Wind tunnel experiment to characterize a wind turbine wake.

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ABSTRACT

Having a well studied behavior of the flow over wind turbines is essential to determine a good design of a wind farm, and, in particular, is necessary to determine the optimum spatial distribution of wind turbine seating.

Turbulence is clearly a complex process, and one which cannot be easily solved. Although some methodologies may give a good solution, sometimes they do not converge to the actual solution. Therefore, experimental studies need to be carried out. Field studies are not easy to develop. The variability of the wind and other atmospheric phenomenon pose challenges moreover, field studies yield very few data. A wind tunnel turns out to be an efficient tool.

Great number of studies about turbine wakes refers to uniform flow conditions. However, it is well known that wind turbines are affected by the atmospheric boundary layer. As a consequence, it is necessary to have a better understanding of such conditions.

In general, the vertical inhomogeneity of the incoming boundary-layer flow, which is modulated by the surface roughness, plays an important role on the distribution of turbulence properties within the turbine wake.

Wind-tunnel experiments were performed to study turbulence in the wake of a model wind turbine placed in a boundary layer developed over rough and smooth surfaces. The tunnels is placed at SAFL (Saint Anthony Falls Lab, University of Minnesota).

Scale effects of the model are a complex to determine. The conditions of a full scale turbine of about 20 meters diameter are not possible to simulate inside a wind tunnel. It is not possible to achieve such a large Reynolds number. However, other authors have observed that small scale models and a prototype have similar qualitative behaviors.

This study focuses on obtaining detailed measurements of the stream-wise and vertical components of the wind speed. Hot-wire anemometry was used to characterize the cross-sectional distribution of mean velocity and turbulence levels at different locations downwind of the turbine for both surface roughness cases.

Special emphasis was placed on quantifying the magnitude and spatial distribution of the velocity deficit and the enhancement of the turbulence intensity in the turbine wake with respect to the incoming boundary-layer flow. These quantities are important factors affecting turbine power output and fatigue loads in wind parks.