Wind turbines over a hilly terrain: performance and wake evolution

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Abstract

The aim of this licentiate thesis is to investigate wind-turbines placed in a complex-terrain environment. This is done by studying the flow around small-scale wind-turbine models placed over a landscape model with hills, and by comparing the results with corresponding data obtained over a flat terrain model. The studied flow features include the wind-turbine wake development and the turbine performance under different conditions, the effects from wake interactions, the influence of the ambient turbulence levels and the influence from a complex topography. Wind-tunnel measurements have been performed using particle image velocimetry and hot-wire anemometry to measure the velocity field. Additionally, numerical simulations, based on RANS modelling and actuator-disc techniques, have been made to support the experimental data and to gain further knowledge about the investigated flow cases.

The results reveal that the hills promote a downward wake deflection behind the turbines and enhance the wind-turbine wake diffusion. As a consequence of this, and with the flow acceleration introduced by the hills, an improved power performance is seen for turbines exposed to wake-interference effects. A correlation is observed between the turbulence levels present in the flow, and the magnitude to which the hill-induced flow gradients influence the wake: Stronger wake deflections due to the hills are seen when the wind-turbine wake is more diffused. This is for instance the case when the wake of two tandem turbines is studied, or when higher ambient turbulence levels are present in the wind tunnel.

A good qualitative agreement is seen when comparing the experimental and numerical results. The simulation results further indicate that the hills give rise to modulations of the wind-turbine wake. It is shown that these modulations can be reasonably captured by means of wake-superposition techniques, given that a wake model with sufficient accuracy is chosen.

Keywords
Fluid mechanics, wind turbines, complex terrain, wind-tunnel measurements