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Optimizing Wind Turbine Blade Geometry for Enhanced Performance and Durability: A Computational Approach

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Abstract : Wind energy is a vital component of the global renewable energy portfolio, with wind turbines serving as the primary means of harnessing this abundant resource. However, the efficiency and stability of wind turbines remain critical challenges in maximizing energy output and ensuring long-term operational viability. This study proposes a comprehensive approach utilizing computational aerodynamics and aeromechanics to optimize wind turbine performance across multiple objectives. The proposed research aims to integrate advanced computational fluid dynamics (CFD) simulations with structural analysis techniques to enhance the aerodynamic efficiency and mechanical stability of wind turbine blades. By leveraging multi-objective optimization algorithms, the study seeks to simultaneously optimize aerodynamic performance metrics such as lift-to-drag ratio and power coefficient while ensuring structural integrity and minimizing fatigue loads on the turbine components. Furthermore, the investigation will explore the influence of various design parameters, including blade geometry, airfoil profiles, and turbine operating conditions, on the overall performance and stability of wind turbines. Through detailed parametric studies and sensitivity analyses, valuable insights into the complex interplay between aerodynamics and structural dynamics will be gained, facilitating the development of next-generation wind turbine designs. Ultimately, this research endeavours to contribute to the advancement of sustainable energy technologies by providing innovative solutions to enhance the efficiency, reliability, and economic viability of wind power generation systems. The findings have the potential to inform the design and optimization of wind turbines, leading to increased energy output, reduced maintenance costs, and greater environmental benefits in the transition towards a cleaner and more sustainable energy future.

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