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OPTIMIZATION ANALYSIS OF SOLAR AND WIND POWER HYBRID POWER PLANT SYSTEMS

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Abstract: Indonesia is a tropical country where getting sunlight all year round is a blessing that must be optimized, and wind energy that always blows is free of emissions and free of gases. The development of these two renewable energies answers the problem of energy depending on fossil energy which causes environmental damage. Utilization of the seasons is very helpful in producing a combination of wind and solar energy, this combination is called hybrid power, these two energy sources aim to complement each other in optimizing the electrical energy produced. This hybrid power plant has been tested and obtained some data, namely the wind speed of 3.9 m/s can produce output voltage on the vertical axis wind turbine of 3.20 Volts. The highest light intensity measured is 110,094 W/m² which produces an input power of 74,907 Watt Pin, 11,484 Watt Pout output power, with an efficiency of 15% on the solar module. Charging the battery from the initial condition of the 12.9 V/100 Ah battery to fully charged 13.64 V/100 Ah takes 25 hours with an average energy of 28.61 W VAWT per hour, and an average hourly energy of 32 solar modules. 66 Wp. And optimization of the performance of the hyrid generator system can operate for 5 hours with a load of 104 watts.

INTRODUCTION

Energy is a basic need that plays a very important role in all aspects of human life and must be managed in an efficient way (Boly, Yamegueu, & Coulibaly, 2021) . The need for energy is increasing along with population growth and increasing community activities (Anisah et al., 2023). So far, the nee d for energy still depends on energy sources from fossil fuels which rely on coal, oil and natural gas which will become increasingly depleted or even run out. The use of fossil fuels will have an impact on environmental problems and encourage humans to utilize renewable energy sources. The increasing need for energy has encouraged the Government to continue to strive to accelerate the development of renewable energy in Indonesia, especially to achieve the renewable energy mix target of 23% in 2025 and 31% in 2050 of the final energy mix in accordance with the national energy policy (Tharo & Anisah, 2022). The use of renewable energy sources has an active role in answering energy problems in the future. Renewable energy is energy that comes from nature that is environmentally friendly and will not run out, such as sun, wind, water, biomass (Taro, Aryza, Anisa, & Putri, 2017).

Solar energy is an environmentally friendly energy source and its availability will never run out. Solar energy is a renewable energy source that is developing quite rapidly in the world including in Indonesia (Tharo, Anisah, & Aryza, n.d.) (Handayani & Ariyanti, 2012). Indonesia's position as a country with a tropical climate that gets sunshine all year round is a blessing that must be optimized. Wind energy is a renewable energy source and has great potential. Wind energy is considered as one of the most practical and perfect energy sources because it is emission-free and free.

Utilizing the seasons is very helpful in producing a combination of wind and solar energy, this combination is called hybrid power, where during the dry season the sun will play more of a role, while in the rainy season the wind will play more of a role in producing electrical energy sources. These two energy sources aim to complement each other in optimizing the electrical energy produced (Laksana et al., 2021) (Bernal-Agustín & Dufo-López, 2009). *Hybrid* Power Plants (PLTH) are power plants consisting of two or more plants with different energy sources. For example, a Solar Power Plant (PLTS) combined with a Bayu Power Plant (PLTB) or what is called *Hybrid* PV-Bayu (Hidayanti, Dewangga, M.P, Sarita, Sumarno, & W, 2019) (Setyono & Astuti, Fadjar Hari Mardiansjah, 2020) (Roy, He, Zhao, & Singh, 2022b).

A solar panel is a device that converts sunlight energy into electrical energy using the photovoltaic effect process , which is why it is also called a photovoltaic cell (*photovoltaic cell* - abbreviated as PV). The electrical voltage produced by a solar cell is very small, around 0.6 V without load or 0.45 V with load. To get a large electrical voltage as desired, several solar cells arranged in series are needed(Roy, He, Zhao, & Singh, 2022a)(Setyono & Astuti, Fadjar Hari Mardiansjah, 2020).

Vertical axis wind turbine (VAWT) is a wind turbine with a vertical or perpendicular axis and the rotor is parallel to the wind direction, so that the rotor can rotate in all cardinal directions. (VAWT) also has several advantages and disadvantages. The advantages are that it has high torque so it can rotate at low wind speeds (Syamsuarnis & Candra, 2020) (Haryuda, Susila, Siregar, & Aris, 2019), . The generator can be placed at the bottom of the turbine, making maintenance easier and the turbine working without being influenced by the direction of the wind. The disadvantage is that the wind speed at the bottom is very low so if you don't use a tower it will produce low rotation, and the efficiency is lower than the *Horizontal Axis Wind Turbine* (Roy et al., 2022b)(Hussain, Al-Ammari, Iqbal, Jafar, & Padmanaban, 2017)(Sovacool, 2009). By utilizing these two sources, it is hoped that the government's plan to create cheap, optimal, efficient and environmentally friendly energy can be realized (Denholm, O'Connell, Brinkman, & Jorgenson, 2015) (Hussain et al., 2017).

RESEARCH METHODS

In writing this thesis, the author collected data in the following way:

1. Identification of the problem is by formulating the background to the objectives of this research.
2. Literature study, namely collecting data from journals and *websites* that are appropriate to the research topic being carried out, namely about combination power plants or *hybrid power*
3. Observation, namely collecting data as input for the simulation, is carried out by direct survey in the laboratory by collecting data, reviewing and identifying the specifications of the hybrid generator.
4. Hold consultations and guidance with supervisors.
5. Exchange ideas and opinions with competent friends and alumni.

The aim of conducting research and data analysis is to determine the performance of the *hybrid* generator system, by obtaining several data, namely the total power produced by the vertical axis wind turbine and the solar module in charging the battery, obtaining data on the charging process and the time required by the combination of the *vertical axis wind generator. turbine* and solar module, and obtain data on how long the performance optimization of the *hybrid* generator can operate when the battery is fully charged. The measuring instruments used to carry out the test are a multitester to measure the amount of input and output voltage and current, as well as an anemometer to measure wind speed.

RESULTS AND DISCUSSION

1. Vertical Axis Wind Turbine Testing

This test uses an anemometer as a wind speed measuring tool and a multitester to determine the performance of *the Vertical Axis Wind Turbine* in producing output voltage. Testing times are from 15.00 WIB to 16.30 WIB

Table 1Wind Speed Testing Using an Anemometer

Temperature (ºC)	Wind speed (m/s)	Voltage (V)
33.4 ºC	1.1m/s	1.02 V
33.4 ºC	1.2m/s	1.07 V
33.3 ºC	1.3m/s	1.18 V
33.3 ºC	1.4m/s	1.28 V
33.3 ºC	1.6m/s	1.47 V
33.2 ºC	1.7m/s	1.62 V
33.2 ºC	1.8m/s	1.69 V
33.2 ºC	1.9m/s	1.71 V
33.2 ºC	2.0m/s	1.78 V
33.1 ºC	2.2m/s	1.84 V
33.1 ºC	2.3m/s	1.89 V
33.1 ºC	2.6m/s	2.03 V
33 ºC	2.8m/s	2.05 V
33 ºC	3.9m/s	3.20 V

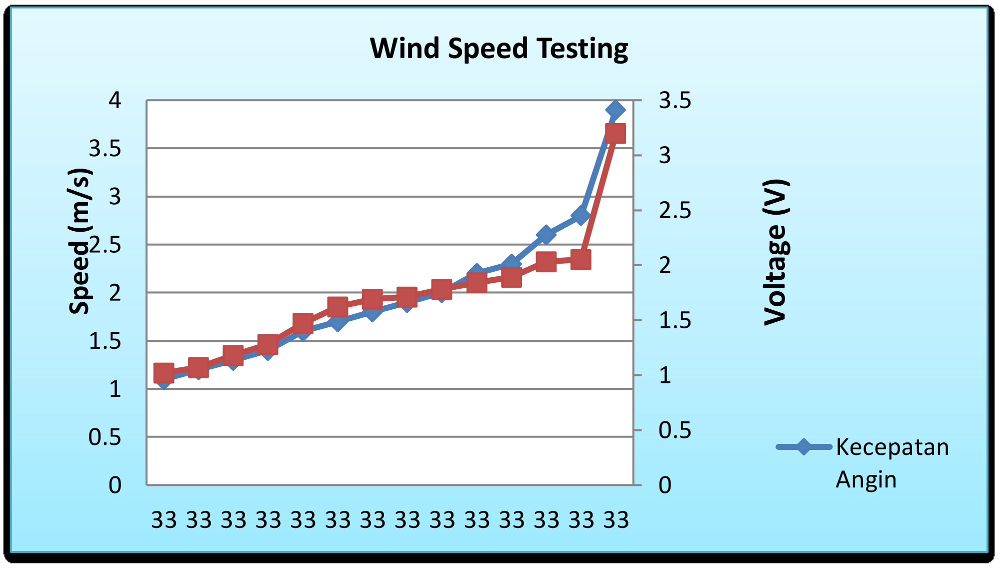

Figure 1 Graph of Wind Speed Testing on VAWT

2. Unloaded Solar Module Testing

This test uses a measurement method with a solar module connected directly to a multitester measuring instrument. This test aims to determine the characteristics of the solar module by measuring the open voltage (Voc) and short circuit current (Isc).

Table 2Data on test results for solar modules without load

Hours (t)	Sunlight intensity (W/m²)	Open voltage (V)	Short circuit current (A)
10.40	97,128	18.90	0.59
10.50	110,033	19.72	0.59
11.00	110,055	19.78	0.58
11.10	109,916	19.26	0.56
11.20	109,938	11.27	0.56
11.30	109,888	19.13	0.55
11.40	109,994	19.52	0.57
11.50	109,944	19.40	0.51
12.00	110,094	19.80	0.58
12.10	100,096	19.86	0.58

The module output voltage is very much influenced by the temperature and intensity of sunlight received by the solar module. The higher the intensity of sunlight, the more open voltage will increase. The highest intensity of sunlight was measured at 100.096 W/m² where the open voltage (Voc) was measured at 19.86 Volts and the short circuit current (Isc) was 0.58 Ampere.

3. Solar Module Testing

load solar module test uses a 12V/ 5 Watt DC LED light load. Measurement of sunlight intensity using the *Lux light meter application* on *a mobile phone* with measurements in lux units so that it is converted to 1 W/m² = 179 Lux. The efficiency of a solar panel is obtained from the electrical power output in watts compared to its surface area. Currently on the market the efficiency of solar cells in circulation is in the range of 14 - 17%.

Table 3Loaded Solar Module Testing

Time (t)	intensity (W/m²)	Solar Module				μ(%)
		Voltage (V)	Current (A)	Pins (W)	Pout (W)	
11.00	110,055	18.87	0.58	74,881	10.94	14 %
11.20	110,091	19.36	0.57	74,905	11.03	14 %
11.40	110,061	19.27	0.56	74,885	10.79	14 %
12.00	110,094	19.80	0.58	74,907	11,484	15 %
12.20	110,055	19.72	0.56	74,881	11.04	14 %
12.40	110,067	19.76	0.58	74,889	11.46	15 %
13.00	101,698	19.30	0.56	69,195	10,808	15 %
13.20	100,642	18.84	0.55	68,476	10.36	15 %
13.40	100,363	18.46	0.56	68,286	10.33	15 %
14.00	97,234	18.50	0.57	66,158	10.54	15 %
14.20	82,804	18.38	0.55	56,339	10,10	17 %

14.40	76,044	18.18	0.53	51,740	9.63	18 %
15.00	80,703	18.02	0.52	54,910	9.37	17 %

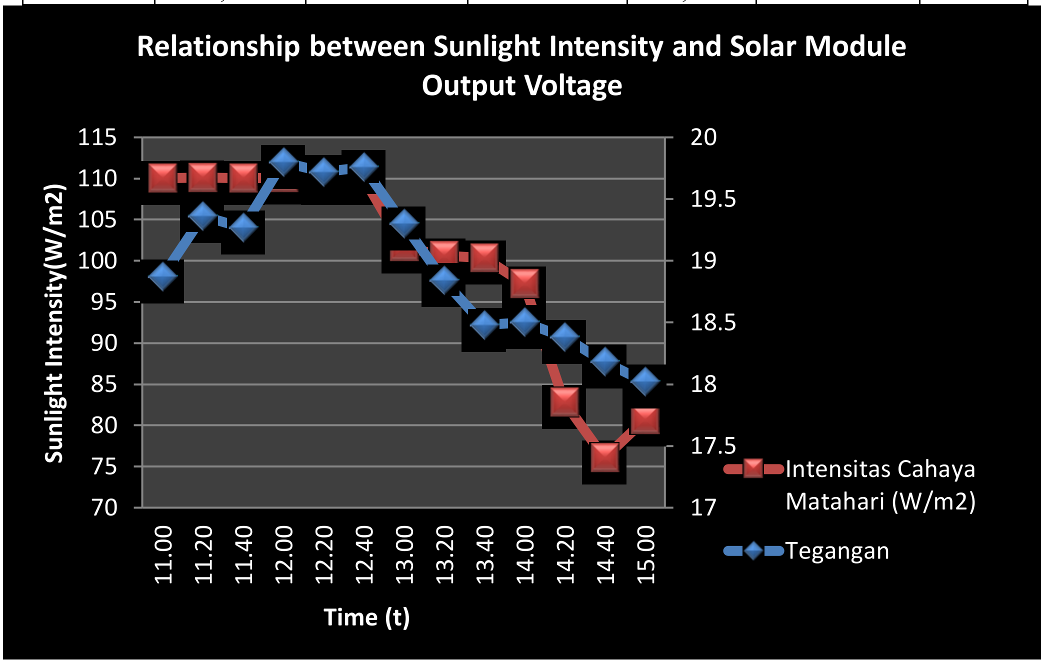

Figure 2. Relationship between solar light intensity and solar module output voltage

The voltage on *photovoltaic cells* is influenced by several factors, including the intensity of the radiation on the solar module. Variations in lighting time greatly influence the current and voltage strength, the better the sunny weather conditions, the greater the current and voltage strength. The most optimal illumination at 12.00 WIB was measured at 110.094 W/m² where the measured voltage was 19.80 Volts and the measured current was 0.58 Amperes. The lowest irradiance was at 14.40 WIB, measured at 76.044 W/m² where the measured voltage was 18.18 Volts and the measured current was 0.53 Ampere. Based on the graph, the lighting time has a big influence on the output voltage. The later in the evening the output voltage will be lower.

The aim of calculating the efficiency value is to determine the percentage of sunlight energy that the solar module can absorb. Following are several equations to determine the input and output power.

$$P_{in} = \text{Intensitas matahari} \times \text{Luas daerah modul}$$
$$= 110{,}094\ W/m^2 \times (63\ cm \times 54\ cm) + (63\ cm \times 54\ cm)$$
$$= 110{,}094\ W/m^2 \times 0{,}6804\ m^2$$
$$= 74{,}907\text{Watt}$$

Meanwhile, the maximum output power of the solar module is calculated using the following equation

$$P_{out} = V_{oc} \times I_{sc} \times FF$$

$$= V_{oc} \times I_{sc} \times \frac{V_{mp} \times I_{mp}}{V_{oc} \times I_{sc}}$$

$$= V_{mp} \times I_{mp}$$

$$= 19{,}80 \times 0{,}58$$

$$= 11{,}484\ Watt$$

So efficiency is obtained using the following equation:

$$\mu = \frac{P_{out}}{P_{in}} \times 100\%$$

$$= \frac{11{,}484}{74{,}907} \times 100\%$$

$$= 15{,}33\ \%$$

4. Battery Charging Testing

Testing battery charging to understand the characteristics and working principles of the battery in the Hybrid generating system, knowing the working voltage of the battery and the effect of charging the battery on the sunlight that hits the solar module and the gusts of wind that rotate the turbine. The test with the battery specifications used is 12 V/ 100 Ah. Where the battery voltage before charging is 12.9 V

Table 4First Day Battery Charging Test Results

Time	Vertical Axis Wind Turbine			Solar Module			Batteray (V)	T (C°)	Radiation (W/m²)	Wind speed (m/s)
	Teg (V)	I(A)	P(W)	V(V)	I(A)	P W)				
11.00	13,18	0.92	12,12	13.51	1.00	13.51	12.90	29	110,022	2.1
11.30	13,13	0.95	12.47	13.84	1.04	14.39	13.24	29	110,083	1.7
12.00	13,13	0.93	12.21	13.96	1.03	14.37	13.36	30	105,860	0.9
12.30	13,14	0.96	12.61	13.86	1.03	14.27	13.26	30	110,055	1.6
13.00	13.20	0.91	12.01	13.88	0.97	13.46	13.28	30	110,072	1,2
13.30	13.20	0.94	12.40	13.91	1.01	14.04	13.31	31.9	110,094	1.0
14.00	13.20	0.96	12.67	13.84	0.96	13.28	13.24	32.8	91,743	1.3
14.30	13,19	0.96	12.66	13.90	0.98	13.62	13.30	32.3	102.57	1.0
15.00	13.23	0.95	12.56	13.99	1.02	14.26	13.39	32.6	98,720	1.3
15.30	13.21	0.96	12.68	13.94	1.03	14.35	13.34	32.4	100.11	1.6
16.00	13,18	0.95	12.52	13.77	1.03	14,18	13,17	32	56,871	1.1

optimal intensity of sunlight was measured at 110,094 W/m² at 13.30 WIT, and the optimal wind speed was measured at 1.6 m/s at 15.30 WIT. The average temperature of the battery charging test on the first day was 31.09 ºC.

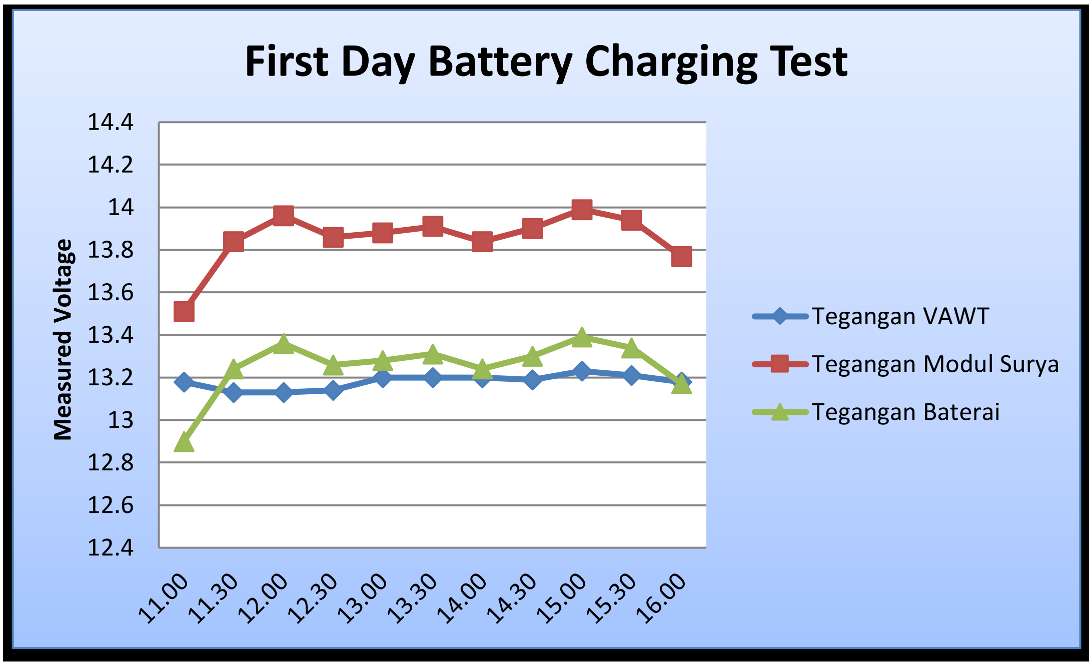

Figure 3 First Day Battery Charging Test Graph

Based on figure 4.9, the output voltage of the solar module is always greater than the vertical axis wind turbine. The highest solar module voltage was measured at 13.99 Volts, while the highest vertical axis wind turbine voltage was measured at 13.23 Volts. The battery voltage condition on the first day at 11.00 WIB was measured at 12.90 Volts, an increase after charging was measured at 13.17 Volts at 16.00 WIB.

CONCLUSION

Based on the test results in research entitled " Optimization Analysis of Hybrid Power Generation Systems in the Electrical Engineering Laboratory at Panca Budi Development University" several conclusions can be drawn as follows:

1. The voltage in the Vertical Axis Wind Turbine test was not optimal, producing an output of 12 Volts, the highest voltage measured was 3.20 Volts at a wind speed of 3.9 m/s.
2. The intensity of sunlight is very influential in testing solar modules with a load of 5 V/DC which produces input power (Pin) of 74,907 Watts, output power (Pout) of 11,484 Watts with an efficiency of 15%.

3. The highest intensity of sunlight in the no- load solar module test was measured at 100.096 W/m² at 12.10 WIB which produced an open voltage (Voc) of 19.86 Volts.
4. The test results for charging the battery from the initial condition of the battery being 12.9 V/100 Ah until it is fully charged at 13.64 V/100 Ah takes 25 hours where the Verical Axis wind turbine produces a total power of 715.25 Watts with an average energy per hour is 28.61 Watts, and the Solar Module produces a total power of 816.59 Watts with an average energy per hour is 32.66 Wp.
5. The test results of the inverter module test results, the inverter voltage output for each load has almost the same AC load output, an average of 224 AC Volts and a Frequency output of 49.9 Hz. The condition of the inverter functions well after being tested because the stability of the voltage provided is in accordance with the PLN standard of 230 VAC and the Indonesian frequency standard of 50 Hz.
6. hybrid generator performance optimization test when the 100 Ah battery was fully charged measured 13.42 Volt DC when set to *the solar charge controller* (*discharge stop) setting* at a voltage of 10.00 V. Capable of supplying the inverter with a load of 104 Watts for 5 hours.
7. The vertical axis wind turbine must be placed in a higher area to maximize wind gusts so that the output of the vertical axis wind turbine is more optimal.
8. The voltage produced by the vertical axis wind turbine is unstable, so a DC to DC converter using the MT-3608 module is needed to stabilize the output of the vertical axis wind turbine at low wind speeds to produce a voltage output of 12 Volts to 28 Volts with an input of 2 Volts.
9. Can calculate the efficiency of the vertical axis wind turbine using the MT-3608 module when the output is stable at 12 V.
10. Can use more solar modules with higher efficiency than in this research, so that the battery can be fully charged more quickly. Using more batteries to store more of the electrical energy produced.

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