The Impact of the Pitch Angle on the Power of the AEOLOS V300 and AEOLOS V600 Wind Turbines

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Abstract: Nowadays wind power has become a promising source for electricity generation because wind power is clean and efficient. The aim of this paper is to study the effect of the variable pitch angle on the performance of the vertical axis wind turbines. The study concerns two type Darrieus wind turbines; AEOLOS-V 300W and AEOLOS-V600 W. The results show that the pitch angle has a significant effect on the output power. The turbines with a variable pitch angle can produce a maximum output power in low wind speed compared to classic turbines, with an increase of 30% on the power coefficient.

1 INTRODUCTION

Wind energy is very essential as one of the cleanest energy sources, it can help to reduce the need for fossil fuels, and the wind turbines are the most efficient tools to explore this clean energy (S. Brusca, 2015) (Taher, 2015) (M. Predescu, 2009) (Arti Tirkey, 2014) (M. Zheng, 2015). Several configurations were developed in the latest years and two types of the VAWTs namely Darrieus and Savonius has been noticed (W. Roynarin, 2004). The vertical axis wind turbines type Darrieus have grown interest to produce electricity, even in urban areas. This type of turbines presents several advantages over the horizontal axis wind turbines (HAWT) such as; a low noise, omnidirectional, able to catch the wind from all directions, uses less material, can be mounted at ground level, running with low wind speed. Despite the low performance of these turbines, they are more suitable for urban areas (M. Ghasemian, 2017).

Many researchers have proposed different optimization techniques to improve the performance of vertical axis wind turbines, such as the effect of the pitch angle control. Figure 1 shows several variations of the pitch angle. M. Elkhoury et al (M. Elkhoury, 2015) carried out the effect of variable pitch angle on the performance of the micro vertical axis wind turbine, the results have shown that the power coefficient increases significantly with the variable-pitch mechanism below TSR=1.5. A. Rezaeiha et al (A. Rezaeiha, 2017), found that a small negative pitch angle β=-2° increases the power coefficient by 6.6% compared with β=0°. G. Abdalrahman et al (Abdalrahman, 2017) found that the wind energy produced by H-type VAWT with the variable pitch control increases by 25% compared to the fixed pitch VAWT cases. M. El-Samanoudy et al (M. El-Samanoudy, 2010) concluded that for a pitch angle equal to 10°, the maximum values of Cp ,Ct and λ have been obtained.

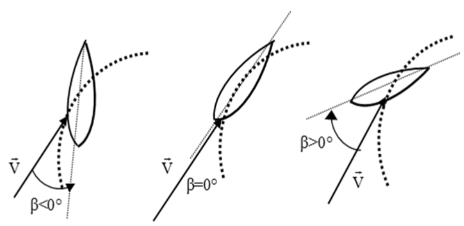

Figure 1: Geometric model of the pitch angle (A. Rezaeiha, 2017)

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Q. Li et al (Q. Li, 2016), found that the Performance of the test wind turbine depends of the blade pitch angles and for a blade pitch angle of 6°, the power coefficient takes a maximum value. Young-Tae Lee et al (Young-Tae Lee, 2015), investigated the effect of the pitch angle on 500 W Darrieus-type vertical-axis wind turbine, and found that when the pitch angle reaches -2° with a helical angle of 0, the Darrieus-type VAWT showed maximum power.

In this work we aim to study the effect of the variable pitch angle on the performance of the vertical axis wind turbines in term to output power and the maximal wind speed, furthermore two types of turbines AEOLOS-V300W and AEOLOS-V-600 W have been examined.

2 METHODOLOGY

2.1 Description of the Studied Turbines

AEOLOS-V blades use the aerodynamic design which limits the maximum rotating speed to 360 rpm even if the wind speed is 30m/s or 40m/s. It is safer and more reliable than traditional vertical axis wind turbines. It could start up with 1.5m/s and has the power output in 2.5m/s to the inverter. This is more efficient than vertical wind turbines with a 3.5m/s or even 4.5m/s start up wind speed. The technical characteristics of the adopted wind turbines provided by the company of AEOLOS Wind turbine have been presented in Figure 2, Figure 3 and Table 1 (AEOLOS WIND TURBINE, 2013).

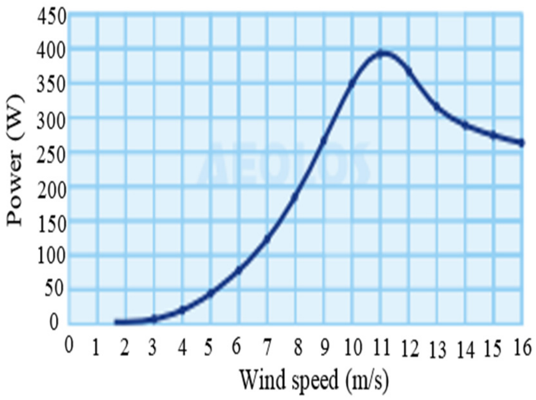

Figure 2: AEOLOS-V300W Power curve

2.2 Effect of the Pitch Angle

2.2.1 Angle of Attack

The angle of attack is expressed as (Mazharul , 2008) (Travis, 2011) (S. Lain, 2010):

$$\alpha_f = \tan^{-1}\left(\frac{\sin(\theta)}{\lambda+\cos(\theta)}\right) \quad (1)$$

Where λ is the tip speed ratio and θ is the azimuth angle.

For the turbines with variable pitch angle, the angle of attack became:

$$\alpha_v = \tan^{-1}\left(\frac{\sin(\theta+\beta)+\lambda\sin(\beta)}{\cos(\theta+\beta)+\lambda\cos(\beta)}\right) \quad (2)$$

Where β is the sinusoidal pitch angle, it depends on the position angle and it varies between -19° and 19°, shown on Figure 5.

2.2.2 Output Power

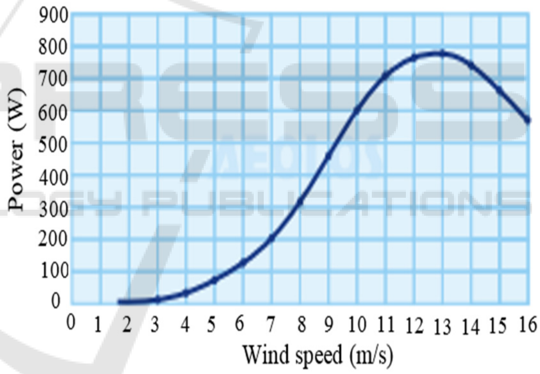

Figure 3: AEOLOS-V600W Power curve

Figure 4: AEOLOS-V turbine

The mechanical power output is expressed as (Mazharul , 2008) (Travis, 2011) (S. Lain, 2010):

$$P = \omega . T \quad (3)$$

Where ω is the rotational velocity and T the total torque, the expression founded is :

$$P_f = \frac{1}{2} rN\rho Sk\omega V^2 \alpha_f{}^2 \left(1 + \lambda^2 + 2\lambda \cos(\theta)\right) \quad (4)$$

Table 1: Technical characteristics of the AEOLOS-V turbines

Geometry and operating conditions	AEOLOS-V-300W	AEOLOS-V-600W
Number of blades[-]	3	3
Chord [m]	0.3	0.3
Rotor Height [m]	1.6	2
Rotor Width [m]	1.2	1.6
Rated Power[W]	300	600
Max Output Power [W]	400	800
Tip Speed ratio[-]	3	3
Rated wind speed [m/s]	10	10
Max wind speed [m/s]	11	13

For the turbines with variable pitch angle, the power output became:

$$P_v = \frac{1}{2} rN\rho Sk\omega V^2 \alpha_V{}^2 \left(1 + \lambda^2 + 2\lambda \cos(\theta)\right) \quad (5)$$

With the tip speed ratio λ is expressed as (Mazharul, 2008) (Travis, 2011) (S. Lain, 2010):

$$\lambda = \frac{r\omega}{V} \quad (6)$$

The wind turbine rotor is characterized by its power coefficient C_p :

$$C_P = \frac{P}{0.5\rho S V^3} \quad (7)$$

Where β is the sinusoidal pitch angle, N is the number of blades, V is the axial flow velocity through the rotor, θ is the angle azimuth angle of the blades, ω is the rotational velocity, r is the radius of the turbine, ρ is the air density, S is the swept area of the rotor and k is the Wake Decay Constant.

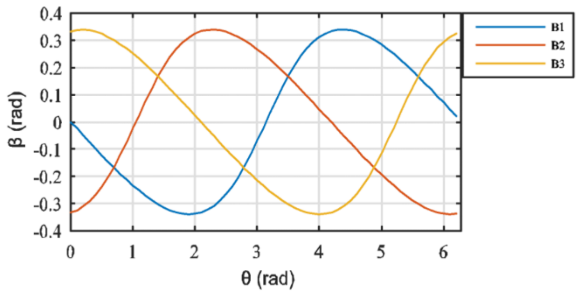

Figure 5: The variation of the sinusoidal pitch angle of the tree blades

3 RESULTS

This section illustrates the MATLAB simulation results.

Figure 6 presents the validation curve of the output power produced by AEOLOS-V 300W and AEOLOS-V 600W with the wind speed. The tested blade pitch angle is sinusoidal and vary between -0.34 rad and 0.34 rad corresponding to -19° and 19°shown on figure 5.

As seen in figure 6, for the turbines equipped with a variable pitch control, AEOLOS-V300W produces a maximal output power (400W) in 8.5m/s instead of 13m/s while AEOLOS-V600W produced a maximal output power (800W) in 10 m/s instead of 13m/s, compared with the turbines with fixed pitch angle.

Table 2 shows a comparison of wind speed corresponding to the maximal output power for both turbines with variable pitch angle and fixed pitch angle.

In term of wind speed, the turbines produce the same power but in low wind speed compared with fixed pitch angle, consequently the turbines don't need a height wind speed to achieve their maximal power output.

The variation of the pitch angle between -19° and

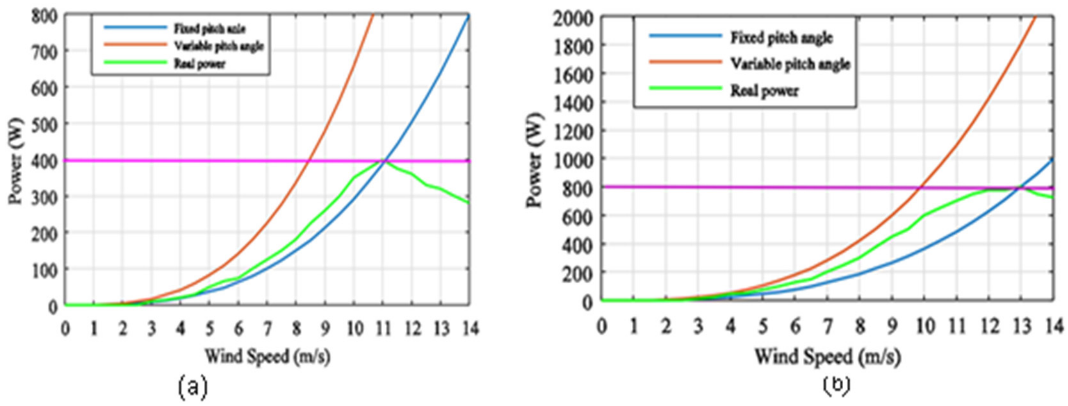

Figure 6: (a) Aeolos-V300W; (b) Aeolos-V600W

19°, affects the power coefficient, and it increases by 30% compared with the fixed pitch angle. Table 3 presents the comparison of the improvement of the Cp in this study with other researches.

As results the variable pitch angle has a satisfactory effect on the vertical axis wind turbines, it increases the power output by 30% compared with fixed pitch angle. And the turbines equipped with the mechanism of variable pitch angle reach their maximal output power in low wind speed compared with basic turbines.

Table 2: The wind speed corresponding on the maximal output power for the variable and fixed pitch angle

	Maximal wind speed	
	Fixed pitch angle	Variable pitch angle
AEOLOS-V 300W	11m/s	8.5m/s
AEOLOS-V 600W	13m/s	10m/s

4 CONCLUSION

This survey has been interested in the study of the effect of the variable pitch angle on the vertical axis wind turbines. The comparison has been carried out in MATLAB and took in consideration AEOLOSV-300W and AEOLOSV-600W wind turbines.
The above results have shown that the variable pitch angle is an essential parameter, it influences positively the performance of the vertical axis wind turbines. In fact, for turbines with variable pitch angle their maximal output power has been reached in low wind speed compared with fixed pitch angle, with a 30 % increase in the Cp factor.

Table 3: The comparison of the improvement of the Cp with other studies

	Pitch angles (degree)	Cp increased by
Rezaeiha 2017	-2	6.6%
G. Abdalrahman 2017	-6,-4, 0, 4, 6	25%
M. El-Samanoudy 2010	10°	19%
Present study	$-19<\beta<19$	30%

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