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Performance Analysis Vertical-Axis Wind Turbine (VAWT) Turbine Convex Savonius

Basuki Winarno[1], R. Gaguk Pratama Yudha[2], Fredy Susanto[3]
[1, 2, 3]Lecturer of Engineering Technology, Politeknik Negeri Madiun (PNM), Jl. Serayu no 84, Madiun, Indonesia-63133
Email address: {basuki, gaguk, fredy}@pnm.ac.id

Abstract**—***The bayu Power Plant (wind) is one of the potential renewable energy sources to generate electrical energy in the future. Wind power plants are working systems that change wind energy to rotate the generator to produce electricity. Based on the nature of renewable wind energy and the diminishing supply of fossil energy, research and development on the use of renewable energy must be in accordance with the needs of geographical location. The theme developed is the utilization of wind energy to generate electrical energy with the title "Performance Analysis Vertical-Axis Wind Turbine (VAWT) Turbine Convex Savonius". This research focuses on the renewal of the Savonius turbine design by providing additional convex fields on the outer side of the savonius blade. Tests were carried out by comparing the results of the flat savonius turbine rotation with convex savonius which had 3 variations in convex angles, testing was carried out at identical wind speeds from 5m / s to 10m / s. and the most efficient blade shape is at 30 ° with an output of 63 Rpm.*

Keywords**—** *VAWT, Blade Savonius, RPM, Savonius.*

I. Introduction

The Bayu Power Plant (PLTB) is a device that can convert wind kinetic energy into electrical energy, or it can be called a Wind Energy Conversion System. The Bayu Power Plant can be an alternative power plant in addition to non-renewable fossil fuels. Electric Power Plant Bayu can change the kinetic energy of wind into electrical energy because it uses parts that include turbines and generators, as well as power electronic components. Turbine in PLTB functions to convert wind energy into mechanical motion that drives electricity generating generators.

The windmill was first used to generate electricity built by P. La Cour from Denmark in the late 19th century. After World War I, a screen with a cross section resembling a plane's propeller angle is now called a propeller or turbine type windmill. Twin angle windmill experiments were carried out in the United States in 1940, a very large size called the Smith-Putman engine, because it was designed by Palmer Putman, a capacity of 1.25 MW made by Morgen Smith Company of York Pennsylvania. The diameter of the propeller is 175 ft (55m) and weighs 16 tons and the tower is 100 ft (34m) tall. (Astu Pudjanarso, 2006).

The interesting thing about wind energy that needs to be developed is because wind is the use of wind energy does not require advanced processing and does not damage the ecosystem because the use of wind does not require changes in natural ecosystems. The purpose of this study was to determine whether the convex savonius turbine output was better than flat savonius.

Adityo Putranto, Andika Prasetyo, and Arief Zatmiko in their 2011 final report entitled Designing Vertical Wind Turbines for Household Lighting, defines that VAWT has the advantage of being able to capture wind from all directions in the Wind Energy Conversion System. The type of turbine used is savonius which has a simple and easily varied form [1].

In this study, we will design and analyze variations in the shape of the blade, in order to produce the maximum output ratio per minute (Rpm). The angle variations of the blade shape will try to be applied and analyzed the angle that best produces high Rpm.

II. Wind Turbine

Wind Turbines (Windmills) convert wind energy into electrical energy. The way it works is simple; the kinetic energy of wind rotates the turbines into mechanical energy that rotates the rotors in the generator of the power plant. This rotation of the rotor produces electrical energy that is utilized.

a) Blade

The research conducted by Adi putranto et al. (2011). Blade is a plate that is formed in such a way in accordance with the design so that it can capture maximum wind energy. The formula used in determining blade size is as follows: The design of this turbine is expected to produce a rotation (n) 50 rpm, at wind speed (v) 5 m / s, with a power of 80 Watts for the number of turbines (Y) 4 in each circuit turbine.

1. *Determine top speed ratio*

$$\lambda_1 = \frac{\pi \times D \times n}{60 \times V} \tag{1}$$

$$\lambda_1 = \frac{3.14 \times 1.5 \times 50}{60 \times 5} = 0.785$$

(Eric Hau, *Wind Turbines Fundamentals* 2005:94)

2. *Koefisien Rotor (Cpr)*
3. *Total cross section (A)*
4. *Diameter Blade (d)*

$$Cpr = \lambda_1 \times Cq_2 \tag{2}$$

$$Cq_2 = \frac{2}{0.785} \times 0.15 = 0.38$$

$$Cpr = \lambda \times Cq_2$$

$$Cpr = 0.785 \times 0.38 = 0.29$$

(Eric Hau, *Wind Turbines Fundamentals* 2005:94)

$$A = \frac{2p}{Cpr \times \rho \times V^3} \tag{3}$$

$$A = \frac{2 \times 80}{0.29 \times 1.2 \times 5^3} = 3.6m^2$$

(Eric Hau, *Wind Turbines Fundamentals* 2005:94)

$$d = \frac{2A}{y \times \pi \times L} \tag{4}$$

$$d = \frac{2 \times 3.6}{4 \times 3.14 \times 0.9} = \frac{7.2}{11.3} = 0.63m$$

(Eric Hau, *Wind Turbines Fundamentals* 2005:94)

$$T = \left(Tan\theta X \frac{1}{2} L \right) \tag{5}$$

1) Student 15^o

$$T = \left(Tan\theta X \frac{1}{2} L \right)$$

$$T = \left(Tan15^o X \frac{1}{2} 0.9 \right) = 12cm$$

2) Student 30^o

$$T = \left(Tan\theta X \frac{1}{2} L \right)$$

$$T = \left(Tan30^o X \frac{1}{2} 0.9 \right) = 26cm$$

3) Student 45^o

$$T = \left(Tan\theta X \frac{1}{2} L \right)$$

$$T = \left(Tan45^o X \frac{1}{2} 0.9 \right) = 45cm$$

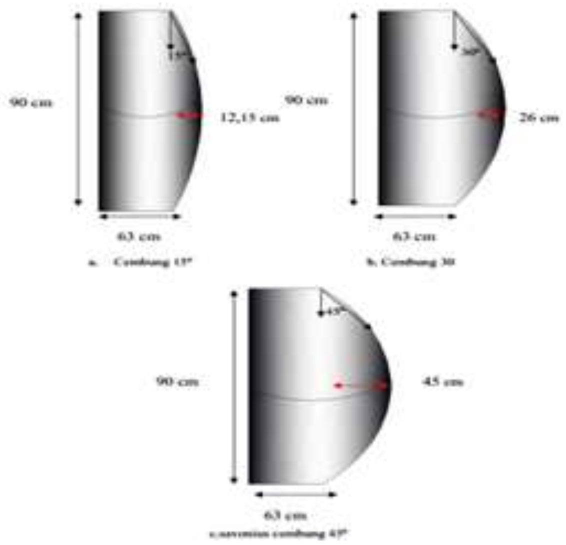

Fig. 1. Blade savonius.

III. MAIN SHAFT AND GEAR

Area of Total Crossing The main shaft of the turbine functions as a blade support and connecting bearings. In systematics, the main shaft functions to connect the mechanical rotation of the blade due to wind rotation. The mechanical motion by the blade by the main shaft towards rotates the gear to drive the generator. The main shaft is made of iron pipe with a size of ¾ that is connected to the bearing.

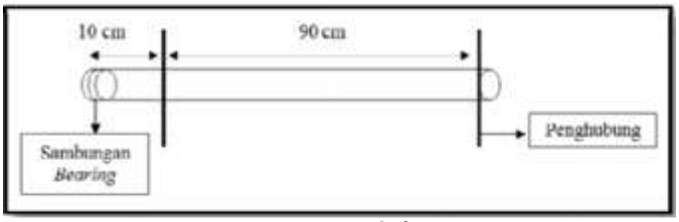

Fig. 2. Main shaft.

Gear is made of low carbon steel material, the gear functions as the successor of the power from the wind turbine to the generator. Gear is used to accelerate the rotation of the turbine on the generator. Used in 2 gears, 1 large gear is mounted on the turbine shaft, while 1 small gear is mounted on the rotor shaft.

The connector is the part of the turbine that is one with the main shaft. At the end of the connector bars will be installed. Bars serve as a place for mounting blades on the main shaft. The connector is made of iron plate measuring 40 x 40 cm and 3 mm thick. Bars are made of elbow iron with a length of 1 meter and are formed in such a way according to the design.

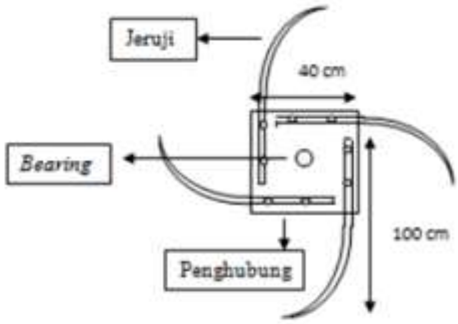

Fig. 3. Blade connector.

IV. RESULTS AND ANALYSIS

The method carried out during testing is a practical method. Practical methods are carried out. Turbines will be tested with artificial conditions that are close to natural conditions. The use of artificial conditions aims to facilitate observation of results. To reach the intended destination, the test is carried out by using a Blower (Fan). Artificial conditions are designed in the workshop room at the Madiun State Polytechnic, the wind that is used as the driving energy source for turbines is generated from electric fans (blowers). The use of a blower is placed in a predetermined position so that the wind spreads and the speed is appropriate.

A. Turbine Rotation Test Data

Data that has been obtained from the next test results will be compared with each other in order to find differences in the characteristics of each type of blade. Data is equipped with the voltage generated by the generator. Data is presented in graphical form.

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TABLE 1. Comparison of turns on 5 m / s winds is loaded.

Jenis Turbin	Kecepatan Putaran Turbin (Rpm)						
	Detik 10	Menit 5	Menit 10	Menit 15	Menit 20	Menit 25	Menit 30
Datar	11	25	25	23	26	24	29
Cembung 15°	12	34	36	36	38	36	35
Cembung 30°	11	33	38	42	43	40	41
Cembung 45°	11	33	35	28	34	35	34

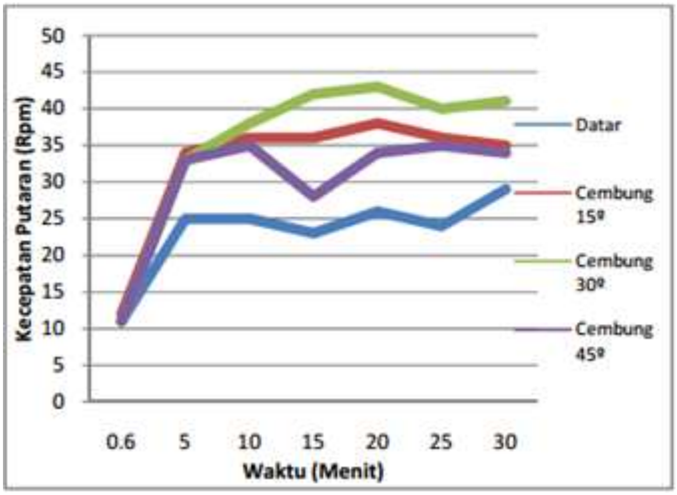

Fig. 4. Graph the turbine rotation ratio at wind speed 5 m / s loaded.

At low speeds (5m / s) with the generator load the initial rotation of the turbine is very slow. Acceleration of all types of turbines at 11-12 Rpm rotation speed. After the generator in steadystate conditions the rotation begins to increase with a convex savonius sequence of 30º, convex savonius 15º and 45º with balanced results, and flat savonius has the lowest round.

TABLE 2. Comparison of turns on 6 m / s winds is loaded.

Jenis Turbin	Kecepatan Putaran Turbin (Rpm)						
	Detik 10	Menit 5	Menit 10	Menit 15	Menit 20	Menit 25	Menit 30
Datar	13	24	26	28	25	29	31
Cembung 15°	12	35	34	37	33	37	36
Cembung 30°	12	38	37	37	40	41	43
Cembung 45°	13	34	31	33	37	35	36

At low speeds (6 m / s) with the generator load the initial rotation of the turbine is very slow. Acceleration of all types of turbines at a rotation speed below 15 Rpm. After the generator in steadystate conditions the rotation begins to increase with a convex savonius sequence of 30º, convex savonius 15º and 45º with balanced results, and flat savonius has the lowest round.

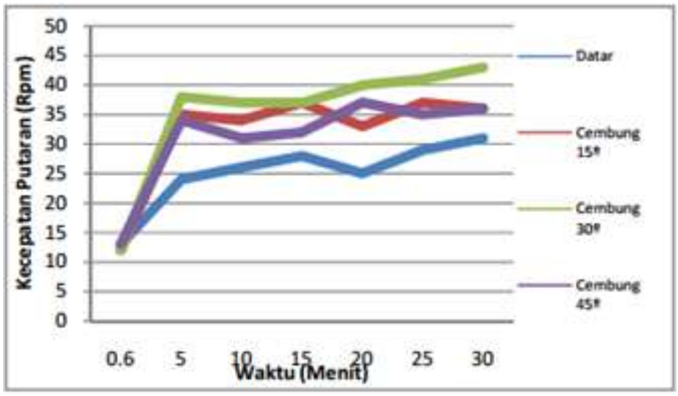

Fig. 5. Graph the turbine rotation ratio at wind speed 6 m / s loaded.

TABLE 3. Comparison of turns on 7 m / s winds is loaded.

Jenis Turbin	Kecepatan Putaran Turbin (Rpm)						
	Detik 10	Menit 5	Menit 10	Menit 15	Menit 20	Menit 25	Menit 30
Datar	13	27	29	25	27	30	30
Cembung 15°	13	35	37	33	34	36	39
Cembung 30°	12	40	42	46	47	43	46
Cembung 45°	12	32	35	36	33	34	37

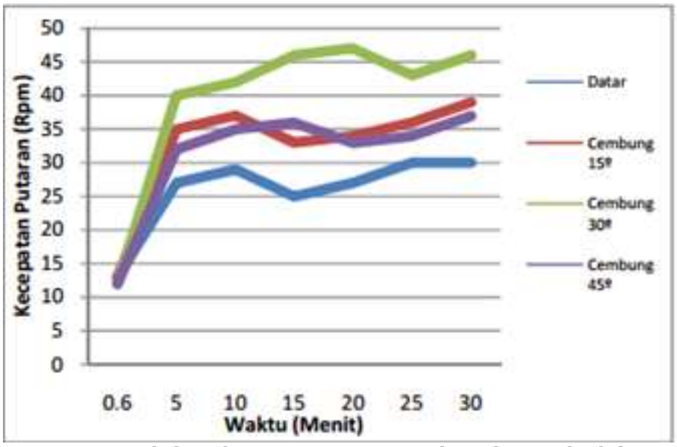

Fig. 6. Graph the turbine rotation ratio at wind speed 7 m / s loaded.

Based on Figure 6 with the generator load, the initial rotation of the turbine is very slow. The rotation speed of the turbine after the steadystate generator in the 5th minute increases with the convex 30º savonius turbine producing the highest rotation. While the flat savonius turbine produces the lowest round.

TABLE 4. Comparison of turns on 10 m / s winds is loaded.

Jenis Turbin	Kecepatan Putaran Turbin (Rpm)						
	Detik 10	Menit 5	Menit 10	Menit 15	Menit 20	Menit 25	Menit 30
Datar	14	29	30	28	31	30	35
Cembung 15°	15	36	38	37	40	38	42
Cembung 30°	14	46	44	41	45	42	48
Cembung 45°	14	36	37	34	44	38	41

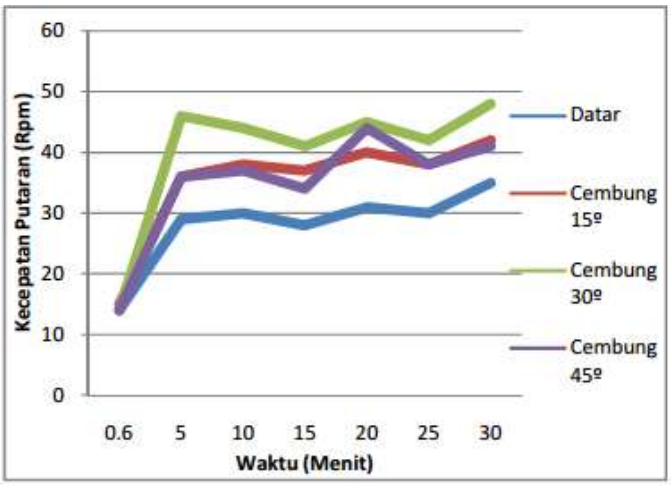

Fig. 7. Graph the turbine rotation ratio at wind speed 10 m / s loaded.

At 10 m / s wind speed the turbine loaded with generator generates the initial low speed due to the generator load, while the condition of the steady state turbine generator results in increased rotation. A convex 30º savonius turbine spins an average of 40 Rpm, a convex 15º and 45º savonius turbine produces an average rotation of 35 Rpm and an average flat savonius of 30 Rpm.

V. CONCLUSION

Based on the testing and analysis of the tests that have been carried out, the conclusions can be taken as follows:

1) Convex savonius turbine design with the highest average rotation speed was obtained at convex 30º savonius turbine at 63 Rpm rotation with an error value of 26% compared to the calculation result rotation.
2) The convex savonius turbine has the characteristic of a linear rotation increase, then with the details of the 30º convex savonius turbine it is a turbine that has the highest initial and final rotation speed. The 45º convex savonius turbine is the turbine with the most linear rotation acceleration at all testing wind speeds. Flat savonius turbines (conventional) have high acceleration but the rotation speed drops at the steady state point.

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