Design of Wind Power Generator for Tambak Houses

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Design of Wind Power Generator for Tambak Houses

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Abstract – *Wind Power Generation (WPG) requires specific wind conditions to generate electrical energy. Indonesia's wind potential enables the development of small-scale power plants. Innovations in windmill technology need to be developed to ensure maximum results in low wind speed conditions. This research proposes the design and implementation of WPG using a vertical axis to provide lighting for pond houses. The goal is to benefit pond workers in coastal areas that lack electricity from the National Electric Company. The manufacturing stages include design and testing. Based on the design results, the dimensions of the propeller area are 0.393m, the frame height is 1.5m, and the wind turbine height is 0.75m. The performance test of the WPG yielded the highest turbine power value at 15.30 WITA, with a turbine power output of 25.38 Watts.*

Keywords: *WPG, VAWT type savonius wind power plant, tambak house*

I. Introduction

Utilization of renewable energy that is used to meet human electricity needs today has been widely used. Both are used for household power sources and lighting for public roads and tambak [1]. At first, the tambak farmers used oil-fired lamps as lighting. However, as time went on, oil prices became more expensive, so they began to switch to using lamps connected to PLN [2]. However, many tambak farmers complain that the basic electricity tariff is expensive because they have to pay a sizable amount to pay for electricity. The design of this wind or wind power plant is expected to solve this problem [3].
The use of renewable energy is currently being developed, namely wind or wind energy. Wind energy can be developed because it does not pollute the environment. The source of wind energy to produce electrical energy is not new. Still, the electrical energy produced is quite limited for several reasons. The potential for wind speed in an area and the duration of the wind in a place are also uncertain [4].
The use of wind power in Indonesia is currently still relatively low. One of the reasons is that wind speeds are still relatively low, ranging from 3m/s to 5m/s, making it difficult to obtain large-scale electrical energy [5]. Even so, the wind potential in Indonesia allows for the development of small-scale power plants [6].
Innovation in designing windmills needs to be developed so that in low wind speed conditions, it can provide maximum results so that a wind power generator is applied using a vertical axis for lighting tambak houses with the hope that it will be helpful to tambak workers who are located in coastal areas that have not been electrified from PLN [7]. Several applications of vertical axis wind turbines, such as [8] discuss the application of vertical axis wind turbines, [9] iscuss the application of vertical axis wind turbines on a home scale, and [10] discuss the application of wind turbines in rural areas.
Based on these problems, developing technology that can be utilized in wind speed conditions that can produce micro-scale (small) electrical energy is necessary. A vertical axis wind turbine is needed in a micro-scale wind power plant for tambak houses to increase the resulting efficiency.

II. Research Methods

This research lasted six months, starting from March to August 2022. Design, manufacture and assembly will take place from March to June, the last two months, namely the construction of tools

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that have been designed and data collection will be carried out in one month final. Data collection will be carried out in Mandalle District, Pangkajene and Islands District.

II.1. Tools and Materials

The tools and materials used in this study are as follows:

TABLE I
RESEARCH TOOLS

No	Tools	Amount
1	Electric welding	1
2	Drill	1
3	L key	1
4	Screwdriver [+],[-]	1
5	Grinding	1
6	Cutting pliers	1
7	Multimeter	1
8	Tachometer	1
9	Meter Clamps	1

TABLE II
RESEARCH MATERIALS

No	Materials	Amount
1	Aluminium plate	2
2	Iron elbow	2
3	Bolt	12
4	Cable	Sufficiently
5	Sd Card Modul	1
6	Isolation	1
7	Pully	1
8	Arduino	1

Data collection technique

The data collection technique that the author uses is the design method starting from:

1. Design and Manufacture

This is done by assembling/assembling tools or components according to the needs of the final project to be made.

2. Testing and Analysis

It is testing to test the circuit made by looking at the current results. From the results, an analysis can be obtained based on the working principle of the tool made.

II.2. Design Stage

The design stage is before Wind Power Generation (WPG) is applied to tambak houses. This stage aims to provide an overview of the system that will run and consider several designs so that the WPG can operate adequately.

Wind Turbine Design

Wind Turbine Blade Design

The savonius wind turbine is made of stainless steel material using 3 (three) blades whose construction model is made portable so that it can be assembled and moved quickly.

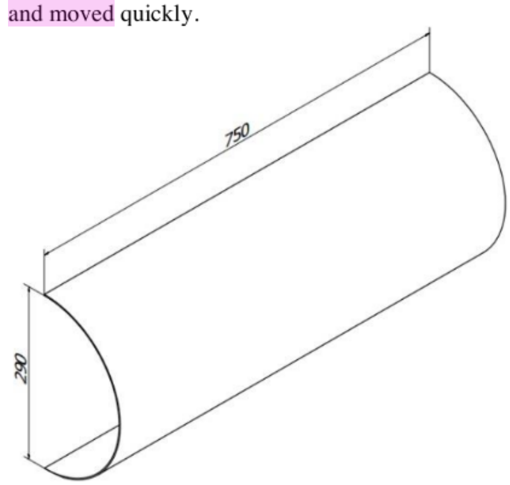


Fig 1. Windmill Blade Design

Wind Turbine Blade House Design

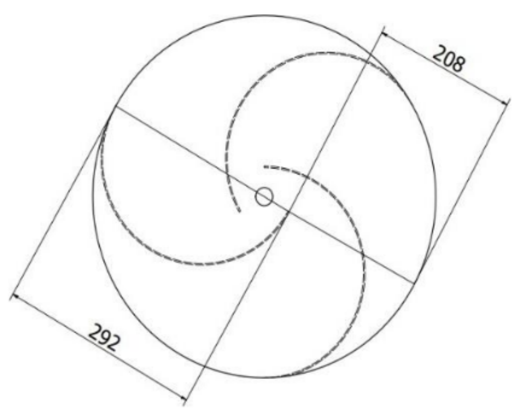


Fig 2. Wind Turbine Blade House Design

Wind Turbine Support Frame Design

The turbine frame used is made of angle iron. This mount will support the savonius turbine and its accessories, namely the generator and its transmission mechanism.

Fig 3. Wind turbine support frame design

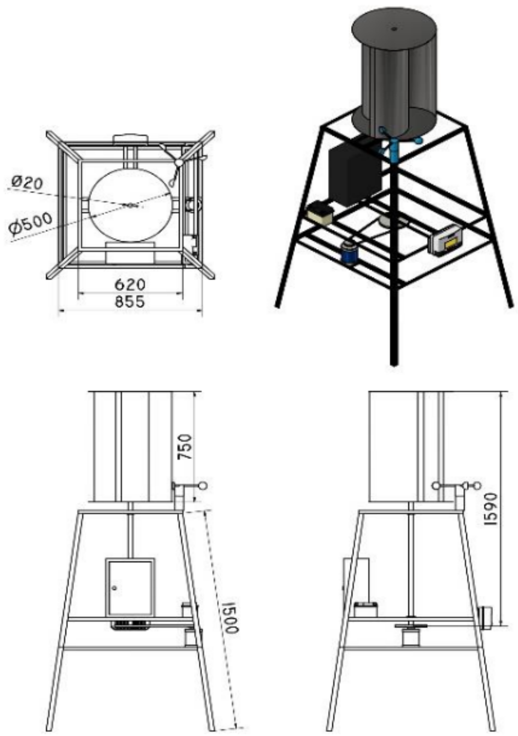


Fig 5. Vertical Axis Wind Turbine 3D Design

Wind Turbine Design

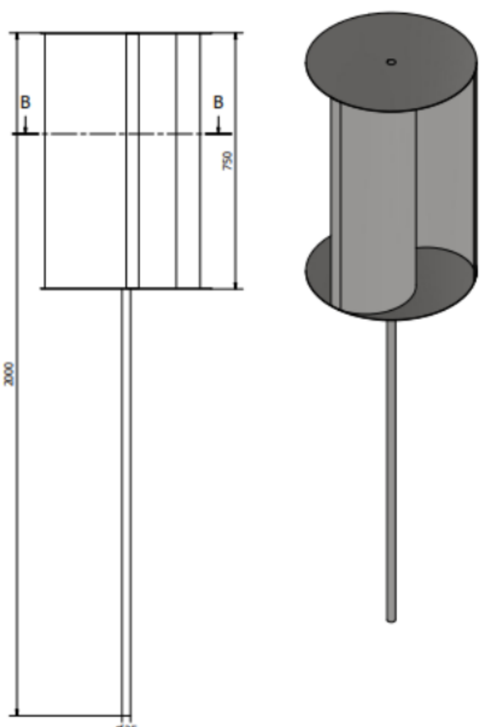
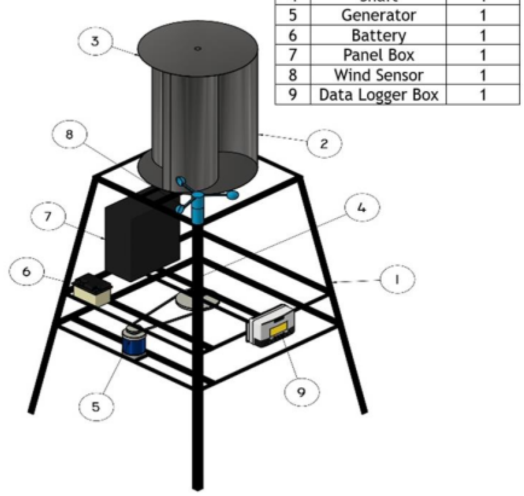


Fig 4. Vertical Axis Wind Turbine Design



Part List		
No	Component	Amount
1	Rangka	1
2	Blade Blades	3
3	Blades House	1
4	Shaft	1
5	Generator	1
6	Battery	1
7	Panel Box	1
8	Wind Sensor	1
9	Data Logger Box	1

Fig 6. Vertical Axis Wind Turbine 2D Design

II.3. *Electrical Design*

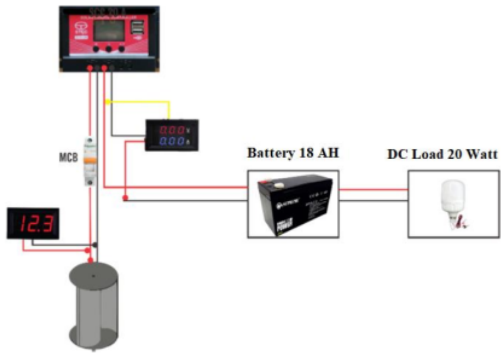


Fig 7. Electrical Schematic

II.4. *Hold Tool Manufacturing And Assembly*

After the tool design stage is complete, we will make and assemble the tool. The steps that must be taken are as follows:

1. Prepare the tools and materials to be used
2. Cutting the plate using a grinder
3. Making savonius type turbine blades
4. Making a savonius type wind turbine frame
5. Installing the wind turbine with its frame
6. Install all the components that have been made

II.5. *Tool Testing Procedures*

After the manufacturing and assembling stages of the tool are completed, the tool testing stage and data collection stage will be carried out. Testing and data collection are carried out with the following steps:

1. Installing a savonius type wind turbine at the test site
2. Assembling the output of a savonius type wind turbine
3. Ensure that the tools and frames used are correctly installed
4. Ensuring that the savonius type wind turbine rotates properly on its axis
5. Assembling the output device on the savonius type wind turbine
6. Prepare measuring tools used
7. Carry out the testing process
8. Retrieve test time data of the tool at wind speed
9. Testing is complete

II.6. *Data Collection Stage*

After the wind power plant testing process, then several parameters need to be recorded, namely:

TABLE III
PARAMETERS TO BE MEASURED IN THE TEST

No.	Parameter	Symbol	Unit	Instrument
1.	Wind Speed	V	m/s	Anemometer
2.	Current	I	Ampere	Digital lcd panel meter
3.	Voltage	V	Volt	Digital lcd panel meter
4.	Turbin Speed	N_t	Rpm	Tachometer
5.	Generator Speed	N_g	Rpm	Tachometer
6.	Turbine Diameter	D	m	Meter

III. Results and Discussion

This chapter will discuss the results and discussion of wind power plants using vertical type wind turbines. The testing of the wind power generator consists of several stages of testing, where the testing time starts from 11:00 a.m. to 19:50 p.m. From the results of the tests obtained, a discussion was carried out regarding the performance of the tools that had been made.

III.1. *Results*

1. Field Survey Results

The field survey aims to determine the tambak house's electricity needs and the factors that influence the design. This then becomes the basis for designing a wind power plant.

Fig 8. Tambak House

Wind speed data measurement is done by the primary method. The primary method is obtained by taking direct measurements.

Fig 9. Savonius type wind turbine

2. Wind Turbine Design Results

After assembling the wind turbine, a WPG is produced, as shown below.

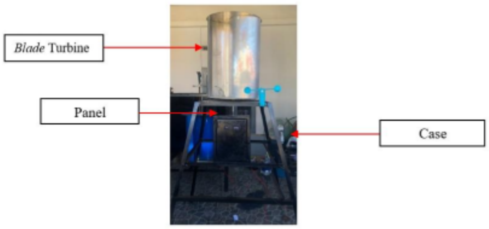


Fig 10. Front look

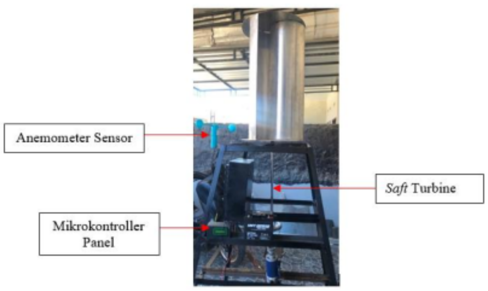


Fig 11. Wind Turbine Mechanical Assembly Results Side View

Figures 10 and 11 show the parts of the wind turbine assembly. The wind turbine that has been made with a frame height of 1.50 cm and has 3 blades. The WPG frame that is made functions as a support and a place to attach the components of the WPG such as turbines, electrical panels, sensors and microcontroller panels. These components are assembled using electric welding and bolts as a seal for each part.

3. Results of Wind Turbine Electrical System Design

Assembling the electrical system of the Wind Power Plant produces a circuit consisting of a Generator as a tool that converts mechanical energy into electrical energy, 1 Phase MCB as a breaker or protector of the electrical system in the event of an excess or short circuit on electricity, SCC as a protector also in charge of carrying out automation on battery / accumulator charging to optimize the system and maintain that battery life can be maximized and finally the battery which functions as a storage place for the electrical energy that has been generated. The following is the result of assembling the electrical system from the WPG.

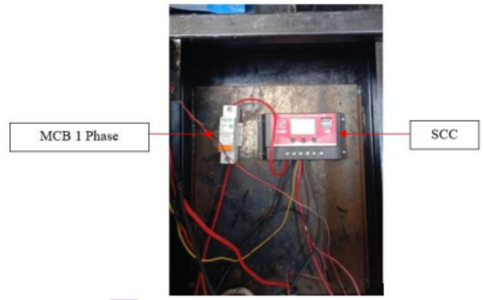


Fig 12. Circuit MCB and SCC

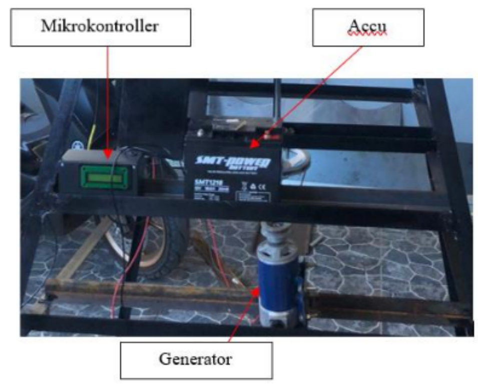


Fig 13. Electrical System

III.2. Discussion

1. Wind Turbine Mechanical Test Results

After assembling the mechanical system, the actual dimensions of the turbine can be known so that the results are obtained in Table 4.

TABLE IV
MEASUREMENT RESULTS FROM WIND TURBINE MECHANICS

Parameter	Value	Unit
ρ (air mass)	1,2	kg/m^2
r (Turbine spokes)	0,5	m

2. Test Results of WPG Without Load

Testing is done in several stages of testing. The first test is when the WPG is without load. This test aims to determine turbine power (P_t), wind power (P_a), generator power (P_g) and input power to the battery (P_b) that can be produced by the WPG that has been made. The WPG that was installed in the yard of the fisherman's pond house was operated for ± 9 hours (details can be seen in Appendix No. 1), so the table of test results is obtained as follows.

TABLE V
TEST RESULTS OF THE NO-LOAD WIND POWER PLANT

No	Time	V_{gen} (V)	Batt Input V (V)	Batt Input I (A)	Wind Speed (m^2/s)	Speed Generator (rpm)
1	11:00	58,3	11,5	0,33	6,2	1182,1
2	11:10	60,6	11,5	0,35	6,3	1191,7
3	11:20	44,7	11,4	0,22	4,6	774,2
4	11:30	49,4	11,5	0,28	4,9	876,4
5	11:40	45,1	11,5	0,23	4,8	853,6
6	11:50	53,1	11,6	0,28	5,7	1086,3
7	12:00	39,1	11,4	0,19	4,4	783,7

Table 5 shows the results of measuring several parameters for 1 hour from the WPG test in the fisherman's pond house. Data is collected every 10 [minutes] using appropriate measuring devices. Based on the table above, it can be calculated:

1) Wind Power (P_a)
To calculate wind power using data in table 4 and data no. 1 in table 5, the wind power value is obtained as follows:

$$P_a = ½ \rho A v^3$$

Based on Table 4, it is known;
Air Density (ρ) = 1,2 kg/m^2
Turbine spokes (r) = 0,5 m
Propeller Area (A) = $\frac{22}{7} \times r^2$
= $\frac{22}{7} \times (0,5)^2$
= 0,393 m^2
Wind velocity (v) = 6,2 m/s
Thus, Wind Power (P_a) = ½ ρAv^3
= ½ × 1,2 kg/m^2 × 0,393 m^2 × (6,2)^3 m/s
= 56,198 Watt

2) Turbine Power (P_t)
To calculate turbine power using the formula in the equation above using data No. 1 in Table 5, the turbine power values are obtained as follows:

$P_t = 0{,}39 \rho A v^3$
= 0,39×1,2 kg/m^3 × 0,393 m^2 × (6,2 m/s)^3
= 43,834 Watt

The complete data calculation results will be presented in Table 8.

3) Power Generators (P_g)
To calculate the power of a 1-phase generator, use the formula in equation using data in No. 1 Table 5. The generator power values are obtained as follows::

$P_g = V \times I$

Is known:
Generator Voltage (V) = 58,3 V
Generator Current (I) = 0,33 A
Then, $P_g = V \times I$
P_g = 58,3 V × 0,33 A
P_g = 19,24 Watt

The complete data calculation results will be presented in Table 8.

4) Battery Power (P_b)
To calculate battery power or input power to the battery using data at No. 1 Table 5, the generator power values are obtained as follows:
Battery Voltage (V) = 11,5 V
Battery Current (I) = 0,33 A
Then, $P_b = V \times I$
P_g = 11,5 V × 0,33 A
P_g = 3,795 Watt

The complete data calculation results will be presented in Table 8.

3. Load Usage Test Results for WPG

The next test was the use of the load on the WPG. The load used in fisherman pond houses is 1 DC 20 Watt lamp. This test aims to determine the load uses Voltage and Current. Data collection was carried out for ± 9 hours every 10 minutes, and data parameters were measured using an avo meter. The following is a table of test results from using the load on the WPG for 1 hour.

TABLE VI
RESULTS OF LOAD USAGE TESTS IN WIND POWER PLANTS

No	Time	DC Load V (V)	DC Load I (A)	Generator Speed (rpm)
1	11:00	11,1	0,75	233
2	11:10	11,1	0,75	322
3	11:20	11,1	0,75	207
4	11:30	11,2	0,75	326
5	11:40	11,2	0,76	266
6	11:50	11,2	0,76	323
7	12:00	11,1	0,75	320

In Table 6 it can be seen the results of measuring the Voltage and Current when the WPG is loaded. Based on data number 1, the electric power (lamps) used for the load can be calculated as follows.

Battery output voltage (V) = 11,1 V
Battery output current (I) = 0,75 A
Then,
$P_{lamp} = V \times I$
P_{lamp} = 11,1 V × 0,75 A
P_{lamp} = 8,23 Watt

4. Results of Testing the Use of Wind Sensors

In this test, the authors compare wind speed measurements on turbines using an anemometer measuring device (manual) and anemometer sensors (automatic), so the following data can be generated.

TABLE VII
RESULTS OF TESTING USING SENSORS AND MANUAL WIND SPEED MEASUREMENT IN SWIFT POWER PLANT

No.	Time	Speed Measurement [m^2/s]	
		Sensor	Manual
1	11:00	1,76	6,2
2	11:10	2,64	6,3
3	11:20	2,76	4,6
4	11:30	2,89	4,9
5	11:40	2,26	4,8
6	11:50	2,89	5,7
7	12:00	2,76	4,4

By comparing these measuring instruments, you can use the following formula to see the error value.

$$error = \frac{difference\ in\ Reading\ Value}{Measure\ Tool\ Value\ (Manual)} \times 100\%$$

$$error = \frac{1{,}76}{6{,}2} \times 100\%$$

The error value obtained from the comparison of the measuring tools above is 28.387%.

5. Analysis of Wind Power Plant Data

Based on the calculations that have been carried out, the results obtained from the analysis table of wind turbine testing data are as follows:

TABLE VIII
RESULTS OF DATA ANALYSIS OF TESTING OF WIND POWER PLANT IN TAMBAK HOUSE

No	Time	Wind Speed [m/s]	P_{wind} [Watt]	$P_{Turbine}$ [Watt]	P_{output} [Watt]	Eff. [%]
1	11:00	6,2	56,198	43,834	19,239	43,890
2	11:10	6,3	58,961	45,990	21,210	46,119
3	11:20	4,6	22,952	17,902	9,834	54,931
4	11:30	4,9	27,742	21,638	12,712	58,747
5	11:40	4,8	26,078	20,341	10,373	50,997
6	11:50	5,7	43,669	34,061	14,868	43,651
7	12:00	4,4	20,086	15,667	7,429	47,417
8	12:10	3,9	13,987	10,910	4,030	36,938
9	12:20	5,4	37,130	28,961	13,208	45,606
10	12:30	5,5	39,231	30,600	16,620	54,313
11	12:40	5,5	39,231	30,600	16,590	54,215
12	12:50	6	50,933	39,728	18,560	46,718
13	13:00	4,7	24,481	19,096	11,825	61,925
14	13:10	6,3	58,961	45,990	21,700	47,185
15	13:20	5,5	39,231	30,600	17,484	57,137
16	13:30	6,5	64,757	50,510	22,505	44,555
17	13:40	6,2	56,198	43,834	19,701	44,944
18	13:50	6,9	77,462	60,421	23,034	38,123
19	14:00	6	50,933	39,728	18,592	46,799
20	14:10	6	50,933	39,728	17,400	43,798
21	14:20	6,2	56,198	43,834	21,080	48,090
22	14:30	6,1	53,522	41,747	20,978	50,250
23	14:40	6	50,933	39,728	18,304	46,074
24	14:50	6,5	64,757	50,510	21,615	42,793
25	15:00	6	50,933	39,728	18,432	46,396
26	15:10	6,4	61,814	48,215	22,400	46,459
27	15:20	4,5	21,487	16,760	8,676	51,766
28	15:30	6,8	74,143	57,832	25,380	43,886
29	15:40	6	50,933	39,728	17,918	45,102
30	15:50	4,4	20,086	15,667	6,840	43,658
31	16:00	5,5	39,231	30,600	13,056	42,666
32	16:10	4,7	24,481	19,096	11,400	59,700
33	16:20	4	15,091	11,771	6,392	54,302
34	16:30	3,8	12,939	10,092	4,316	42,765
35	16:40	4,1	16,252	12,676	6,273	49,486
36	16:50	4,3	18,748	14,623	6,858	46,898
37	17:00	3,9	13,987	10,910	5,130	47,020
38	17:10	4	15,091	11,771	6,137	52,136
39	17:20	4,6	22,952	17,902	10,972	61,288
40	17:30	4,3	18,748	14,623	6,894	47,144
41	17:40	5,1	31,279	24,398	11,136	45,644
42	17:50	5,3	35,105	27,382	12,584	45,957
43	18:00	4	15,091	11,771	5,712	48,525
44	18:10	4,8	26,078	20,341	9,724	47,806
45	18:20	3,9	13,987	10,910	4,704	43,116
46	18:30	5,1	31,279	24,398	11,256	46,135
47	18:40	5,1	31,279	24,398	10,186	41,750
48	18:50	5,4	37,130	28,961	12,558	43,361
49	19:00	4,9	27,742	21,638	9,834	45,447
50	19:10	4,8	26,078	20,341	8,720	42,870
51	19:20	5,2	33,155	25,861	11,850	45,822
52	19:30	4,4	20,086	15,667	7,220	46,083
53	19:40	5,4	37,130	28,961	12,506	43,182
54	19:50	5,6	41,410	32,300	14,056	43,517

6. Graph of Wind Power Plant Data Analysis Results

1) Relationship of Wind Speed to Time

The following is a graph of the relationship between wind speed to time taken from 11.00 WITA to 19.40 WITA.

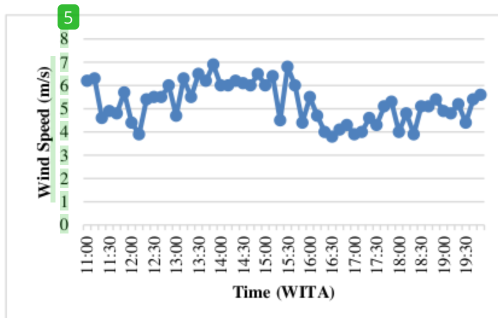


Fig 14. Graph of Wind Speed Against time

Based on the graph above, it can be concluded that the wind speed at the time the data collection began fluctuated. The highest value for wind speed is 6.9 m/s at 13.50 WITA. At the same time, the lowest value for wind speed is 3.8 m/s at 16.30 WITA. From 12.10 WITA to 12.50, the chart trend is increasing from a value of 3.9 m/s to 6 m/s. In addition, the measured wind speed also had a value that remained in the range of ±6 m/s, namely at 13.30 WITA to 15.10 WITA.

2) Relationship of Turbine Power Value and Output Power to Time

The following is a graph of the relationship between turbine power and output power to Time taken from 11.00 WITA to 19.40 WITA.

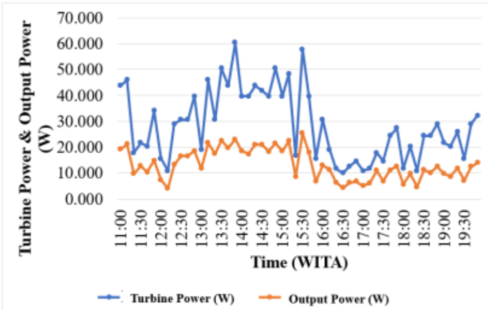


Fig 15. Graph of turbine power and output power against time

Based on Figure 15, it can be seen in the graph that the turbine power and output power fluctuate. This is influenced by the wind speed that occurs during the experiment. The wind speed value will affect the turbine power value and output power results. The higher the wind speed value, the turbine power and output power are, the higher the power generated. The power generated by the turbine occurs at 13.50 WITA with a value of 60.421 Watt, while the highest output power is at 15.30 WITA with a turbine power value of 25.380 Watts. The lowest value of the turbine power generated by the WPG is 10.092 Watt at 16.30 WITA, while the lowest output power is 4.030 Watt at 12.10 WITA.

3) Correlation of Turbine Power Value and Output Power to Time

The following graph shows Efficiency results against Time taken from 11.00 WITA to 19.40 WITA.

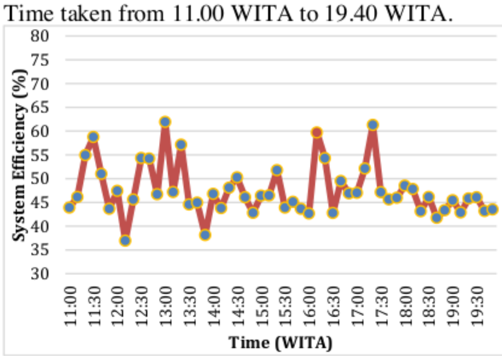


Fig 16. Graph of Efficiency Against Time

From the graph above, we can see that the optimum efficiency was obtained at 13.00 WITA with a value of 61.925% and the lowest efficiency was obtained at 12.10 WITA 36.938 %. This is because the turbine power value increases as the wind speed increases. However, at the maximum wind speed, the generator power generated tends to be constant, so the resulting efficiency decreases.

IV. Conclusion

From the results of the discussion in the previous chapter, the following conclusions can be drawn:

1. The research that has been carried out has resulted in a wind power plant with a propeller area of 0.393 m, a frame height of 1.50 m and a wind turbine height of 0.75 m. The WPG that has been made has fulfilled the lighting needs, namely a DC 20 Watt lamp in the pond house.
2. The results of data analysis prove that wind speed has a value that changes every 10 minutes of data collection. This relates to the resulting output power. The greater the value of the wind speed, the greater the output power generated by the WPG. The highest output power based on the test was at 15.30 WITA with a turbine power value of 25.380 Watt.

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