Keywords: wind turbine, cold climate, smart de-icing, ice detection, rotor blade, acoustic waves

Ice detection for smart de-icing of wind turbines

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Icing on a wind turbine rotor blade is a problem in the operation of wind turbines in cold climates. Ice detection is a critical process to get a workable cost-effective wind turbine de-icing system. The paper presents the theoretical models, methods, algorithms, principles, and a demonstrator that are the basis for developing a new technique for detecting icing on rotor blades of a wind turbine based on acoustic wave propagation in composite structures. Two methods have been proposed: guided acoustic wave propagation and bulk acoustic wave propagation in composite structures. Analysis of computer simulations and the results of experimental study obtained by using the developed demonstrator in cold climate lab has shown that the integration of the guided acoustic wave propagation and the bulk acoustic wave propagation methods provides an efficient scientific approach to be used for the design of new ice detection system for wind turbines in cold climate regions. In particular, the guided acoustic wave propagation method makes it possible to detect ice and icing area location on the rotor blades. Several criteria (Icing Index, Frequency Factor Index, others) have been proposed for ice detection of composite structures.

Bulk acoustic wave propagation method makes it possible to identify the time-varying spatially heterogeneous "landscapes" over the blade surface for each of the following eight ice parameters: thickness, the volumetric bulk density, bulk and shear moduli, stress relaxation time, porosity, and volume and shear viscosities. These data are necessary for smart, energy-efficient de-icing systems. The identification algorithm is computationally efficient and can be implemented in the real-time mode.

A LIDAR (Light Detection And Ranging) for the detection of early ice growth on the wind turbine blades has also designed, tested and evaluated in this project. LIDAR uses laser pulses that emit at two different wavelengths and is capable of distinguishing between a thin layer of ice and water covering the turbine blades. The results of the tests that have been carried out in the project are undeniable. LIDAR detects early ice growth by measuring the difference in reflectivity of a surface by using two different laser wavelengths. The limitation of LIDAR is that it cannot be used to determine the amount of ice on the sheet, only if there is ice or not.

The obtained results[1-6] can be used to develop smart de-icing systems for wind turbines operating in cold climates, and can lead to new future products that are sought after by wind power industry. Since the efficient ice detection systems can increase wind turbine profitability, the results contribute to an increased ability to establish multiple wind turbines in cold regions.

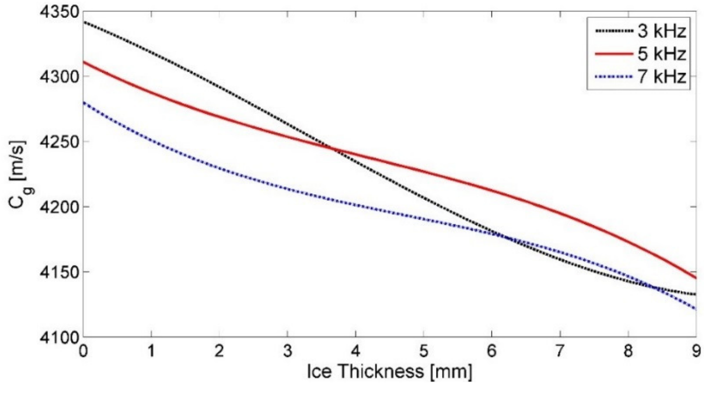

Figure 1: Group velocity versus ice thickness for different excitation frequencies.

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