Experimental study the performance of a 6-bladed Savonius vertical axis wind turbine using polyvinyl chloride material

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ABSTRACT

The Savonius U type wind turbine is a vertical axis turbine that can operate at low wind speeds. In general, the performance of this turbine is influenced by several factors, one of which is the shape of the turbine blade. This research aims to test the design results of a 6 blade Savonius turbine with a blade length of 50 cm made from polyvinyl chloride (PVC) by varying the dimensions of the blade diameter. The variables that vary between blade length and blade diameter are D/L=0.10, D/L=0.13, D/L=0.18, and D/L=0.20. The aim of this research is to determine the effect of variations in the parameters above on turbine rotation and the electrical power produced in a direct current (DC) generator at each variation in wind speed. From the research results, it is known that the trend graph of the relationship between turbine rotation and wind speed has a linear correlation. In simple terms, this turbine can be applied to DC voltage loads such as lighting using light emitting diode (LED) lamps with a maximum power capacity of ± 16 watts, while the overall efficiency (OE) is 50.25%.

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1. INTRODUCTION

The utilization of renewable energy that currently has great potential to be developed is wind energy. Wind energy sources to produce electrical energy are not new, but the electrical energy produced is certainly very limited due to several such as the potential of local wind speed and energy conversion equipment that has not been effective [1]. Indonesia has a potential wind energy source of about 9.29 giga watt (GW), but the total installed capacity for wind power (WP) generation is still 1.6 mega watt (MW). Equipment systems that utilize wind energy in Indonesia are still relatively low, but actually have great potential, namely the main cause of the lack of utilization of wind energy in the Indonesian region due to low wind speeds, which range from 3 m/s to 5 m/s making it difficult to produce electrical energy on a large scale [2]. While the potential for wind in Indonesia is available almost all year round, making it possible to develop small-scale power generation systems with innovation in modifying windmills needs to be developed so that in low wind speed conditions can produce electrical energy [3].

There are many types of wind turbine designs, based on the shape of the rotor/turbine wheel, wind turbines are divided into two types, namely horizontal axis wind turbines and vertical axis wind turbines

(VAWT) [4]. The VAWT has three rotor models namely; i) Savonius, ii) Darrieus, and iii) H rotor. Savonius turbines utilize drag forces while Darrieus and H rotors utilize lift forces [5]. The Savonius turbine was invented by a Finnish scholar named Sigurd J. Savonius in 1922, with its simple turbine construction and composed of two half-cylindrical blades. One of the best-designed VAWT models that uses a combination of drag and lift to generate power, thus having excellent startup torque and efficiency is the Lenz model [6].

Previous research has tested the Lenz II model vertical axis windmill prototype with 3 blades [7]. The results of this study found that the generator output voltage without load at the generator rotor rotation speed of 210 rpm to 500 rpm produced an output voltage of 6 volts to 14.8 volts [8]. On the other hand, the rotation of the generator rotor at 365 rpm to 480 rpm can produce an electric voltage of 12.2 volts to 14.8 volts and an electric current of 1.73 ampere (A) to 3.1 A [9], while testing the 4-bladed Savonius turbine with variations of cover and without cover. This study aims to determine blade rotation, output power (OP), and tip speed ratio (TSR) of open and closed Savonius blades. From the results, it is known that the open Savonius blade is more effective in absorbing wind energy, where this model produces a rotation of 35.4 rpm at a wind speed of 2.5 m/s, 39.8 rpm at a wind speed of 2.6 m/s and 54.2 rpm at a wind speed of 3 m/s.

The open Savonius blade produces a TSR that is greater than the closed Savonius, namely 0.63 with a wind speed of 2.5 m/s, 0.68 with a wind speed of 2.6 m/s, and 0.80 TSR at a wind speed of 3 m/s [10]. VAWT are very suitable for use as alternative power plants in areas that have low to moderate wind speeds [11]. Effect of wind speed and blade angle on performance of twelve blade Savonius type vertical shaft wind turbine. The results of this study focus on the effect of wind speed and loading on the performance of 12 blade Savonius type vertical shaft wind turbines. In the variation of blade angles, namely -5°, 0°, 5°, and 10°, it shows that the best performance, power efficiency occurs at a blade angle of 5 degrees, with a wind speed of 3.4 m/s [12].

Regarding the effect of the number of blades on the performance of the Savonius turbine, it is found that turbines with 3 and 4 blades turbine blades produce a small rotation but a greater torque force than with 2 blades. In the use of turbines with 3 blades produces greater rotation than turbines with 4 blades and has a torque that tends to be the same [13]. In research that has been done before, the type of wind turbine that will be designed and tested is a wind turbine with a vertical shaft Savonius type U semicircle 6 blades made of PVC by varying the blade length/blade and blade diameter in order to determine the rotation of the turbine shaft and the performance of the output voltage of the DC generator [14].

In this study, the design of a wind turbine with a semi-circular U-type Savonius vertical shaft of 6 blades made of PVC, by varying the blade length and blade diameter, will be tested with several examples of wind speed to determine the rotation of the turbine shaft and the voltage output performance of the DC generator. The independent variable that is the focus of observation is the variation of blade length and blade diameter that is varied is 600 mm, 500 mm, and 400 mm. While the diameter of the blade that is varied at each blade length is 50 mm, 64 mm, 88 mm and 100 mm. The electrical power released by the generator and the overall efficiency (OE) were highest at the blade dimension variation D/L=0.17 with the wind speed at 4.4 m/s, this blade dimension is considered the most effective.

2. METHOD

The design of the vertical wind turbine semicircular U model with variations in blade dimensions, vertical wind turbine manufacturing, tool set up, and testing/data collection, design model, turbine manufacturing design in this study [15] as in Figure 1. In Figure 1 this type of turbine generally moves slowly compared to horizontal axis wind turbines. However, this type of turbine produces considerable torque when compared to horizontal axis wind turbines. Rotors that work under the influence of drag forces generally have a large initial torque but have a smaller efficiency when compared to rotors that work with lift forces.

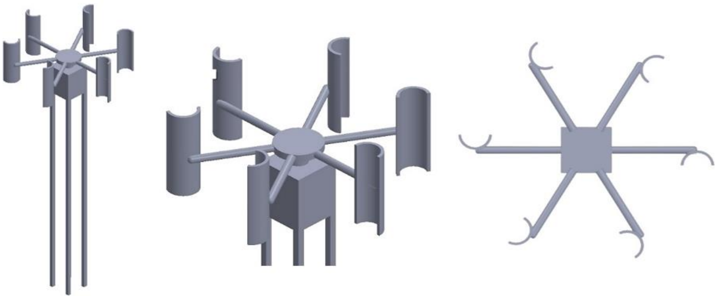

Figure 1. Turbine design model

Testing in this study uses three variables, namely: i) independent variables which are variations in blade length of 600 mm, 500 mm, and 400 mm, while the diameter of the blade that is varied at each blade length is 50 mm, 64 mm, 88 mm, and 100 mm as in Figure 1, ii) dependent variables which are factors that are observed and measured to see the influence of the independent variable, namely wind power (Pw), TSR, generator electrical power (Pg) and OE (η), and iii) control variables are variables that can be controlled so that the influence of the independent variable on the dependent variable is not influenced by other factors not included in the study, namely data collection time at 14.00-17.00 WIB, wind speed data collection that will be included in the test is in the range of 2.2-4.5 m/s (local wind conditions), fixed blade/blade length of 50 cm and constant load resistance of 98 ohms and the test tower height is 4 meters.

The generator is the most important component in the wind turbine system, where its function is to convert the rotary motion (mechanical) energy on the drive shaft into electrical energy. The voltage and electric current produced by the generator can be alternating current (AC) or direct current (DC) and the output voltage can be from low voltage (12 volts) or up to a voltage of 680 volts or more, in this study the generator used is a DC generator. As for knowing the electrical parameters that come out of the DC generator in Figure 2, it is measured directly using a voltmeter and ampmeter [16]. In Figure 2 is a DC generator specification with length=18 cm, diameter=11.2 cm, output shaft diameter=2.5 cm/25 mm, mounting length 20 cm, mounting dimensions 19×8.5×11.5 cm and thickness of iron mounting plate 2 mm, while the technical specifications are strong current (I) 0 A (no load) and rotated at a speed of 836 rpm, then the output voltage of 163 Vdc. If the generator is installed with a load of 1 A (nickel wire), the speed will drop to 333 rpm, the voltage will drop to 18.8 Vdc and if a load of 1 A is installed, there will be a speed drop of ±40% [17].

Figure 2. DC generator

2.1. Dimension of blades

The blade dimensions cause changes in the physical and mechanical characteristics of the blade so the blade characteristics are considered as dependent variables in this study: i) blade mass, ii) stress in the main body of the blade, iii) stress in the blade root and connecting parts, iv) deformation, and v) strain. With the rotational speed of wind turbine blades with lower mass it is always desirable to design parts with low induced stress, less deformation, and minimum weight, hence these characteristics are studied and discussed so dimensions also affect other characteristics such as initial behavior of rotor, flange mass, rotor mass, blade cost, flange cost, and blade life which have not been studied and hence not included in the scope of this research paper. Is a slab construction with a certain shape and cross section, water as a working fluida flows through the space between the blades, thus the turbine wheel will be able to rotate and, on its blade, there will be an acting force [18].

2.2. U-type Savonius turbine

The U-type Savonius wind turbine is one of the wind turbines suitable for areas with low-speed wind potential, one part of the turbine is the blade that serves to capture the wind, so for different wind speed areas different wind turbine designs are needed. In converting wind kinetic energy to turn into electrical energy through a very sequential work system process between the components of the turbine with each other, in a U-type Savonius wind turbine work system can be explained, namely wind gust energy produces wind speeds that vary at any time. It is a wind turbine suitable for development in areas with low wind speeds with a u-type horizontal axis Savonius wind turbine design for low wind speeds with a drag-type device consisting of two or three vertical-half-cylindrical blades with two blades like the shape of the letter S [19].

2.3. Electric power

Electric power is the ability of an electrical equipment to do business due to changes in work and changes in electric charge per unit time, the ability is intended for an electrical equipment to do work due to changes in work and changes in electric charge per unit time. With the amount of electrical power carried out by electrical equipment is influenced by the presence of electric voltage, electric current strength, and electrical resistance in a closed electrical circuit, as well as its state from time to time based on the amount of electrical power that determines the amount of electrical power required by electrical equipment to work optimally which shows the amount of energy required by electrical equipment to be able to work per unit time [20]. The energy generated during the fault is stored in the supercapacitor energy storage system, which allows the generator to remain functional for a period of time, even if it is disconnected from the power grid, in this way the normal fault clearing process can be performed shortly after reconnection, the generator can supply power to the grid, ensuring the reliability of the power system.

2.4. Variables and testing formulas

Is an air movement that occurs due to differences in air pressure in high air pressure areas to areas that have low air pressure and one of the renewable energies that can be utilized as WP [21], as (1) to (4):

$$Wind\ Power\ (P_w = \frac{1}{2}\rho A v^2) \tag{1}$$

$$Tip\ Speed\ Ratio\ (TSR = \frac{\pi D n}{60 v}) \tag{2}$$

$$Output\ Power\ (P_g = V.I) \tag{3}$$

$$Overall\ Efficiency\ (\eta = \frac{P_g}{P_w} x100\%) \tag{4}$$

3. RESULTS AND DISCUSSION

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily. The discussion can be made in several sub-sections.

3.1. Training data

Width is the distance from one side to the other measured at a perpendicular angle, while height is the vertical distance of an object with the dimensions of length can be recognized by its symbol, namely length (L) and dimension (D) is the distance from one side to the other, measured at an angle perpendicular to the length of the object which states the distance between vertical ends and width. In this study, the D/L discussed is the dimension and length of the blade. In Table 1 the test dataset to get an analysis of wind speed and rotation against wind speed will affect the voltage generated, so this test requires the number of blades for each area is 0.150, 0.192, 0.264, and 0.300. The training data [22] used in this research is using dependent variables including WP, TSR, generator OP and OE with four training datasets based on air density D/L=0.10, D/L=0.13, D/L=0.18, and D/L=0.20.

Table 1. Dataset training

Dimension of blade	Wind speed, v (m/s)	Shaft rotation, n (rpm)	DC voltage (volts)	Number of 6 blades area
D/L=0.10	4.4	28.11	18.10	0.150
(L=500 mm. D=50 mm)	4.0	26.88	15.49	
	3.9	25.65	12.97	
	3.8	24.42	10.54	
D/L=0.13	4.3	29.33	20.10	0.192
(L=500 mm. D=54 mm)	4.0	27.33	16.96	
	3.8	26.06	14.36	
	3.7	25.12	12.01	
D/L=0.18	4.4	34.54	24.96	0.264
(L=500 mm. D=88 mm)	4.0	33.12	20.25	
	3.9	32.65	19.08	
	3.8	32.17	18.25	
D/L=0.20	4.3	33.96	22.45	0.300
(L=500 mm. D=100 mm)	4.0	31.93	19.88	
	3.8	31.07	18.14	
	3.7	30.65	17.21	

3.2. Testing data

The testing data [23] used in this study is to use dependent variables including WP, TSR, generator OP and OE with four testing data based on with reference to D/L=0.10, D/L=0.13. D/L=0.18 and D/L=0.20, then the following calculation can be done:

3.2.1. Wind power

Is an air movement that occurs due to differences in air pressure in high air pressure areas to areas that have low air pressure and one of the renewable energies that can be utilized as WP [24], as (5):

$$P_w = \frac{1}{2}\rho A v^2 \tag{5}$$

L=500 mm; D=50 mm (D/L=0.10)

$P_{w1} = 0.5 * 1.125 * (4.4 * 4.4 * 4.4) = 7.2$
$P_{w2} = 0.5 * 1.125 * (4.0 * 4.0 * 4.0) = 5.4$
$P_{w3} = 0.5 * 1.125 * (3.9 * 3.9 * 3.9) = 5.0$
$P_{w4} = 0.5 * 1.125 * (3.8 * 3.8 * 3.8) = 4.6$

L=500 mm; D=64 mm (D/L=0.13)

$P_{w1} = 0.5 * 0.192 * (4.3 * 4.3 * 4.3) = 8.6$
$P_{w2} = 0.5 * 0.192 * (4.0 * 4.0 * 4.0) = 6.9$
$P_{w3} = 0.5 * 0.192 * (3.8 * 3.8 * 3.8) = 5.9$
$P_{w4} = 0.5 * 0.192 * (3.7 * 3.7 * 3.7) = 5.5$

L=500 mm; D=88 mm (D/L=0.18)

$P_{w1} = 0.5 * 0.264 * (4.4 * 4.4 * 4.4) = 12.6$
$P_{w2} = 0.5 * 0.264 * (4.0 * 4.0 * 4.0) = 9.5$
$P_{w3} = 0.5 * 0.264 * (3.9 * 3.9 * 3.9) = 8.8$
$P_{w4} = 0.5 * 0.264 * (3.8 * 3.8 * 3.8) = 8.1$

L=500 mm; D=100 mm (D/L=0.20)

$P_{w1} = 0.5 * 0.300 * (4.4 * 4.4 * 4.4) = 13.4$
$P_{w2} = 0.5 * 0.300 * (4.0 * 4.0 * 4.0) = 10.8$
$P_{w3} = 0.5 * 0.300 * (3.8 * 3.8 * 3.8) = 9.3$
$P_{w4} = 0.5 * 0.300 * (3.8 * 3.8 * 3.8) = 8.5$

3.2.2. Tip speed ratio

Is a comparison of wind speed with the tip speed of the blade, the higher the TSR, it will affect the value and shape of the blade by comparing the linear velocity of the tip of the rotor corners with the wind speed [25], this can be proven as (6):

$$TSR = \frac{\pi D n}{60 v} \tag{6}$$

L=500 mm; D=50 mm (D/L=0.10)

$$TSR1 = \frac{3.14 * 1 * 28.11}{(60 * 4.4)} = 0.334$$
$$TSR2 = \frac{3.14 * 1 * 28.11}{(60 * 4.0)} = 0.352$$
$$TSR3 = \frac{3.14 * 1 * 28.11}{(60 * 3.9)} = 0.344$$
$$TSR4 = \frac{3.14 * 1 * 24.42}{(60 * 3.8)} = 0.336$$

L=500 mm; D=64 mm (D/L=0.13)

$$TSR1 = \frac{3.14 * 1 * 29.33}{(60 * 4.3)} = 0.357$$
$$TSR2 = \frac{3.14 * 1 * 27.33}{(60 * 4.0)} = 0.358$$
$$TSR3 = \frac{3.14 * 1 * 26.06}{(60 * 3.8)} = 0.359$$
$$TSR4 = \frac{3.14 * 1 * 25.12}{(60 * 3.7)} = 0.355$$

L=500 mm; D=88 mm (D/L=0.18)

$$TSR1 = \frac{3.14 * 1 * 34.54}{(60 * 4.4)} = 0.411$$

$$TSR2 = \frac{3.14 * 1 * 33.12}{(60 * 4.0)} = 0.433$$

$$TSR3 = \frac{3.14 * 1 * 32.65}{(60 * 3.9)} = 0.438$$

$$TSR4 = \frac{3.14 * 1 * 32.17}{(60 * 3.8)} = 0.443$$

L=500 mm; D=100 mm (D/L=0.20)

$$TSR1 = \frac{3.14 * 1 * 33.96}{(60 * 4.4)} = 0.413$$

$$TSR2 = \frac{3.14 * 1 * 31.93}{(60 * 4.0)} = 0.418$$

$$TSR3 = \frac{3.14 * 1 * 31.07}{(60 * 3.8)} = 0.428$$

$$TSR4 = \frac{3.14 * 1 * 30.65}{(60 * 3.7)} = 0.434$$

3.2.3. Output power

Is the amount of energy absorbed or generated in a circuit from an energy source such as an electric voltage will produce electrical power while the load connected to it will absorb the electrical power [26], the equation formula is as (7):

$$P_g = V.I \tag{7}$$

L=500 mm; D=50 mm (D/L=0.10)

$P_{g1} = 18.10 * 0.18 = 3.34$
$P_{g2} = 15.49 * 0.16 = 2.45$
$P_{g3} = 12.97 * 0.13 = 1.72$
$P_{g4} = 10.54 * 0.11 = 1.13$

L=500 mm; D=64 mm (D/L=0.13)

$P_{g1} = 20.10 * 0.21 = 4.12$
$P_{g2} = 16.96 * 0.17 = 2.93$
$P_{g3} = 14.36 * 0.15 = 2.10$
$P_{g4} = 12.01 * 0.12 = 1.47$

L=500 mm; D=88 mm (D/L=0.18)

$P_{g1} = 24.96 * 0.25 = 6.36$
$P_{g2} = 20.25 * 0.21 = 4.18$
$P_{g3} = 19.08 * 0.19 = 3.71$
$P_{g4} = 18.25 * 0.19 = 3.40$

L=500 mm; D=100 mm (D/L=0.20)

$P_{g1} = 22.45 * 0.23 = 38.33$
$P_{g2} = 19.88 * 0.20 = 37.34$
$P_{g3} = 18.14 * 0.19 = 26.26$
$P_{g4} = 17.21 * 0.18 = 35.36$

3.2.4. Overall efficiency

Is the efficiency of electrical power in an effort that can be done in reducing the use of electrical power efficiently in running something by not wasting time, energy and costs [27], the equation formula is as (8):

$$\eta = \frac{P_g}{P_w} x100\% \tag{8}$$

L=500 mm; D=50 mm (D/L=0.10)

$$\eta 1 = \frac{3.34}{7.2} x100\% = 46.51$$
$$\eta 2 = \frac{2.45}{5.4} x100\% = 45.35$$
$$\eta 3 = \frac{1.72}{5.0} x100\% = 34.2$$
$$\eta 4 = \frac{1.13}{4.6} x100\% = 24.48$$

L=500 mm; D=64 mm (D/L=0.13)

$$\eta 1 = \frac{4.12}{8.6} x100\% = 48.01$$
$$\eta 2 = \frac{2.93}{6.9} x100\% = 42.46$$
$$\eta 3 = \frac{2.10}{5.9} x100\% = 35.50$$
$$\eta 4 = \frac{1.47}{5.5} x100\% = 26.90$$

L=500 mm; D=88 mm (D/L=0.18)

$$\eta 1 = \frac{6.36}{12.6} x100\% = 50.25$$
$$\eta 2 = \frac{4.18}{9.5} x100\% = 44.03$$
$$\eta 3 = \frac{3.71}{8.8} x100\% = 42.17$$
$$\eta 4 = \frac{3.40}{8.1} x100\% = 41.71$$

L=500 mm; D=100 mm (D/L=0.20)

$$\eta 1 = \frac{5.14}{13.4} x100\% = 38.33$$
$$\eta 2 = \frac{4.03}{10.8} x100\% = 37.34$$
$$\eta 3 = \frac{3.36}{9.3} x100\% = 36.26$$
$$\eta 4 = \frac{3.02}{8.5} x100\% = 35.36$$

Table 2 is a recapitulation of the results of the calculation of the blade dimensions with the test results that have been carried out previously, in the blade dimensions section the respective values are DL=0.10, DL=0.13, DL=0.18, and DL-0.20, while the average OE value is DL=0.10 average values 37.66%, DL=0.13 average values 38.22%, DL 0.18 average values 44.54% and DL=0.20 average values 36.82%. Figure 3 shows that the greater the wind speed that hits the blade. the smaller the TSR produced. The relationship between wind speed and TSR on the blade is related to the drag force that occurs. The lower the wind speed, the greater the drag force generated. But in detail, the drag force variable is not analyzed in this test. From the test results the blade dimension with the variation of D/L=0.18 has a greater TSR than the others with a value of 0.44 at a wind speed of 3.8 m/s.

If you look at the data at D/L=0.20 which has a larger blade area (A), it will produce a much smaller TSR due to the absorption of more wind energy, resulting in a greater drag force and making it more efficient. However, this is not the case when influenced by the weight of the blade which is getting heavier, it can result in the rotation produced also decreasing so that the heavy load greatly decreases the energy produced even at a wind speed of 3.7 m/s as shown in Figure 4. Figure 5 highest generator OP is 6.36 watts at D/L=0.18 with a wind speed of 4.4 m/s and a constant load resistance of 98 ohms this OP becomes large because it is influenced by the voltage and current obtained through high turbine rotation while the highest OE is also owned by this type of blade dimension variation D/L=0.18 has an efficiency of 50.25% at a wind speed of 4.4 m/s. This happens because the generator OP increases even though the absorbed WP is low compared to the blade dimension D/L=0.20. The phenomenon that occurs at blade dimension D/L=0.18 shows a good efficiency concept. where the generator has a large OP when the WP is low.

Table 2. Recapitulation the calculation results of variable dimensions and blades

Blades of dimension	Wind speed, v (m/s)	Shaft rotation, n (rpm)	DC voltage, V (volts)	Current, I (A)	Load resistance (ohms)	WP. Pw (watt)	TSR	OP. Pg (watt)	OE (η)
0.10	4.4	28.11	18.10	0.18	98.0	7.2	0.334	3.34	46.51
	4.0	26.88	15.49	0.16	98.0	5.4	0.352	2.45	45.35
	3.9	25.65	12.97	0.13	98.0	5.0	0.344	1.72	34.29
	3.8	24.42	10.54	0.11	98.0	4.6	0.336	1.13	24.48
0.13	4.3	29.33	20.10	0.21	98.0	8.6	0.357	4.12	48.01
	4.0	27.33	16.96	0.17	98.0	6.9	0.358	2.93	42.46
	3.8	26.06	14.36	0.15	98.0	5.9	0.359	2.10	35.50
	3.7	25.12	12.01	0.12	98.0	5.5	0.355	1.47	26.90
0.18	4.4	34.54	24.96	0.25	98.0	12.6	0.411	6.36	50.25
	4.0	33.12	20.25	0.21	98.0	9.5	0.433	4.18	44.03
	3.9	32.65	19.08	0.19	98.0	8.8	0.438	3.71	42.17
	3.8	32.17	18.25	0.19	98.0	8.1	0.443	3.40	41.71
0.20	4.3	33.96	22.45	0.23	98.0	13.4	0.413	5.14	38.33
	4.0	31.93	19.88	0.20	98.0	10.8	0.418	4.03	37.34
	3.8	31.07	18.14	0.19	98.0	9.3	0.428	3.36	36.26
	3.7	30.65	17.21	0.18	98.0	8.5	0.434	3.02	35.36

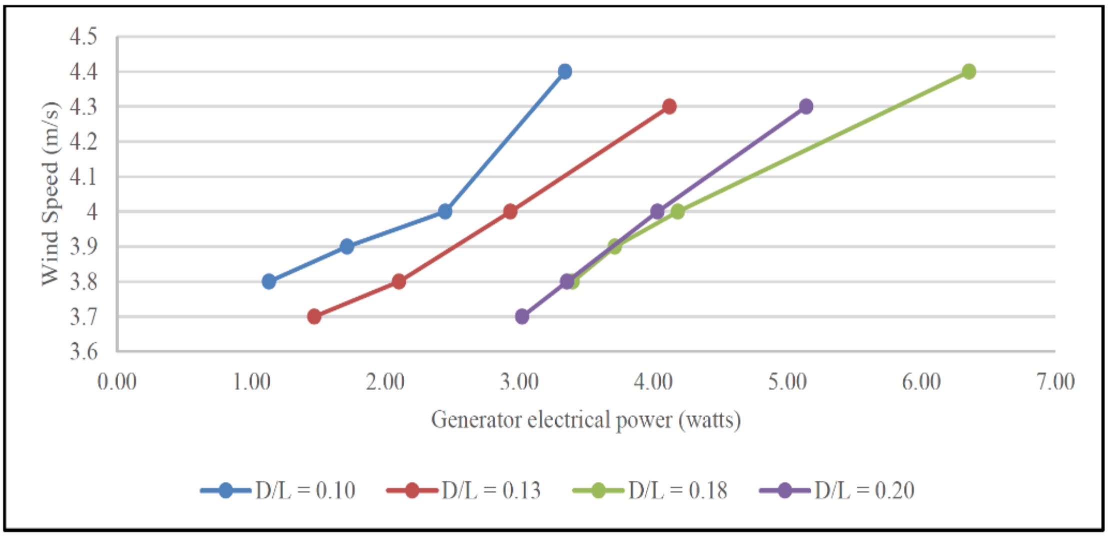

Figure 3. Graph of wind speed and generator electrical power relationship

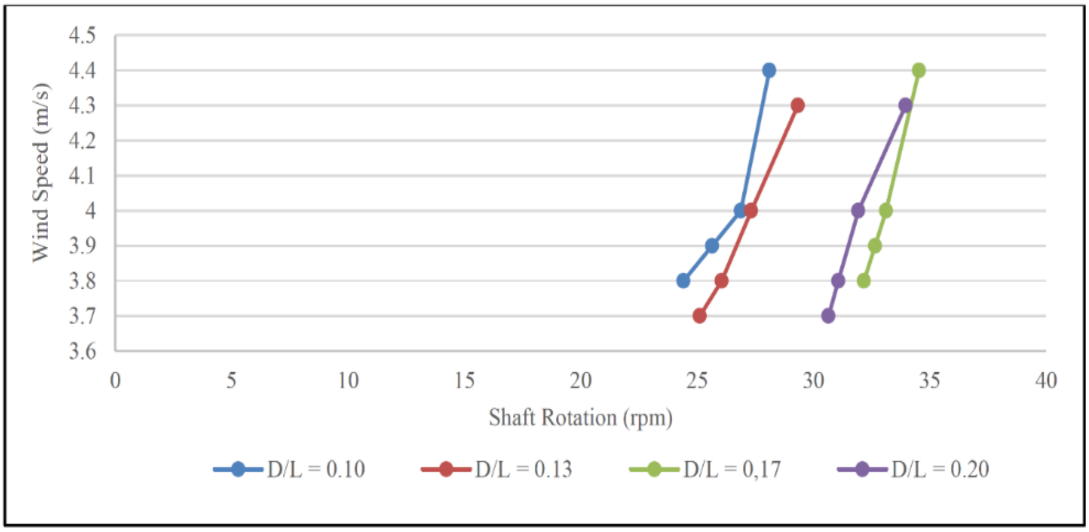

Figure 4. Graph of the relationship between wind speed and shaft rotation

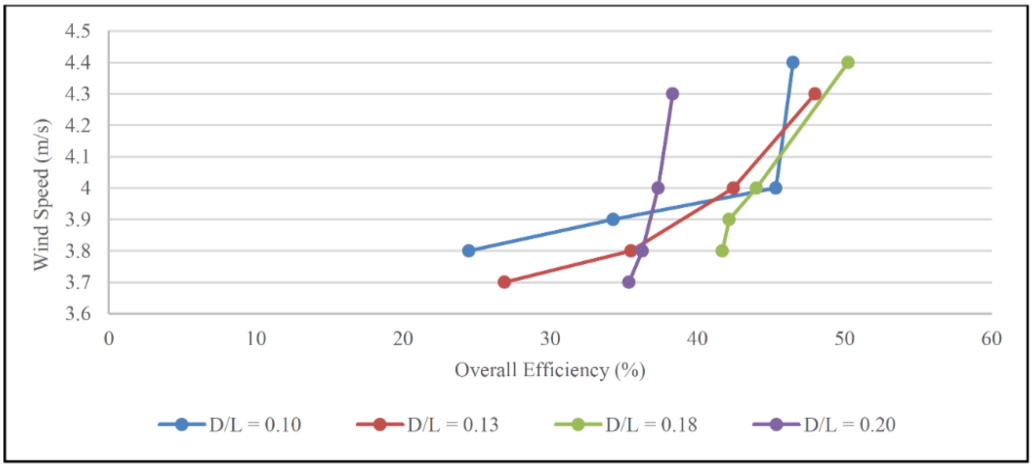

Figure 5. Graph of wind speed and OE relationship

Figure 6 in another analysis related to the electrical output issued by the generator the blade dimension at D/L=0.18 is known to have the largest DC voltage output compared to the others which is 24.96 V as shown in the graph in Figure 6. The magnitude of this voltage is certainly influenced by the rotation of the turbine shaft. because the higher the rotation of the shaft which is influenced by wind speed, the greater the voltage released. Because of that to see the effective blade dimension variation the loading resistance (resistance) is made constant at 98 ohms.

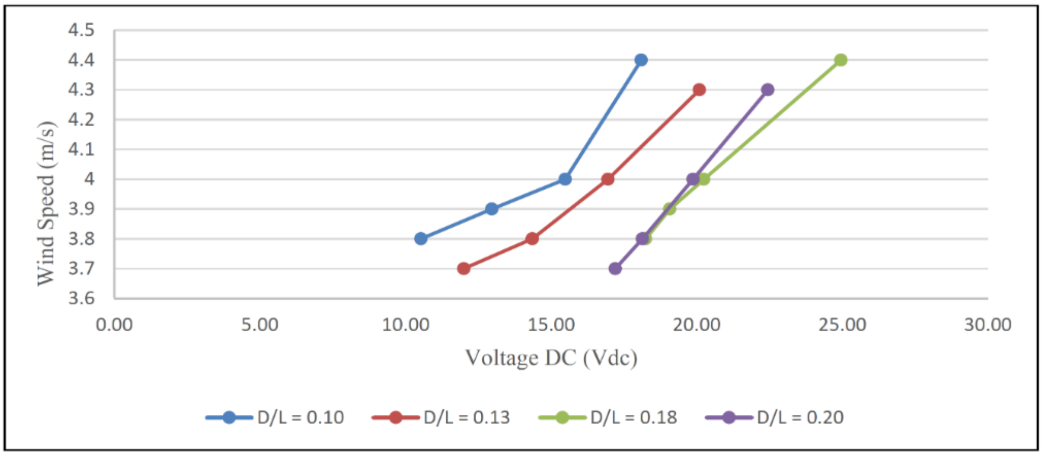

Figure 6. Graph of wind speed and voltage relationship

Figure 7 shows that the greater the wind speed that hits the blade. the smaller the TSR produced, the relationship between wind speed and TSR on the blade is related to the drag force that occurs the lower the wind speed. the greater the drag force produced. From the test results the dimensions of the blade with the variation of D/L 0.18 have a TSR that is greater than the others with a value of 0.44 at a wind speed of 3.8 m/s. If you look at the data at D/L=0.20 which has a larger blade area (A). Will also produce a much smaller TSR because it absorbs more wind energy, giving rise to a greater drag force, this can be influenced by the heavier weight of the blade so that the rotation produced also decreases even at a wind speed of 3.7 m/s.

The graph of the relationship between wind speed and electric current speed in Figure 8 shows that the greater the wind speed the greater the speed of the electric current generated by the electromagnetic field in the generator. The relationship between wind speed and current (I) is in line with the rotation of the shaft in the generator. The greater the rotation received by the generator the faster the electron charge to move and this will have implications for the size of the loading received. From the test results. the dimensions of the blade with a variation of D/L=0.17 have a greater current speed than the others with a value of 0.25 A at a wind speed of 4.4 m/s.

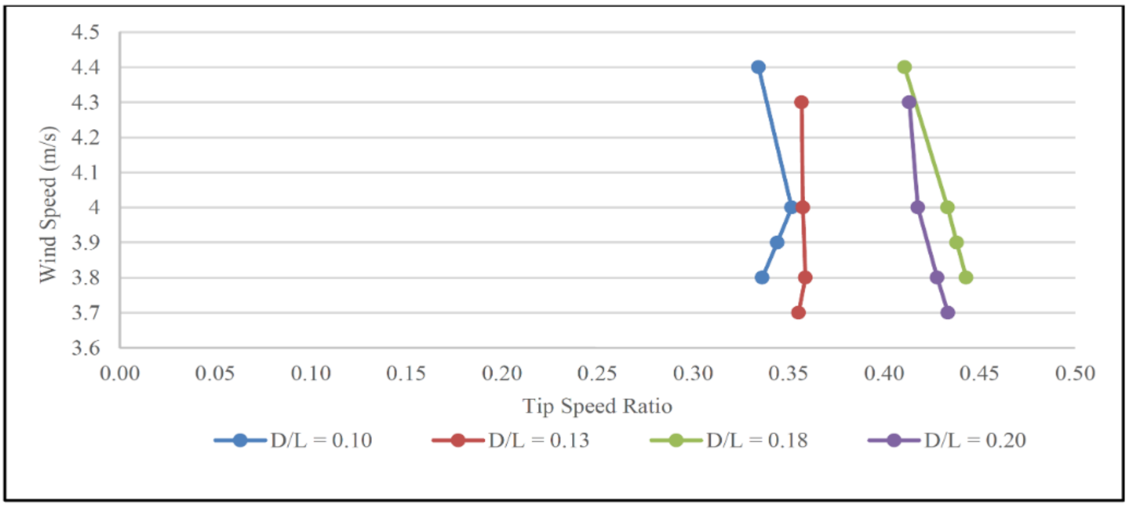

Figure 7. Graph wind speed and TSR relationship

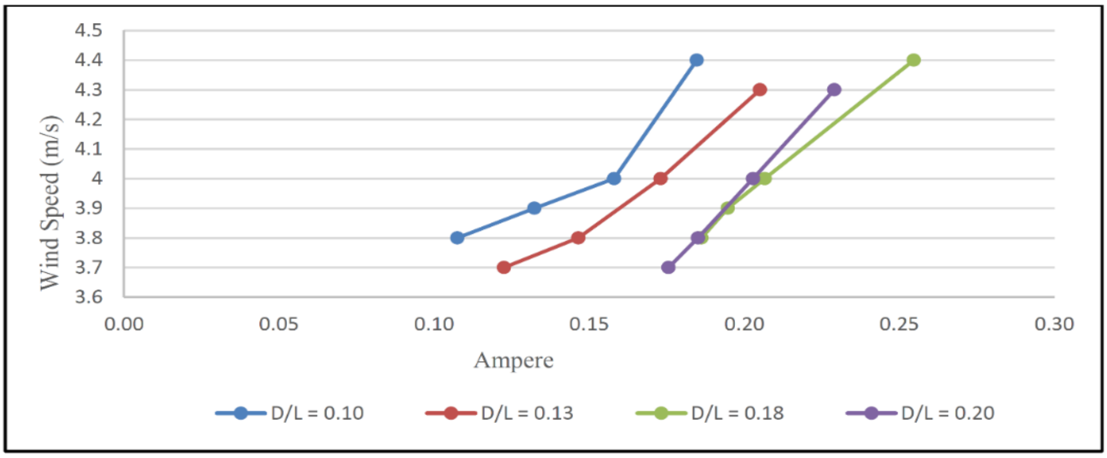

Figure 8. Graph of the relationship between wind speed and current speed

4. CONCLUSION

From the results of analysis and experimental studies, the performance improvement of a 6-blade Savonius VAWT uses PVC material based on DC voltage using a blade length of 50 cm by varying the dimensions of the blade diameter. The variables that vary between blade length and blade diameter are D/L=0.10, D/L=0.13, D/L=0.18, and D/L=0.20. The results of the analysis of the influence of variations in the parameters above on turbine rotation and the electrical power produced in the DC generator at each variation in wind speed, so it can be concluded that: i) the rotation of the turbine shaft will increase as the turbine rotation increases, the higher the wind speed and this variable is proportional straight in each test, ii) the electrical power released by the generator and the highest OE at varying blade dimensions D/L=0.18 with a wind speed of 4.4 m/s is the best and most effective choice for a wind turbine, and iii) with a voltage 40.70 volts and a current speed of 0.42 A produced by the blade model D/L=0.18 for charging a 12 volt battery with an effective resistance below 98 ohms. In simple terms, this turbine can be applied to DC voltage loads such as lighting light emitting diode (LED) lamps with a maximum power capacity of ±16 watts, while the OE is 50.25%.

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