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The Effect of The Angle of Attack of the Electric Power Generated on Prototype of the Horizontal Axis Wind Turbine

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Abstract. Institut Teknologi Kalimantan (ITK) is one of the new university where located in the middle of the forest in Balikpapan. The power source of electrical energy only comes from PLN. As the increasing of students, the demand of electric power also increase, then development of new energy is needed. Based on BMKG data in 2018, the average wind speed in Balikpapan ranges from 5 km / h - 18 km / h. Based on the wind speed data, a horizontal axis wind turbine (HAWT) will be made. This HAWT is using three blades with a several variation of the angle of attack (AoA) to determine the efficiency level of the wind turbine. The variations of attack angles are 10°, 15°, 20° and 25°. Beside that, the wind turbine testing is carried out at several wind speeds of 3.8 m/s, 4.3 m/s, 5.8m/s. The experiment results show that the largest electric power is generated in the test of the horizontal axis wind turbine with variation of 250 attack angle at 5.8 m/s that is equal to 118.7 mW

Keywords: wind turbine; angle of attack; power; wind speed.

1. Introduction

Indonesia is one of the countries which has longest coastal and many natural potentials that can be utilized for energy f. Based on the National Energy Management blueprint issued by the Ministry of Energy and Mineral Resources (ESDM) in 2005 on fossil energy sources, petroleum in Indonesia in 2004 are expected to be run out within 18 years if there is no new exploration is done. While the gas is expected to run out within 61 years and coal will be run out within 147 years. Therefore, it is necessary to explore the non-fossil energy sources. Based on data from ESDM in 2005 on the utilization of non-fossil energy sources, the utilization of wind energy sources is still very small. The potential of wind energy source in Indonesia is 9.29 GW while the installed capacity is only 0.5MW [1].

The Kalimantan Institute of Technology is one of the new state universities that established in 2015 and is located in the middle of a forest in Balikpapan. The development of ITK campus is very significant accompanied by the increase of infrastructure facilities, the number of students and human resources. So that the consumption of electrical energy needs also increased. Currently, the electricity supply is obtained from PLN which has several times a blackout in rotation. This can disrupt the teaching and learning process on campus. So the development of non fossil energy source is needed. The location of ITK is very strategic and supported by the availability of natural resources that have the potential to be developed. One of them is wind resources. So wind turbines can be developed to help meet of electricity needs in the campus ITK.

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The horizontal axis wind turbine is a wind turbine that has the greatest efficiency because the blades always move perpendicular to the wind, receiving power through all rounds [2]. The number of blades in horizontal axis wind turbine only three. Because if the number of blades more than three, although it can increase the working of the wind turbine, but when the wind impulse is larger then the blades will receive more pressure and can cause damage. While if the number of blades less than three, then it should be designed with more complex curves to obtain near-high wind pressure when using three blades, in addition to the magnet in generator must be stronger and it will require more funds.

In a small-scale horizontal wind turbine, the blade design greatly affects the power generation [3]. The shape of the blade uses the airfoil profile to be more aerodynamic. One of the factors influencing the power generated is the tip speed ratio (λ) as an assumption on the design of the blade design. In this design $\lambda = 3$ is used [4]. Blade manufacturing process is done by designing in CAD software followed by printing designs that have been made using Balsa wood.

This is intended to reduce errors in the airfoil profile of the blade and Balsa wood is sturdy but lightweight.

2. Research Methodology

2.1. Research Variables

Some of the research variables that are determined are:

· The control variable is a constant fixed variable. In this research, the control variables are rotor diameter with length of 100cm and $\lambda = 3$.

- The independent variable is a variable that affects the dependent variable. Independent variables include angle of attack and wind speed.
- Dependent variable or output variable is a variable whose value will change to certain factors. In this study the dependent variable is the power generated by the wind turbine.

2.2. Design of Horizontal Axis Wind Turbine

The manufacture of horizontal axis wind turbines prototype can be divided into seven stages. The seven stages are the determination of rotor diameter, rotor blade design, hub design, pole and base design, shaft selection, gear and generator, nacelle design and installation of components.

- Determination of rotor diameter

The specified rotor diameter is 920 mm shown in Figure 1. The length of the radius of the rotor consists of the total length of one blade plus the distance of the blade to the center of the hub.

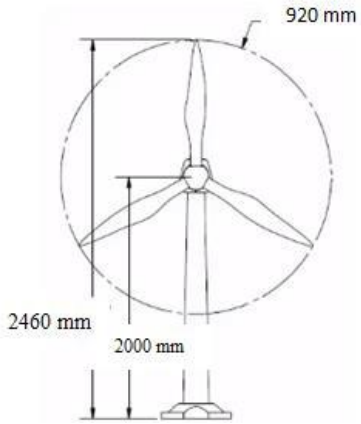


Figure 1. Rotor diameter

- Design of rotor blade

The design of the wind turbine blade is using airfoil NACA 4412, Figure 2. In order to make it easier to design the blades, it is necessary to design each layer of the airfoil and then integrate the design of the layer. A rotor with diameter of 920mm will be made from several layers, which each layer consisting of the airfoil design along with the size that includes the thickness and width of the blade of the leading edge [5]. After determining the rotor diameter, the next step is to determine the tip speed ratio or the speed ratio of the rotor tip to the wind speed [6]. In this research, tip speed ratio become control variable with value equal to
3. NACA 4412 has the meaning as follows:

1. The first number shows the maximum chamber percentage on the chord of 4%.
2. The second number shows the maximum chamber distance from the leading edge of 40%.
3. The third and fourth numbers show the maximum airfoil percentage thickness on the chord of 12%.

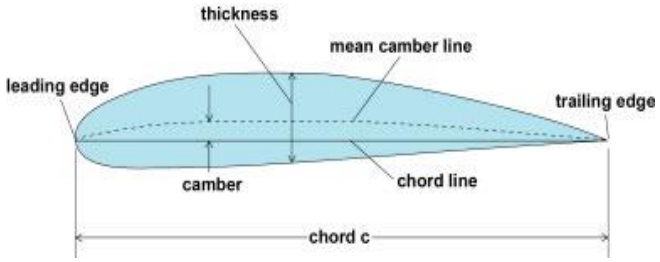


Figure 2. Airfoil profile

- Designing hubs

Hub, as can be shown in Figure 3, is one part of the wind turbine that serves as the rotor connector and becomes the center of rotation. It also reduces wind turbine resistance to wind, protects the components attached to the hub, and as the key of the rotor balancing. A half-spherical hub keeps the airflow on the hubs laminar and minimizes the turbulence.



Figure 3. The shape of hub

- Pole and base design

The poles is used to withstand the weight on the wind turbine body. The weight is overall weight including the weight of other components such as blades, hubs, nacelles and etc. The load will arise due to the wind. The design of the pole in this study is divided into two, namely the upper mast (upper mast) associated with nacelle and bottom mast (bottom mast) associated with the base. Since only a prototype that will made in this research, the base for the wind turbine pole can be designed and paired with a pole. The pole and base design can be seen in Figure 4.

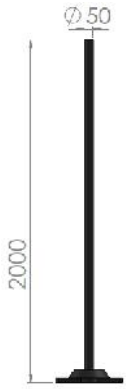


Figure 4. Pole and base design

- Shaft, gear and generator

The gear transmission ratio (Figure 5) is 1:3, which means that if the rotation speed at the rotor of 1 rpm will be transmitted to 3 rpm for the generator. Selection of generator of the size according to the prototype. Generator serves as a tool that converts mechanical energy into kinetic energy. The generator used is a permanent magnet generator [7].

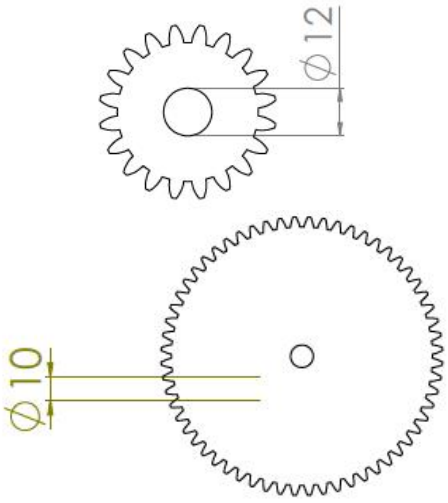


Figure 5. Gear Transmission

- Design nacelle

Nacelle is house for important components in wind turbines such as generators, bearings, shafts, and gears. In this design, the designed nacelle is simply a simple wind turbine that does not use brakes and clutches, yaw systems and tails.

- Installation of wind turbine components

The assembly as shown in Figure 6 is performed on all components of the horizontal axis wind turbine. Connecting the hub with the blades by setting the angle of attack, then the center of the hub is connected to a low rotation rotor shaft. The low rotation rotor axis is connected to large diameter gears and small diameter gears connected to the generator shaft. The upper pole is joined by the bottom pole and the base and the top pole with nacelle are added with a stronger adhesive. Installation of the blade with the hub is also balanced with distance between the tip of the blade.

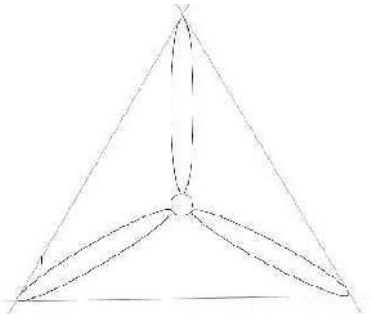


Figure 6. Process of distance equilibrium

3. Result and Discussions

The data are collected from the prototype of horizontal axis wind turbine with three blades. The tachometer is preinstalled on the gear for lap speed testing. The mounting of the blades is done according to the angle variations of the angle of attack ie. 10°, 15°, 20° and 25°. The data are collected when wind turbine rotation is in steady condition. The data obtained from the test results are wind speed, rotation speed, currents and voltage. The value of electric power is obtained by using equation (1).

$$P_{listrik} = V_{out} \cdot I_{out} \quad (1)$$

The value of electric power is obtained based on the calculation of the test result data using equation (1), can be seen in Table 1.

Table 1. HAWT testing results

Angle of Attack (AoA)	Wind speed (m/s)	Power (mW)	Rotation (rpm)
10^0	3.8	23.6	106.3
	4.3	75.2	149.1
	5.8	98.7	168.0
15^0	3.8	31.8	115.9
	4.3	80.9	165.5
	5.8	102.0	189.0
20^0	3.8	41.5	130.7
	4.3	87.5	187.9
	5.8	107.8	224.3
25^0	3.8	46.4	147.9
	4.3	99.1	192.2
	5.8	118.7	254.7

Variations of angle of attack is done to determine the effect of the angle of attack on the electrical power generation in horizontal axis wind turbine. Variations of attack angle tested are at 10^0, 15^0, 20^0 and 25^0. The magnitude of the attack angle will affect the momentum of movement of wind turbine blades. Theoretically, the momentum will increase if the speed also increase. But if the pounded surface has an angle, the momentum will depend on the angle of attack. This causes the blade thrust will vary based on the angle.

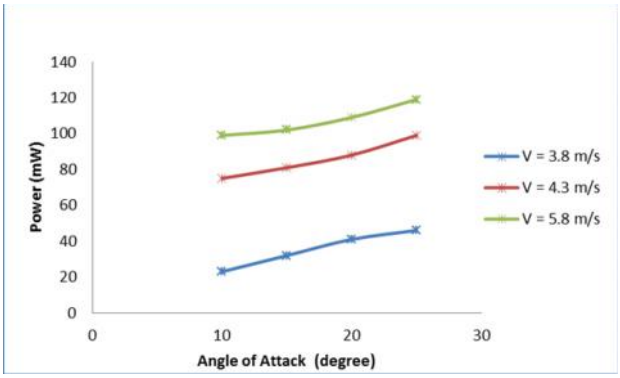


Figure 7. Comparison of AoA, wind speed, and power

Table 1 shows the electrical power data generated by the horizontal axis wind turbine prototype. The largest electric power is generated in wind turbine design with 25^0 attack angle with 5.8 m/s wind speed that is equal to 118.7 mW. While the lowest electrical power value obtained in the design of wind turbines with an attack angle of 10^0 with 3.8 m/s wind speed is 23.6 mW.

The increased of the wind speed will increase resulting spin. The highest rotation speed is generated at 25^0 angle attack test with 5.8 m/s wind speed of 254.7 rpm. While the smallest rotation speed is generated on wind turbine testing with wind speed 3.8 m/s and angle of attack 10^0 with 106.3 rpm.

Theoretically, to rotate the blade, the shape of blade must be an airfoil, just like in this study. Because of the shape of airfoil, the blade will has higher coefficient lift (C_L) than coefficient drag (C_D) because of pressure under blade is much higher than the above. Although the calcutation of C_L and C_D are not counted in this study, but based on the results, the higher AoA, C_L/C_D also increased, that's why the rotation speed also increased. However, based on the experiment, it also can be concluded that the blade still can produce high C_L until AoA 25^0 for all wind speed variation. The higher rotation speed of rotor hence big power generated also higher. A large electric power will produce an optimum Coefficient of power. Coefficient of power is a power efficiency that will show the maximum efficiency in which the wind turbine will work. The first step in finding the coefficient of power is to look for the axial force of the wind turbine. Before calculating the axial force, first measure the required data ie rotor diameter, wind speed before passing through the rotor and wind speed after passing through the rotor. From the calculation of coefficient of power Cp value of 0.351. reduce errors in the airfoil profile of the blade and Balsa wood is sturdy but lightweight.

4. Conclusion

Based on the results of research on the design of horizontal axis wind turbine with three blades and $\lambda = 3$, obtained the largest electric power 118.7 mW at the test with wind speed 5.8 m / s and rotation speed of 254.7 rpm. It can be concluded that the large angle of attack affects the amount of power generated.

References

[1] ESDM Department, Blueprint Pengelolaan Energi Nasional 2005-2025, 2005.
[2] Y. Daryanto, "Kajian potensi angin untuk pembangkit listrik tenaga bayu," Yogyakarta : Balai PPTAGG – UPT – LAGG, 2007.
[3] R.A. Kishore, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 116,2013, pp. 21-31.
[4] R.M. Huda, R. Illa, "Effect of tip speed ratio on power generated of horizontal axis wind turbine with three blades," Proceeding SNTTM XVI, pp. 126-129, 2017.
[5] J.F. Manwell, McGowan, A.L. Rogers, "Wind energy explained –theory, design and application," John Wiley & Sons Ltd: Chichester, 2002.

[6] G. Ingram, "Wind turbine blade analysis using the blade element momentum method, Version 1.1," Durham: Durham University, 2011.
[7] C. J. Bhai, C. W. Whei, W. C. Po, T. C. Wen, "System integration of the horizontal-axis wind turbine: the design of turbine blades with an axial-flux permanent magnet generator," Journal Energies. ISSN 1996-1073, 2014, pp. 7774-7793.