Novel investigation of the different Omni-direction-guide-vane angles effects on the urban vertical axis wind turbine output power via three-dimensional numerical simulation

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**Abstract**

The aim of this study is to present the effects of different Omni-direction-guide-vane (ODGV) angles on the performance of the vertical axis wind turbine (VAWT). For this purpose, five different straight-bladed VAWTs have been simulated via three-dimensional (3D) computational fluid dynamics (CFD). Hence, the VAWT without ODGV covering, were simulated and validated via CFD and experimental fluid dynamics (EFD) data, respectively in the first step. Indeed, grid and time step independency test as well as the effect of domain size, have been conducted and a suitable agreement was found based on comparison of the CFD and EFD results. In the next step, the VAWT was shrouded by ODGV cover and the whole system was simulated for 52 angles of the ODGV in four different tip speed ratios (TSR), to investigate the impact of guide vanes angles on the VAWT performance. Results of this study indicated that output power of the VAWT with $\alpha = 20^\circ$ and $\beta = 55^\circ$ ODGV guide vanes, was improved 40.9%, 38.5%, 35.5% and 35.2%, respectively in four different TSR including 0.745, 1.091, 1.901 and 2.53.

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**1. Introduction**

Nowadays, renewable energy sources like solar and wind energy are widely applied to generate electricity and other energy barriers. Using the innovative design play an important role to harvest more energy from different sources [1]. Among the renewable energy resources, wind energy is one of the most promising renewable energy sources and is widely employed to generate electric power for different areas. Kinetic energy of the wind is captured by wind turbines and calculated by multiplying air flow speed ($v$ (m/s)) and half of air density ($\rho$ (kg/m$^3$)). Typically, wind turbines are divided into two main types, vertical axis wind turbine (VAWT) and horizontal axis wind turbines (HAWT). Among these two types, HAWT is more efficient and employed to produce electrical power in large scale. However, it has some drawbacks especially in the urban areas.

Regarding the requirements of HAWT such as sustained wind velocity and yawing mechanism, VAWTs are more efficient in complex urban terrains in harnessing the wind power. Because of the lower noise emission and construction cost of the VAWTs, it is suitable for urban areas [2–4]. However, VAWT has some disadvantages such as lower performance compare with horizontal turbines. To overcome this drawback, Chong et al. [5] introduced an innovative idea named Omni-direction-guide-vane (ODGV) to improve the performance of the VAWT. Indeed, ODGV could be deployed even in weak low wind speed and turbulent conditions commonly found in urban areas where conventional VAWT are not suitable. It is also capable to accelerate with on-coming wind to improve its energy output and starting characteristic of the wind turbine. In general, HAWT and VAWT have differences and that related specifications of these wind turbine types are listed in Table 1.

A review of the past researches indicate that experimental studies have been conducted as a common solution to determine the performances of the novel wind turbine design [6,7]. Furthermore, different methods, taking into considerations cost and time of experimental studies, have been employed to simulate the flow behavior and performance of the vertical axis turbines such as blade-element models [8], vortex methods [9], two-dimensional (2D) models using CFD [10,11] and three dimensional (3D) CFD simulations [12–14]. As an example, Wekowa et al. [10] applied the CFD numerical technique to investigate aerodynamic performance of the VAWT and specifications of the flow. The authors employed an authenticated CFD model and stable wind simulations at two different wind speeds, to forecast $C_p$ for turbine. As well, a set of numerical simulations were done using united 2D CFD code to investigate the aerodynamic performance of a novel