Vawt Helix Turbine Design For Microhybrid Plants

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Abstract. *Conventional power plants that exist today can cause environmental damage, such as air pollution and the erosion of fossil reserves. Therefore, humans continue to innovate to develop environmentally friendly power plants. One of them is the combined wind turbine and solar cell technology to create a more effective solution called a Hybrid power plant. This research proposes a VAWT Helix Turbine Design for Microhybrid Power Plant. The design is according to the wind speed and solar radiation for the Madiun city area. BMKG data shows that the average wind speed is 3 m/s to 7 m/s. Meanwhile, the sun's heat is on average 25°C to 36°C. The wind turbine uses 3 blades of helix type and the solar cell used is Monocrystalline. The design was designed using the AutoCAD program and simulated using Qblade software. The blades are made using 3D Printing Polylactic Acid (PLA) and then printed using a 3D Printer. Simulation results using Qblade show the average value when the wind speed is 3 m/s produces an average power within 11.4 Watt. When the wind speed is 4 m/s, the average power is 33.7 Watt. When the wind speed of 5 m/s produces an average power of 80.2 watts.*

Keywords: Design VAWT Helix; Microhybrid Power Plants; Qblade; Solar Panel; Wind Turbine.

1. INTRODUCTION

Electricity is able to support almost all human activities, it is not surprising that humans depend on electrical energy. Basically, electrical energy comes from conventional generators which utilize the movement of an object. Currently, conventional power plants can cause environmental damage. Further research needs to be carried out to minimize and stop this impact. As time goes by, humans innovate to develop environmentally friendly power plants. One of them is microhybrid generator technology. A microhybrid generator is a generator consisting of several types of generators integrated on a micro scale. Hybrid plants can be a combination of electricity generation from renewable energy sources and electricity generation from conventional energy sources (non-renewable energy) or also a combination of renewable energy power plants.

The type of wind energy and solar energy is very important. Wind energy is used to drive wind turbines, while solar energy is used to supply solar cells. Wind turbine and solar cell technology are combined into one, creating a more effective solution. The design is designed to efficiently adapt to the characteristics of urban wind speed and solar radiation in the city of Madiun. Data obtained from BMKG shows that the average wind speed is 3 m/s to 7 m/s. Meanwhile, the average heat from the sun is 25°C to 36°C. The wind turbine designed is the Type Helix Vertical Axis Wind Turbine which has the advantage of a wind turbine shape that can operate in various wind directions, and has a lower wind startup speed compared to

horizontal turbines. Monocrystalline solar panels have a higher efficiency level than polycrystalline types.

In this research, a VAWT Helix turbine design was created for a Microhybrid generator. The Type Helix Vertical Axis wind turbine design was designed using the AutoCAD program and simulated using Qblade software. QBlade software is reliable and has high accuracy for analyzing wind turbines. Optimization of wind turbine design through experiments and various computational techniques using QBlade to analyze the performance of smaller capacity winds has been carried out. The blade is made using 3D Printing Polylactic Acid (PLA) material because it has the best dimensional quality then printed using a 3D printer to make it easier, faster and more detailed.

The VAWT helix turbine design for this microhybrid generator can be used as an environmentally friendly alternative generating power and is capable of supplying an electricity source. The test results of battery charging using the Hybrid system have been proven and can run optimally with a wind speed rotating the turbine of 4.9 m/s and the battery voltage has been able to increase by 0.2 volts within 1 hour of charging.

2. RESEARCH METHODS

To obtain maximum results, it is necessary to determine the research method. Some of the methods used are:

a. Study literature. By collecting the required information data from several sources, for example from books, journals or the internet. Then create a flow diagram to make it easier to understand the process and how the tool works.

b. Calculate the required parameters then carry out design simulations with the Qblade application. This stage is very important and determines the success of the tool design being made.

c. Survey the test location by determining the location in the Madiun State Polytechnic electrical engineering laboratory on Jl Serayu 84 Madiun City and evaluate the system design by taking place in the Industrial Machinery Laboratory. Ensure wind speed by testing using two blower wind sources. One blower has a power of ± 305 watts with a wind speed for each blower of 3-5 m/s. Then ensure that there is a solar heat source in that place.

d. Make frame hardware to support the blade and solar panels that are able to support and maximize the performance of the tool. The wind turbine and solar panel frames are made from iron plates and angle iron pipes so that they match the design that has been made.

e. Next, carry out testing to find out whether the hardware is working properly so that you can know the level of effectiveness of the turbine design that has been made. Then make improvements if there are still deficiencies before continuing by measuring voltage, current and wind speed during testing.

Literature Study

Wind Turbine

Vertical axis wind turbines (VAWT) have the main rotor shaft/axis arranged perpendicularly. The main advantage is that the turbine does not have to be pointed into the wind to be effective. This advantage is very useful in areas where the wind direction varies greatly. VAWT is able to utilize wind from various directions. With a vertical axis, the generator and gearbox can be placed close to the ground and more easily accessible for maintenance purposes. Figure 1 shows several types of vertical axis wind turbines. One of them is the helix shape. The Helix turbine is a type of windmill with a vertical axis that is capable of converting horizontal wind energy into rotational kinetic energy. This mill was developed by Professor Gorlov from North Eastern University in 1995.
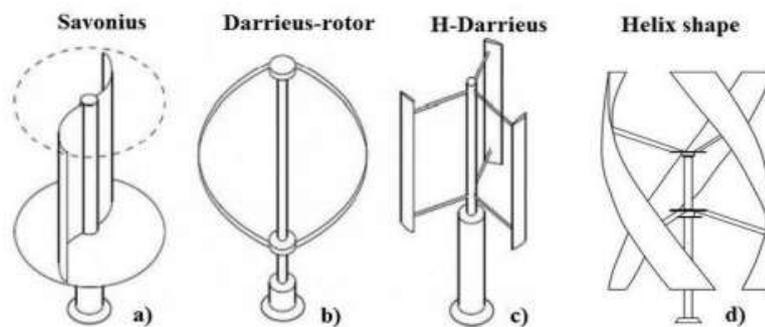
Picture 1. Wind Turbine.

Airfoil

An airfoil is an object that has a wing-like shape, when placed in a fluid flow it will produce a lifting force that is greater than the drag force [14]. The airfoil has a sharp tip as in Figure 2. The pointed tip is useful for ensuring air flow. The choice of airfoil affects the torque produced by the turbine. The type of airfoil used is NACA 4418 and the number of blades to maintain stability is 3 blades. The higher the CL / CD per alpha ratio of an airfoil, the better the lift and drag forces.
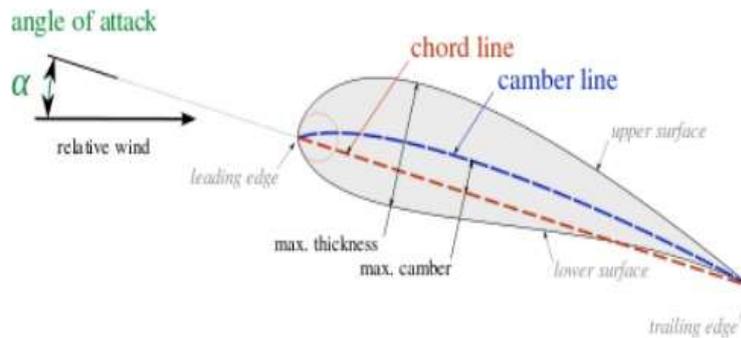
Picture 2. Airfoil.

Tip Speed Ratio (TSR)

Tip Speed Ratio is the ratio of rotor tip speed to wind speed [15]. Vertical type wind turbines (VAWT) tend to have a lower Tip Speed Ratio than horizontal type (HAWT). TSR can influence the number of blades used in designing a turbine.

Power Coefficient (CP)

Power Coefficient is a comparison between the power produced by the rotor and the power produced from the wind. A comparison between CP and TSR in graphic form is in Figure 3 below.
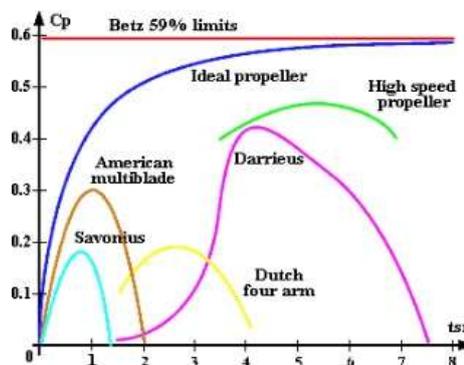
Picture 3. Comparison of CP and TSR.

Solar Cell

Solar Cell is a component that can convert solar energy (sun) into electrical energy using a principle called photovoltaic.

Blade Creation Parameters

Electric Power

$$P = \frac{1}{2}\rho A_\omega V^3 \tag{1}$$

P : Electric power (watts)

ρ (read Rho): Air density (kg/m3)

V : Effective wind speed according to rotor (m/s)

A_ω : Rotor swept area (kg/m3)

Rotor Mechanical Power

$$P = Tw \tag{2}$$

P : Rotor mechanical power (watts)

ω (read omega) : $\dfrac{n\pi}{t}$ rad/s2 where n is the shaft rotation (rpm)

Tip Speed Ratio

$$\lambda = \frac{R\omega}{v} = \frac{2\pi n R}{v}$$

$$\tag{3}$$

λ : (pronounced lamda) : Tip Speed Ratio

n : Number of rotations of the wheel per second (rps)

V : Wind speed (m/s)

Rotor Swept Area

$$Aw = 2RH \tag{4}$$

A_ω : rotor swept area (m2)

R : Radius (m)

H : Rotor height (m)

Rotor Height

$$H = AR \times 2R \tag{5}$$

R : Radius (m)

AR : Aspect ratio

H : Rotor height (m)

Turbine Rotor Radius

$$\tag{6}$$

$$R = \sqrt{\frac{A\omega}{4 \times AR}}$$

R : Turbine rotor radius (m)

AR : Aspect ratio

$A\omega$: Rotor swept area (m2)

Solidity

The minimum solidity value (σ) for a VAWT is 0.4 with a number of blades of 3. Diameter or chord is a measure of the width of one blade.

$$\sigma = \frac{NB}{D} \tag{7}$$

σ (pronounced sigma): Solidity value

NB: Number of blades

D : Diameter or Chord

Geometry Calculations

Geometry calculations using the Microsoft Excel application. The results of the geometric calculations are as shown in table 1. The fixed parameters used are rho value 1.225, wind speed (V) 5 m/s, turbine rotor radius (R) 0.2 meters and several variations in turbine height. It can be seen that as the turbine height increases, the value of the electrical power and turbine power produced becomes greater.

Table 1. Geometric Calculations With Variations In Turbine Height.

Power Electrical (Watt)	Power Turbine (Watt)	Rho	V (m/s)	Aw (m²)	R (m)	H (m)	AR
30,625	12,25	1,225	5	0,4	0,2	1	2,5
45,9375	18,375	1,225	5	0,6	0,2	1,5	3,75
61,25	24,5	1,225	5	0,8	0,2	2	5
765625	30,625	1,225	5	1	0,2	2,5	6,25
91,875	36,75	1,225	5	1,2	0,2	3	7,5

Prototype Blade Design

The prototype design was designed using AutoCAD software. In Figure 4, you can see the results of the blade design that will be printed using a 3D printer. The inner part is designed to be hollow to reduce the weight capacity of the blade so that it can be printed lighter but still strong. Blades with a length of 1 meter cannot be printed directly with a 3D printer. The maximum dimensions that can be printed by a 3D printer are 20 cm x 20 cm x 20 cm. So for the printing process, 1 blade is divided into 5 parts, each 1 part measuring 20 cm, then joined together using G glue, so that the length reaches 1 meter with a total weight of 1 blade ± 683 grams.
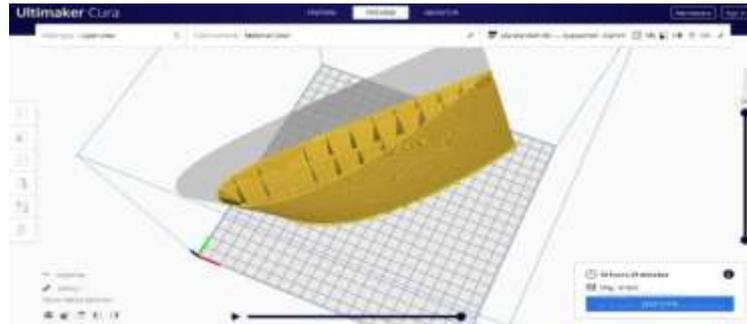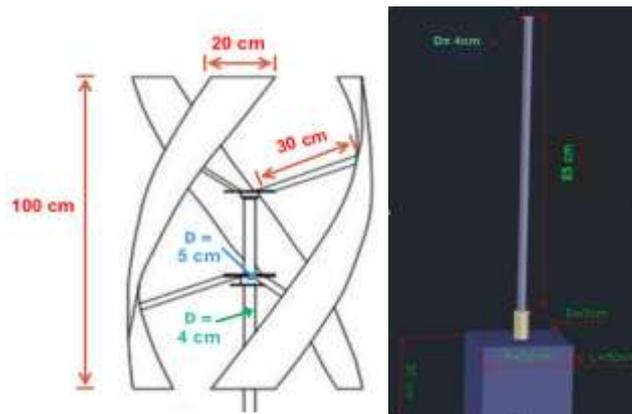
Figure 4. Blade Design Before Printing.

Tower Prototype Design

The design of the tower size to support the blade is shown in Figure 5. with the following specifications and dimensions:

Rotor diameter　: 4 cm

Length of blade　: 100 cm

Width of the blade : 20 cm

Figure 5. Desain Tower Blade.

Solar Panel Prototype Design

The solar panel used is a 50 WP monocrystalline type with a load requirement of 15 W x 12 hours of light = 180 Wh with the assumption that the load usage at night = 70% so the total load = 180 x 70% = 126 Wh. The solar panel design and component box are in Figure 6.
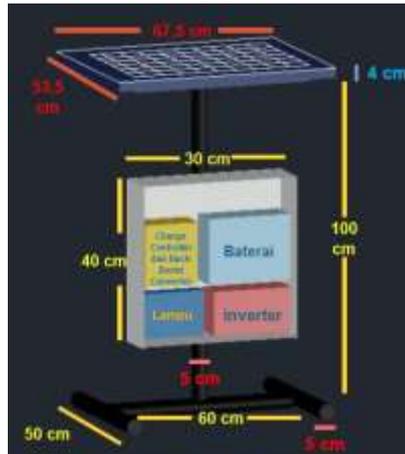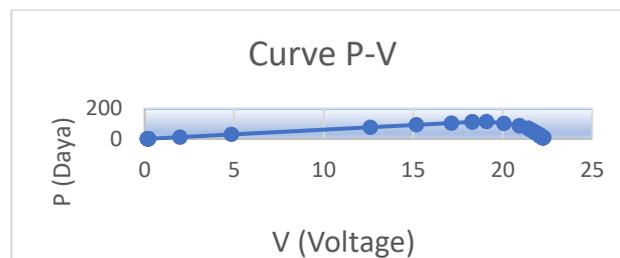
Figure 6. Solar Cell Design.

The design in Figure 6 will later be used to retrieve solar cell data where the data taken is the characteristics of the solar cell. These characteristic data are I-V curve data and P-V curve data. Data collection was carried out in real time at 13.00 WIB and is presented in Figure 7 and Figure 8:
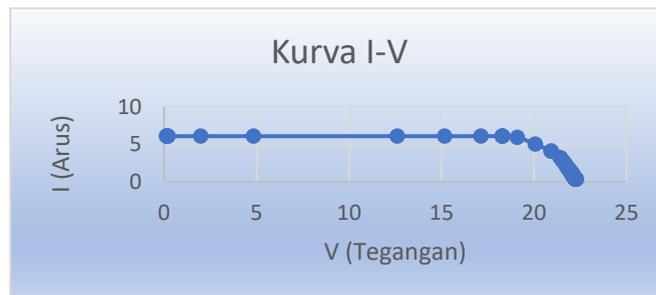
Figure 7. Solar Cell I-V Curve.

Figure 8. Solar Cell P-V Curve.

From the results of Figure 7 and Figure 8, it can be seen that in Figure 7 the I-V curve has the highest current value of 6.09 Amperes and the voltage value of the I-V curve is 22.27 Volts. This value is the maximum value of the I-V curve characteristics. Meanwhile, in Figure 8, in the P-V characteristic curve, the highest power value is 113.28 Watts and the voltage value is 22.27 Volts.

3. RESULTS AND DISCUSSION

QBlade Results and Simulation

Qblade is used as blade design software for wind turbines, both vertical and horizontal, by deter-mining the NACA type, determining blade parameters and analyzing characteristics. In the blade design, the NACA 4418 airfoil type was used (Figure 9.). Meanwhile, Figure 10 is a blade design showing the rotor and size according to the NACA 4418 airfoil type.
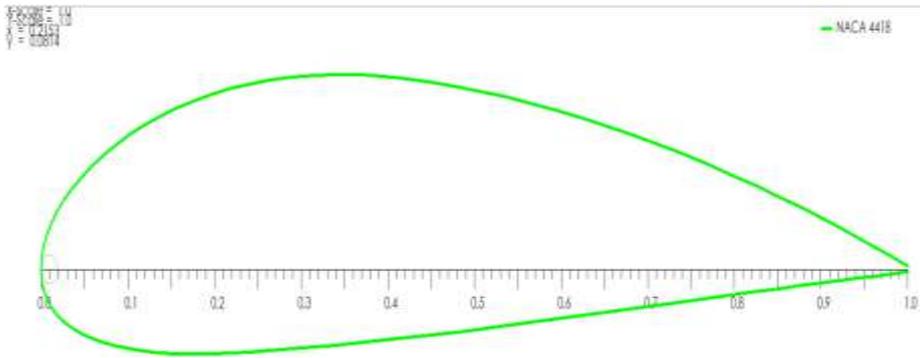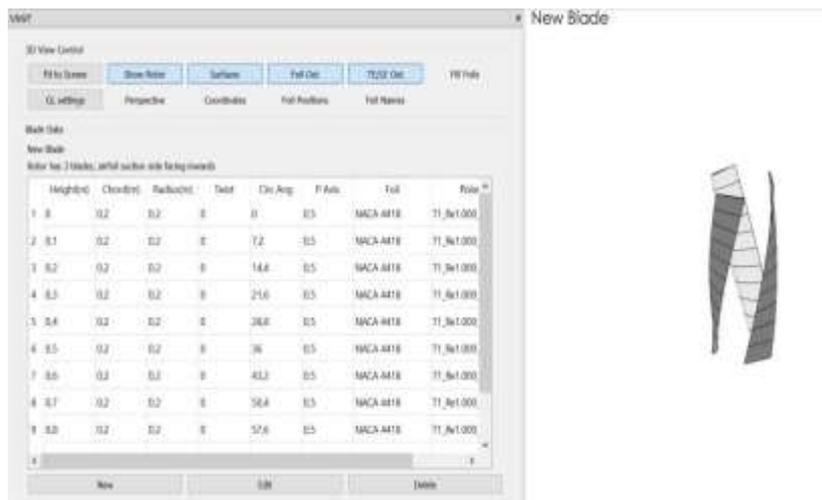

Figure 9. Airfoil NACA 4418.

Figure 10. Blade Design in Qblade Software.

CL/CD Simulation

Simulation to find the value of aerodynamic characteristics in the form of lift coefficient (CL) and drag coefficient (CD) at higher and lower angles of attack as well as average output power (Avarage Power) with 3 variations of wind speed, namely at a speed of 3 m/s , speed 4 m/s and speed 5 m/s. The higher the CL/CD value ratio per Alpha, the lift force and drag force show better values. The simulation results are as shown in Figure 11.
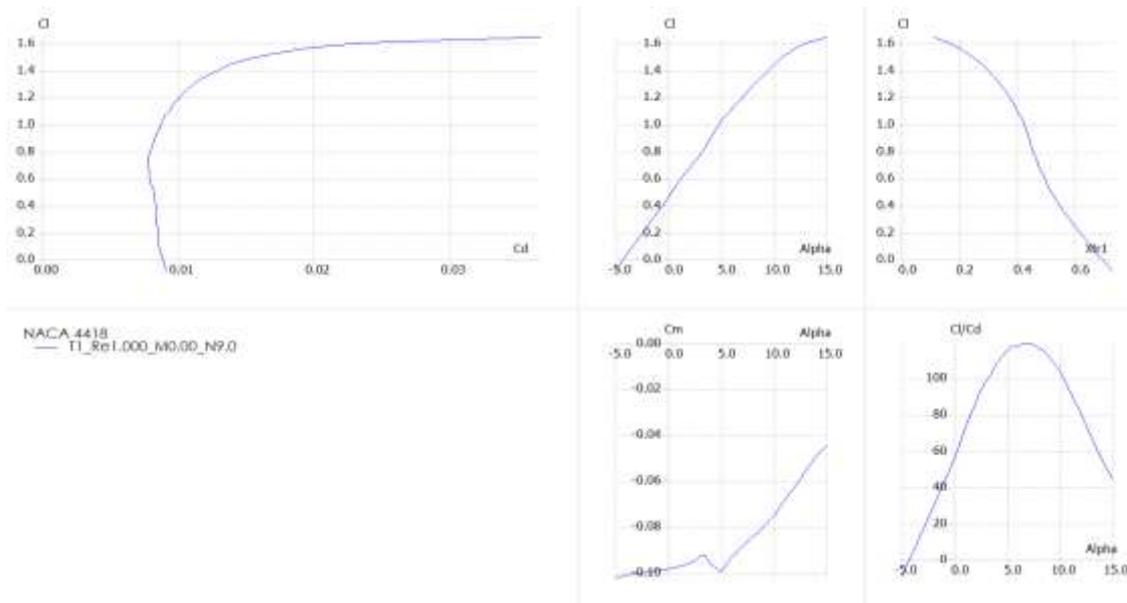
Figure 11. CL / CD Per Alpha graph.

Simulation at a Speed of 3 m/s

The simulation results using a blower with constant speed at a wind speed of 3 m/s are shown in table 2. At a wind speed of 3 m/s it can produce 8 watts to 14 watts of power with a Pressure Coefficient reaching 1.3 to 2.13. If the simulation results are graphed, it is shown in Figure 12.

Table 2. Qblade Simulation Results With Speed 3 M/S.

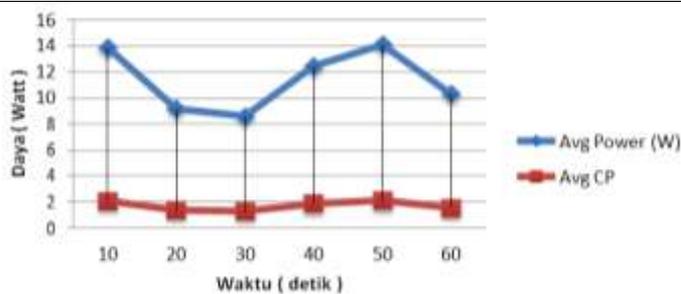| Time (detik)	Avg Power (Watt)	Avg CP
10	13,87	2,09
20	9,15	1,38
30	8,6	1,3
40	12,44	1,88
50	14,08	2,13
60	10,29	1,56

Figure 12. Graph of Simulation Results with a Speed of 3 m/s.

Simulation at a Speed of 4 m/s

The simulation results using a blower with constant speed at a wind speed of 4 m/s are shown in table 3. At a wind speed of 4 m/s it can produce 32 watts to 35 watts of power with a Pressure Coefficient reaching 2 to 2.2. If the simulation results are graphed, they are displayed as shown in Figure 13.

Table 3. Qblade Simulation Results With A Speed Of 4 M/S.

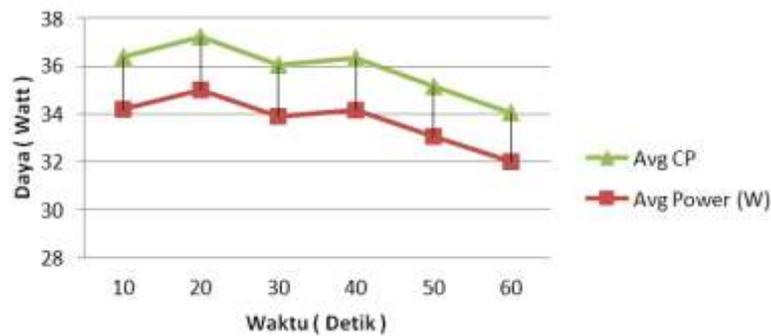| Time (detik)	Avg Power (Watt)	Avg CP
10	34,2	2,18
20	35	2,23
30	33,9	2,16
40	34,16	2,18
50	33,06	2,1
60	32,01	2,04

Figure 13. Graph of simulation results with a speed of 4 m/s.

Simulation at a Speed of 5 m/s

The simulation results using a blower with constant speed at a wind speed of 5 m/s are shown in table 4. At a wind speed of 5 m/s it can produce 69 watts to 103 watts of power with a Pressure Coefficient reaching 2.1 to 3.3. If the simulation results are graphed, they can be seen in Figure 14.

Table 4. Qblade Simulation Results With A Speed Of 5 M/S.

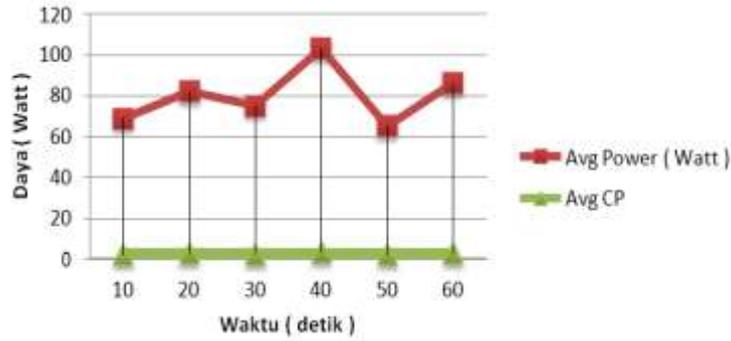| Time (detik)	Avg Power (Watt)	Avg CP
10	69	2,27
20	82,2	2,69
30	75,25	2,46
40	103,2	3,37
50	65,13	2,13
60	86,43	2,82

Figure 14. Graph of Simulation Results with a Speed of 5 m/s.

Prototype Results

Prototype Blade

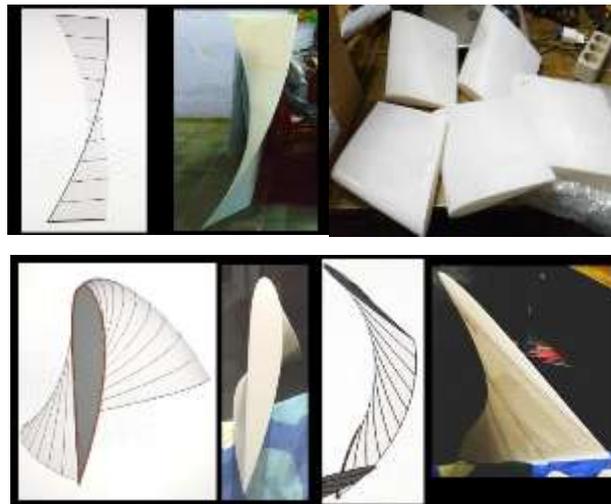The print results using a 3D printer weighing 683 grams on each blade can be seen in Figure 15.

Figure 15. 3D Printed Blade.

Prototype Tower

The final shape when the blade and tower are installed together is seen in Figure 16.

Figure 16. Tower Blade.

Solar Panel Prototype

The final results for the solar panel prototype are shown in Figure 17.

Figure 17. Solar Cell Size.

4. CONCLUSION

The microhybrid generator is capable of working separately, which means that if only one is used it can work or if both can be used simultaneously. If the wind speed is not able to rotate the turbine so that no power is obtained from the turbine, the solar panels can still work as a separate generator so that they can meet the desired power supply. then the turbine will move and produce power so that it gets power according to need. Vertical Axis Wind Turbine with Helix type with 3 blades capable of rotating at low scale speeds and not just centered on one point. Wind speed can affect the RPM of the generator which will affect the power output obtained. Simulation results using Qblade where parameters such as wind speed and radiation values obtained from real time measurements show the average value when the wind speed is 3 m/s is 11.4 Watts and at a wind speed of 4 m/s the average power is 33.7 Watt. Meanwhile, a wind speed of 5 m/s produces an average power of 80.2 watts. With the simulation on Oblade, the final data obtained is to support real time data collection. So the existence of simulations on Oblade further strengthens the final data obtained in this research.

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