The effect analysis of wind speed variation to the horizontal axis wind turbine design with Q-blade

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The effect analysis of wind speed variation to the horizontal axis wind turbine design with Q-blade

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Abstract. Wind energy is renewable energy that environmentally friendly. One of the utilizations of wind energy is conversing the wind turbine. The wind turbine is an energy conversion device to convert wind energy into mechanical energy and convert it into electricity through the generator. The size of the power produced by wind turbine depends on the wind speed and the type of turbine that is used. In this research, the researchers design the wind turbine with wind speed variations. The purpose of the designing and the analysing the wind speed is to design a low wind turbine using number of blade 5 model. The objective of this study was to design a wind turbine with variations in wind speed of 2 m/s, 3 m/s, 4 m/s, 5 m/s and 6 m/s using number of blade 5 model wind turbine horizontal axis, rotor diameter of 1.4 m and this rotor used NACA 4412 air foil type. The method that is used in this study is Blade Element Momentum (BEM) and Q-Blade software for designing the simulation. The results of this study, the researchers found there is an increase in power as the wind speed increases.

Keywords: wind turbine, Q-blade software, Blade Element Momentum (BEM)

1. Introduction

Energy consumption using fossil energy sources is increasing every year in the world. Therefore, the environment pollution is huge due to the used of fossil energy. On the other hand, the renewable energy is quite potential in Indonesia. The use of renewable energy has an important role in reducing the use of fossil energy and it may help Indonesia to avoid energy crisis. One of the most potentials in Indonesia is wind energy. Renewable energy in Indonesia can be maximumly utilized for energy needs to support sustainable development and human needs in the energy sector [1]. The Utilization of wind energy conversion can be used by using a horizontal axis wind turbine. Unfortunately, in real conditions not all regions in Indonesia have the ideal wind potential. In this planning, a wind turbine design with low wind potential will be made, therefore, the design uses a number of blades of 5 to increase the output power. The researcher may also vary several speeds in order to predict the output power according to the real wind speed.

This research is using Q-blade software. Numerical analysis research with Q-blade software and using the BEM method, airfoil DU86-084, E387, SD2030 and SG6041, were selected for the design of wind turbine rotor blades with airfoil type E387 in the tip speed ratio (TSR) design with the highest power coefficient [2]. BEM theory is used to design and analyse the 300 watt wind turbine with design procedures codified in MATLAB to simplify routine. Airfoil used by air foil SG6040 and SG6041 was selected as hub and tip airfoil assumption a wind speed of 5m/s. The analysis showed a maximum annual energy production (AEP) of 538 kWh and a maximum torque of 15 Nm [3]. The design of a three-blade wind turbine using the 4418-airfoil type using Q-blade software using the BEM method, as a stage in the future. More aspects are also needed to be considered such as CFD analysis and stress analysis of the material. The performance analysis shows that the design of wind turbine blades can obtain a relatively high-power coefficient of 0.45 [4]. In this research, four airfoils NACA 4412, SG6043, SD7062 and S833 have been selected and investigated in Q-Blade. The results showed that the CP power coefficient of NACA 4412 on the tip speed ratio was superior to the other three airfoil [5].

2. Methods

This research was using HAWT (Horizontal Axis Wind Turbine) model with blade 5 number. The blade design uses Airfoil NACA 4412 with a rotor diameter of 1.4 m. The researcher was varying the wind speed 2-6 m/s and variations of Rpm 50, 100, 150, 200, 250 and 300 using Q-blade software and the BEM (Blade Element Momentum) method. BEM is used to predict wind turbine blades to increase performance with principle of calculating the aerodynamic force on the blade element.

2.1 Blade Element Momentum Method

Blade Element Theory has two methods. First, this theory uses momentum theory or disk actuator theory with a mathematical model. Second, Blade Element Theory is used to calculate the aerodynamics of the blade. The theoretical blade element is frequently used to calculate the blade elements on each airfoil [6]. This equation can be iterated as a solver. Iteration uses two variables, named axial and radial in BEM Theory. Then the variables can be defined as follows [7].

$$\alpha = \frac{1}{\frac{4FSin^2\,\varphi}{(\sigma\, C_N)}+1} \tag{1}$$

$$\alpha' = \frac{1}{\frac{4F\,Sin\,\varphi\,Cos\,\varphi}{(\sigma\, C_T)}-1} \tag{2}$$

where is, φ is inflow angel, C_T and C_N is tangential and normal force coefficient and σ is solidity [8]. It can be expressed as:

$$\alpha = \frac{cB}{2\pi r} \tag{3}$$

c is the chord length, *B* is the number of blades, and *r* is the disk radius.
The tangential C_T and C_N is force coefficient in the wind turbine:

$$C_T = C_L\,Sin\,\varphi - C_D\,Cos\,\varphi \tag{4}$$

$$C_N = C_L\,Cos\,\varphi + C_D\,Sin\,\varphi \tag{5}$$

2.2 Q-blade Airfoil

The representation of Q-blade Airfoil and rotor blade design is presented on Fig. 1 dan Fig. 2 below.

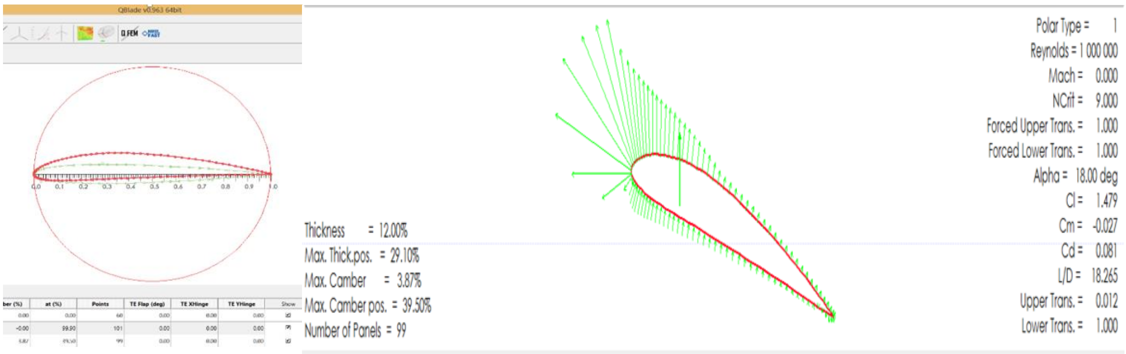

Figure 1. Airfoil pressure profile NACA 4412.

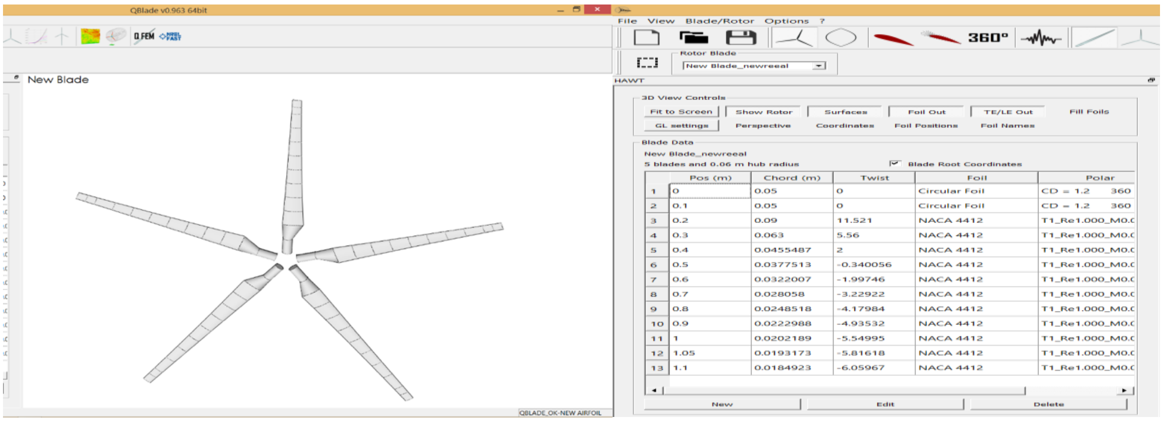

Figure 2. Rotor blade design.

3. Results and Discussions

This research discussed about the analysis of wind turbine design with five blades. This research will be carried out by varying the wind speed of the TSR (Tip Speed Ratio) to determine the wind turbine output power. In this study also carried out variations in the RPM of wind speed.

In figure 3, it shows the relationship between wind speed of 2 m/s to 6 m/s with Tip Speed Ratio, it can be seeing the maximum TSR value is at the TSR value of 7 and the maximum wind speed of 6 m/s is due to the determinants of TSR such as wind speed and rotation on the rotor, so that with the increasing turbine rotation then the resulting TSR will increase like the Figure 3.Based on all wind speed tests, the maximum TSR value at a maximum speed of 6 m/s with five blades is as big as at TSR 7 with an output power value of 250 Watt while for the lowest value at a wind speed of 2 m/s is generated, namely TSR 7 with a value of 10 Watt. Therefore, it can be seen that the variation in wind speed greatly affects the TSR value generated by the turbine.

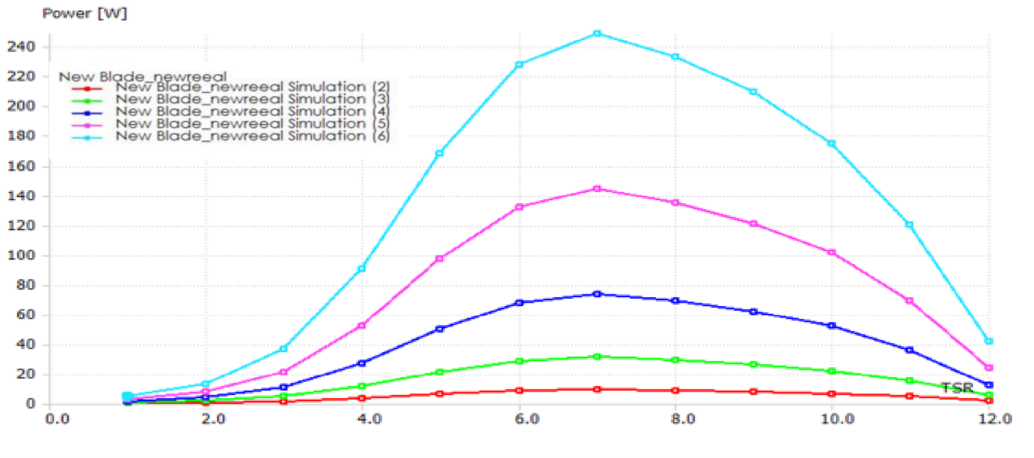

Figure 3. Effect of wind speed variations on TSR.

Figure 4 shows the effect of TSR on Power Coefficient (Cp) at a wind speed of 6 m/s. It can be seen that the overall value of the maximum power coefficient on TSR 7 is 0.45. for TSR 1 to TSR 6 indicates an increase in CP.

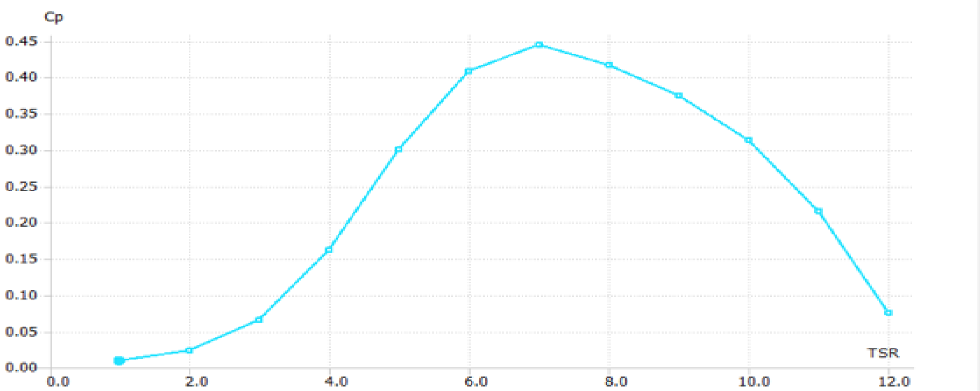

Figure 4. Effect of wind speed 6 m/s on TSR.

However, at TSR 8 to TSR 12 there is a decrease, this is because at low TSR the flow angle through the blade is in accordance with the conditions of the turbine design being made, while at high TSR, the flow angle through the blade is quite large and when the flow passes through the blade, flow spacing occurs. which causes the rotor to experience a decrease in lift force and an increase in drag force. A decrease in lift and an increase in drag forces the torque in the rotor to decrease so that the output power decreases.

Further evaluation is to examine the variation of wind speed toward variation of rotational speed which presented on Fig. 5.

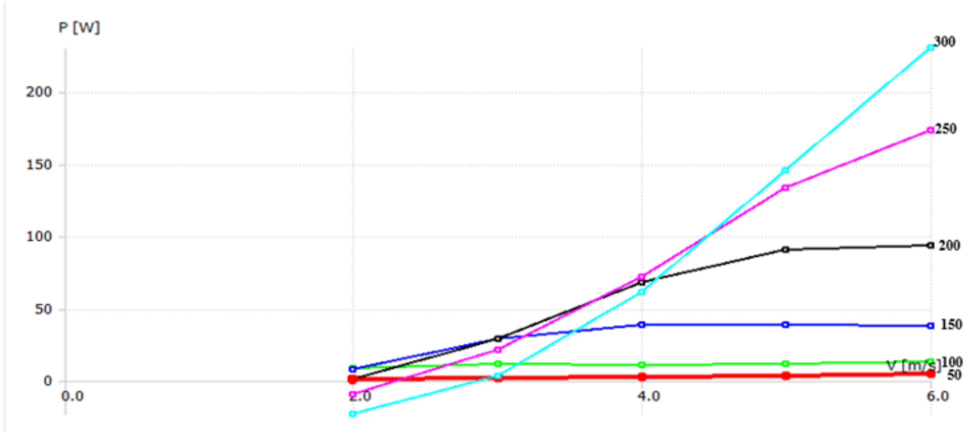

Figure 5. Variation of wind speed toward variation of rotational speed (1/min).

Figure 5 shows that the wind speed is directly proportional to the resulting rotational speed. The greater the wind speed, the greater the turbine rotation is produced, the greater the wind energy, the greater the energy that the turbine converts into increased rotation. From the graph above, it can be seen that at 300 rpm the power is 247 Watt with a maximum wind speed of 6 m/s. while for the minimum rotation at 50 rpm that occurs at wind speed 6 m/s with output power 9 Watt.

4. Conclusions

The results of five blades wind turbine simulation, based on variations in wind speed and variations in rotational speed, shows that the higher the wind speed was resulting high output power according to the design. Moreover, the power coefficient is influenced by the speed of the wind in and out. The greater the power coefficient value, the greater the wind which is converted depending on the TSR value.

References

[1] Daryanto Y, Yohanes F. A. dan F. Hasim 2005 BPPT Tangerang
[2] Priyanka R. Dhurpate and Kailashnat B. Sutar 2016 Imperial Journal of Interdiciplinary Research (IJIR) **1426** 1430
[3] Naveen Prakash Noronha, M. Krishna 2020 International Journal of Advance Science and Technology **8877** 8885
[4] Abdul Goffar Al Mubarok 2018 International Journal of Scientific & Engineering Research **1018** 1021
[5] Ali Said, Mazharul Islam, Mohiuddin A.K.M, Moumen Idres 2019 International Journal of Recent Technology and Engineering (IJRTE) **153** 157
[6] G. Ingram 2011 Durham University **5** 21
[7] V.Esfahanian, A. Salavati Pour, et all 2013 J.Wind.Eng.Ind.Aerodyn **35**
[8] J. F. Manwell, J. G. Mcgowan, A. L. Rogers.,2009 Wiley. **131** 677