Albahit journal of applied sciences ISSN 2708-244X, e-ISSN 2708-8936, Vol. 3, Issue 1, 2022, 6-9

Tilt Angle Adjustment Effect on the Performance of Savonius Wind Turbines

Mohamed Suleman Basher[1*], Gehad. G. Hamdan[2]
[1]Mechanical Engineering Department, Faculty of Technical Engineering, Bright Star University, Al-Brega , Libya
[2]Faculty of Petroleum Engineering, University of Al-Jufra, Zellah, Libya
*www.alzway418@gmail.com

***Abstract*—The Savonius wind turbine is a type of vertical axis wind turbine that is simply composed of two or three arc-type blades which can generate power even under poor wind conditions. The effect of straight guide vanes, on the power production of a two-bladed Savonius wind turbine is investigated using transient computational fluid dynamics (CFD). The aim of this paper to evaluate the effectof guide vane on the performance of Savonius wind turbine. The results concluded that, the power that generated by the Savonius wind turbine increases significantly compared with Savonius wind turbine without guide vane. The maximum improvement attained to 74.7% at wind speed of 8.5 m/s.**

***Key words*—Wind Energy, Guide Vane, Savonius Rotor Performance, Tilt Angle, CFD**

I. INTRODUCTION

Vertical-axis wind turbines have been tested to be effective devices to extract energy from the wind. VWATs have been used to generate mechanical and electrical energy at a range of scales, from small-scale applications through the large-scale electricity production [1]. one of (VAWTs) is Savonius wind turbine. It has simple structure, relatively low operating speeds, and an ability to capture wind from any directions. it has low aerodynamic efficiency [2]. Researchers worked to enhance the Savonius turbine performance by changing the structure of the turbine. Kamoji et al [3] and Gupta et al [4] studied the aerodynamic characteristics of a modified Savonius turbine with helical blades, while Golecha et al [5] and Altan and Atilgan [6] [7] placed a guide vane in front of the turbine to deflect flow for the returning blade. McTavish et al [8] proposed a modified blade shape and carried out both steady and transient CFD simulations. Kamoji et al [9] and Kacprzak et al [10] studied the performance of modified turbines with spline-type and Bach-type blades, with an increase in efficiency 16% found in the case of using spline-type blades. Tian et al [11] carried out CFD simulations of Savonius with elliptical blades. It is noted that the most recent studies use numerical methods, followed by a comprehensive verification with or without validation, to study the effect of rotor configurations. CFD models allow for performing a relatively affordable analysisof the most promising improvements of diverse devices or processes as the first step before a real prototype is built and tested. The present paper examines numerically the influence of straight guide vane designs towards improving of Savonius performance. straight guide vane design introduces in this paper at different tilt angles.

II.MATERIALS AND METHODS

The objective of this paper is to find the highly efficient Vertical Axis Wind Turbine by studying the aerodynamic characteristics of the blades of Savonius rotor. The basic parts are divided into two parts. The first part of this research is numerical investigation. This computational investigation was done using ANSYS software. The flow field was designed on a 2-D model. The mesh was generated with ANSYS and basic investigation was run on FLUENT to determine the torque coefficient. And values of velocity and torque are extracted and then used to calculate torque and power coefficient. The second part is to study numerical results and to make a final conclusion.

III. MATERIALS

Savonius wind turbine model with two blades as shown in Figure 1 will be used. The model was built with overlap ratio (e: d) equal to 0.15. Aspect ratio (D: h) up to 1.0 and end plate parameter (Do: D) equal to 1.1 [12]. Dimensions of the blades of Savonius wind turbine model are diameter of blades d = 160 mm ; gap e = 0.15 x d = 0.15 x 160 = 24 mm ; shaft diameter a = 15 mm ; rotor diameter D = 160 + 160 – 24 = 296 mm ; rotor height h = 320 mm; end plate diameter Do = 1.1 x D = 1.1x 296 = 325.6 mm ; and thickness of blades and end plates t = 2 mm , was made from aluminum [13] are shown in Figure 2.

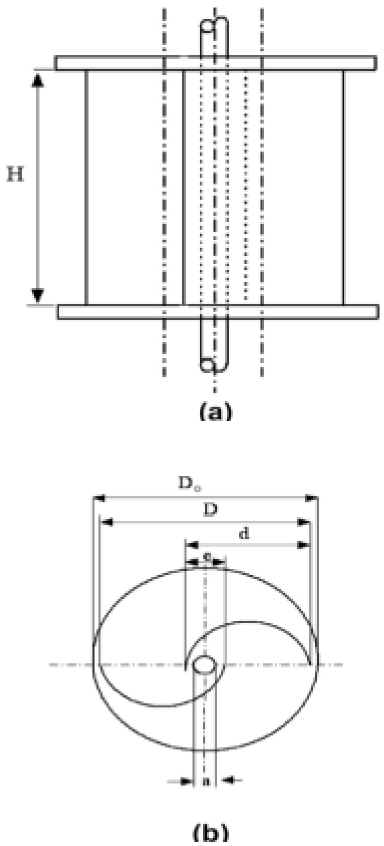

Fig.1. Model of a single-stage Savonius rotor.

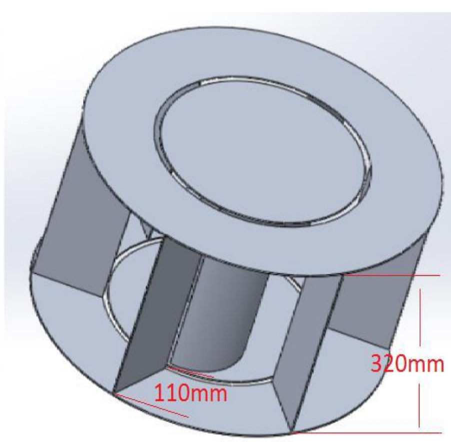

Fig.2. design of guide vane.

IV. Mathematical Expressions and Symbols

Every Savonius wind turbine is characterized by the swept area AS. This area influences the energy output of the turbine, and the larger it is, the more energy the turbine collects

$$As = H * D$$

Where
H is the height of the turbine
D is rotor diameter [12].

The tip speed ratio of the rotor is defined by the equation:

$$\lambda = \frac{v\ rotor}{v} = \frac{\omega\ d}{v}$$

Where
v is the wind speed
ω is the angular velocity of the turbine
d is the diameter of the semi-cylindrical blade [12].

The torque coefficient Ct is the ratio between the torque in the rotor and the theoretical torque that the wind can cause:

$$C_T = \frac{T}{T_o} = \frac{T}{(^1/_4\ \rho v^2 As\ d)}$$

Where
T is the torque in the rotor
ρ is the air density.

The power coefficient Cp is the ratio of the extracted power from the wind to the available power in the wind:

$$Cp = \frac{P}{P_o} = \frac{T\ \omega}{(^1/_2\ \rho v^3 As\ d)}$$

Using these factors, we can learn about the

turbine's characteristics and analyze its performance.

V. Results and Discussion

A series of simulation has been carried out. Those simulation used two-blade Savonius wind turbine without guide vane and with guide vane at different tilt angle. The results were taken from simulation is torque (T) at various wind speed (v) in order to know Savonius wind turbine performance. Here are the wind speed variations in the experiments:

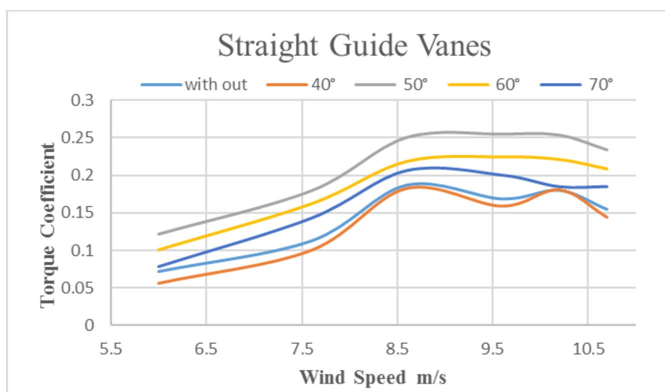

Fig. 3. Variation between Torque Coefficient and wind speed with straight guide vanes at different tilt angle.

The torque coefficient of Savonius wind turbine with guide vane as shown in Figure 3 increased compared to the Savonius wind turbine without guide vane design. Maximum torque coefficient (Ct) that produced by the Savonius wind turbine without guide vane was 0.1869 at the wind speed 8.6 m/s and 0.1685 at 9.6 m/s. The Savonius wind turbine with straight guide vane attained of 0.2502 at

9.6 m/s. Which means increased about 66.1% compared to Savonius wind turbine without guide vane.

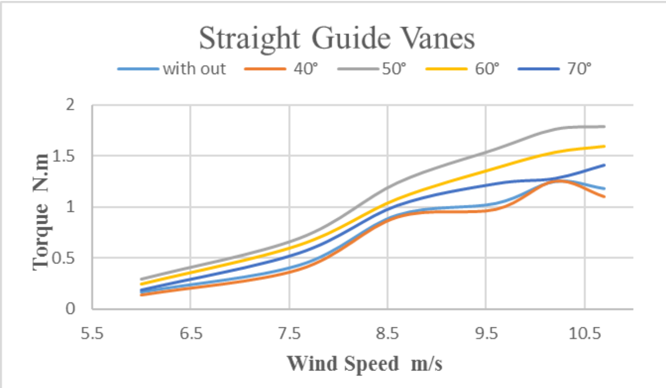

Fig.4. Variation between Torque and wind speed with straight guide vanes at different tilt angle.

The torque improvement ratio when using the guide vane at an angle of 50° as shown in Figure 4. This is due to the guide vane blocked up the wind on the convex blade and directed the wind smoothly into the concave blade of a turbine. It consequently increased Savonius wind turbine rotation, so that the Savonius wind turbine generated higher power than the Savonius wind turbine without guide vane at all wind speed. as shown in the figure 5.

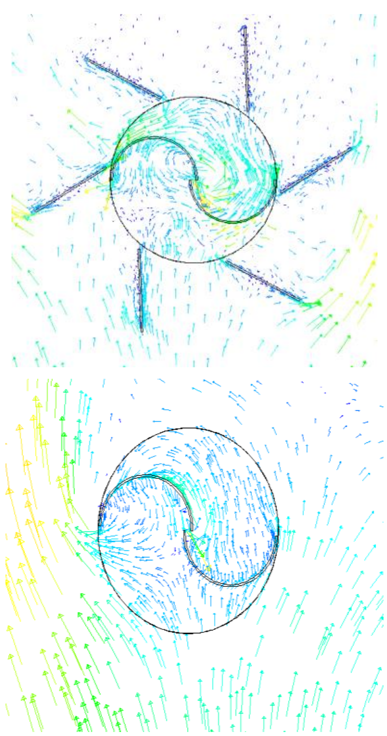

Fig. 5. Flow direction.

Maximum torque of Savonius wind turbine with straight guide vane was 1.786 N.m at 10.7 m/s that is improves about 66.1% compared to maximum torque of Savonius wind turbine without guide vane.static pressure Contours for 50° and 10.6 m/s.

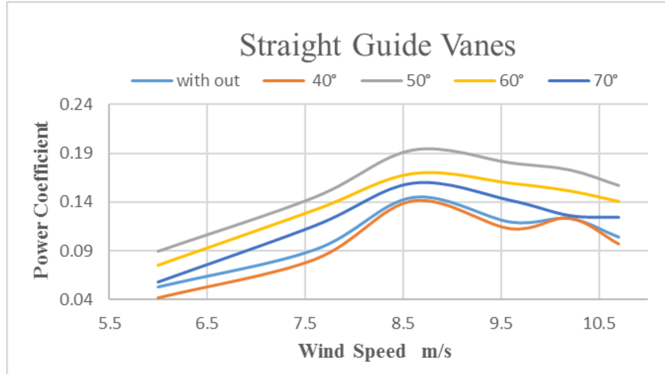

Fig. 6. Variation between power coefficient and wind speed with straight guide vanes at different tilt angle

Figure 6 show correlation between power coefficient (Cp) and wind speeds (v) for Savonius wind turbine without guide vane and with straight guide vane. There is increase of power that generated by Savonius wind turbine accordingly with the increase of wind speed. Figure 6 also illustrates that the addition of guide vane increased the power coefficient significantly compared to wind turbine without guide vane. The maximum power coefficient of Savonius wind turbine without guide vane was attained 0.1443 at 8.6 m/s. The maximum power coefficient of Savonius wind turbine with straight guide vane 0.19317. The power coefficient increased about 74.4%.

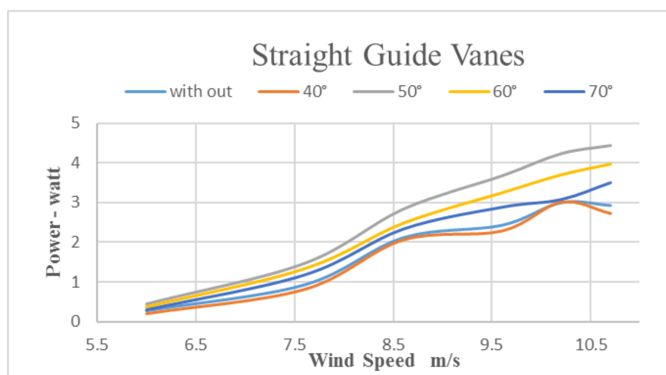

Fig. 7. Variation between power and wind speed with straight guide vanes at different tilt angle.

Maximum power of Savonius wind turbine as shown in Figure 7 with straight guide vane was 4.440 watt at 10.7 m/s that is improves about 66.1% compared to maximum power of Savonius wind turbine without guide vane.

The pressure distribution (pa) on the blades are shown in Figure 8. The high-pressure area shows on the concave side and the low-pressure area on the convex side. The difference in pressure between the convex and concave sides of the blades causes the turbine rotating.

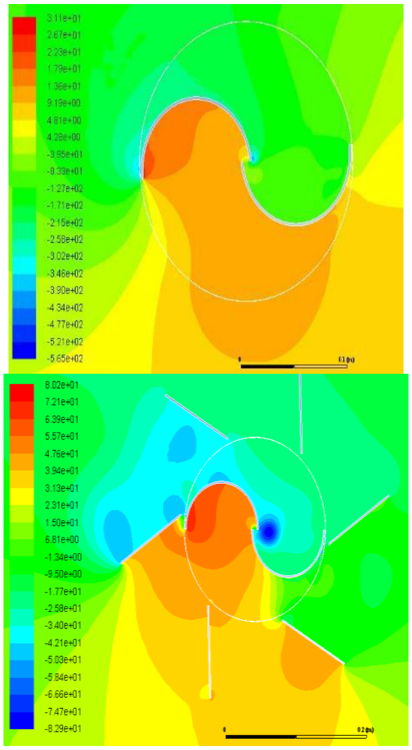

Fig. 8.static pressure Contours for 50° and 10.6 m/s. (a) without guide vane; (b) straight guide vane.

VI. CONCLUSION

In this paper a series of simulation has been carried out to study the effect of guide vane on the performance of Savonius wind turbine. Those simulation used two-blade Savonius wind turbine without guide vane and with guide vane at different tilt angle. The results show that, the best tilt angle to improve Savonius wind turbine performance is 50°. The Cp that attained by turbine increases up to 74.4% compared without guide vane, the maximum improvement attained to 74.7% at wind speed of 8.5 m/s.It has been proven that the addition of guide vane supports the improvement of the Savonius wind turbine. The guide vane helps to block up wind direction on to convex blade and direct it to concave blade. They are able drive and prevent the wind that might be escaped to the upper or bottom sides

References

[1] W. Tong, Wind power generation and wind turbine design. WIT press, 2010.

[2] N. H. Mahmoud, A. A. El-Haroun, E. Wahba, and M. H. Nasef, "An experimental study on improvement of Savonius rotor performance," *Alexandria Eng. J.*, vol. 51, no. 1, pp. 19–25, 2012

[3] M. A. Kamoji, S. B. Kedare, and S. V Prabhu, "Performance tests on helical Savonius rotors," *Renew. Energy*, vol. 34, no. 3, pp. 521–529, 2009.

[4] R. Gupta , D. Bachu, R. D. Misra, "Performance Analysis of a Helical Savonius Rotor with Shaft at 45° Twist Angle Using CFD," *Mechanical Engineering Research,* vol. 3, pp. 118-129, 2013.

[5] K. Golecha, T. I. Eldho, and S. V Prabhu, "Influence of the deflector plate on the performance of modified Savonius water turbine," *Appl. Energy*, vol. 88, no. 9, pp. 3207–3217, 2011.

[6] B. D. Altan and M. At\ilgan, "An experimental and numerical study on the improvement of the performance of Savonius wind rotor," *Energy Convers. Manag.*, vol. 49, no. 12, pp. 3425–3432, 2008.

[7] B. D. Altan, M. At\ilgan, and A. Özdamar, "An experimental study on improvement of a Savonius rotor performance with curtaining," *Exp. Therm. fluid Sci.*, vol. 32, no. 8, pp. 1673–1678, 2008.

[8] S. McTavish, D. Feszty, and T. Sankar, "Steady and rotating computational fluid dynamics simulations of a novel vertical axis wind turbine for small-scale power generation," *Renew. energy*, vol. 41, pp. 171–179, 2012.

[9] M. A. Kamoji, S. B. Kedare, and S. V Prabhu, "Experimental investigations on single stage modified Savonius rotor," *Appl. Energy*, vol. 86, no. 7–8, pp. 1064–1073, 2009.

[10] K. Kacprzak, G. Liskiewicz, and K. Sobczak, "Numerical investigation of conventional and modified Savonius wind turbines," *Renew. energy*, vol. 60, pp. 578–585, 2013.

[11] W. Tian, B. Song, and Z. Mao, "Numerical investigation of a Savonius wind turbine with elliptical blades," *Proc. CSEE*, vol. 34, pp. 5796–5802, 2014.

[12] U. K. Saha, S. Thotla, and D. Maity, "Optimum design configuration of Savonius rotor through wind tunnel experiments," *J. Wind Eng. Ind. Aerodyn.*, vol. 96, no. 8–9, pp. 1359–1375, 2008.

[13] M. H. Ali, "experimental Comparison Study for Savonius Wind Turbine of Two and Three Blades At Low Wind Speed," *International Journal of Modren Engineering Research (IJMER),* vol. 3, no. 5, pp. 2978-2986, 2013.