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Optimization of H-type Darrieus VAWTs: A preliminary review

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ABSTRACT – Presently, urban wind energy generation has received increasing attention and among various type of wind turbines, vertical axis wind turbines (VAWTs) are the most optimal wind energy harvester for urban and domestic applications. This is attributed by their numerous advantages, the primary being able to operate with any wind direction (omni-directional). Moreover, these turbines have low manufacturing, installation and maintenance costs. However, several critical issues regarding their power efficiency have limited their wide applications. This paper is intended to provide a preliminary review of optimization methods in the literature with the aim of improving the performance of small-scale Darrieus VAWTs.

1. INTRODUCTION

Various renewable energy initiatives introduced by the government has seen to be one of the main contributing factors in the increasing demand of renewable energy consumption around the world. One of the renewable energy resources is wind energy. Previously, research in wind energy field are mostly focus on the optimization and commercialization of horizontal axis wind turbine (HAWT). In the recent years, however, wind energy market has shifted towards small-scale energy generation in remote and urban areas. This has brought attention to the use of VAWT as the most suitable energy converter in urban areas. However, low power output and self-starting ability are the two major drawbacks of VAWTs that have restricted their wide application in commercial scale. The main objecttive of this paper is to provide a preliminary review on different optimization methods to enhance VAWT performance.

2. VERTICAL AXIS WIND TURBINE

VAWT can be divided into two types according to the operating mechanism of the blade, i.e. drag-based and lift-based VAWT. The Savonius and the Darrieus turbine are the two most popular designs of the drag-type and lift-type VAWTs, respectively. The increasing interest in the use of VAWTs could be attributed to numerous advantages such as omni-directional capability, low noise and vibration and low manufacturing, installation and maintenance cost. Figure 1 shows the type of Darrieus VAWT according to different blade designs. Due to manufacturing difficulty of the blade, Darrieus VAWT design relied heavily on straight blade (H-rotor).

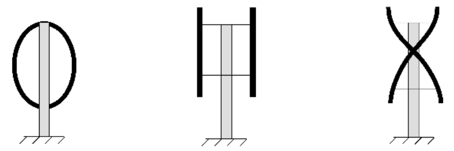

Figure 1 Type of Darrieus VAWT.

3. PARAMETRIC DESIGN OPTIMIZATION

VAWTs have such a complex aerodynamic characteristics that greatly influence their performance. These aerodynamic complexities are usually influenced by various geometrical and operational parameters such as airfoil profile, blade pitch angle and turbine solidity. Therefore, in-depth understanding of these factors and their impact on the turbine performance are essential in order to produce an ideal design of VAWT.

3.1 Blade profile

Blade is one of the key components in VAWT where the forces generated on the blade will determine the power output of the turbine. Cambered blade is believed to be able to improve the self-starting ability of VAWT. This has been proven in a numerical study conducted by [1]. Figure 2 shows the difference between cambered and symmetry blade.

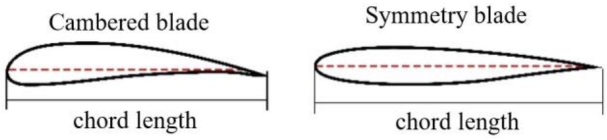

Figure 2 Difference between cambered and symmetry blade.

Blade thickness is also an important factor that taken into consideration when choosing a suitable blade. According to [2], the use of thinner airfoil profile is strongly recommended to optimize turbine power output.

3.2 Pitch Angle

Blade pitch angle is one the main parameters for performance optimization of VAWT as it is very simple to apply with low cost involved. Pitch angle can be installed in 3 ways: with positive angle (> 0°), with zero angle (= 0°) or with negative angle (< 0°), as shown in Figure 3.

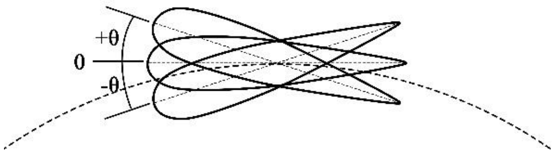

Figure 3 Installation of blade pitch angle.

Several studies have been conducted to provide detailed understanding of the impact of fixed and variable pitch angle for VAWT [3-4]. Moreover, based on the literature, the application of variable pitch angle instead of fixed pitch angle is recommended where the pitch angles are dynamically adjusted according to azimuthal angle of the blade, hence, could reduce the generation of negative torque throughout the rotation.

3.3 Solidity

Solidity plays an important role in determining the performance of VAWT in term of turbine power output and self-starting ability. Solidity can be defined as the ratio of blade area to swept area ($\sigma = N.c/D$) where N is the number of blades, c is the blade chord length and D is the turbine diameter.

From the literature [5-6], a good consensus can be seen regarding the turbine solidity, in which high solidity turbine performs better at low TSR and has better self-starting ability while low solidity turbine works optimally at high TSR. In addition, low solidity turbine has flatter power curve and wider operating range of TSR while turbine with high solidity has sharper curve and narrower operating range.

4. OTHER OPTIMIZATION METHOD

Apart from the optimization of parametric design to improve VAWT performance, the application of flow enhancing equipment such as guide vanes, deflectors and concentrators have been introduced in the literature [7]. The use of these equipment as addition to the turbine structure are proven to increase the rotor rotational speed and improve self-starting ability of the turbine.

Besides that, various new designs of VAWT with innovative solution have been proposed in the literature in order to solve problems in conventional VAWT design. For instance, cross axis wind turbine (CAWT) that has been developed by Chong et al. [8] showed a better performance compared to the conventional VAWT with an increase in rotational speed about 70% with well improved starting behaviour.

Arrangement of VAWTs in a cluster could also improve their power performance as the wake from the neighbouring turbine can severely affect the condition of the incoming wind. For example, Vergaerde et al. [9] conducted wind tunnel tests of individual and paired VAWT to study their performance and found that the latter showed a net increase in the power coefficient between 13% - 16%.

5. CONCLUSION

Based on the literature review, it could be concluded that VAWT has a huge potential as urban wind energy converter and offer economically viable energy solution for remote areas. However, several major issues regarding its performance has limited the use of this turbine in commercial scale. Therefore, in order to increase the use of VAWT, the problems associated with various configurations should be overcome and factors and parameters that have significant impacts on turbine performance should be comprehensively understood.

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