Educate Technik: JOURNAL of ENGINEERING SCIENCES
Vol. X No. X, 2025
Avaliable Online at:
https://journaljies.com/jes/index

ANALYSIS OF VERTICAL WIND TURBINE PERFORMANCE TULIP MODEL

Baso Alauddin[1*], Aslim Muda Azis[2]
[1*, 2] Universitas Pejuang Republik Indonesia, Fakultas Teknik, Program Studi Teknik Mesin, Makassar, Indonesia
basoalauddin84@gmail.com
mesinkonversi@gmail.com

Article History **Received:10 Juni 2025** **Revised:12 Juni 2024** **Accepted:13 Juni 2025**

Abstract
Wind turbines are the primary medium used to convert wind energy into electrical energy. The design of a wind turbine plays a crucial role in determining the performance of the Wind Power Plant. The tulip model wind turbine with a vertical axis serves as an alternative for generating electrical energy because the development of the tulip model turbine is very economical, such as being able to operate at low wind speeds. This study aims to assess the performance of a two-blade tulip model wind turbine, including the input power and output power of the generator, as well as the efficiency of the generator used. The research was conducted using an experimental method by varying the wind speeds at 2 m/s, 3 m/s, 4 m/s, and 5 m/s. The testing was carried out directly at a coastal area. The results obtained from the data analysis show that the maximum power generated to rotate the blades or rotor of the turbine is 409.9 watts at a wind speed of 5 m/s. Meanwhile, the highest output power produced by the wind turbine is 241.839 watts, and the efficiency of the generator is 0.47%.

Keywords: tulip model wind turbine, wind speed, power, efficiency

https://doi.org/

INTRODUCTION

The high demand for energy requires the creation of various alternative energy sources to meet it. The use of renewable resources has become a necessity and continues to be developed to avoid energy crises or shortages, especially to meet the needs of island communities (Rochman & Sembodo, 2018). According to Hotman and Harun (1987), wind energy is one of the fastest-growing renewable energies in the world. “Wind is a renewable energy source. Humans have long used wind as an energy source.” Wind energy is a highly versatile renewable energy source. Wind energy can be used for various purposes, such as generating electricity, pumping water for irrigation, drying or cutting crops, aerating fish/shrimp ponds, and more. Additionally, wind energy can be harnessed on sloped lands or highlands, and even in the sea, unlike hydropower plants. Wind is an important potential energy source for some regions of Indonesia, but it has not been widely utilized. In fact, Indonesia is a potential area for developing wind power plants because it is an archipelagic country with two-thirds of its area covered by the sea and a very long coastline (Fadila & Zakaria, 2020).

The use of unique power plants does not involve combustion to generate electricity, but the unique generator itself uses energy already available in nature to produce electricity. Examples of such unique power plants include solar energy, Hydroelectric Power Plants (PLTS), Hydroelectric Power Plants (PLTA), and Wind Power Plants (PLTB). Wind Power Plants (PLTB) are one of the non-traditional power plants, with wind energy as the primary source for generating electricity.

METHOD

This study uses a quantitative experimental method to analyze the performance of the tulip model wind turbine in generating electricity using wind power. This design aims for the turbine to work as expected. The results of this analysis are intended for regions that do not yet have electricity.

RESULTS AND DISCUSSION

Measurements or data collection were conducted in a laboratory using an intake or air channel that has been conditioned. The input power is the power possessed by the wind before being converted or before the wind passes through the turbine. Not all of this power can be converted into mechanical energy by the turbine. To calculate the wind capture power (input power), refer to the equation below:

$$P_{in} = \frac{1}{2} \times \rho \times A \times V^3$$

The power of the wind turbine (P_{out}) is the power produced by the wind turbine due to the rotation of the blades or rotor. The rotation of the wind turbine generates kinetic energy, which is then converted into electrical energy. The formula to calculate the power of the wind turbine is:

$$P_{out} = \tau \times \omega$$

Where: (P_{out}) = power generated by the wind turbine (watt) = torque on the rotor (Nm) (λ) = rotational speed of the shaft or turbine blades (rpm) The speed ratio (λ) of the generator to produce power (P), then the tip speed ratio (TSR) at the rotor (λr) is given by:

$$\lambda r = \frac{\omega \times r}{V}$$

Where (λr) = speed ratio (radian/s) (ω) = rotational speed of the generator shaft = 44.7 rpm (r) = radius of the turbine (turbine blades) (V) = wind speed = 3 m/s

$$\omega = \frac{2 \times \pi \times n}{60}$$

Where N = Turbine rotation 44,7 rpm π = 3,14

$$\omega = \frac{2 \times 3.14 \times 44{,}7\ rpm}{60} = 4{,}679\ radian/s$$

Thus, the tip speed ratio (TSR) is obtained as

$$\lambda r = \frac{4{,}679 \ \times \ 0{,}45}{3} = \frac{2{,}105}{3}$$

$$\lambda r = 0{,}70$$

The shaft speed (SS) is calculated using the equation: Shaft speed:

$$SS = \frac{60 \times \lambda r \times V}{\pi \times D} = \frac{60 \times 0{,}70 \times 3}{3{,}14 \times 0{,}9} = \frac{126{,}32}{2{,}826} = 44{,}7\ rpm$$

To determine the torque, the following equation is used:

$$T = \frac{V^2 \times r^3}{\lambda} = \frac{9 \times 0{,}0911}{0{,}70} = 1{,}168\ Nm$$

The tangential force on the blade is generated by the presence of the lift component in the plane of rotation. This tangential force on the rotor has a certain distance (lever arm) along the axis of rotation (shaft), and the product of these two quantities is often referred to as torque (T). If the rotor then rotates at a certain speed (w), the power (P_{out}) generated can be calculated as:

$$P_{out} = \tau \times \omega$$

Where:
P_{out} = power generated by the wind turbine (watt)
T= torque 1.168 Nm
w = rotational speed of the shaft or turbine blades 44.7 rpm

$$P_{out} = 1{,}168 \times 44{,}7 = 52{,}237\ Watt$$

To calculate the area of the turbine blade, the following equation is used:

$$P_{out} = \frac{1}{2} \times C_p \times \rho \times V^3 \times A$$

Where Cp = power coefficient = 0.59 (Betz Number)
Thus, the area of the water turbine blade can be calculated using the formula:

$$A = \frac{2 \times P_{out}}{C_p \times \rho \times V^3} = \frac{2 \times 52{,}237}{0{,}59 \times 1{,}225 \times (3)^3} = \frac{104{,}47}{19{,}514} = 5{,}353\ m^2$$

The total energy used to rotate the turbine blades (P_{in}) is as follows:

$$P_{in} = \frac{1}{2} \times \rho \times A \times V^3 = 0{,}5 \times 1{,}225 \times 5{,}353 \times (3)^3 \; P_{in} = 88{,}537 \, watt$$

Efficiency is the ratio between the power generated by the wind turbine and the power provided by the wind, or it is commonly referred to as the power coefficient. To calculate the power coefficient, the following equation is used:

$$\eta_t = c_p = \frac{T \times \omega}{P_{in}} = \frac{52{,}237 \, Watt}{88{,}537 \, Watt} \times 100\% = 59{,}00$$

As it is known, the kinetic energy possessed by the wind cannot be entirely converted into mechanical force or work. Therefore, there is energy loss, and the ratio between the power generated and the power available from the wind is called the power coefficient.

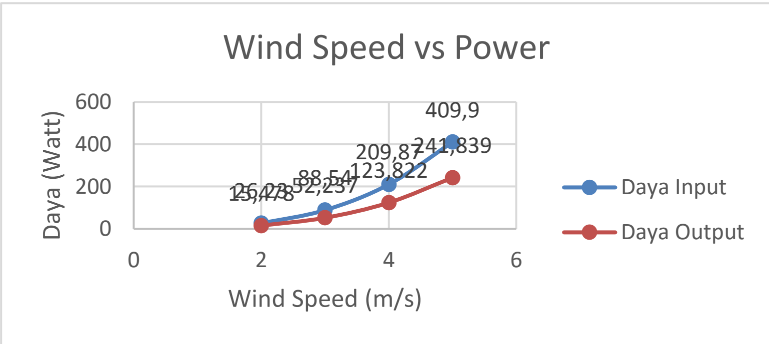

Figure 2.1 Wind speed vs Power

From the graph, it can be seen that as the wind speed increases, the input power used to rotate the turbine blades (rotor) also increases. Similarly, the output power, or the power used to rotate the generator, also increases. This is evident from the graph, where at a wind speed of 2 m/s, the power used to rotate the turbine blades is 26.23 watts. This power increases as the wind speed increases. The maximum power generated to rotate the blades (or rotor) of the turbine is 409.9 watts at a wind speed of 5 m/s. Meanwhile, the highest output power produced by the tulip-type wind turbine is 241.839 watts at a wind speed of 5 m/s, with a power coefficient or efficiency of 0.59%.

From the image, it can be seen that the torque produced by the tulip-type wind turbine with two blades increases. The graph shows that as the wind speed increases, the speed also increases.

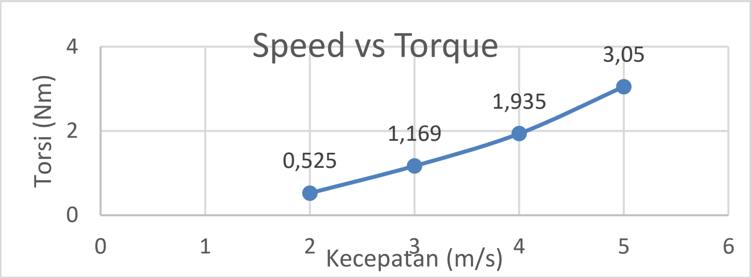

Figure 2.2 Speed vs Torque

The rotation or torque produced increases as the wind speed increases. At a wind speed of 3 m/s, the torque generated is 1.169 Nm, while at a wind speed of 2 m/s, the torque is 0.525 Nm. The maximum torque produced is 3.05 Nm at a wind speed of 5 m/s.

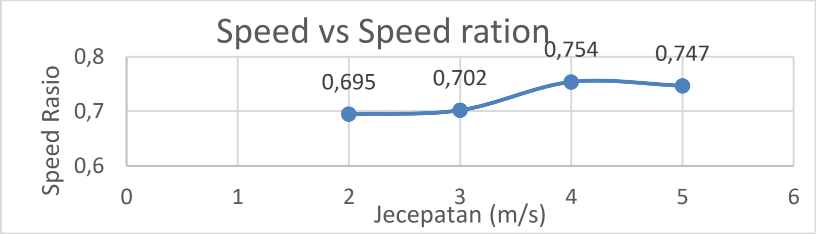

Figure 2.3 Speed vs speed ration

From the graph, it can be seen that as the wind speed increases, the speed ratio also increases. At a wind speed of 2 m/s, the speed ratio is 0.695, and at a wind speed of 3 m/s, the speed ratio is 0.702. At a wind speed of 4 m/s, the speed ratio is 0.754, while at a wind speed of 5 m/s, there is a decrease in the speed ratio to 0.747. This decrease is due to the power coefficient produced being only 0.47%.

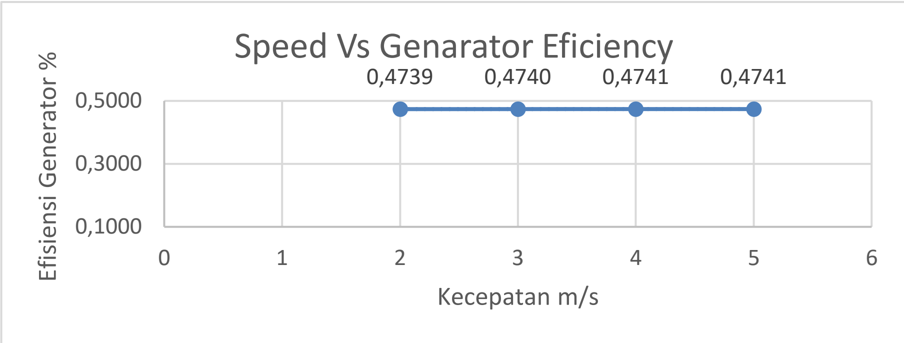

Figure 2.4 Speed vs Genarator Eficiency

The efficiency of the wind turbine or generator is the ratio between the power absorbed by the wind turbine or generator and the available wind power. From the graph, it can be seen that the efficiency produced by the wind turbine generator is 0.474%, and it is the same at all wind speeds. This occurs due to power losses or the ratio between the rotational speed of the turbine shaft (pulley) and the generator pulley shaft.

CONCLUSION

Based on the results of the research and the analysis discussion, it can be concluded that as the wind speed increases, the input power used to rotate the turbine blades (rotor) also increases. Similarly, the output power, or the power used to rotate the generator, also increases. This is evident from the graph, where at a wind speed of 2 m/s, the power used to rotate the turbine blades is 26.23 watts, and the generated torque also increases. As for the speed ratio, it increases with the wind speed, but at a wind speed of 5 m/s, the speed ratio decreases to 0.747. The maximum power generated to rotate the blades (or rotor) of the turbine is 409.9 watts at a wind speed of 5 m/s. Meanwhile, the highest output power produced by the tulip-type wind turbine is 241.839 watts at a wind speed of 5 m/s, with a generator efficiency of 0.59%.

REFERENCES

Amsor, R. M., & Iskandar, R. (2017). Performansi Turbin Angin Poros Vertikal Tipe Savonius 2 Tingkat Untuk Pengisian Baterai Sebagai Penerangan Lampu Perahu Nelayan Kota Padang. METAL: Jurnal Sistem Mekanik Dan Termal, 1(1), 9. https://doi.org/10.25077/metal.1.1.9-19.2017.

Ardiatama, B., Tiyasmihadi, T., & Budianto. (2020). Rancang Bangun Mesin Turbin Angin Vertikal Savonius Sebagai Penggerak Pompa Air. 219–224.Ardiyansyah, M., & Artikel, I. (2022). Jurnal

Inovasi Mesin Analisis Teoritis Penggunaan Jenis Turbin Angin terhadap Output Daya Listrik. 4(2), 56–63.

Fadila, A., & Zakaria, I. (2020). Rancang Bangun Turbin Angin Tipe Darrieus Tiga Sudu Rangkap Tiga dengan Profil NACA 0006. Eksergi, 15(3), 102. https://doi.org/10.32497/eksergi.v15i3.1785

Guanabara, E., Ltda, K., Guanabara, E., & Ltda, K. (2022). No Title. Makasudede, Y. (1953). Bab 2 tinjauan pustaka. 8–45.

Matematika, F., Ilmu, D. A. N., Alam, P., & Maret, U. S. (2010). Dengan Modifikasi Rotor Savonius L Untuk.

Ridwan, & Latief, A. (2019). Pengaruh Jumlah Sudu Pada Turbin Angin Sumbu Vertikal Terhadap Distribusi Kecepatan Dan Tekanan. Jurnal Ilmiah Teknologi Dan Rekayasa, 24(2), 141–151. https://doi.org/10.35760/tr.2019.v24i2.2392

Rochman, S., & Sembodo, B. P. (2018). Rancang Bangun Generator Turbin Angin Putaran Rendah Sebagai Pembangkit Energi Listrik Alternatif Di Daerah Pesisir. Wahana, 70(1), 25–34. https://doi.org/10.36456/wahana.v70i1.156

Setiawan, G. (2019). Prinsip Kerja Generator AC dan DC. In Gastronomía ecuatoriana y turismo local. (Vol. 1, Issue 69).\

Guanabara, E., Ltda, K., Guanabara, E., & Ltda, K. (2022). No Title. Makasudede, Y. (1953). Bab 2 tinjauan pustaka. 8–45.