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論　　文　　要　　旨

Thesis Abstract

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主論文題名　（Title）

Advancing Hybrid Vertical Axis Wind Turbines: Computational, Experimental, and Smart Technology Innovations for Wind Energy Optimization

内容の要旨　（Abstract）

Wind energy has emerged as a crucial component of sustainable power generation, with vertical axis wind turbines (VAWTs) gaining attention due to their adaptability to varying wind conditions. However, optimizing VAWTs for improved efficiency and self-starting capability remains a challenge. To address this, this dissertation investigates the optimization of hybrid Savonius-Darrieus VAWTs using computational fluid dynamics (CFD) and experimental validation to enhance performance across different operational conditions.

Building upon the fundamental principles of hybrid Savonius-Darrieus wind turbines, a comprehensive analysis is conducted to understand their advantages and challenges. The combination of Savonius (drag-based) and Darrieus (lift-based) designs aims to improve self-starting capability while maintaining a high-power coefficient. CFD simulations indicate that a hybrid turbine with an optimal rotor radius ratio of 0.5 achieves a 12.5% increase in power coefficient compared to a conventional Darrieus turbine. These findings establish the groundwork for further optimization and experimental validation.

To validate the numerical findings, an experimental study on hybrid wind turbine performance at high tip speed ratios (TSR) is conducted. Various design modifications, including blade shape, rotor radius ratio, and solidity, are tested to assess their impact on power output. The results demonstrate that a hybrid model with a Savonius overlap ratio of 0.2 improves self-starting torque by 18.7% while maintaining a power coefficient (Cp) of 0.34 at TSR 1.6. This confirms the effectiveness of hybrid configurations in improving turbine startup and performance.

Building on these results, an innovative smart hybrid VAWT with an adaptive rotor-switching mechanism is introduced. This system transitions between hybrid and pure Darrieus modes based on wind conditions, optimizing efficiency at different TSRs. Experimental validation confirms that the smart hybrid turbine achieves a 21% increase in efficiency at higher TSRs compared to conventional hybrid designs, ensuring stable performance under fluctuating wind speeds. These advancements further highlight the potential of adaptive wind turbine systems in enhancing energy capture.

To assess real-world applicability, the wind energy potential of the proposed smart hybrid turbine in Banjarmasin, Indonesia, is evaluated. The study analyzes local wind conditions and turbine adaptability, demonstrating a 347.46% higher power output than conventional hybrid models. These results emphasize the feasibility of deploying hybrid VAWTs in regions with variable wind patterns.

Overall, this research advances the design and implementation of hybrid Savonius-Darrieus VAWTs, contributing to the development of more efficient and adaptable wind energy solutions. By integrating computational analysis with experimental validation, the findings provide a robust foundation for future improvements. Future work will focus on refining control strategies and exploring advanced materials to further enhance turbine performance and sustainability.

Keywords: *Computational fluid dynamics, Darrieus, moment coefficient, power coefficient, Savonius, smart hybrid, tip speed ratio, vertical axis wind turbines, wind power potential, wind speed.*

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