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POWER GENERATION POTENTIAL BASED ON WIND SPEED VARIATIONS IN WIND POWER PLANT PROTOTYPES

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Abstract

Future energy is a term for developing renewable energy (RE) potential as a solution or alternative to fulfill the needs of increasing energy consumption. Conventional energy production depends on dwindling fossil energy sources, its renewal takes hundreds of millions of years, and its side effect can increase global warming. One renewable energy source that is environmentally friendly and available in nature with unlimited quantities is wind. Indonesia is an archipelago country with a tropical climate that can use wind energy as a wind power plant (PLTB), either on the coast or hills. A wind power plant (PLTB) is a generator that converts wind energy into electrical energy by using turbines as movers and generators as power generators. This paper aims to determine the wind energy potential for electricity generation based on wind variations. Data collection in this study uses a small-scale PLTB prototype built by design and then measured using a multimeter and anemometer. The wind turbines used for generating electricity are four blades with a length of 45 cm and a breadth of 7 cm. The tool used as a generator is a DC motor with a capacity of 12 volts. Based on the field testing results, it found that when the highest wind speed of 3,5 m/s, the DC motor produced a current of 0,011004 Amperes and a voltage of 0,426563 Volts and at the lowest wind speed of 1,9 m/s, the DC motor produced a current of 0,005961 Amperes and a voltage of 0,231563 Volts. It can be concluded that the wind speed, type, and size of the blades and the specification of the generator greatly influence electric power generation.
Keywords: Wind, Renewable Energy, PLTB, Wind Turbine.

1 Introduction

The increase of energy consumption in a country is one of the impacts of the growth of community and technology that continues to develop rapidly. Shiosansi stated that one of the characteristics of modern society depends on fossil fuel and nuclear to the provision of infrastructure operation to obtain the production of necessities and other crucial human services [1]. The needs for large energy and the dependence on fossil energy sources make the availability of fossil energy decreasing and are expected to run out [2]. Currently, much renewable energy is developed as a source of alternative energy to fulfill the needs of conventional energy. Renewable energy has advantages, such as being environmentally friendly, relatively easy to obtain, easy to renew naturally or by human engineering [3]. One of the renewable energy sources that can be used as alternative energy is wind energy. The potential of wind energy in Indonesia can reach 9.3 GW and the total capacity installed is approximately 0.5 MW [6]. In some areas in Indonesia, a large amount of potential wind can be used to build a wind power plant (PLTB) and save the use of conventional fuel. The electrical energy that can be generated by PLTB depends on the wind speed [7]. PLTB is a generator whose operation uses wind energy as driving energy to generate electrical energy. This generator can convert wind energy into electrical energy using a wind turbine that will drive the generator. Prototype of PLTB can be built in areas with sources of wind energy at a stable speed, for instance, the coast [9]. Indonesia has the potential of sea wind energy with an average speed of 3.4 - 4.5 m/s, which requires further study regarding the utilization of sea wind in various regions. There are many advantages to build a PLTB prototype with a distance of approximately 10 meters on the coast, including the location factor that has many wind energies, a factor of stable wind speed, a land factor that does not disturb the community mobility, as well as reducing wind park effect on wind turbines.

Many studies about this topic have been conducted to increase the performance of PLTB, for example, Muhammad Iqbal and R M Sisdarmanto Adinandra studied making a 100-watt wind power system, and the wind turbine prototype design used was 0.38 meters in diameter. The results of the study show that the highest efficiency value of the wind turbine was 6.86% at a wind speed of 6 m/s [10]. Sunardi and Zeazelia Erwinda Sorometa also conducted a study regarding the design of the wind power plant prototype in the tropics for agricultural irrigation, and the turbine prototype design was a vertical axis wind turbine (VAWT). The results of the test show that the highest value of voltage was 6.16 V and the highest current was 0.51 A at a wind speed of 3.4 m/s [11].

Based on the explanation above, a study regarding the potential of electricity generation using the PLTB prototype requires to conduct. Data collection of potential power generation was conducted by measuring the voltage and current value generated by the generator based on the variations in wind speed. The design of the prototype consisted of the wind turbine blade with a diameter of 1 meter and a12 volt DC motor as a generator. The voltage and current values were measured using a digital multimeter, while the wind speed value was measured using an anemometer.

2 Methodology

The working principle of the PLTB prototype was by using wind energy to produce electrical energy. Wind energy will twist the turbine so that it generates rotation in the turbine shaft. The wind turbine will make the generator works and generates electrical energy. The prototype system was designed using 4 wind turbine blades with 45 cm length and 7 cm width and 12 V DC motor as a generator. A multimeter was used to measure the voltage and current values generated by the DC motor, while an anemometer was used to measure wind speed with m/s unit. The load used in this study was Light Emitting Diode (LED). The configuration of the wind power plant prototype design system (PLTB) can be seen in Figure 1.

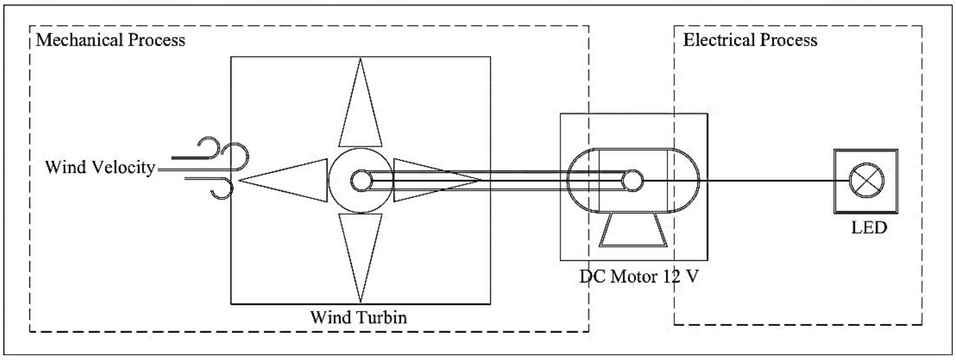

Figure 1. PLTB prototype system configuration

The configuration of the testing system for the design of the wind power plant (PLTB) prototype in this study is shown in Figure 2.

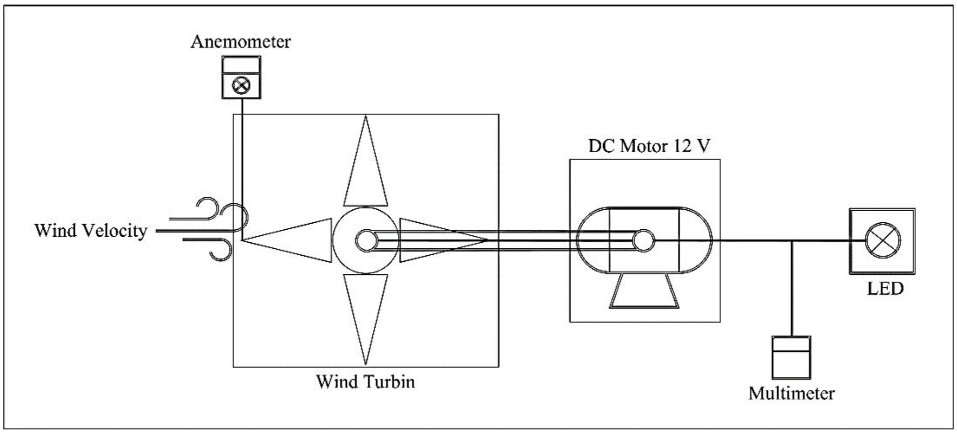

Figure 2. PLTB prototype system testing configuration

The meassurements of this prototype is shown in Figure 3 below

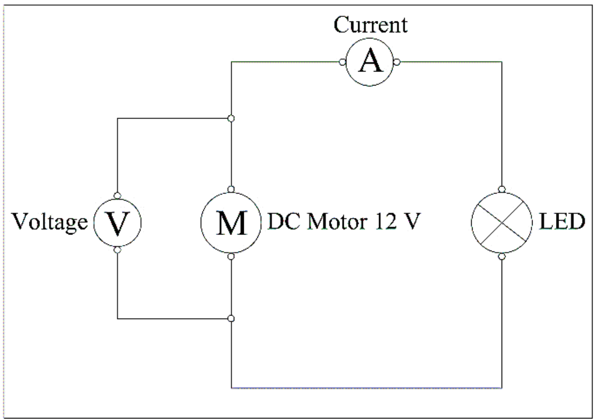

Figure 3. The Circuit of Current and Voltage Measurement

The main component used in this study is shown in table 1.

Table **1**. Specification for the components of the proposed system

No	Component	Quantity	Specification
1	Digital Anemometer	1	-
2	Digital multimeter	1	-
3	Pipe 0,5 inch	1	Length = 40 cm
4	Pipe 6 inch	1	Length = 40 cm
5	Pipe ¾ inch	1	Length = 70 cm
6	DC Motor	1	12 Volt DC
7	Bolt M22	1	D = 22 mm
8	Iron clamp	1	2 Inch
9	Red LED	1	0,036 Watt
10	Jumper cable	Sufficiently	-
11	Bearing	1	D = 2 cm
12	Reducing Socket	1	¾ Inch – ½ Inch
13	Clipboard	Sufficiently	-

To determine the potential for generating electrical power generated by a wind turbine rotation, theoretically can use the following equation (1).

$$\text{Pm} = \frac{1}{2}\rho A v^3 Cp(1) \qquad (1)$$

We are given the blade length with l = 1 m. Inserting the value for blade length as the radius of the swept area into equation (2), we have :

$$A = \pi\, r^2 \qquad (2)$$

$$A = 3{,}14 \text{ x } (0{,}5)^2$$

$$A = 0{,}785\ m^2$$

Table **2**. Calculation of The Theoretical Electric Power Potential in PLTB Prototype

No	Wind Speed (m/s)	Theoretical Power (Watt)
1	3,2	9,34
2	3,5	12,22
3	2,7	5,61
4	2,5	4,46
5	3,3	10,25
6	2,1	2,64

No	Wind Speed (m/s)	Theoretical Power (Watt)
7	2	2,28
8	2,3	3,47
9	1,9	1,96
10	2,3	3,47

3. Results and Discussion

The test is carried out by using a digital anemometer based on variations in wind speed different sizes, and diameters of the wind turbine. Then the data collection process has variations and comparisons of various wind speeds. The wind speed obtained in the process test ranges from 1,9 m/s – 3,5 m/s. A digital multimeter measures the current and voltage values to get real power data generated by the DC motor. The data from the result of testing the PLTB prototype in this study are shown in table 3. The data was obtained based on the testing time and wind speed so that the voltage and current were obtained

Table **3**. Output Parameters of The Wind Power Based on Wind Speed

No	Time	Wind Speed (m/s)	Voltage (V)	Current (A)
1	01-08-2021	3,2	0,3926	0,0100
2	02-08-2021	3,5	0,426563	0,010981
3	03-08-2021	2,7	0,3491	0,0094
4	04-08-2021	2,5	0,3047	0,0089
5	05-08-2021	3,3	0,4192	0,0104
6	06-08-2021	2,1	0,2659	0,0078
7	07-08-2021	2	0,2438	0,0073
8	08-08-2021	2,3	0,2803	0,0083
9	09-08-2021	1,9	0,231563	0,005961
10	10-08-2021	2,3	0,2806	0,0085

Table 3 shows the result of current and voltage measurements based on wind speed, and it shows that the highest wind speed occurred on 02-08-2021 with a value of 3,5 m/s and produced a voltage of 0,426563 V and a current of 0,010981 A. The lowest wind speed occurred on 09-08-2021 with a value of 1,9 m/s and had a voltage of 0,231563 V and a current of 0,005961 A.

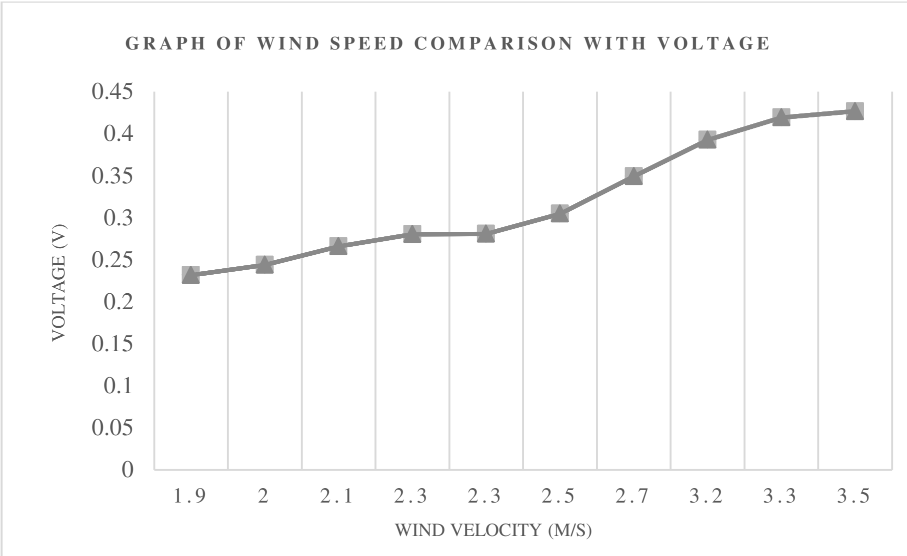

Figure 3. The curve of line voltage vs wind speed

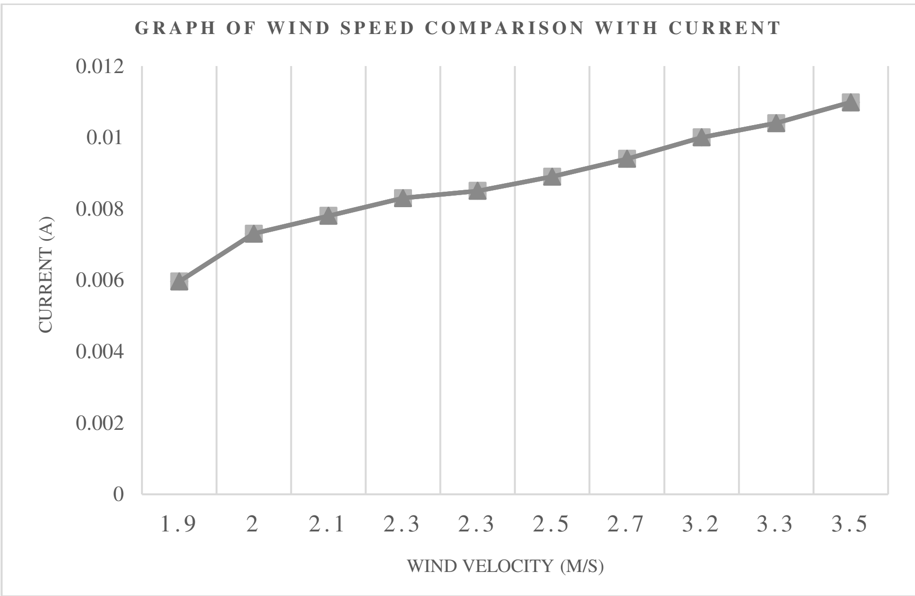

Figure 4. The curve of line current vs wind speed

Based on Fig. 3 and Fig. 4, the graphs show that each variation in wind speed has affected the output of the DC motor or generator. The higher the speed received by the wind turbine, the faster the rotation of the generator, so that the voltage and current output from the generator is greater. It shows that the wind speed is directly proportional to the resulting voltage and current. To obtain the total power output at the generator, we can use the power formula between current and voltage. The result of the total output power on a DC motor or generator are presented in Table 4.

Table **4**. The Total Output Power of Generator Based on Wind Speed

No	Time (WITA)	Wind Speed (m/s)	Power (watt)	LED Condition
1	01-08-2021	3,2	0,003926	OFF
2	02-08-2021	3,5	0,004684	OFF
3	03-08-2021	2,7	0,003282	OFF
4	04-08-2021	2,5	0,002712	OFF
5	05-08-2021	3,3	0,004360	OFF
6	06-08-2021	2,1	0,002074	OFF
7	07-08-2021	2	0,00178	OFF
8	08-08-2021	2,3	0,002326	OFF
9	09-08-2021	1,9	0,00138	OFF
10	10-08-2021	2,3	0,002385	OFF

In Table 4 can be seen that up to the highest wind speed at a speed of 3,5 m/s, the potential energy obtained has not been able to occur for the LED load. That is because the current and voltage are relatively small. That happens because the rotation of the wind turbine is not optimal.

Comparison between the power generated by the generator based on direct testing with power theoretically aims to see the differences that occur in the calculation of equation (1) which has been calculated in Table 3. It is calculated based on the cross-sectional area of the wind turbine with ideal conditions without considering other factors that can disrupt the stability of the results generator output to the wind turbine. The comparison is shown in Table 5 below, with the wind speed is sorted from the lowest to the highest wind speed.

Table **5**. Total Power Produced by Generator and Theoretical Power

No	Wind Speed (m/s)	Total Power (watt)	Theoretical Power (Watt)
1	3,2	0,003926	9,34
2	3,5	0,005767	12,22

No	Wind Speed (m/s)	Total Power (watt)	Theoretical Power (Watt)
3	2,7	0,003282	5,61
4	2,5	0,002712	4,46
5	3,3	0,004360	10,25
6	2,1	0,002074	2,64
7	2	0,00178	2,28
8	2,3	0,002326	3,47
9	1,9	0,001459	1,96
10	2,3	0,002385	3,47

Based on Table 5, the difference between the total power generated by the generator with the theoretical ratio is too significant. It can be seen in the table, for the highest wind speed of 3,5 m/s, the result of the total power generated by a DC motor or generator is 0,005767 Watt, while the theoretical power potential calculation can reach 12,22 Watt.

The efficiency value of the DC motor or generator is obtained by calculating the output power compared to the input power.

Table **6**. PLTB Prototype Generator Efficiency

No	Wind Speed (m/s)	Efficiency %
1	3,2	0,04%
2	3,5	0,05%
3	2,7	0,06%
4	2,5	0,06%
5	3,3	0,04%
6	2,1	0,08%
7	2	0,08%
8	2,3	0,07%
9	1,9	0,07%
10	2,3	0,07%
Mean		0,06%

In Table 6, it can be seen that the average generator efficiency only reaches 0.06%. The highest efficiency value was 0.08% at speeds of 2 m/s and 2.1 m/s. The work efficiency of this generator does not reach the ideal work efficiency of the common generator because a good generator has a work efficiency of 80% to 100%.

Based on the results obtained in the PLTB prototype test, it can be analyzed that the stability of wind speed impacts the generator rotation, in which a low and unstable wind speed makes turbine performance not optimal. Moreover, the height factor also impacts generator rotation, where the closer to the ground, the lower the wind speed. The height of the prototype in this study was 70 cm, making the wind energy received is less optimal. Furthermore, other factors making the generator output not reach the expected results are materials, size, angles of the blade used. This prototype used 4 blades made of pipes, making the wind turbine have a weight that made the generator rotation not optimal. The density between blades also becomes an important indicator because it affects the rotation of the turbine. A small number of the blade and placing the blade at a wrong angle can cause the wind to easily cross the blade gap so that the power around the blade is less and results in low speed of blade rotation. Moreover, the diameter of the turbine also has an effect, where the turbine diameter will be directly proportional to the generator output. The wider the blade, it will generate more power.

3 Conclusions

Based on the results obtained in the PLTB prototype test, wind speed stability impacts the generator output. The higher the wind speed, the higher the voltage generated.

1. By using a wind turbine with a surface area of 0.785 m^2, the theoretical power generated reaches 12.22 watts.
2. The results of the current and voltage test in the PLTB prototype when the highest wind speed of 3.5 obtained the voltage value of 0.426563 V and the current value of 0.01098 A.
3. The highest generator efficiency that can be generated is when the wind speed of 2.1 m/s and 2 m/s with an efficiency value of only 0.08%. With an efficiency value that is far from the ideal work parameter of the generator, it shows that the PLTB prototype cannot be used in a low and unstable wind speed.

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