The Effect of Wind Speed on the Power Generated in a Wind Power Plant Prototype

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Abstract. Bayu or known as wind is one of several renewable energy sources that have the potential to produce electrical energy. Wind conditions that are not the same between places affect the energy produced. This wind condition is closely related to wind speed, so an experiment is needed to determine the effect of wind speed on the power generated on the PLTB prototype. The method used is to directly measure the power generated by the PLTB prototype which is loaded with different wind conditions. The results obtained with a wind speed of 3.5 m/s capable of producing an average power of 0,0188 watts, then at a wind speed of 4 m/s capable of producing an average power of 0,0241 watts, and a wind speed of 4.3 m/s capable of producing an average power of 0,0283 watts, this shows that wind speed affects the power generated.

Keywords: Prototype · Wind Speed · renewable energy · power generated · Wind Power Plant

1 Introduction

Beginning in the 1970 s, fossil energy began to be reduced in electricity generation because of the resulting impact, we all know that the resulting impact is very unfriendly to the environment, not only that fossil energy too, if used continuously its availability is decreasing and over time it will run out, therefore we can take advantage of the abundant and abundant availability of energy, this energy is called renewable energy. This energy is very suitable to be developed or researched because this energy has many advantages other than its abundant availability [1].

Wind power is one of the abundant renewable energy sources in our country and is environmentally friendly because it reduces CO_2 gas emissions, therefore we can get unlimited electricity from wind energy. Wind or known as wind power can be used in the manufacture of electrical energy. Actually, wind power itself has been used by one of the countries that earned the nickname of the state of the mill, namely the Netherlands [2]. The workings of this windmill are quite simple, namely the rotation of the turbine caused by the wind is forwarded to the generator rotor where this generator has a copper coil that functions as a stator so that an emf (electromotive force) occurs. The electricity generated can be stored in batteries or used directly for loads such as lamps [3].

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The purpose of this study was to collect power data that can be generated by the PLTB prototype with different wind speeds to determine the effect of wind speed on the power generated [4].

2 Methods

2.1 Research Location

The location of this research is the Advanced Electrical Laboratory, Faculty of Engineering, Mulawarman University, which is located at Jl. Sambaliung, Sempaja Selatan, Samarinda Utara, Kota Samarinda, Kalimantan Timur.

2.2 Research Procedures

This research was conducted by taking power data that can be generated by the PLTB prototype with different wind speeds to determine the effect of wind speed on the power generated.

2.3 Tools and Materials

This research was conducted using the following tools and materials.

1. Miniature windmill set

   Output voltage: DC 0.1 V-18 V
   Output current: 0.01-0.3A
   Rated speed: 200-6000 rpm
   Motor size: 24.5 x 34.2 mm
   Blade size: r: 4.5 cm d:9 cm

2. Fan
3. Led light

   Voltage 3.2~3.4 volt Current 15 ma

4. Multimeter
5. Ammeter
6. Anemometer

2.4 Research Stages

This research was conducted with the following stages (Fig. 1).

2.5 Block Diagram

This research was conducted with the following block diagram (Fig. 2).

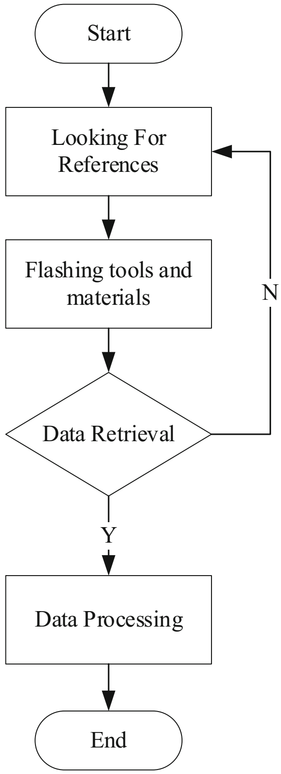

Fig. 1. Research flow chart

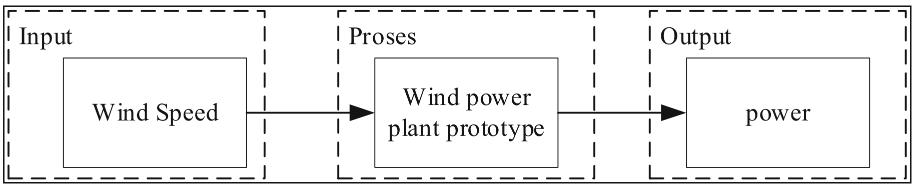

Fig. 2. Research block diagram

3 Result and Discussion

3.1 Experiment Results

This study was conducted with 3 trials for 100 s with different wind speeds for the first experiment with a wind speed of 3.5 m/s, the second experiment with a wind speed of 4 m/s and the third experiment with a speed of 4.3 m/s presented in following Tables 1, 2 and 3.

Table 1. Experiment wind speed 3.5 m/s.

NO	Time(s)	Voltage (v)	Current (a)	Indicator
1	20	2,77	0,006	Dim
2	40	2,81	0,008	Bright enough
3	60	2,79	0,007	Dim
4	80	2,78	0,006	Dim
5	100	2,72	0,007	Dim

Table 2. Experiment wind speed 4 m/s.

NO	Time(s)	Voltage (v)	Current (a)	Indicator
1	20	2,82	0,009	Bright enough
2	40	2,82	0,008	Bright enough
3	60	2,77	0,007	Dim
4	80	2,82	0,009	Bright enough
5	100	2,83	0,010	Bright

Table 3. Experiment wind speed 4,3 m/s.

NO	Time(s)	Voltage (v)	Current (a)	Indicator
1	20	2,80	0,008	Bright enough
2	40	2,83	0,010	Bright
3	60	2,82	0,009	Bright enough
4	80	2,86	0,012	Bright
5	100	2,84	0,011	Bright

3.2 Power Calculation

This study calculates the theoretical power of wind energy into electrical energy produced. This calculation includes wind power calculations, wind turbine power calculations, generator power calculations and research results calculations [5].

3.3 Wind Power Calculation

$$Pw = {}^{1}/_{2} \cdot \rho a \cdot A \cdot v^{3}$$

With:
a: wind density at a certain time (1.2 kg/m^3)

A: Area of wind swept (m^2)
v: wind speed at a certain time. (m/s)
The area of the wind swept area can be found by the following formula:

$$A = \pi \cdot r^2$$

With:
A: Area of wind swept (m^2)
π: phi 3,14
r: Turbine circle radius/turbine length (m)
In this study using r of 4.5 cm from the formula for the area of the wind-swept area
$A = 3{,}14 \cdot (4{,}5/100)^2$
$A = 3{,}14 \cdot 0{,}002025$
$A = 0{,}0063$

In the yield of 0,0063 m^2 then we input the value of the area of the wind-swept area into the equation for calculating wind power with wind speeds of 3.5 m/s, 4 m/s and 4.3 m/s

for wind speed 3.5 m/s
$Pw = ½ \cdot \rho a \cdot A \cdot v^3$
$Pw = ½ \cdot (1{,}2\ kg/m^3) \cdot (0{,}0063\ m^2) \cdot (3{,}5\ m/s)^3$
$Pw = 0{,}1620$ W
for wind speed 4 m/s
$Pw = ½ \cdot \rho a \cdot A \cdot v^3$
$Pw = ½ \cdot (1{,}2\ kg/m^3) \cdot (0{,}0063\ m^2) \cdot (4\ m/s)^3$
$Pw = 0{,}2419$ W
for wind speed 4.3 m/s
$Pw = ½ \cdot \rho a \cdot A \cdot v^3$
$Pw = ½ \cdot (1{,}2\ kg/m^3) \cdot (0{,}0063\ m^2) \cdot (4{,}3\ m/s)^3$
$Pw = 0{,}3005$ W

3.4 Wind Turbine Power Calculation

$$Pa = Pw \cdot Cp$$

With:

C_p: Power coefficient

In this study using a horizontal axis wind turbine with 3 blades so that the Cp value is 0.45

For wind speed 3.5 m/s

$Pa = Pw \cdot Cp$

$Pa = 0{,}1620\ W \cdot 0{,}45$

$Pa = 0{,}0729\ W$

For wind speed 4 m/s

$Pa = Pw \cdot Cp$

$Pa = 0{,}2419\ W \cdot 0{,}45$

$Pa = 0{,}1088$

For wind speed 4,3 m/s

$Pa = Pw \cdot Cp$

$Pa = 0{,}3005\ W \cdot 0{,}45$

$Pa = 0{,}1352$

3.5 Generator Power Calculation

Generator power calculation is done by calculating the maximum power generated by the generator which can be known from the generator specifications.

$P_{gen} = V_{gen} \cdot I_{gen}$

$P_{gen} = 18\ v \cdot 0{,}3\ A$

$P_{gen} = 5{,}4\ W$

From the results of the calculation of the power of the turbine generator, it can be 5.4 watts when compared with the results of the calculation of wind turbine power, the calculation results of the generator power are much larger so that the generator is able to produce maximum power from the theoretical calculation of wind turbine power.

3.6 Generated Power Calculation

The calculation of the resulting power is done by calculating the voltage and current data obtained in the study with the formula [6].

$$P = V \cdot I$$

The power results are obtained as follows (Table 4).

Table 4. Average power generated

No	Time(s)	Speed 3.5m/5	Speed 4m/5	Speed 4.3 m/5
1	20	0,01662	0,0253	0,0224
2	40	0,02248	0,0225	0,0283
3	60	0,01953	0,0193	0,0253
4	80	0,01668	0,0253	0,0343
5	100	0,01904	0,0283	0,0312
Average		**0,01887**	**0,0241**	**0,0283**

4 Discussion

Theoretical calculations of wind power that can be generated into electrical energy are quite varied for a wind speed of 3.5 m/s and a power of 0.1620 watts, for a wind speed of 4 m/s, a power of 0.2419 and a wind speed of 4, 3 m/s in the power of 0.3005 watts. From this theoretical calculation, the power that can be generated is directly proportional to the wind speed because the greater the wind speed, the greater the power generated [7].

After calculating the theoretical wind power that can be generated, we need to take into account the wind turbine power as well. Wind turbine power is the wind power that sweeps the turbine in the conversion into electrical energy which is influenced by the type of turbine. In this study using a horizontal axis turbine type with 3 blades, according to the betz constant the power coefficient for a horizontal axis turbine with 3 blades has a power coefficient of 0.45 so that the results can be obtained from speeds of 3.5 m/s, 4 m/s and 4.3 m/s are 0.0729 watts, 0.1088 watts and 0.1352 watts. From the theoretical calculation of wind turbine power, besides being influenced by the power coefficient, it is also influenced by wind power so that the greater the wind power, the greater the turbine power and wind power is influenced by wind speed [8].

Furthermore, in this study to calculate the generator power to determine the power generated by the generator. In this study, the generator used has specifications for Output voltage: DC 0.1V-18V and for Output current: 0.01–0.3A so that the maximum power that can be generated by the generator is 5.4 watts. From the calculation of the generator power, which is large enough to allow turbine power to be generated.

After calculating the generator power, it is necessary to calculate the power generated in this study. This study collects data with different wind speeds, namely with wind speeds of 3.5 m/s, 4 m/s and 4.3 m/s and the average power generated is 0.0188, 0.0241, and 0.0283. When compared with the theoretical calculation of the turbine power produced, it certainly has a considerable difference. This difference can occur due to a simple wind turbine where the turbine used is not as complete as the generator turbine. in general.

From the calculation of the resulting power, it can be seen that the greater the wind speed, the greater the power generated. At a wind speed of 3.5 m/s, the highest power is 0.0224 watts with an average power output of 0.018 watts. At a wind speed of 4 m/s the highest power is 0.0283 watts with an average power generated of 0.0241 watts. At a

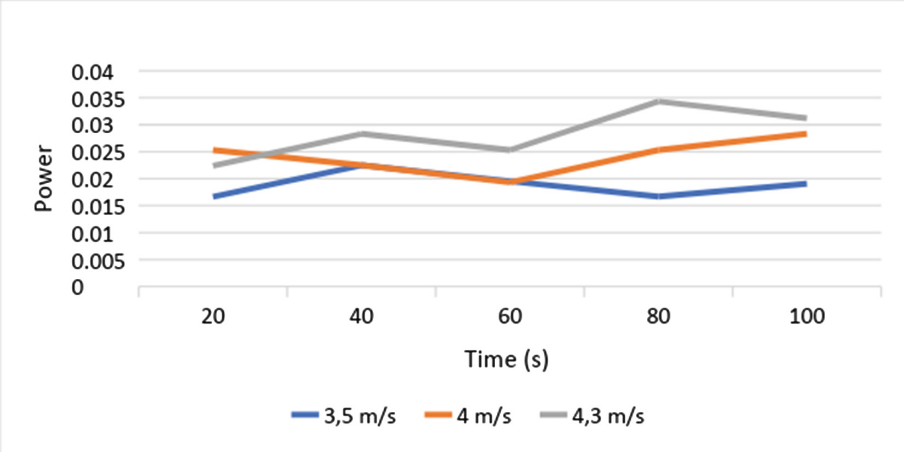

Fig. 3. Generated power graph against time

wind speed of 4.3 m/s, the highest power is 0.0343 watts with an average power output of 0.0283 watts.

From this data it can be seen that the greater the wind speed the greater the power that can be generated which can be seen in the following graph (Fig. 3).

5 Conclusion

The results obtained with a wind speed of 3.5 m/s capable of producing an average power of 0.0188 watts, then at a wind speed of 4 m/s able to produce an average power of 0.0241 watts, and a wind speed of 4.3 m/s. s is able to produce an average power of 0.0283 watts, this shows that wind speed affects the power produced.

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