Aerodynamic Aspects of Wind Energy

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The aerodynamics of wind turbines concerns, briefly speaking, modelling and prediction of the aerodynamic forces on the solid structures of a wind turbine and in particular on the turbine rotor blades. Aerodynamics is the most central discipline for predicting performance and loadings on wind turbines. Aerodynamic modelling may also concern design of specific parts of wind turbines, such as rotor blade geometry, or performance predictions of wind farms. In this presentation I will present and discuss different wind turbine concepts and especially focus on the aerodynamic properties of wind turbine rotors and associated wakes.

The wake behind a rotor consists essentially of a number of helical vortices that owing to roll-up effects mainly concentrates in tip and root vortices. The wake can generally be divided into two distinct parts, the near wake and the far wake. Near wake features are related to the genesis of the vortex system where the presence of the rotor is felt directly. The far wake is usually the downstream position where the wake dynamics no longer depends on the rotor characteristics. In the past five years we have been studying wakes behind wind turbine blades using analytical tools as well as numerical simulations based on LES methodology and the so-called actuator line technique. From these studies we have shown that helical wakes are inherent unstable and we have elucidated how the ambient turbulence influences the stability properties. Furthermore, we have identified one of the main instability mechanisms to be related to vortex pairing. Another part of the work has been focused on the interaction of wakes originating from two or more rotors placed close to each other. This is in particular of importance for wind turbines located in wind farms. In the presentation I will first give the theoretical background for the stability analysis and present the numerical techniques used. Next, I will show some basic results from the stability analysis and numerical simulations of both single wakes and interacting wakes, including comparisons to experimental results.