as undesired (lack of the control system or fast variation of the wind direction) but voluntary misalignment could be also used to improve the overall wind farm power yield. Farm control is becoming always more crucial in wind energy and voluntary misalignment is one of the strategies being investigated [1-3]. Indeed, the appropriate misalignment of a wind turbine can improve the rate of production and the lifetime of the downstream one. Applying this solution though needs a better comprehension of the consequences of this kind of maneuvers in terms of wake interactions. The present paper illustrates an experimental modelling of the misalignment process. This operation was reproduced in a wind tunnel under dynamic variations of the yaw angle and its effects in terms of wake deviation at a fixed downstream (3.5D) distance were investigated by the use of Particle Imaging Velocimetry (PIV). This is only the first step of a more articulated experimental project that will bring to reproduce this kind of yaw maneuvers at different scales and flow conditions. Indeed the last step will consist on the reproduction of a dynamic yaw variation in the presence of the atmospheric boundary layer to evaluate its impact on this kind of maneuver.

2 Experimental set-up and preliminary results

The condition of dynamic misalignment here is reproduced in the Eiffel-type wind tunnel at PRISME laboratory generating an isotropic and turbulent flow (HIT) (Fig1). According to the actuator disc concept, broadly used in literature [4-8], the model of the wind turbine used in this work are 0.1 m diameter porous discs. Two different porosity are tested in order to evaluate the influence of the induction factor. The evolution of the wake misalignment due to the yaw maneuver is studied at 3.5 diameters downstream the yawed disc by the use of stereo PIV. According to the full scale condition, the yaw variation takes $10\tau_0$, where τ_0 is the aerodynamic time scale based on the inflow velocity and disc diameter ($\tau_0 = D/V_0$). So wind tunnel experiments, corresponding to a reduction scale of 1:800, are performed taking into account this similarity law.

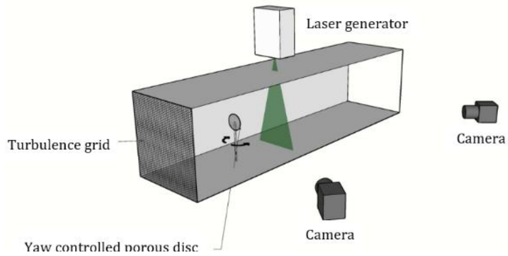

Figure 1 Experimental PIV setup

Multiples of τ_0 until $10\tau_0$ represent the yaw motion, investigations have been done until $15\tau_0$ in order to take into account the advection delay, see [9] for more details about the experimental set-up and the methodology. The wake deviation is determined by the estimation of the variation of the wake centre position. Different methods where tested [4,8,10] but finally the wake centre was determined by the calculation of a weighted average of the velocity deficit position where the weighting is chosen as the exponential of the instantaneous local velocity deficit such as in [4]. The time evolution of the wake deviation angle θ and the yaw angle γ are shown in fig.2. From these results, it is possible to compare the wake deviation timing with the maneuver timing, and moreover to retrieve the influence of the maneuver strategy.

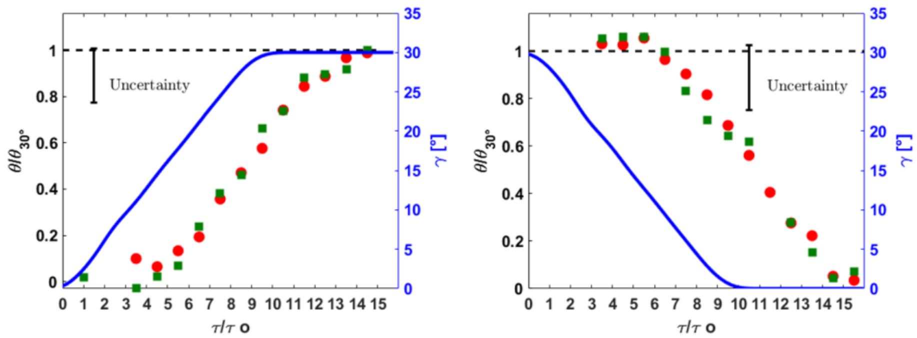

Figure 2 Time evolution of θ and γ downstream of the disc (x/D = 3.5) during a dynamic yaw variation at 6 m/s flow rate. Yaw increment (left), yaw decrement (right). Symbols: red porosity 57%, green porosity 67 %. Dashed black line represents θ value for a static 30° yaw angle γ.

Acknowledgements

The present work is part of a PhD co-funded by Labex Caprysses and Engie.

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