Effect of Number of Blades on Performance in Vertical Axis Wind Turbine Three-Phase Permanent Magnet Model

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Abstract. The application of wind turbines in an area as a power plant will always experience obstacles in choosing the type and number of blades used to produce stable electricity according to the specifications of the wind turbine itself. Low wind speeds to be able to produce electricity in a wind turbine can be done by choosing the right type and number of blades. Assuming that the larger the area of the blade slapped by the wind, the greater the conversion of wind power that is converted into electrical power. With this assumption, the author tries to increase the number of blades on a covinous type wind turbine to determine its effect on the electrical power produced and to find out the number of blades that are suitable for the wind turbine to be applied in the author's area of origin, namely Badung Regency, Bali. This research was conducted using an analysis method for data collected at a laboratory scale, with confounding factors minimized. Data on electric current and voltage were recorded for the turbine generator at three wind speed levels with blade numbers of 2, 3, 4, 5, and 6. The study found that electrical power increased with both higher wind speeds and more blades, but odd-numbered blades consistently produced more power than even-numbered ones. In Badung Regency, the optimal configuration was 6 blades, generating 628.18 Watts at the highest wind speed of 5.47 m/s, suitable for a 500-5000 Watt generator.

Keywords: Number of Blade, Sovineus Type, Wind Turbines

1 Introduction

Fossil-based energy and natural minerals are used very massively, such as oil, natural gas, and coal, which in the conversion of energy into other energy that we can use is mostly used by burning, this burning is suspected to produce by-products which cause environmental damage and decline in quality (Yıldız, 2018). human life. As fossil energy becomes increasingly scarce, we have developed various environmentally friendly alternative energy sources.

Wind power plants, which in Indonesia are usually called wind power plants, are power plants that have been developed in developed countries with high wind potential. These countries include the United States, China and several European countries which

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topographically have flat stretches of land or vast seas without barriers. In Indonesia, which has a mountainous and hilly landscape, the potential for wind energy is quite high in seaside or coastal areas. Indonesia's existence between the mainland of India and Australia means that the wind flow can change at any time. The Monsoon wind flow from India during the rainy season and Elnino from Australia during the summer cause the wind direction to change and also fluctuate greatly. Data from the Central Statistics Agency states that in 2023 the lowest average wind speed will occur in November, namely 5 knots (2.57 m/s), and the highest speed will occur in February with an average speed of 9.9 knots (5.09 m/s).

Regardless of the influence of topography, we must still be able to utilize the potential of wind energy optimally with vertical axis wind turbines on a small scale or household scale. As quoted from the Journal of Electrical and Vocational Engineering, Padang State University, the success of this wind turbine is very dependent on the available wind potential as well as its design and technology (Syamsuarnis & Candra, 2020). On a small scale, we can still harvest maximum wind energy by installing it in large quantities in each house (Zhang et al., 2023). With a generator with a vertical wind turbine axis, we can minimize the influence of sudden changes in wind direction, so that the energy we channel to rotate the generator to produce electricity can be continuous without interruption (Eltayesh et al., 2021). A low-cost micro wind turbine, capable of generating up to 24 kW at 8 m/s, was successfully designed for Pacific island countries like Fiji, where wind speeds are typically lower, making it suitable for generating electricity in remote areas (Deo et al., 2016).

On a small scale, wind power plants with fluctuating wind speeds usually use a permanent magnet generator that produces DC to be stored temporarily in an electric power storage battery, which is then converted by an inverter into AC so we can use it in household appliances (Gavali et al., 2021). To produce a stable current, it is necessary to have a stable speed and torque of the generator drive shaft (Li et al., 2012).

In this research, the author analyzes the effect of the number of wind turbine blades on the electrical power produced at various wind speeds, using blade configurations of 2, 3, 4, 5, and 6 blades. The study aims to determine the optimal number of blades that produce the highest electrical power output. Experiments are conducted on a vertical axis wind turbine with a capacity of 500-5000 watts, modified to accommodate different blade numbers. The research addresses two key questions: how much electrical power a vertical axis wind turbine generate with varying blade numbers and wind speeds, and which blade configuration and wind speed result in electrical power that meets the 500-5000 watt generator specifications.

2 Methodology

This research was carried out using an analysis method for data that will be taken at a laboratory scale by conditioning confounding factors to a minimum. The data taken is data on the electric current and voltage produced by the generator on the wind turbine at 3 levels of wind speed on each wind turbine with the number of blades, namely 2 blades, 3 blades, 4 blades, 5 blades, and 6 blades. Data was taken 3 times for each wind speed variation and there were 3 variations in data col-lection with a certain number of blades.

Figure 1. Wind turbine purchased for the experiment

In this study, various instruments were used, including an anemometer, tachometer, DC watt meter, distance measuring instrument, time display clock, two tripods, and stationery. Before data collection, several preparatory steps were conducted, beginning with the procurement, manufacture, and assembly of the necessary components. First, a wind turbine was purchased, as shown in Figure 2, with the following specifications: Savonius-type model XP3, capable of producing 500-5000 watts of power, with voltage options of 12/24/48 volts, an initial wind speed of 1.3 m/s, and a maximum wind speed safety of 40 m/s. The turbine's propeller had a diameter of 52 cm and a height of 75 cm, made of nylon material, and operated with a 3-phase system. Following the turbine purchase, six turbine blades were manufactured for the experiments, as depicted in Figure 3. In addition to these, other essential components, such as a fan with a speed controller, a tachometer, an anemometer, and a multimeter, were procured to facilitate data collection. Figure 3 shows the data retrieval component arrangement.

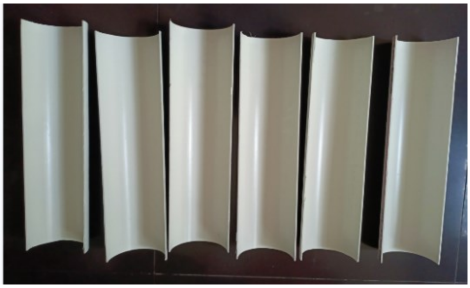

Figure 2. Manufactured turbine blades used in the experiment

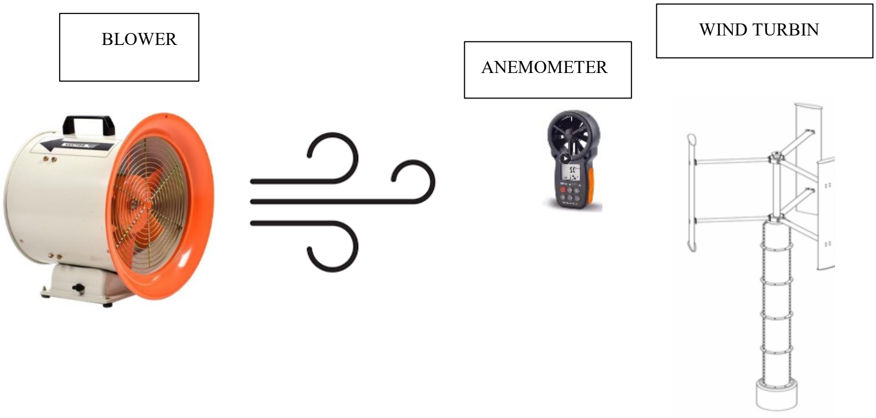

Figure 3. Data retrieval scheme

3 Result and Discussion

3.1 Result

The first data collection was conducted using a 6-blade wind turbine, and the results are shown in Table 1. The second data collection was performed on a 3-blade wind turbine, as shown in Table 2. The third set of data was obtained from a 5-blade wind turbine, and the results are presented in Table 3. For the fourth data collection, a 4-blade wind turbine was used, with the data shown in Table 4. Finally, the fifth data collection was carried out using a 2-blade wind turbine, and the results are provided in Table 5.

Table 1. Current and voltage measurement data at 3 wind speed variations on a 6-blade wind turbine

No	Wind velocity (m/s)	Wind turbine rotation (RPM)	Wind turbine generator voltage (volt)	Wind turbine generator current (ampere)
1	3.9	662.4	2.22	51.8
2	3.7	625.8	2.08	50.7
3	3.7	625	1.7	58.6
4	4.8	754	2.58	102.2
5	4.8	792.6	2.54	108.9
6	4.7	720.1	2.56	106.5
7	5.5	855.7	3.78	163.6
8	5.4	821.4	4.08	183
9	5.5	836.7	3.12	168.3

Table 2. Current and voltage measurement data at 3 wind speed variations on a 3 blade wind turbine

No	Wind velocity (m/s)	Wind turbine rotation (RPM)	Wind turbine generator voltage (volt)	Wind turbine generator current (ampere)
1	3.9	213.5	1.58	41.9
2	4.1	245.6	1.47	40.8
3	3.9	219.7	1.45	39.8
4	5	320.8	2.03	86.3
5	4.9	337.9	1.93	77.8
6	4.9	332.1	2.13	80.3
7	5.7	368.3	2.48	118.3
8	5.9	370.1	2.52	106.7
9	5.4	347.9	2.61	120.2

Table 3. Current and voltage measurement data at 3 wind speed variations on a 5-blade wind turbine

No	Wind velocity (m/s)	Wind turbine rotation (RPM)	Wind turbine generator voltage (volt)	Wind turbine generator current (ampere)
1	4	419.1	2.08	54.4
2	4.1	413.2	1.96	60.7
3	4.3	432	2.02	50.1
4	4.7	533.4	2.49	117.8
5	4.5	517.4	2.52	108.4
6	4.9	525.5	2.71	110.1
7	5.4	675.3	3.42	147.4
8	5.3	671.1	3.5	137.2
9	5.6	655.7	3.48	132.3

Table 4. Current and voltage measurement data at 3 wind speed variations on a 4-blade wind turbine

No	Wind velocity (m/s)	Wind turbine rotation (RPM)	Wind turbine generator voltage (volt)	Wind turbine generator current (ampere)
1	4.2	327.1	1.2	40.3
2	3.7	324.7	1.25	42.7
3	3.9	340.4	1.27	39.1
4	4.9	429.9	2.2	86.3
5	4.7	411.7	2.28	77.8
6	4.9	420.3	2.24	80.3
7	5.1	570.3	2.5	118.3
8	5.1	556.3	2.54	106.7
9	4.8	560.4	2.48	120.2

Table 5. Current and voltage measurement on a 2-blade wind turbine

No	Wind velocity (m/s)	Wind turbine rotation (RPM)	Wind turbine generator voltage (volt)	Wind turbine generator current (ampere)
1	4.2	121.1	1.13	20.6
2	3.9	118.4	1.13	19.9
3	4	119.7	1.12	17.1
4	4.7	166.4	1.28	39.1
5	5	167.5	1.29	40.4
6	4.5	164.5	1.23	40.7
7	5.1	213	1.65	79.3
8	5.3	212.9	1.64	80.8
9	4.8	209.5	1.7	78.6

3.2 Discussion

After obtaining the data, the average wind velocity and electrical power were calculated by multiplying voltage and current. Table 6 summarizes the results for different blade configurations. The 6-blade turbine generated the highest power (628.18 watts) at a wind speed of 5.47 m/s, while the 2-blade turbine produced the lowest power across all wind speeds. Figure 4 shows the relationship between wind speed and power for each configuration.

Table 6. Average speed and electrical power calculation results in data

Number of Blades	Wind velocity (m/s)	Electrical power (watt)
6	3.77	107.40
	4.77	271.02
	5.47	628.18
5	4.13	111.23
	4.70	288.47
	5.43	481.75
4	3.93	50.47
	4.83	182.49
	5.00	288.43
3	3.97	61.25
	4.93	165.38
	5.67	291.89
2	4.03	21.63
	4.73	50.75
	5.07	132.35

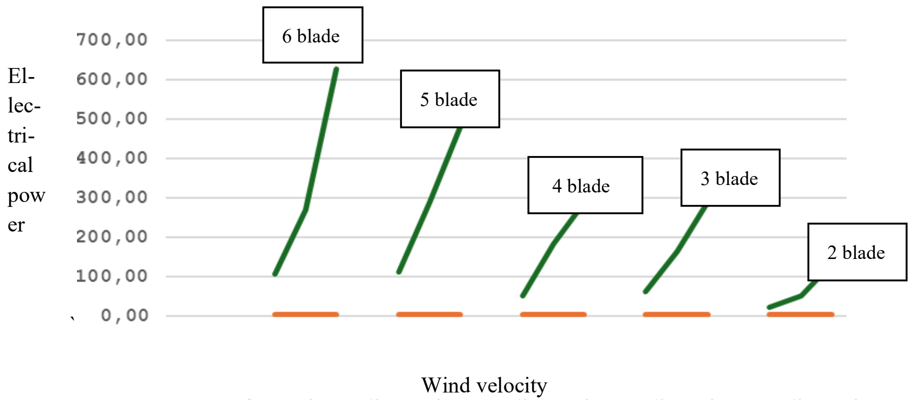

Figure 4. The relationship between wind speed and the power generated in various numbers of wind turbine blades

The effect of blade number on power at different wind speeds was analyzed separately. At low speeds (Table 7), the 5-blade turbine generated the highest power (111.23 watts), as seen in Figure 5. At medium speeds (Table 8), the 5-blade turbine again performed best, followed by the 6-blade turbine (Figure 6). At high speeds (Table 9), the 6-blade turbine produced the most power (628.18 watts), as shown in Figure 7, confirming that the 6-blade turbine performs best at higher wind speeds.

Table 7. Electric power at low speed

Number of Blades	Electrical power (watt)
2	21.63
3	61.25
4	50.47
5	111.23
6	107.4

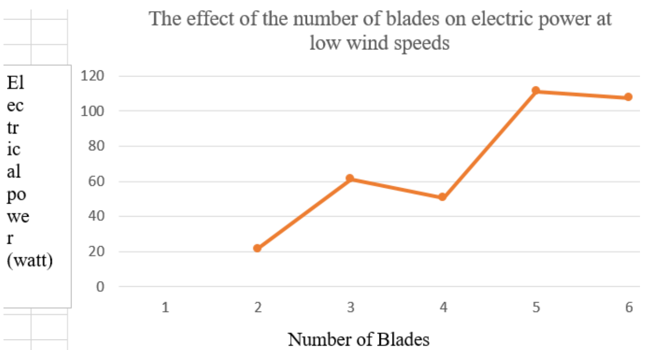

Figure 5. Relationship between number of blades and electric power at low speed

Table 8. Electric power at medium speed

Number of Blades	Electrical power (watt)
2	50.75
3	165.38
4	182.49
5	288.47
6	271.02

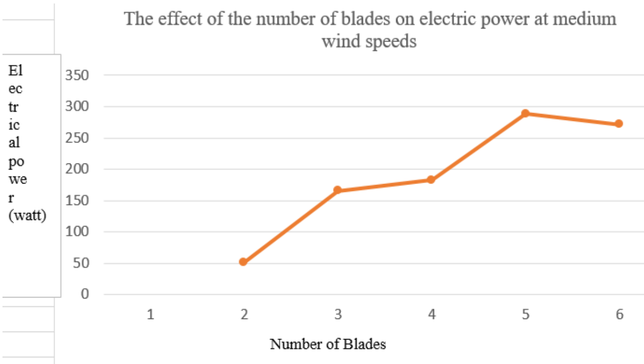

Figure 6. Relationship between the number of blades and electric power at medium speed

Table 9. Electric power at high speed

Number of Blades	Electrical power (watt)
2	132.35
3	291.89
4	288.43
5	481.75
6	628.18

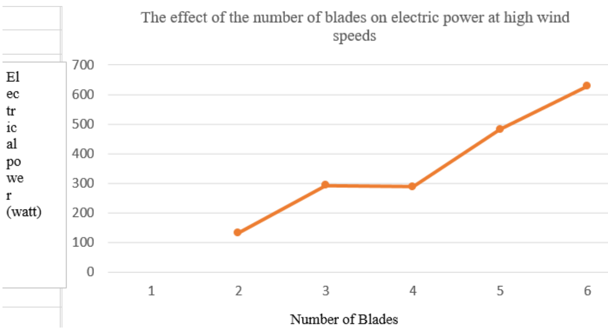

Figure 7. Relationship between the number of blades and electric power at high speed

4 Conclusion

The study concludes that the number of blades and wind speed significantly impact the electrical power output of a vertical-axis wind turbine. As wind speed increases, power output generally rises with more blades, from 2 to 6. However, a notable pattern shows that odd-numbered blades consistently generate higher power compared to even-numbered ones, indicating that turbines with odd-blade numbers are more efficient. In the context of Badung, Bali, where wind speeds range from 2.57 to 5.47 m/s, a Savonius wind turbine with 6 or more blades is the most suitable configuration for optimal performance, generating 628.18 Watts, which falls within the acceptable range for the local wind conditions and generator specifications.

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