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Entitled

AERODYNAMIC & AEROACOUSTIC PERFORMANCE OF WIND TURBINE BLADES FEATURING ENHANCED FLOW-CONTROL

by

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Abstract

Wind energy, being one of the cleanest and most sustainable sources, has undergone remarkable growth in recent years due to advancements in aerodynamics and increased power output. The research community is actively pursuing the development of cutting-edge solutions to further optimize wind turbine technology, ensuring its maximum efficiency and revolutionizing the landscape of wind power.

This research aims to design and develop flow-control devices for wind turbine blades, employing both active and passive control mechanisms, namely morphing trailing-edge and slot-profile, respectively. The objective is to enhance wind turbine performance across a wide range of wind speeds. The morphing trailing-edge mechanism focuses on adjusting the local mean-camber through trailing-edge morphing, resulting in augmented blade lift and torque, consequently reducing the wind turbine's cut-in speed. Conversely, the slot-profile mechanism manages boundary layers by suppressing flow separation and delaying stall, harnessing greater lift and torque, and effectively reducing the rated wind speed.

Numerical investigations form the core of the research methodology, providing insights into various flow parameters such as pressure and velocity fields, surface flow, skin friction, boundary layers, flow separation, and wake profiles to analyze the influence of developed flow-control mechanisms. These flow-control devices will eventually be integrated into the National Renewable Energy Laboratory (NREL) Phase-VI research wind turbine for performance analysis. The research promises to deliver significant power augmentation and increased productivity of wind turbines, particularly during off-design operating conditions, a critical advantage for regions characterized by low average wind speeds, such as the Middle East and South-East Asia.

Furthermore, the research outcomes hold potential for broader applications in the field of rotorcraft and unmanned aerial vehicles. These flow control techniques can be implemented on rotors and/or propellers, generating greater lift at relatively lower RPM, thereby resulting in substantial fuel/power savings and increased flight endurance.

Keywords: wind turbines, flow-control, aerodynamics, aeroacoustics, adaptive morphing, slot, CFD