Numerical Simulation of Ice Accretion on Wind Turbines

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Icing of wind turbines is a major concern in elevated or northern areas since it causes significant production losses, reduces the lifetime and represents a safety risk. Icing occurs when snowflakes or supercooled water droplets freeze on the surface of the turbine. The shape of the ice however, depends on many variables like point of operation, the geometry of the wind turbine, the temperature, the droplet diameter or the Liquid Water Contend (LWC). Ice accretion mechanisms and their effects on wind turbine operation need to be considered already at an early stage of development. While tools to calculate ice accretion on simplified 2D geometries (e.g. blade profiles) are commonly in use, the simulation of 3D icing of complex geometries like a rotating wind turbine is still a very challenging task.

The simulation method presented in this paper is a fully 3D icing simulation tool, capable of predicting ice accretion on wind turbines and its effect on the performance, taking into account detailed information of the geometry and atmospheric environmental conditions. It is shown how different simulation methods are effectively coupled to yield valuable information for design engineers. The icing simulation is based on a detailed calculation of the flow field around the wind turbine by means of Computational Fluid Dynamics (CFD), taking into account unsteady effects due to blade rotation. Based on the flow field and the calculation of droplet collection efficiency, ice accretion is simulated, considering ambient meteorological conditions.

Results of the simulation like the size and shape, as well as extend and weight of the ice are presented for different icing scenarios. By calculating droplet shadow regions, the simulation of droplet impingement reveals information regarding effective placement of instrumentation, thus reducing distracting ice accretion. Furthermore it is shown how the simulation method is used to evaluate thermal anti-icing systems.