The Design, Simulation and Testing of an Omni-direction Deflector for Vertical Axis Wind Turbine

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Abstract: Research have shown a growing interest in vertical axis wind turbines (VAWTs) due to their numerous benefits especially the omni-direction feature. However, VAWTs exhibit lower efficiency and difficult to self-start. In this research, an omni-direction deflector (ODD) has been proposed to enhance the performance of a straight-bladed VAWT. Three-dimensional numerical simulations have been performed to analyze the aerodynamic characteristics of a straight-bladed NACA 0021 VAWT and the effects of a flat plate deflector. Sliding mesh method was employed to simulate the rotational motion of the VAWT using ANSYS Fluent at tip speed ratio (TSR) of 2.58. The unsteady flow CFD simulation was validated with the wind tunnel experiment data available in the literature. A few parameters including the position, the inclination angle and the length of the flat plate deflector were investigated. The simulations showed that the augmented flow occurred at the near wake region of the flat plate deflector. This flow was directed and accelerated by the deflector about 25% higher than the oncoming wind flow before impinging with the turbine; hence the coefficient of power (CP) of the VAWT improved significantly. From the simulation results, the optimum parameters for the flat plate deflector were placed at the horizontal distance of 2R from the rotor axis, a vertical distance of 0.66H from the lower edge of the VAWT, no inclination angle, and 1.5H for the plate length. With these parameters, the average coefficient of torque increases about 46.95% compared to the VAWT without the deflector. The research was extended for the development the ODD where it comprises six flat plate deflectors evenly surround the VAWT with a distance of 0.66H from the lower edge of the VAWT rotor blade. Simulations with the same setup were performed with the ODD. In order to simulate wind flow from all direction, the ODD was oriented at 0° and 30° with the oncoming wind. The simulation shows a higher average CP of 35.48% and 37.63% were achieved for the ODD place at 0° and 30° respectively. In addition, lab tests were conducted to verify the effects of the ODD on a five-bladed VAWT with the oncoming wind speed at 6 m/s. From the result, both the simulation and experiment results showed a good agreement on the performance enhancement with the presence of the ODD. The ODD accelerates and directs the oncoming wind towards the VAWT, hence, improve the CP of the VAWT significantly. From the lab tests, the maximum CP achieved was 0.051 and 0.049 at TSR 0.9 when the ODD oriented at 0° and 30° with the oncoming wind, compared to the bare turbine of 0.0413 at TSR 0.8, it was about 23.5% and 18.6% increased respectively. Furthermore, a higher rotational speed, wider TSR range, and better self-start ability were achieved with the employment of the ODD in the lab tests. The design of the ODD has a good potential as it can be easily retrofitted to the existing VAWT system hence enhance the performance.

Keywords: Omni-direction deflector; power augmentation; vertical axis wind turbine; coefficient of power; computational fluid dynamics (CFD); experiment