Inverse design of wind turbine blades for extreme weather applications

Ice accretion on rotor blades in cold climates considerably worsens the aerodynamic performance of wind turbine systems. Typically, ice accretion leads to reduction of lift generation and increase in drag resulting in power loss typically in the range of 15-20% which may go up to 30% at sites with particularly high risk of icing. Furthermore, ice accumulation also affects safety and lifetime of the wind turbine systems.

Air flow field around a blade

The main objective of this research project is to develop a methodology to design the shape of wind turbine blades considering ice accretion on the blade under different atmospheric conditions. The methodology involves three steps:

- The inverse design process for bare blade determines a blade shape if an initial blade shape and the required pressure or velocity distribution around the blade are known. These initial conditions are determined according to given performance constraints.
- The air velocity field in the proximity of the blade obtained in the previous step is determined.
- The trajectories of water droplets in the air velocity field obtained in the previous step are simulated. Results provide the local ratio of droplets that hit the blade surface. Then, the local ratio of droplets that freeze to the blade surface is calculated from the heat balance. Finally, the local rate of accreted ice mass is obtained together with the shape of the iced blade.

This procedure has been implemented in Matlab, and provides the shape of the iced blade [1]. The procedure has been developed originally for horizontal axis wind turbines, but it was also successfully applied for vertical axis wind turbines [2]. The bare blade shape was obtained according to the initial requirements; however, the ice accretion on the turbine blade may reduce turbine performance considerably. Therefore, the main challange is to improve this design procedure by including the minimization of ice accretion as an input parameter. Application of the blade shape obtained enables to widen the operating conditions of the wind turbine.

Selected publications on the topic

1. Kollar, L. E., Mishra, R., Inverse Design of Wind Turbine Blades for Extreme Weather Applications, EEERG Internal Report, University of Huddersfield, UK, March 2014.
2. Kollar, L. E., Mishra, R., Jain, A., Inverse Design of Blade Shapes for Vertical Axis Wind Turbines, *28th International Congress on Condition Monitoring and Diagnostic Engineering*, Buenos Aires, Argentina, 2015, to be submitted.