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Optimizing the Geometry of an Empty Concentrator-Diffuser Augmented Wind Turbine Using Genetic Algorithm

The growing demand for electricity in off-grid regions, combined with rising global energy needs driven by population growth, underscores the urgent need to explore renewable energy alternatives to fossil fuels key contributors to carbon emissions and climate change. Wind energy offers a sustainable option but is challenged by its variability and low-speed performance in certain regions. This study investigates a performance enhancement strategy using an empty concentrator-diffuser augmented wind turbine (CDaugWT) to boost wind speed at the rotor, enabling continuous operation in areas with average wind speeds below 4 m/s.
A velocity augmentation model served as the objective function, correlating the augmentation ratio with six geometric parameters. A Genetic Algorithm (GA), an evolutionary optimization method, was used to determine the optimal design. Results showed that wind speed at the throat could be increased by up to 1.981 times. These findings closely aligned with results from response surface methodology (RSM), with only a 1.4 % deviation, validating the accuracy of the GA approach.
The optimized geometric values included a diffuser angle of 10.1°, concentrator angle of 20.0°, concentrator length of 396.3 mm (0.66 Rth), diffuser length of 994.8 mm (1.65 Rth), throat length of 74.5 mm (0.12 Rth), and flange height of 104.4 mm (0.17 Rth), where Rth is the throat radius. Computational Fluid Dynamics (CFD) simulations further validated these results, showing only a 0.58 % difference.
The study confirms that integrating optimization algorithms such as GA into the design process of CDaugWT systems can significantly enhance wind turbine performance making wind energy more viable for low-wind-speed regions.

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