Optimization of the Design of Small-Scale Vertical-Axis Wind Turbines Suitable for Low Wind Conditions in Vietnam Using CFD Simulation Combined With Artificial Intelligence

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The increasing need for clean energy sources makes wind energy a major focus in this regard; however, currently, most wind turbines are installed in high-wind-speed locations, which are not suitable for Vietnam's urban and lowland regions because of the low, turbulent, and fluctuating wind speeds. This study aims to solve this problem by optimizing the blade shape of small-scale vertical-axis wind turbines, which can function in turbulent and fluctuating winds but have low efficiency. The study used a combination of Computational Fluid Dynamics (CFD) and Genetic Algorithm. In this study, CFD simulations were done using ANSYS Fluent software for aerodynamic analysis of NACA0012 and NACA4412 airfoil shapes. Then, a Genetic Algorithm was used in MATLAB for optimization of the shapes for maximum efficiency. Finally, experimental validation was done for the optimized shapes. The study found that NACA0012 performs stably at 6-8 degrees, while NACA4412 performs better at 4-6 degrees with higher efficiency but is more prone to stall. After optimization, NACA4412 performed better at 29V compared to 23V for the original blade at 4.1 m/s, while NACA0012 showed little difference. The novelty in this study is the combination of CFD and AI in a fast and efficient optimization technique. The limitation of the study is the experimental setup in the lab, which does not include a real turbine setup. Future studies will include real-world testing. The study has great potential for developing efficient wind energy in Vietnam's urban regions at a low cost.

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