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Optimizing Vertical-Axis Wind Turbine Performance and Determining Optimal Velocity and Deflector Configuration Based on Wind Speed

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Abstract

In the realm of wind energy harnessing, Vertical-axis Wind Turbines (VAWTs) have emerged as promising alternatives. However, they face persistent challenges due to their low efficiency and poor self-starting properties. This study addresses these limitations and aims to unlock the full potential of VAWTs by conducting a comprehensive investigation. The focus of this research lies in determining the optimal operating velocities to enhance the performance of Savonius-type VAWTs, leveraging advanced deflectors. The study delves into an in-depth analysis of the optimal deflector distances and angles for the turbine, taking into account different geographical areas with varying wind velocities. To achieve this, a Savonius-type VAWT equipped with advanced wind deflectors was meticulously designed and tested. Utilizing SOLIDWORKS software, sophisticated turbine models were crafted, which were then subjected to rigorous analysis using ANSYS Fluent, Computational Fluid Dynamics (CFD) software. The research methodology involved conducting simulations across a range of wind velocities, spanning from 1 ms^{-1} to 8 ms^{-1}, and changing the deflector distance from 100 cm to 150 cm from the centre of the turbine, and the deflector angle from 12 to 45 degrees. During the simulations, critical indicators of turbine performance, including moment coefficient, moment, force coefficient, and force acting on the blade, were closely examined. The study uncovered significant variations in the power output of the Savonius-type vertical-axis wind turbine (VAWT) fitted with an advanced deflector system, especially at lower wind speeds. Notably, the study revealed that at different wind velocities, the optimum deflector configuration changed, with the highest energy-generating capacity observed at 1 m/s for the wind turbine equipped with advanced deflectors. Outperforming the turbine lacking a deflector system, this inventive method demonstrates the capacity to notably boost energy generation. This novel method underscores the capacity for substantial improvements in energy production. Additionally, the research offers valuable insights into customized deflector distance and angle combinations, optimizing turbine performance for specific wind velocity ranges. By strategically positioning the deflectors, higher energy output can be achieved, making the VAWT system more adaptable and efficient across diverse wind conditions

Keywords: Vertical-axis wind turbine, Wind deflectors, Computational Fluid Dynamics, SOLIDWORKS, ANSYS Fluent