TURBINE WAKE SENSITIVITY TO DIFFERENT ATMOSPHERIC STABILITIES

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ABSTRACT

In this work the sensitivity of the wake phenomenon behind a wind turbine is studied for different atmospheric stabilities generated in the diurnal cycle and during summer and winter. This phenomenon has a significant impact on the wind farm power production and efficiency.

RESUMEN

En este trabajo se estudia la sensibilidad del fenómeno de estela detrás de una turbina eólica ante las distintas estabilidades atmosféricas que se generan en el ciclo diurno y durante verano e invierno. Este fenómeno tiene un impacto significativo en la producción energética y eficiencia de un parque eólico.

Keywords: turbine wake, atmospheric stability, turbulence intensity.

1) INTRODUCTION

Currently, wind energy in Argentina is growing within the energy matrix, thanks to the support of the national law Nº 27191 that specifies an increment of renewable energy sources in the electric generation. This implies the need to develop and construct many large capacity wind farms, which require, for the design and management, to take into account the wind turbine wake phenomenon. This phenomenon implies a reduction on the wind speed and an increase of turbulence behind the turbine, reducing the power output of those turbines downstream.

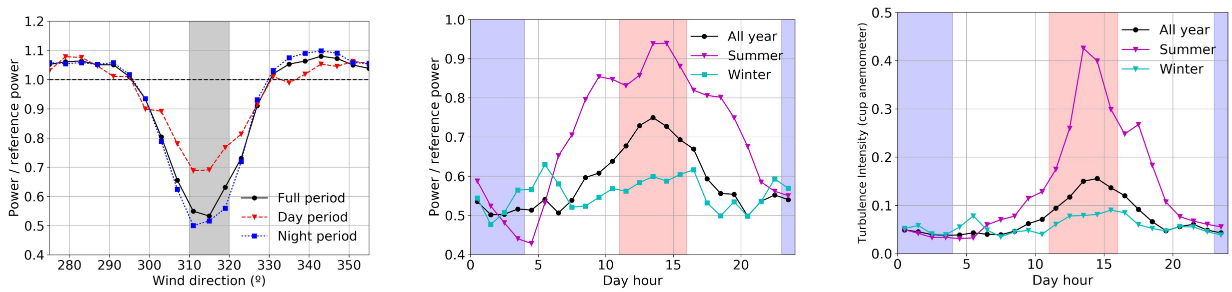
The intensity of the wake phenomenon depends both on the turbine's structural and operating characteristics as well as on the atmospheric conditions present in the atmospheric boundary layer. In Schepers et al. (2012) a sensitivity analysis of the wake in an offshore wind farm for different atmospheric stabilities is performed, finding that for stable conditions, typically during night, the wake remains intense for a long distance downstream. Conversely, during unstable conditions, mostly around noon, an intense mixture of the wake is produced reducing its impact.

In this work, the wake analysis is extended to an onshore wind farm located in Patagonia, analyzing how the wake phenomenon varies depending on the different atmospheric stabilities generated in the diurnal cycle and during summer and winter.

2) METHODOLOGY AND RESULTS

Measurements along a period of six years, from 03/2012 to 04/2018, of a meteorological mast and turbines power output in the Rawson wind farm are used to develop the study of the wake phenomenon. This farm is located on land at 43º S latitude, 10 km far from the coast. From all wind mast measurement, the mean wind speed and direction as well as the wind speed standard deviation at turbine hub height are used. From these variables, the longitudinal turbulence intensity of the cup anemometer can be obtained as the ratio between the standard deviation and the average wind speed for a 10 minutes period. In Wharton et al. (2012) it is shown that the turbulent intensity is an indicator of the atmosphere stability and the mixture of the wake.

In this work, the power output difference between two turbines near the mast is used, in order to obtain a good correlation between the mast measurements and the turbines power output. These both turbines are Vesta V90 model, with 80m of hub height and 90m of diameter, separated at 4.7 diameters of distance. From the wind speed distribution range, measurements between 5m/s and 9m/s are chosen, corresponding to the range in which the wind speed is above the cut-in value and the turbine applies the same resistance effect on the flow. In addition, a distinction is made between the diurnal period, from 11 to 16, and the nocturnal period, from 23 to 4, in order to isolate the effects due to the predominant atmospheric stabilities in those two intervals.



(a) (b) (c)

Figure 1: (a) wake impact on the reference turbine power output. Variation of the maximum power deficit (b) and the turbulence intensity (c) for the diurnal cycle .

Figure 1(a) shows the power output relation between the upstream and downstream turbine, called reference power, for a wind direction range of +/- 40º centered in the direction of maximum interference. A marked difference is observed in the wake impact during the night and day hours, identifying the maximum deficit zone, between 310º and 320º, as the most sensitive characteristic to stability changes. That is why in Figure 1(b) the maximum deficit is plotted throughout the diurnal cycle, making also the distinction between winter and summer months. It is observed that during summer the wake effect varies considerably, being weaker during daylight hours. Contrarily, during the winter the wake remains fairly uniform throughout the entire diurnal cycle. Finally, Figure 1(c) shows the variation of the turbulent intensity for the same data set used to obtain the maximum deficit. A marked correlation of the maximum deficit to the variation of the turbulent intensity can be observed. It can be concluded that the wake phenomenon depends strongly on the stability conditions, and the variation should be taken into account in the design and operation of wind farms.

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