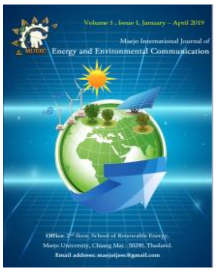
Maejo International Journal of
Energy and Environmental Communication



ARTICLE

Study on performance of a savonius wind turbines related with the blade angle

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ARTICLE INFOR

Received 16th June 2019
Accepted 01st August 2019

Keywords:
Vertical axis wind turbine
Power coefficient
Torque coefficient

ABSTRACT

This research aimed to compare the performance of Savonius vertical axis wind turbines through blade numbers and different blade angles. In this study, applicable turbines having 4, 6, 8, 12, 16 and 18 numbers of blades with the angles of the blades of -15°, -5°, 0°, 5° and 15°, respectively. The rotor used was a semicircle shaped blade made from PVC material and has a blade diameter of 6 cm and 30 cm for both rotor diameter and height. The turbine was tested deadweight range of 0-0.49 kg at 4 m/s wind speed. The results showed that the blade angle has a positive effect on increasing the power and torque coefficient of Savonius wind turbine, specifically on blades less than 16. The highest power and torque coefficient was obtained from the turbine having16 blades at an angle of 5°. This configuration also found that the maximum power and torque coefficient in the tip speed ratio ranging from 0.3-0.4 are 0.2519 and 0.5858, respectively.

1. Introduction

Thailand's integrated energy blueprint is comprised of five plans focusing on energy efficiency, oil, gas, power development, and alternative energy. Nowadays, renewable energy has become a major part of the national energy supply to replace fossil fuels and reduce oil imports. The government of Thailand aims to increase the ratio of renewable energies to 30% of total consumption by 2036. By these, a need to focus on biomass, solar and wind utilization is necessary to generate power and increase the current from 220 MW to 3002 by 2036 (Energy Policy and Planning office [EPPO], n.d.). However, in Northern Thailand has a wind speed ranging from 2-4 m/ (Thailand Royal Thai Airforce Renewable Energy, n.d.) which is considerably low. Vertical axis wind turbines (VAWTs) are suggested as a better choice when compared with wind rotors with a Horizontal axis wind turbines (HAWT) under weak and unstable wind areas. Savonius type vertical axis is a wind turbine that can be operated at all wind direction, has low cut-in speed and high torque but has a rather low power performance (Chaichana, 2016).

A number of researchers have experimentally and numerically examined the effects of various design parameters of Savonius wind turbine such as designing the cowling and wind booster devices from Alam et al. (2013); Longanathan et al. (2015) and Korprasertsak (2015). It was found out that the designs were able to increase the angular speed of VAWT, thus leads to an increase in mechanical power generation and to reduce the loss in the torque. Saha et al. (2008) and Mahmoud et al. (2012) further attempt was made to investigate the performance of two-stage rotor system by adjusting numbers of blades as well as two-stage shaft co-axis counter-rotating wind turbine performance (Chaichana et al., 2015). However, the use of such designs causes an increase in cost and difficulty in manufacturing costs. Therefore, this study aims to adjust to minimize the cost and difficulty by

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adopting and combining the method described by Longanathan et al. (2014); Li et al. (2015) and Longanathan et al. (2017): adjust the blade angles (β) to improve the performance for each blade number (NB) without changing the basic structure and a simple construction of a Savonius wind turbine.

2. Materials and methods

2.1. Wind turbine and wind tunnel

The Savonius wind turbine prototype with 4, 6, 8, 12, 16 and 18 blades were used which had a semicircle shaped blade. They are made from polyvinyl chloride (PVC) material and end plates made from the acrylic sheet with 0.3 mm thickness shown in Figure 1. It was an H-type design of the diameter of the blade and rotor 6 cm and 30 cm, respectively, and 30 cm of height rotor. The turbine was tested with 6 configurations with different angles at a wind speed constant of 4 m/s and over a range deadweight (0-0.49 kg). The first configuration was the 4 bladed with blade angle orientation from -15°, -5 °, 0 °, 5 ° and 15 ° displayed in Figure 2, and the 2nd-6th configuration was 6, 8, 12, 16 and 18 blade with the same blade angles of orientation, respectively.

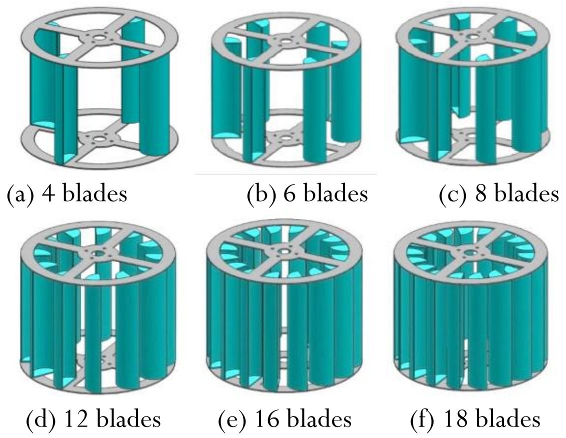


Figure 1. Prototypes of the Savonius wind turbine.

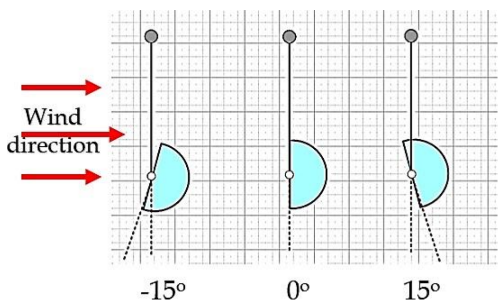


Figure 2. Example of blade angles for the individual blade

Tests were undertaken at open type circuit tunnel with a rectangular test section of 1.2 m x 1.2 m, the length of the wind tunnel was 9.5 m and powered by an electric motor with 1.5 hp. The wind tunnel can be adjusted wind speeds in the range of 0-7.6 m/s. The turbulence intensity measured about 0.1% when the experiment is performed at a test section of 7.5 m from the inlet wind tunnel was expressed in Figure 3.

Figure 3. Wind tunnel laboratory view

2.2. Experimental setup

The contents of measurement for the whole experimental apparatus were shown as follows. The wind turbine setup was positioned in the middle of the wind tunnel test section area. And then, hot wire type anemometer which is installed in front of wind rotor use to log the recorded data was consists of wind speed and air temperature. Such flow speed can be regulated now by setting the inverter. Finally, the installation of the brake horsepower system was positioned below the tunnel to measure torque, which is the difference between the dead weight and load cell reading produces the tangential force on the pulley. The signal from the load cell is shown by the data logger software and rotational speed recorded by a laser sensor tachometer illustrated in Figure 4.

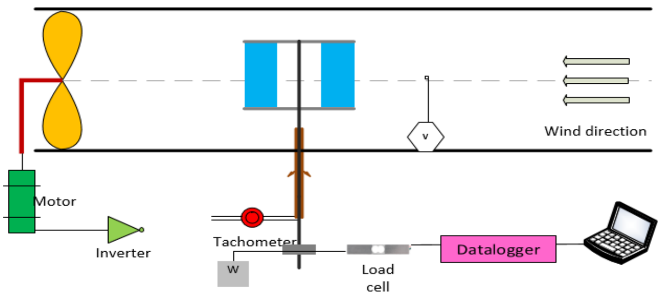


Figure 4. Schematic diagram of experimental setup

2.3. Data processing method

Torque and rotational speed at 4 m/s wind speed each configuration tested were analyzed to calculate the power coefficient, CP and torque coefficient, CT using the following formula:

$$C_P = \frac{P_o}{P_w} = \frac{\Delta T\omega}{0.5\rho A V^3} \quad (1)$$

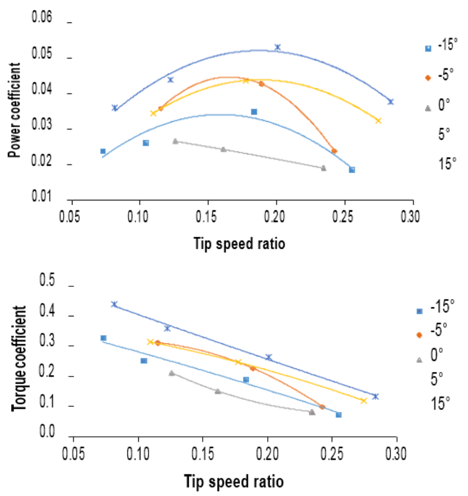
$$C = \frac{C_p}{T\lambda} = \frac{\Delta T}{0.5\rho A V^2 R} \quad (2)$$

where T is the torque, ω is angular velocity of rotor, ρ is the density of air, A is the swept area, V is mainstream wind speed and R is the rotor radius. The torque coefficient represents the aerodynamic efficiency of wind turbine with a function of the tip speed ratio (TSR, λ) which is defined as:

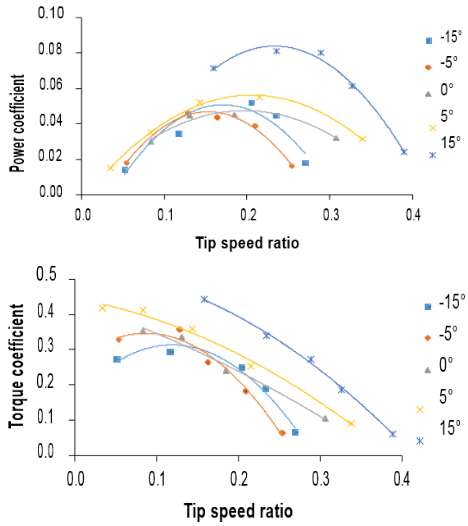
$$\lambda = \frac{R\omega}{V} \quad (3)$$

3. Results and discussion

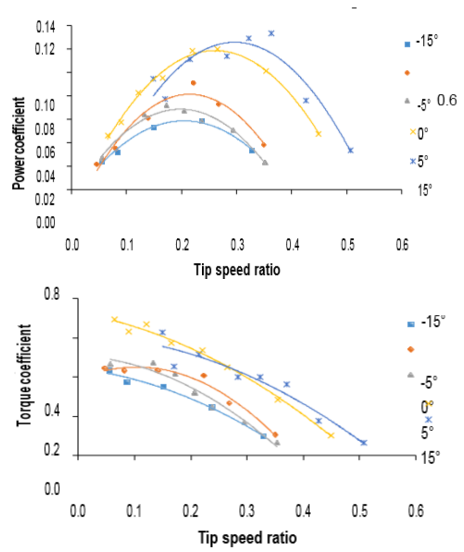
In this research, the mainstream wind speed is set at 4.0 m/s (the wind potential in Thailand of the average maximum wind speed), by analyzing the power and torque coefficient at different blade angles of each blade wind turbine. And then, compare the maximum power coefficient of the optimized blade angle that has been analyzed at different numbers of blades.



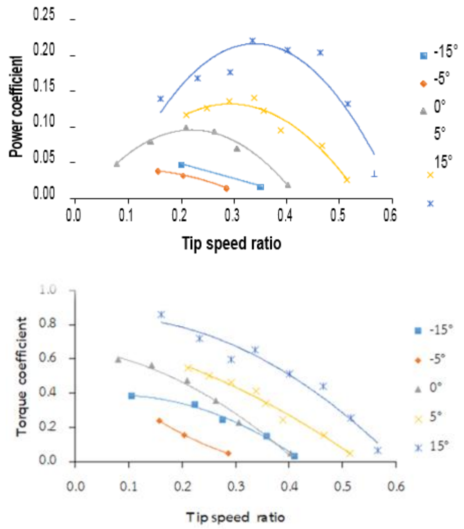
(a) Power and torque coefficient for 4 blades



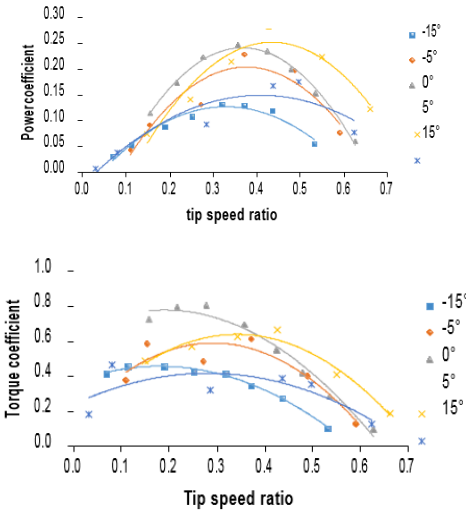
(b) Power and torque coefficient for 6 blades



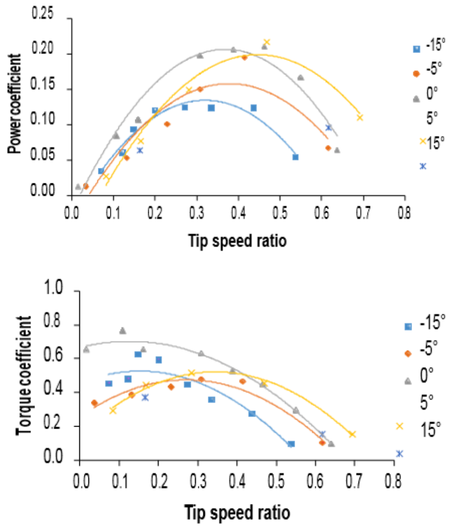
(c) Power and torque coefficient for 8 blades



(d) Power and torque coefficient for 12 blades



(e) Power and torque coefficient for 16 blades



(f) Power and torque coefficient for 18 blades

Figure 5. Power and torque coefficient as a function of TSR for the number of blades is from 4-18 at different blade angles (a-f)

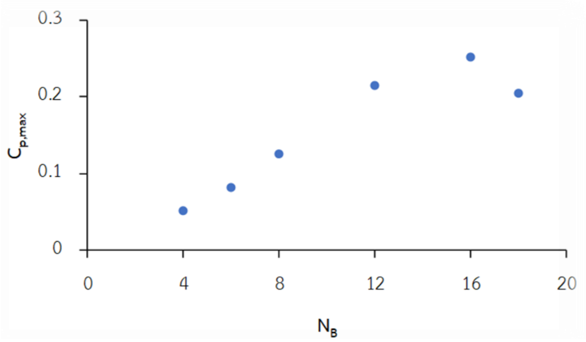


Figure 6. Maximum power coefficient at the optimized blade angle for 4-18 blades

Table 1. Compared the power and torque coefficient for different number of blades.

N_B	β (°)	CP, max	CT(Cp,max)	TSR(Cp, max)
4	15	0.0519	0.2731	0.19
6	15	0.0833	0.3470	0.24
8	15	0.1259	0.4197	0.30
12	15	0.2157	0.6345	0.34
16	5	0.2519	0.5858	0.43
18	0	0.2050	0.5396	0.38

The maximum power coefficient at the range of 4-12 blades turbine with an angle of 15°, and 5° for 16 blades turbine when comparing the baseline configuration (0°). It is also found that the power coefficient increased about 85.33, 77.20, 84.11, 127.37 and 4.54 %, respectively, and 18 blades were 0° blade angle when comparing the blades angle for all. Torque coefficient was decreased by increasing the tip speed ratio for all blade angle configurations presented in Figure 5. When compared to the maximum power coefficient of the optimized blade angle for 4, 6, 8, 12, 16 and 18 blades. It was found that the power coefficient was 0.0519, 0.0833, 0.1259, 0.2157, 0.2519 and 0.2050, respectively (Figure 6). These prove were shown in table 1.

Conclusions

The results revealed that the blade angle has a positive effect on increasing the power and torque coefficient of Savonius wind turbine specifically with those having below 16 blades. It was also found out that the 16-blade wind turbine configuration has the most power coefficient at a 5° blade angle among others. This configuration showed that the maximum power coefficient of 0.2519 was in the range of 0.3-0.4 tip speed ratio which has a 4.5% increase in power compared to that of turbines at 0° blade angle.

Nomenclature and Abbreviation

β	Blade angles
Ct	Torque coefficients
Cp	Power coefficient
HAWT	Horizontal axis wind turbines
NB	Blade number
TSR, λ	Tip speed ratio
VAWTs	Vertical axis wind turbines

Acknowledgments

The authors would like to acknowledge the following supporters of this research from the School of Renewable Energy, Maejo University "Project and development of the renewable energy potential graduates. ASEAN", Energy Policy and Planning Office, Ministry of Energy and Graduate School Maejo University.

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