Performance Test of Winglet Horizontal Shaft Wind Turbine Against Cut In Speed

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Abstract. Wind turbines are devices that convert wind kinetic power into electrical energy through generators. Currently there has been a lot of research on horizontal shaft type wind turbines to improve systems that work optimally. This study uses a 3 blade horizontal winglet wing turbine wind turbine with variations in pitch angle to increase the cut in speed value. The pitch angles used are 0°, 2°, 4°, 6°, 8°, and 10°. This study uses an NACA 4412 aerofoil with winglets added to the blade tip. The research method used in this study is the experimental method. The results showed that the highest cut-in speed values of three, four and five blades were obtained at a pitch angle of 10° at wind speeds of 2.3 m/s, 1.8 m/s and 1.8 m/s.

Keywords: Horizontal Axis Wind Turbine, Winglet, NACA 4412 Cut in Speed, Number of Blade

1. Introduction

One of the renewable energies that can be used on a small scale is wind energy. Wind energy is one of the leading most utilized sources of renewable energy for sustainable electricity production [1]. Utilization of wind energy can use the Wind Energy Conversion System (WECS) using a wind turbine. The wind turbine is a tool that can convert wind kinetic power into electricity through a generator [2]. There are two types of wind turbines, namely horizontal axis wind turbines and vertical axis wind turbines. To get optimal turbine rotation at low wind speeds, blade variations are required. Despite the recent economic challenges, global wind turbine installations are able to record healthy growth rates year over year. The development of new turbines that are more reliable and efficient is one way to respond to these competitive pressures [3]. The wind turbine is a tool that utilizes wind energy as a power source that can produce usable power. Windmills were first used in the Sistan and Khorasan regions of eastern Iran during the 19th century. The first windmills used wings that rotated around a vertical axis perpendicular to the ground [4].

Currently, there has been a lot of research on horizontal axis type wind turbines to improve systems that work optimally. To improve the performance of a horizontal axis wind turbine at low wind speeds, several ways are needed. Several ways to improve performance are by optimizing the airfoil, namely by adding variations in the pitch angle. The pitch angle can affect the initial rotation speed of the turbine [5]. The type of airfoil suitable for small-scale wind turbines HAWT is the type of airfoil that follows the National Advisory Committee for Aeronautics (NACA) standards. One of the most commonly used is the NACA 4412 because it has a high cl / cd ratio [6].

2. Method

The research method used in this research is the experimental method. The activities carried out in this study include the preparation of wind turbines, tool set up, data collection and data analysis. This research was conducted to determine the effect of the pitch angle on the resulting cut in speed. This
study uses a NACA-4412 winglet airfoil which will be tested for its effect on the cut in speed produced by wind turbines at wind speeds of 1.5 m/s to 5 m/s with 0.1 m/s intervals.

The variation of the pitch angle used in this study is 0°, 2°, 4°, 6°, 8°, and 10°. Data collection is done by measuring and recording the wind speed when the turbine starts rotating. The instrument used for data collection was a digital anemometer. The data collection steps began with alternating variations in the pitch angle. The test data was tested four times for each variation. Data collection was carried out for 13 days from May 5 to May 19 2020 at 08.30 am to 17.00 pm.

The horizontal turbine design in this study uses a blade with an additional winglet at the end of the blade.

![Figure 2.1. Three, four, and five Blade Horizontal Winglet Turbines](image)

The pitch is a modification to the blade that changes the angle of the blade sweep thereby increasing the turbine's performance in the initial rotation.

![Figure 2.2. Pitch 0°](image)  ![Figure 2.3. Pitch 2°](image)  ![Figure 2.4. Pitch 4°](image)  ![Figure 2.5. Pitch 6°](image)  ![Figure 2.6. Pitch 8°](image)  ![Figure 2.7. Pitch 0°](image)

3. **Discussion**

A horizontal winglet wind turbine has been tested to determine the effect of variations in the pitch angle on the cut in speed. Test result data can be seen in the table as follows:
Table 1. Cut in speed for variations in pitch angle

| Variasi pitch angle | Cut in Speed (m/s) |  |
|---------------------|--------------------|-----------------------|
|                     | Three blade        | Four blade            | Five blade |
| 0                   | 3.5                | 2.8                   | 2.5        |
| 2                   | 3.2                | 2.8                   | 2.3        |
| 4                   | 3.0                | 2.5                   | 2.2        |
| 6                   | 2.7                | 2.3                   | 2.0        |
| 8                   | 2.5                | 2.0                   | 1.9        |
| 10                  | 2.3                | 1.8                   | 1.8        |

Figure 3.1. Pitch angle relation to cut in speed

Figure 3.1. shows that the greater the pitch angle, the easier the turbine will be to rotate. The three blades variation has the best initial rotation speed obtained at a pitch angle of 10° at a wind speed of 2.3 m/s. The four blades variation has the best initial rotation speed obtained at a pitch angle of 10° at a wind speed of 1.8 m/s. Variation of five blades has the best initial rotation speed obtained at a pitch angle of 10° at a wind speed of 1.8 m/s. Variation of three blades from 0° to 10° pitch angle shows a decrease in wind speed for the initial rotation of the turbine. Variations of four blades for 0° and 2° pitch angles show the same cut in speed value of 2.8 m/s. 2° to 10° pitch angle results in a decrease in wind speed for the cut in speed value. Variation of five blades from a pitch angle of 0° to 10° shows a decrease in wind speed for the cut in speed value. A pitch angle of 10° for four and five blades results in the same cut in speed value of 1.8 m/s.

The number of blades affects the cut in speed. The greater the number of blades, the easier the turbine will turn. This is because the turbine will rotate by utilizing the lift force, so that the more blades that turn, the more lift forces acting on the turbine blades [7]. The more blades will make it easier for the turbine to work at low wind speeds. According to [8] the more blades, the easier the turbine will turn.

Apart from the number of blades, the pitch angle can also affect the cut in speed. The greater the pitch angle, the better the cut in speed. In research [9] that 10° pitch angle resulted in the optimal cut in speed. In addition, in research [10] the ratio of pitch angles of -4°, 0°, 4°, 8°, 12°, 16°, 20° and 24°, the optimal pitch angle is 12°.
4. **Conclusion**

From the results of the research that has been done, a conclusion can be drawn as follows:

1. Based on the test results, it can be seen that the variation in the number of blades can affect the cut in speed.
2. Based on the test results, it can be seen that variations in the pitch angle affect the cut in speed.
3. The more the number of blades and the larger the pitch angle used, the easier the turbine will turn.
4. The number of blades five and the pitch angle of $10^\circ$ produce the best cut in speed value.

5. **Reference**

[1] N. A. Satwika, R. Hantoro, S. Sarwono, and G. Nugroho, “Experimental investigation and numerical analysis on horizontal axis wind turbine with winglet and pitch variations,” *Eng. J.*, vol. 23, no. 6, p. 345, 2019, doi: 10.4186/ej.2019.23.6.345.

[2] S. Nugroho, L. Diana, J. Pratilastiarso, E. Trisianto, and A. I. Gunawan, “Experimental Study on Clark-Y Horizontal Axis Wind Turbine with Winglet,” in *Proceedings - 2018 International Conference on Applied Science and Technology, iCAST 2018*, 2018, pp. 613–616, doi: 10.1109/iCAST1.2018.8751587.

[3] G. R. Fischer, T. Kipouros, and A. M. Savill, “Multi-objective optimisation of horizontal axis wind turbine structure and energy production using aerofoil and blade properties as design variables,” *Renew. Energy*, 2014, doi: 10.1016/j.renene.2013.08.009.

[4] A. R. Winslow, “Urban Wind Generation : Comparing Horizontal and Vertical Axis Wind Turbines at Clark University in Worcester , Massachusetts,” 2017.

[5] B. Zhu, X. Sun, Y. Wang, and D. Huang, “Performance characteristics of a horizontal axis wind turbine with fusion winglet,” *Energy*, vol. 10, no. 11, p. 094, 2017, doi: 10.1016/j.energy.2016.11.094.

[6] R. Febriyanto *et al.*, “Study experimental of blade NACA 4412 with pitch angle on horizontal wind turbine,” *J. Phys. Conf. Ser.*, vol. 1153, no. 1, 2019, doi: 10.1088/1742-6596/1153/1/012137.

[7] A. Rachman, R. Balaka, J. Delly, and Y. Gunawan, “Simulation on the effect of the blade number on the rotational characteristic on a horizontal axis river current turbine,” *Int. J. Energy Environ. Eng.*, vol. 4, no. 1, pp. 1–8, 2013, doi: 10.1186/2251-6832-4-32.

[8] I. M. Adi Sayoga, I. K. Wiratama, M. Mara, and A. D. Catur, “PENGARUH VARIASI JUMLAH BLADE TERHADAP AERODINAMIK PERFORMAN PADA RANCANGAN KINCIR ANGIN 300 Watt,” *Din. Tek. Mesin*, vol. 4, no. 2, pp. 103–109, 2014, doi: 10.29303/d.v4i2.59.

[9] A. R. Sudhamshu, M. C. Pandey, N. Sunil, N. S. Satish, V. Mugundhan, and R. K. Velamati, “Numerical study of effect of pitch angle on performance characteristics of a HAWT,” *Eng. Sci. Technol. an Int. J.*, vol. 19, no. 1, pp. 632–641, 2016, doi: 10.1016/j.jestch.2015.09.010.

[10] M. N. Haque, M. Ali, and I. Ara, “Experimental investigation on the performance of NACA 4412 aerofoil with curved leading edge planform,” *Procedia Eng.*, vol. 105, no. Icete 2014, pp. 232–240, 2015, doi: 10.1016/j.proeng.2015.05.099.