Analysis effect of wind speed variation on the design horizontal axis wind turbine with Qblade software

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Abstract. Wind energy is renewable energy environmentally friendly energy. One of the utilization of wind energy conversion 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 turbines, one of which depends on the wind speed and type of turbine used. So in this research, research will design wind turbines with wind speed variations. The purpose of the design and analysis of variations in wind speed is to design a low speed wind turbine and use model with a number of blades 5 wind turbine. The object of this study was the design of wind turbines with variations in wind speed of 2 m/s, 3 m/s,4 m/s, 5 m/s and 6 m/s with a number of blades 5 wind turbine horizontal axis, rotor diameter of 1.4 m and this rotor used NACA 4412 airfoil type. The method use Blade Element Momentum (BEM) and design simulation used Q-Blade software. The results of the design of wind turbines with wind speed variations show that there is an increase in power as the wind speed increases.

Keywords: Wind Turbine, Qblade Software,Blade Element Momentum (BEM).

1. Introduction

Energy consumption in the world is increasing plus the use of fossil energy sources so that the impact caused by using fossil energy is very large, one of which is environmental pollution. In fact, in Indonesia the potential for renewable energy is very potential. The use of renewable energy is very influential in reducing the environmental impact it produces and there is no energy crisis in Indonesia. One of the potentials in Indonesia is the use of wind energy. Renewable energy in Indonesia can be maximally utilized for energy needs to support sustainable development and human needs in the energy sector [1]. Utilization of wind energy conversion can be used by using a horizontal axis wind turbine. However, in real conditions not all regions have ideal wind potential. In this planning, a wind turbine design with low wind potential will be made, so that the design uses a number of blades of 5 to increase the output power. In addition, the writer will also vary several speeds, this is in order to predict the output power according to the real wind speed. This research uses Qblade software. Numerical analysis research with Qblade software and using the BEM method, airfoils 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]. Design and analysis of the 300Watt wind turbine using BEM theory, with design procedures codified in MATLAB to simplify routine. Air foil used by Airfoil SG6040 and SG6041 was selected as hub and tip airfoil assumption a wind speed of 5m/s. 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 qblade software using the BEM method, that is stage in the future. More aspects are also needed to be consid- ered such as CFD analysis and stress analysis of the material The performance analysis shows that the designed wind turbine blades can obtain a relatively high power coefficient of 0.45 [4]. In the research four airfoils NACA 4412, SG6043, SD7062 and S833 have been selected and investigated in QBlade. 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. Method

In this research using HAWT (Horizontal Axis Wind Turbine) model with number of blades 5. The blade design uses Airfoil NACA 4412 with a rotor diameter of 1.4 m. This research by varying the wind speed 2-6 m / s and variations of Rpm 50, 100, 150, 200, 250 and 300 and using Qblade software using 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 elementally.

3. Blade Element Momentum Method

Blade Element Theori 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 usually used to calculate the blade elements on each airfoil [6]. This equation can be iterated as a solver. Iteration uses two avariables, namely axial and radial in BEM Theori. Then the variables can be defined as follows [7].

$$\alpha = \frac{1}{\frac{4\,Sin^2\,\phi}{(\sigma\,C_N)}+1} \qquad (1)$$

$$\alpha' = \frac{1}{\frac{4\,Sin\,\phi\,Cos\,\phi}{(\sigma\,C_T)}-1} \qquad (2)$$

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

$$\alpha = \frac{cB}{2\pi r} \qquad (3)$$

c is chord length, B Number of blade, and r is disk radius.
The tangential C_T and C_N is force coefficient in the wind turbine and then:

$$C_T = C_L \, Sin \, \phi - C_D \, Cos \, \phi \qquad (4)$$

$$C_N = C_L \, Cos \, \phi + C_D \, Sin \, \phi \qquad (5)$$

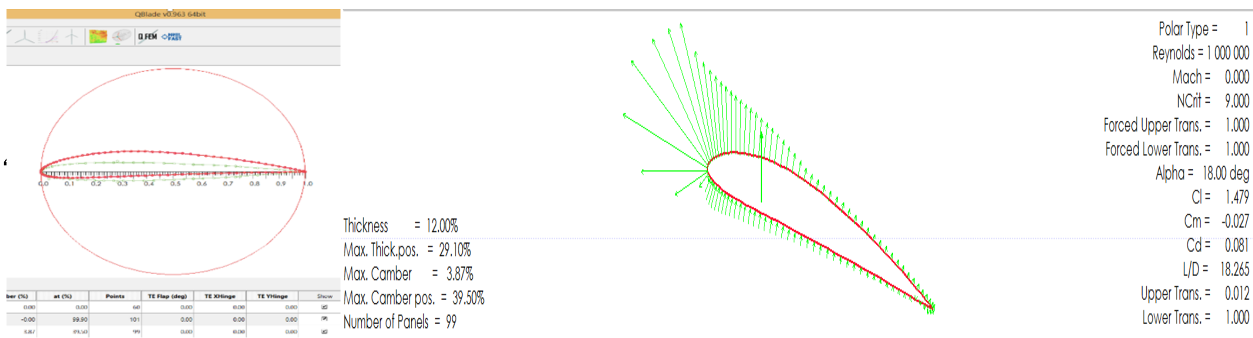

Figure 1. Airfoil Pressure Profile NACA 4412

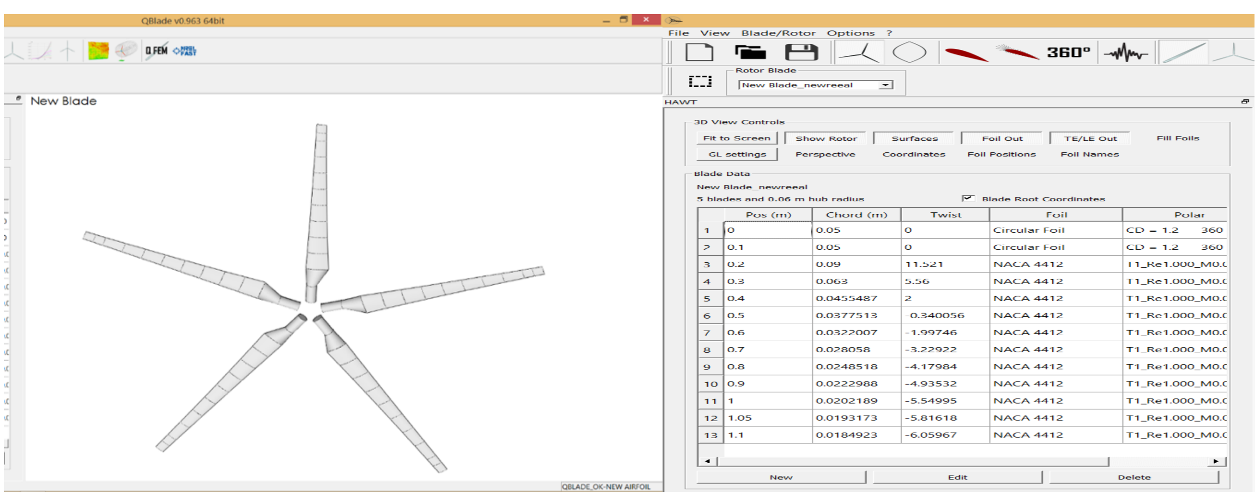

Figure 2. Rotor Blade Design

5. Results and Discussions

This research will discuss about the analysis of wind turbine design with number of blades 5. 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.

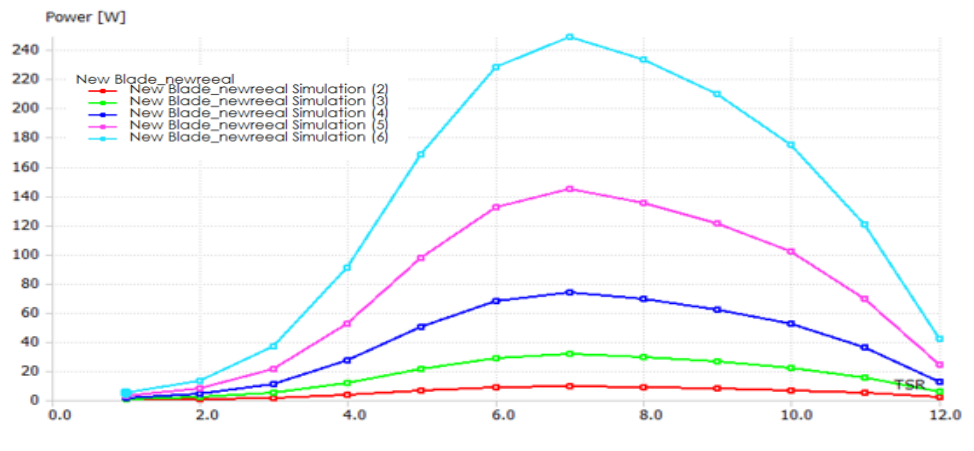

Figure 3. Effect of wind speed variations on TSR

From figure 3 show the relationship between wind speed of 2 m/s to 6 m/s with Tip Speed Ratio, it can be see 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 above. For all wind speed tests, the maximum TSR value at a maximum speed of 6 m/s with a number of blade 5 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. So that it can be seen that the variation in wind speed greatly affects the TSR value generated by the turbine.

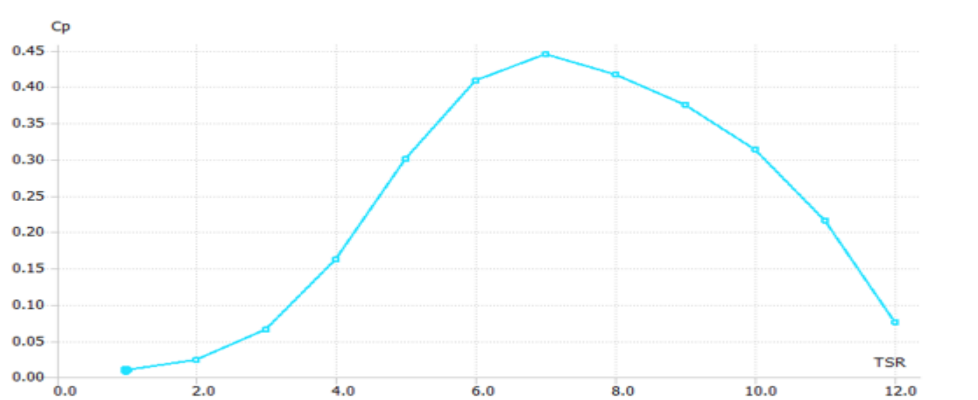

Figure 4. Effect of Wind Speed 6 m/s on TSR

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. 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.

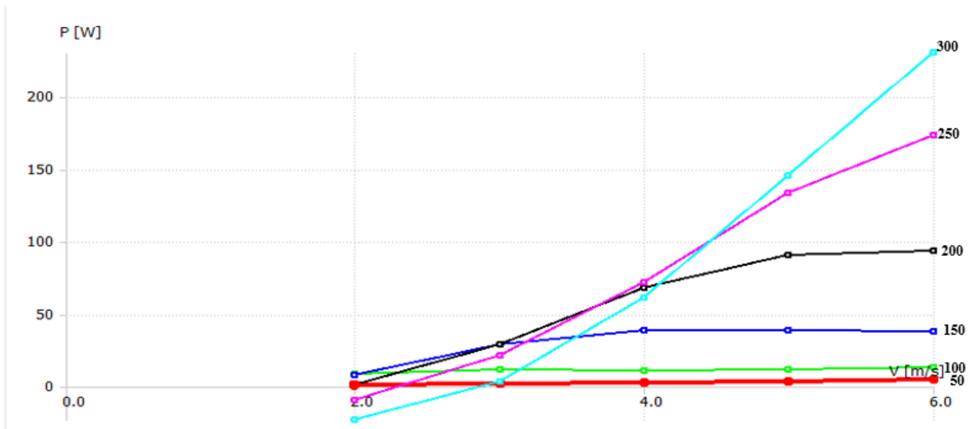

Figure 5. Variasi Kecepatan angin terhadap variasi Rotational Speed (1/min)

Figure 05 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.

6. Conclusions

The simulation results of wind turbine testing with a number of blades of 5, based on variations in wind speed and based on variations in rotational speed, show that the higher the wind speed, the higher the wind speed and the resulting high output power according to the design. And Then 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.

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