Design of a Portable Power Plant Using Solar and Wind Energy with Hybrid Charge Control Method

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Abstract

New Renewable Energy is an environmentally friendly solution for electricity generation, particularly through the utilization of wind and solar energy. In Indonesia, which has a tropical climate, both energy sources can reduce dependence on fossil fuels and carbon emissions. This research aims to design a portable power plant that integrates solar and wind energy using the Hybrid Charge Control method.[1] Testing was conducted at two different locations: Pantai Indah Kapuk 2 (PIK2) and VI Rusun Ujung Menteng. The results showed that in PIK2, the solar power plant reached a peak power of 3.459 W at 1:00 PM, while the wind source produced a peak power of 0.66 W at 5:00 PM. At the Rusun Ujung Menteng location, the highest recorded power from the solar panel was 3.048 W at 2:00 PM, and the wind source reached 0.82 W at 5:30 PM. The use of a DC motor in this system increased the voltage to 4 Volts but also presented issues requiring attention in torque management and cable material selection. The Charge Control method was applied to equalize the battery voltage at a level of 12.4 V. The researchers demonstrated the significant potential of portable renewable energy-based power plants for sustainable energy needs in Indonesia.

Keywords *— New Renewable Energy, Portable Power Plants, Hybrid Charge Control*

1. INTRODUCTION

New Renewable Energy (EBT) is an environmentally friendly source of electricity generation, particularly from wind and solar power, which can produce electricity to reduce the use of fossil fuels and carbon emissions.[1] Wind and solar energy are inexhaustible resources, and both can be found in Indonesia's tropical climate. In contrast, fossil fuels, when used continuously, will deplete over time, and it takes a long time to replenish them Each type of wind turbine and solar panel comes in various sizes and serves different purposes depending on the scale; for example, there are large-scale plants designed for industrial electricity generation.[2]

A hybrid energy system combines two or more sources of new renewable energy to achieve sustainability and obtain more efficient energy results. [3] Each individual energy source has its limitations; for instance, solar energy requires sunlight, while wind energy depends on varying wind speeds. By integrating renewable energy technologies, it is possible to overcome the limitations that a single energy source may have. For example, solar energy can assist wind energy in generating electricity, and conversely, wind energy can enhance rotor speed when wind speeds are low. Therefore, researchers aim to harness the potential of both solar and wind energy. [4]

Solar energy operates on the principle of photovoltaics applied in solar cells, which are semiconductor elements that convert sunlight into electrical energy. Solar panels are collections of solar cells, while solar modules consist of multiple solar cells [5] Two physical variables influence the voltage and electrical current produced by solar cells: the intensity of solar radiation received by the solar cells and the ambient temperature. If the ambient temperature rises while the intensity of solar radiation remains constant, the voltage of the solar panel will decrease, while the electrical current it generates will increase (Sugiarto et al., 2020).

For wind energy, the researcher intends to use vertical-axis wind turbines. Previous studies have indicated that Vertical Axis Wind Turbines (VAWT) are ideal for both real-time and standalone systems (SAS), adjusting to wind conditions to generate power as an alternative energy source. (Azis et al., 2023) Vertical-axis wind turbines (VAWT) and horizontal-axis wind turbines (HAWT) are two distinct types of wind turbines. The VAWT operates independently of wind direction and can be installed on a vertical axis. [6] Research on portable Vertical Axis Wind Turbines (VAWT) has been conducted by many researchers. Wind turbines operate on a simple principle of converting wind into electricity. Wind turbines are categorized based on their axis into Vertical Axis Wind Turbines (VAWT) and Horizontal Axis Wind Turbines (HAWT). Among these, horizontal three-blade turbines have a higher power coefficient (Cp) compared to other types, reaching 49% at a tip speed ratio (TSR) of approximately 7. However, none exceed the theoretical Cp limit of 59% according to Betz's theory. In contrast, all types of vertical turbines have lower Cp values, with the Savonius type having the lowest maximum power coefficient of 0.15 at a TSR of approximately 0.8 [7].

Based on the research mentioned above, the researcher aims to design a Portable Hybrid Solar Panel Wind Turbine that can be easily transported without compromising its primary function as an alternative energy source. The researcher envisions that the Portable Hybrid Solar Panel Wind Turbine can be used to charge mobile phones, laptops, and household devices requiring low electrical power. The researcher hypothesizes that the portable Hybrid Solar Panel and Wind Turbine can function effectively.

2. RESEARCH METHOD

A literature review is carried out by comparing similar studies that utilize the same references. This comparison can serve as a foundation for evaluation and is anticipated to aid in the development of a new system include:

1. Based on the literature from [8][7][9][10][11][12] The VAWT (Vertical Axis Wind Turbine) is an efficient solution for harnessing wind energy that is not dependent on wind direction due to its vertical shaft design. With the ability to rotate around a vertical axis, VAWTs facilitate easy installation and maintenance, making them an ideal choice for various locations, including urban areas. This design also supports the efficient production of renewable energy.
2. Based on the literature from [13][4][14][1][15] They focus more on the development of solar panels due to the significant potential for renewable energy and sustainability it offers. With the increasing efficiency of solar energy conversion, solar panels have

become an environmentally friendly solution that reduces dependence on fossil fuel sources and supports the reduction of carbon emissions.

3. Based on the literature from [16][17] Their research focuses more on the development of hybrid power plants to achieve optimal efficiency. By combining various energy sources, such as solar and wind power, these hybrid systems can maximize the utilization of available resources, enhance energy supply stability, and reduce dependence on a single energy source.

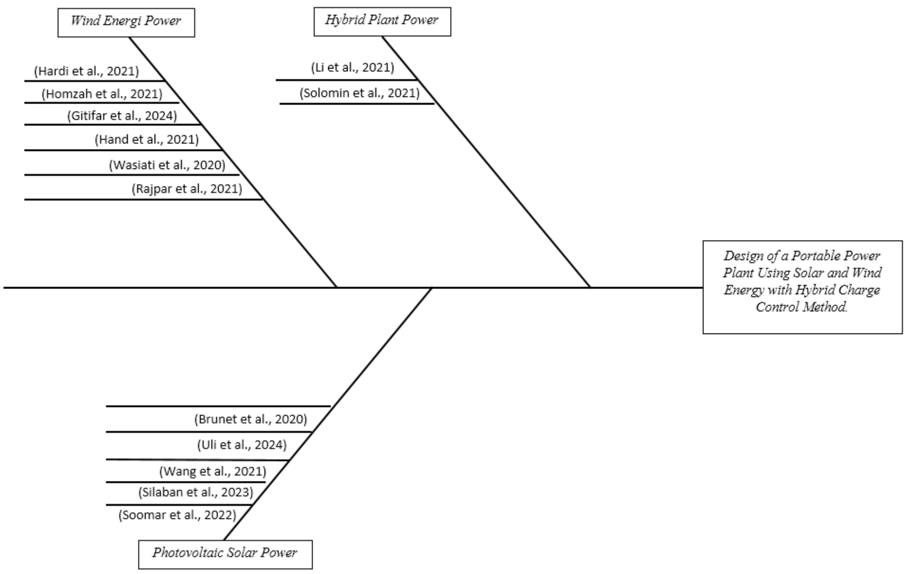

Figure 1. Fishbone Diagram Mapping Research Topics

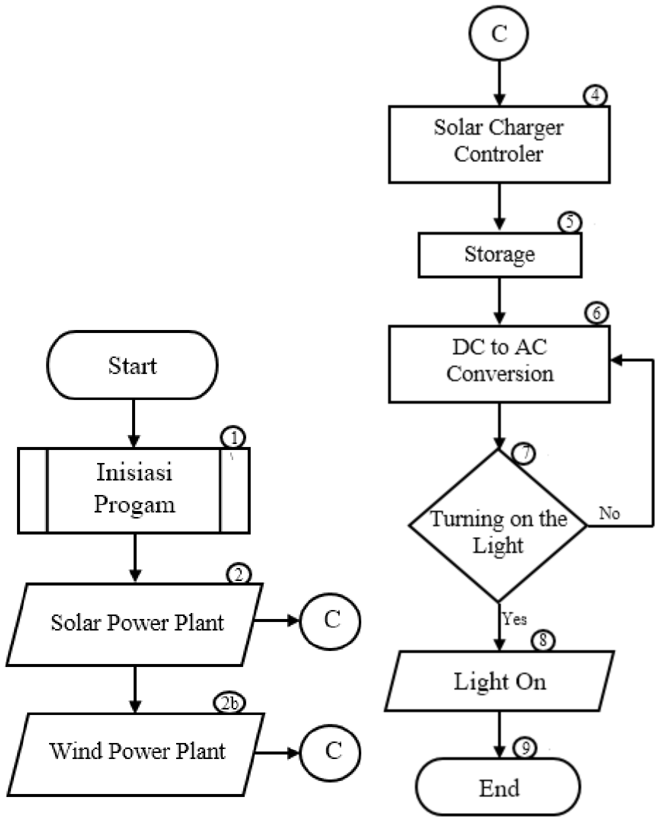

Figure 2. Control System Flowchart

Figure 1 shows a fishbone literature mapping diagram, aligning with the research topic. This diagram visually organizes various studies and main areas of focus, making it easier to identify relationships and gaps in the literature. As a result, researchers can better understand the existing context and determine the next steps for development.

This research conducts experiments to test a portable power generation device that utilizes solar and wind energy. Additionally, testing is performed on a DC motor to increase the wind rotor speed, which can help enhance the power output generated by wind energy.

2.1. Flowchart

Figure 2 shows the control flow of the planned charging system is illustrated. Below is an explanation of each step in the flow diagram:

1. The process begins with program initiation.
2. The solar power plant provides a source of electricity.
3. The wind power plant contributes a source of electricity.
4. The generated electricity is then hybridized at the Solar Charge Control output.
5. After hybridization, the energy source is stored in storage.
6. Once in storage, the electricity from the battery is redirected to the inverter to convert DC to AC.
7. After conversion to AC, the electricity is used to power a lamp. If the lamp does not turn on, it indicates that the electricity in storage has been depleted.
8. If the lamp lights up, the system is operational.
9. End.

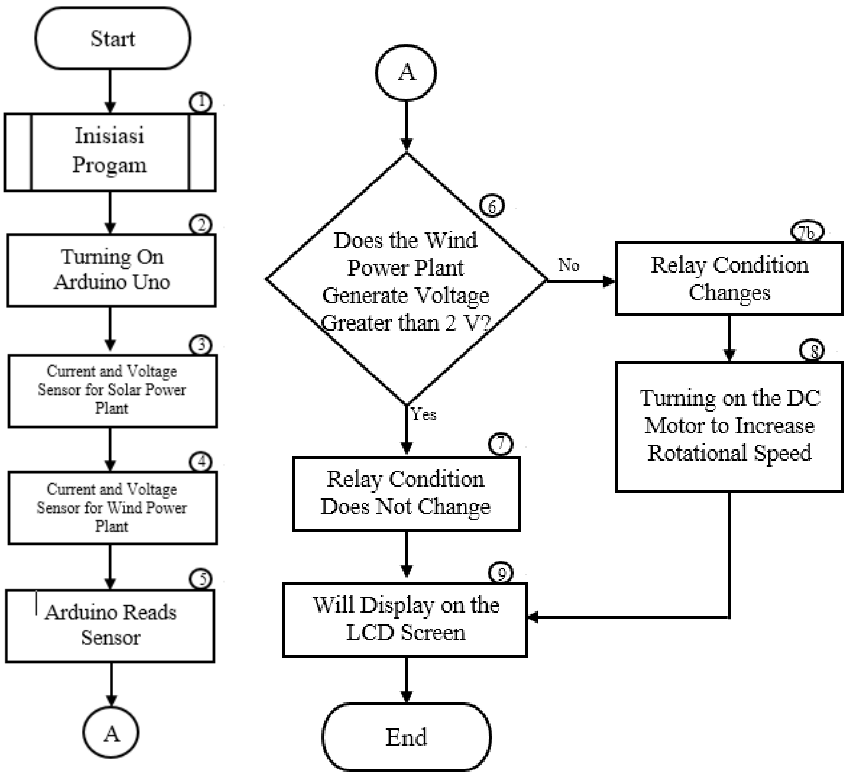

Figure 3. Control Charging System Flowchart

In Figure 3, the flow of the control system planned for the charging system is illustrated. Below is an explanation of each step in the flow diagram:

1. Initiate Program: The process begins with the initiation of the program.
2. Power On Arduino Uno: The Arduino Uno is powered on.
3. Solar Power Plant Sensor Reads Current and Voltage: The sensor located at the solar power plant measures the current and voltage.
4. Wind Power Plant Sensor Reads Current and Voltage: The sensor located at the wind power plant also measures the current and voltage.
5. Arduino Receives Data from Sensors: Once the sensors have taken their readings, the Arduino receives the data provided by the sensors.
6. Arduino Monitors Voltage from Wind Power Plant: The Arduino checks the voltage from the wind power plant, which is expected to be 2 Volts.
7. If Voltage is Not 2 Volts, Relay Condition Remains Unchanged: If the voltage does not meet the specified condition, the relay state will not change. 7b. If Voltage is 2 Volts, Relay Condition Changes: If the voltage is correct, the relay state will change.
8. Activate DC Motor to Increase Wind Speed: Once the relay state changes, the DC motor is activated to increase wind speed.
9. LCD Displays Current Voltage and Relay Status: The LCD will display the current voltage readings and indicate whether the relay is activated or not.
10. End: The process concludes.

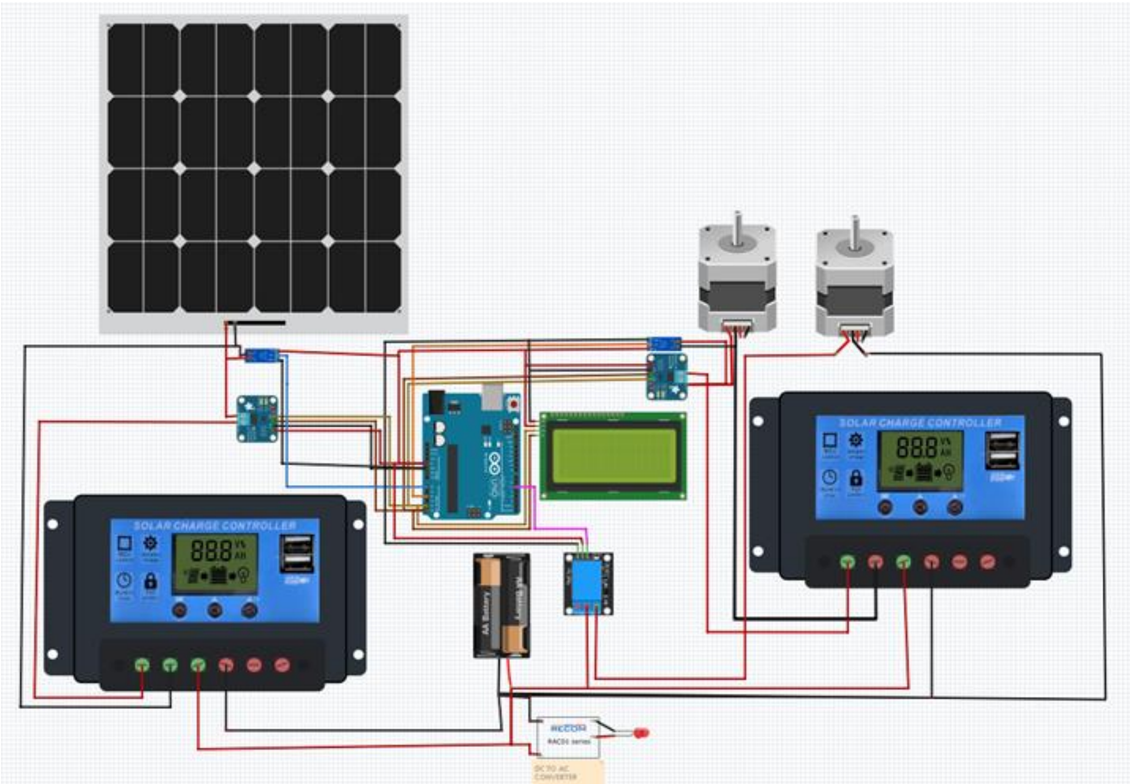

Figure 4. Wiring Diagram

Figure 5. The Result Prototype

2.2. Electrical Diagram

Figure 4 shows a wiring diagram that illustrates the integration between the solar power generation system and the wind power generation system. The combination of these two energy sources forms a Hybrid power generation system designed to enhance the availability of alternative energy.

2.3. Math Formula

The battery endurance time and charging time can be calculated using the basic calculations below:

$$P = V \times I \tag{1}$$

$$Charger\ time = Battery \frac{Capacities}{charging\ power} \tag{2}$$

3. RESEARCH RESULTS AND DISCUSSION

3.1. The Result Prototype

Figure 5 shows the prototype design that has been combined with solar panel technology and wind turbines into one system to generate alternative electricity. The system uses a Hybrid Charge Controller to manage battery charging, ensuring optimization of the available resources. The result is a prototype designed to provide a portable solution for electricity supply in remote locations or environments with limited energy sources. Continuous evaluation is conducted to ensure reliable system performance and adaptability in various environmental conditions.

3.2. Voltage and Current Testing at Pantai Indah Kapuk (PIK) 2

Table 1 shows the testing was conducted six times, specifically from 08:00 to 09:00, in the afternoon from 13:00 to 14:00, and in the evening from 17:00 to 17:30. Therefore, the researchers conducted the testing in an empty field at the construction site of a shop house in the Pantai Indah Kapuk 2 area. Figure 6 shows the graph of solar power testing and Figure 7 shows the graph of wind turbine testing at PIK 2.

Table 1. Testing at PIK 2

No	Solar				Wind			
	Time (hour:min)	Voltage (Volt)	Current (Ampere)	Power (Watt)	Rotation (rpm)	Voltage (Volt)	Current (Ampere)	Power (Watt)
1	08.00	10.93	0.20	2,186	88	2.93	0.10	0.293
2	09.00	10.93	0.30	3,279	75	1.93	0.10	0,193
3	13.00	11,53	0.30	3,459	75	1.95	0.10	0,195
4	14.00	11,10	0,30	3.33	82	2.72	0.10	0,272
5	17.00	4,10	0,20	0,82	93	3.30	0,20	0,66
6	17.30	3.98	0,20	0,796	89	3.05	0,10	0,305

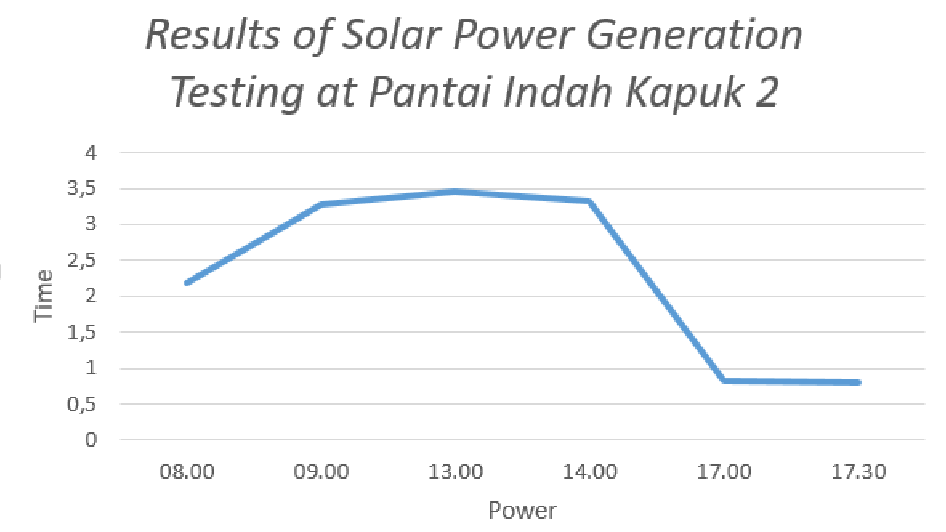

Figure 6. Results of solar power generation testing at Pantai Indah Kapuk 2

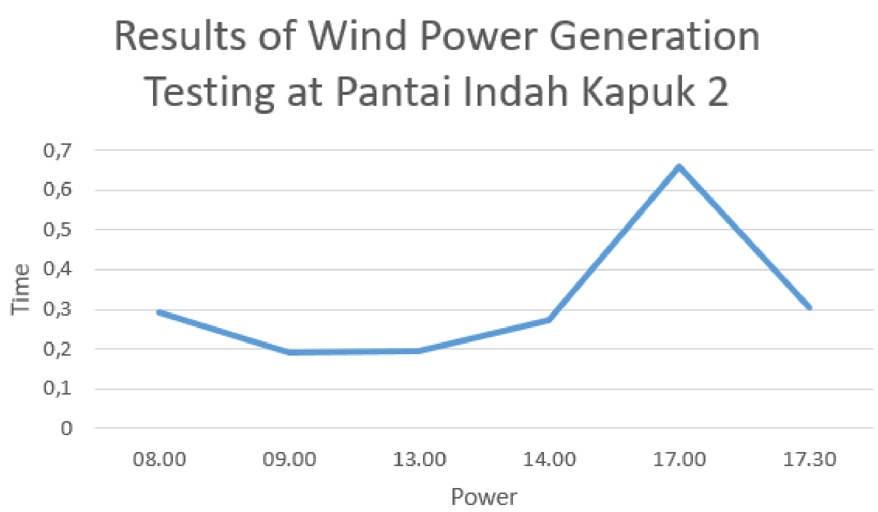

Figure 7. Results of wind power generation testing at Pantai Indah Kapuk 2

3.3. Results of Voltage and Current Testing at Rusun Ujung Menteng

Table 2 shows the testing was conducted six times, specifically in the morning from 07:30 to 08:00, in the afternoon from 13:00 to 14:00, and in the evening from 17:00 to 17:30. The testing took place on the rooftop of KRusun Ujung Menteng because permission to conduct the tests had been obtained. Figure 8 shows the graph of solar power testing and Figure 9 shows the graph of wind turbine testing at Rusun Ujung Menteng.

Table 2. Testing at Rusun Ujung Menteng

No	Solar				Wind			
	Time (hour:min)	Voltage (Volt)	Current (Ampere)	Power (Watt)	Rotation (rpm)	Voltage (Volt)	Current (Ampere)	Power (Watt)
1	07.30	8,20	0,20	1,64	87	2,10	0,20	0,42
2	08.00	8,16	0,20	1,632	87	5,08	0,20	1,016
3	13.00	11,83	0,20	2,366	91	3,33	0,20	0,666
4	14.00	10,16	0,30	3,048	76	4,13	0,10	0,413
5	17.00	6,90	0,20	1,38	42	2,72	0,10	0,272
6	17.30	4,10	0,20	0,82	91	3,36	0,20	0,672

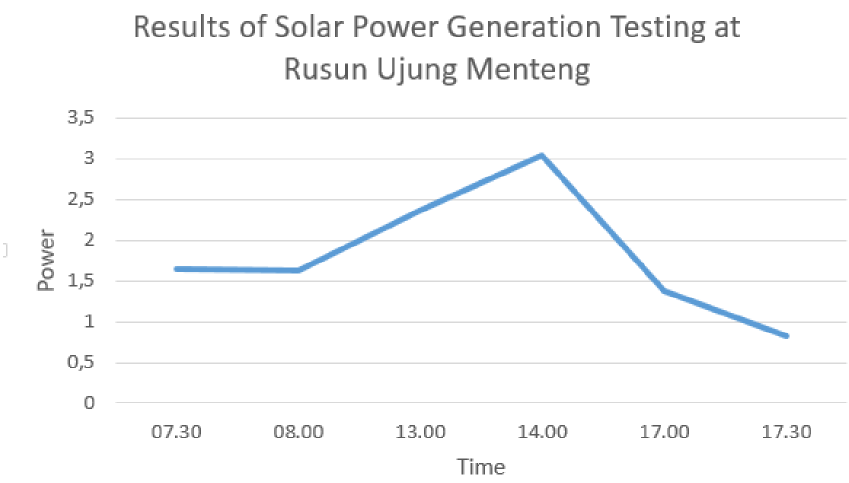

Figure 8. Results of solar power generation testing at Rusun Ujung Menteng

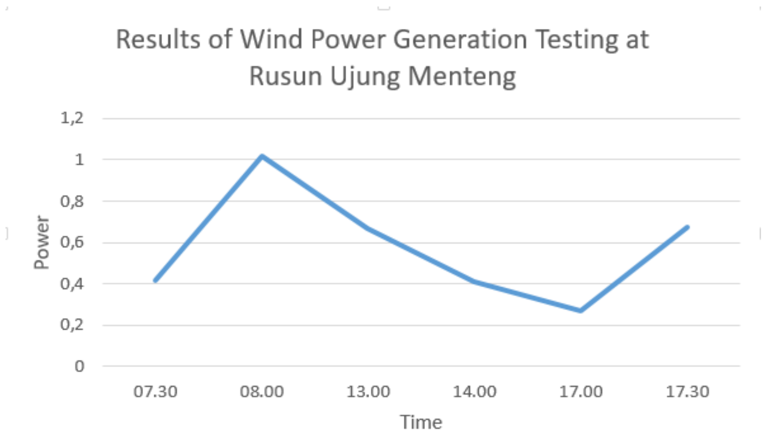

Figure 9. Results of wind power generation testing at Rusun Ujung Menteng

Figure 10. Relay Indicator on

3.4. Active Relay Results

Figure 10 shows the results of the active relay successfully increased the rotor speed and boosted the voltage of the DC generator. At 08:00 on the rooftop of Rusun Ujung Menteng, the relay successfully powered the DC motor, raising the voltage from 1.9 V to 5.03 V. However, this caused a problem: the cable burned due to the DC motor not being strong enough to rotate the rotor.

4. CONCLUSION

Based on the process and results of the final project regarding the design of a portable power generation system using solar and wind energy with the Hybrid Charge Control method, the following conclusions can be drawn:

1. Successful Testing: The design of the portable power generation system using solar and wind energy with the Hybrid Charge Control method was successfully tested in two different locations, namely at Pantai Indah Kapuk 2 (PIK2) and KRusun Ujung Menteng.
2. Testing Results at Pantai Indah Kapuk (PIK2): In the solar power generation test, the highest power obtained was 3.459 W at 13:00. Meanwhile, for wind power generation, the highest voltage was recorded at 17:00 with a power output of 0.66 W. At KRusun Ujung Menteng, the highest result from the solar panel was 3.048 W at 14:00, and the highest power from the wind generation was 0.82 W at 17:30.
3. Use of DC Motor: The use of a DC motor in the power generation system to increase the speed of the Wind Power Generation (PLTB) showed a voltage increase of up to 4 Volts. Although the generated voltage was adequate, the torque produced was quite large and could cause the cable to burn. This indicates the need for special attention to torque management and the selection of appropriate cable materials to prevent damage and ensure that the system operates safely and efficiently.
4. Charge Control Method: The Charge Control method implemented in the battery charging process was designed to equalize the voltage at 12.4 Volts. However, the voltage equalization performed in parallel was less efficient because the input voltage from the solar and wind power generation was less than 5 Watts.

5. SUGGESTED

Based on the research results obtained, there are several recommendations for future research in developing more efficient portable power generation systems that utilize solar and wind energy using the Hybrid Charge Control method. First, researchers are advised to select higher-quality DC motors to reduce the risk of cable burning, which can disrupt system performance. Additionally, the development of a tracking system for solar panels is highly recommended, allowing the panels to move in alignment with the sun's direction and enhance energy capture efficiency. Furthermore, it is crucial for future researchers to integrate the use of sensors within this system. With the appropriate sensors, the system can collect accurate data on various parameters, such as solar radiation intensity and wind speed. This data will be very useful in optimizing the performance of the Hybrid Charge Control system, as well as improving efficiency in energy collection and storage.

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