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INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF ICED WIND TURBINE BLADE

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ABSTRACT

The issue of icing on wind turbines presents a significant operational challenge, especially in Canada's northern regions, where cold climates and harsh winter conditions prevail. Ice accumulation on wind turbine blades can severely reduce performance, leading to energy losses between 20% and 50% during icy conditions. This buildup of ice increases mechanical stress on the turbines, potentially resulting in costly maintenance, shortened component lifespan, and even operational failures. Ice formation alters the aerodynamic properties of the blades, increasing drag, vibration, and imbalance, all of which raise serious safety concerns. Two primary types of ice configurations occur in such environments: glaze ice and rime ice. Glaze ice forms from large, supercooled water droplets that hit the surface, spread, and then freeze, commonly during freezing rain events at temperatures near 0°C. This type of ice is dense and smooth, causing a significant increase in blade weight and altering its aerodynamic profile, which drastically reduces efficiency. Rime ice, in contrast, forms when small, supercooled water droplets freeze instantly upon contact in windy, misty conditions, typically at temperatures below -10°C. This ice type is lighter and rougher than glaze ice but still disrupts airflow by roughening the blade surface, which increases drag and reduces aerodynamic performance. This study investigates the impact of these ice formations on the NACA 64_3-618 airfoil model. Using Large Eddy Simulation (LES), airflow over the iced airfoil was simulated at a Reynolds number of 137,000, with angles of attack ranging from -10° to 10°. The results indicate that the lift coefficient increases consistently with the angle of attack across all scenarios. However, the drag coefficient exhibits fluctuating behavior due to the varying aerodynamic profiles caused by the different ice formations. Glaze ice significantly increases drag, particularly at higher angles of attack, leading to a more pronounced reduction in aerodynamic efficiency compared to rime ice.