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Analysis Of The Optimal Charging System On A Plant Sprayer Using A 100 Watt Capacity Solar Panels

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Abstract

Problems arise when the electrical energy generated by solar panels is not constant throughout the day due to changes in the sun's position. One way to address this is to adjust the panel's angle—either manually or automatically—in accordance with the sun's movement. The objectives of this study are to analyze the electrical charging system of a plant sprayer equipped with a 100-watt solar panel, to determine the optimal angle for the solar panel to generate electrical energy, and to measure the voltage, current, and power produced by the solar panel during the battery charging process. The analysis method was used to determine the effect of variations in the solar panel angle on the voltage, current, and electrical power generated. The study aimed to identify the optimal angle for generating electrical energy to charge the pump system and to assess the performance of the solar-powered crop sprayer at various panel tilt angles during charging, based on field test results. Research Findings: Optimal Charging System: The battery charging system for the crop sprayer achieves optimal performance when a 100-watt solar panel is installed at a tilt angle of 20^∘. At this angle, the solar panel produces the highest average current (3.873 A) and the highest charging power (72.409 W) compared to a 10^∘ tilt or a 0^∘ flat position. Power Increase Characteristics: Changes in the tilt angle were found to affect the charging power linearly and in the same direction. Every 1° increase in tilt angle (up to the test limit of 20°) will increase the battery charging output of the sprayer by a constant 1.036 watts. The difference in power efficiency only becomes statistically significant when the angle is changed directly from the horizontal position (0°) to the optimal angle (20°). Conclusions from this study: Charging Time Conditions: The charging duration is not affected by changes in the solar panel tilt angle. This is due to the protection system in the sprayer's Solar Charge Controller

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(SCC), which limits the maximum current threshold to ensure battery safety, thereby keeping the charging time constant.

Keywords: Optimal Charging System, Plant Sprayer, 100 Watt Capacity Solar Panels

INTRODUCTION

Indonesia's electricity demand continues to increase in line with the development of the industrial, agricultural, and residential sectors. Dependence on fossil fuels such as oil, natural gas, and coal creates various problems, including limited availability, rising prices, and negative environmental impacts such as greenhouse gas emissions. Therefore, the development of environmentally friendly, renewable, and independently exploitable alternative energy sources is necessary, one of which is solar energy.

Solar energy is an abundant renewable energy source that can be converted into electricity through photovoltaic (PV) panels. However, solar panel performance is significantly affected by solar radiation intensity, geographic location, ambient temperature, and the panel's tilt angle relative to the sun. Improperly tilted solar panels can reduce the amount of electrical energy generated. Therefore, optimally adjusting the solar panel angle is necessary to maximize solar energy absorption.In this context, sentiment analysis becomes an important field of study for understanding public opinion trends on certain issues (Ashari et al., 2020). Sentiment analysis allows processing text data to identify the emotions, opinions, and attitudes of social media users toward a topic (Aziz et al., 2024).

On the other hand, the use of electrical energy in the agricultural sector is growing, one example being in modern irrigation systems such as crop pumps. Crop pump systems function to automatically distribute water to crops without relying on manual labor. However, using electricity from the PLN grid or conventional fuels is often inefficient and environmentally unfriendly, especially in rural or remote areas. Therefore, integrating solar panels as a power source to operate crop pumps is an innovative, efficient and sustainable solution.

Problems arise when the electrical energy generated by solar panels is inconsistent throughout the day due to changes in the sun's position. One way to address this is to manually or automatically adjust the panel's angle according to the sun's movement. This adjustment is expected to increase the voltage, current, and power output, thus optimizing the charging process of the electrical storage system (battery) and supporting the continuous operation of the plant's pumps.

Based on this background, a scientific study is needed to analyze the optimal charging

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system for a crop pump using a 100-watt solar panel to charge the battery. This research is expected to contribute to the development of renewable energy technologies in the agricultural sector and provide an alternative solution for areas without access to conventional electricity.

RESEARCH METHOD

Research location for “titled “Analysis of the optimal charging system on a plant sprayer using a 100 watt solar panel "namely at the author's residence at Jalan Dalig Raya Ujung Siantar Timur, Pematang Siantar City, North Sumatra, 21131. The research period was officially ratified by the Head of the Mechanical Engineering Study Program, Faculty of Engineering and Water Resources Management, HKBP Nommensen University, Pematangsiantar. The tool construction period was 2 months.

1. Tool Preparation

1. Prepare the solar panel circuit → solar charge controller → sprayer battery.
2. Discharge the sprayer battery to 10 - 20%.
3. Mount the solar panel on a stand that can be tilted.
4. Prepare measuring instruments (lux meter, multimeter).
5. Ensure the weather is clear before starting the test.

2. Research Variables

1. Independent Variable (X)

The independent variable is using an angle of 0.10.20 of the solar panel to see changes in the electrical energy charging of the pump.

2. Dependent Variable (Y)

The dependent variable is the output or result that is influenced by the panel angle, namely:

1. Panel output voltage (V)
2. Panel output current (A)
3. Charging power (Watts)
4. Battery charging time (hours)

3. Control Variables

Controlled variables to ensure consistent research results:

1. The weather conditions are sunny
2. The sprayer battery capacity remains the same.
3. Fixed pump load (water as medium).
4. Fixed panel location.
5. The light intensity is in bright or measurable conditions.

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3. Testing process

1. Charging Test at Panel Angle Variations

For each corner of the panel (0°, 10°, 20°) is done

step following:

1. The panel is directed towards the sun at a specified angle.
2. A multimeter is connected to read the panel voltage and current.
3. Battery charging starts and the stopwatch is activated.
4. Noted
   - Panel voltage (V)
   - Panel current (A)
   - Time until battery is charged
   - Weather conditions
5. Power is calculated

The results from each angle will be compared to see the most efficient angle.

6. Data Collection Methods

The data collection method in this study was conducted through direct measurements (field experiments) to obtain data consistent with the problem formulation

Data Analysis Techniques

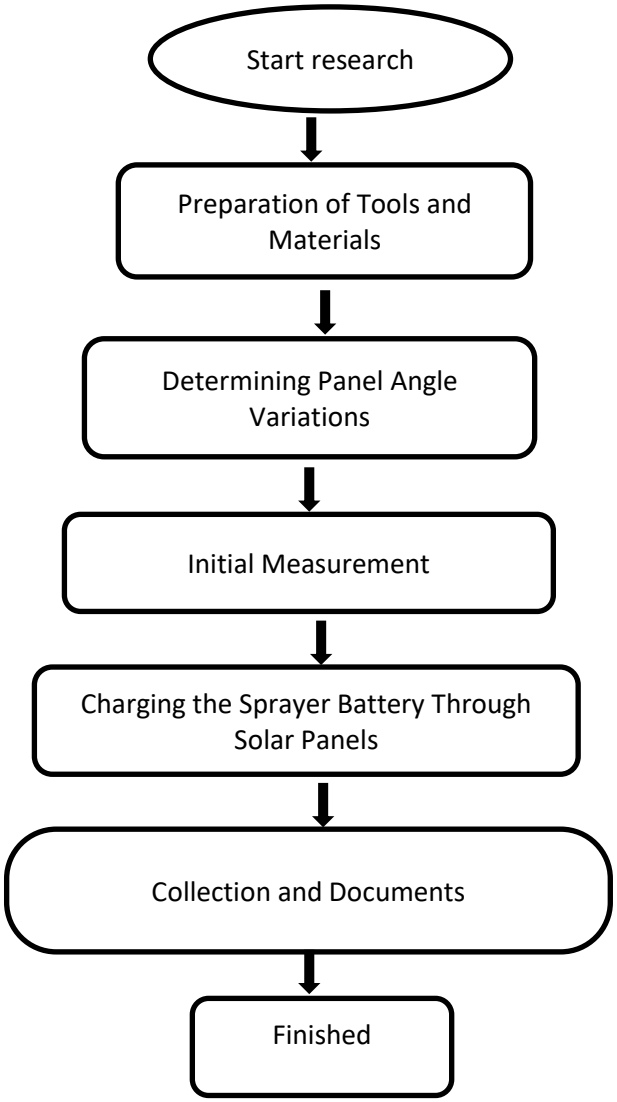
Data analysis is the process of processing, calculating, and interpreting measurement results to obtain meaningful information in accordance with the research objectives. In the context of this research, data analysis was conducted to determine the effect of variations in the angle of the solar panel on the amount of voltage, current, and electrical power produced. What is the optimal angle to produce electrical energy for charging the pump system, to determine the performance of solar energy-based plant pumps at several panel tilt angles to charging, based on the results of field testing.

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RESULTS AND DISCUSSION

Results

This research demonstrated the assembly of a battery charging system using solar panels as the primary energy source. The system consists of solar panels as the primary source of electrical energy, a solar charge controller to regulate charging, and a battery to store the electrical energy.

The solar panels are mounted on a support frame designed with three tilt angles: 0°, 10°, and 20°. The multiple angles are used to determine the most effective position for the panels to receive sunlight.

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The circuit begins with a solar panel connected to a solar charge controller. The output of the solar charge controller is then connected to a 12V 8Ah battery. A multimeter is also used in this system to measure voltage and current values during the testing process.

Based on the assembly results, the system can work well where the solar panels are able to produce electrical energy and charge the battery gradually according to the sunlight intensity conditions.

Solar Panel Voltage and Current Testing

To determine the effect of solar panel tilt angle on the resulting voltage and current, data collection was conducted from 9:00 a.m. to 3:00 p.m. WIB at hourly intervals.

Data for the 0° angle tester for the first trial

Time	Sun Intensity (w/m^2)	Wind velocity (km/h)	Initial Battery Voltage (v)	Current Panel (A)	Panel Voltage (v)	Battery Final Voltage (v)	Charging time
09-10 WIB	257 (w/m^2)	3 km/h	11.5 v	1.5 A	17.2 V	11.6 V	1 hour
10-11 WIB	464 (w/m^2)	5 km/h	11.5 v	2.8 A	17.8 V	11.8 V	1 hour
11-12 WIB	568 (w/m^2)	6 km/h	11.5 v	3.5 A	18.2 V	12.0 V	1 hour
12-13 WIB	584.44 (w/m^2)	5 km/h	11.5 v	3.7 A	18.3 V	12.1 V	1 hour
13-14 WIB	563.28 (w/m^2)	5 km/h	11.5 v	3.4 A	18.1 V	12.0 V	1 hour
14-15 WIB	416.29 (w/m^2)	5 km/hour	11.5 v	2.5 A	17.6V	11.8 V	1 hour

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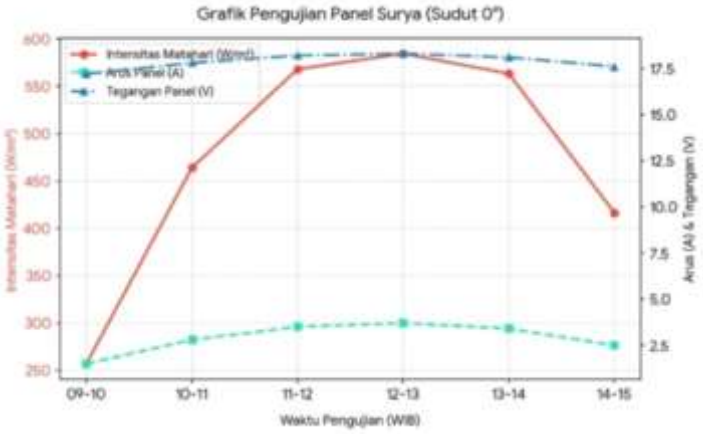


Figure.1 First Test Graph

Based on the first test data at an angle of 0° (Table 4.1), it can be concluded that the performance of the solar panel is greatly influenced by daily fluctuations in solar intensity, where the values of light intensity, current, and panel voltage managed to reach their peak simultaneously at 12:00–13:00 WIB at 584.44 W/ 3.7A, and 18.3 V. The increase in solar intensity was proven to be directly proportional to the significant increase in electric current due to more optimal light absorption, while the panel voltage value tended to be stable and constant in the range of 17.2 V to 18.3 V since the morning. The results of this energy conversion accumulatively made a positive contribution to the power storage system, which was shown by the increase in the final battery voltage from an average of 11.50 V to 11.88 V at the end of the test.m^2

Second Experiment

Time	Sun Intensity (w/m^2)	Wind velocity (km/h)	Initial Battery Voltage (v)	Current Panel (A)	Panel Voltage (v)	Battery Final Voltage (v)	Charging time
09-10 WIB	257 (w/m^2)	3 km/h	11.5 v	1.4 A	17.0 V	11.6 V	1 hour
10-11 WIB	464 (w/m^2)	5 km/h	11.5 v	2.7 A	17.6 V	11.7 V	1 hour
11-12 WIB	568 (w/m^2)	6 km/h	11.5 v	3.6 A	18.1 V	12.0 V	1 hour

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12-13 WIB	584.44 (w/m^2)	5 km/h	11.5 v	3.6 A	18.2 V	12.1 V	1 hour
13-14 WIB	563.28 (w/m^2)	5 km/h	11.5 v	3.3 A	18.0 V	11.9 V	1 hour
14-15 WIB	416.29 (w/m^2)	5 km/hour	11.5 v	2.6 A	17.5 V	11.8 V	1 hour



Figure 2.Test Graph of the Second Experiment

Based on Table 4.1.1, it shows that the battery charging process using solar panels works most optimally during the day (12.00–13.00 WIB) with a peak solar intensity of 584.44 W/m², which produces a maximum current of 3.6 A and a panel voltage of 18.2 V. Overall from morning to evening, this test recorded an average solar intensity value of 475.62 W/m², an average panel current of 2.9 A, and an average panel voltage of 17.73 V. The performance of the solar panels effectively succeeded in increasing the battery voltage from an initial condition of 11.5 V to reach an average final voltage of 11.85 V.

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Table 4.2 test data for the 10° angle of the first trial using a 100 W solar panel

Time	Sun Intensity (w/m^2)	Wind velocity (km/h)	Initial Battery Voltage (v)	Current Panel (A)	Panel Voltage (v)	Battery Final Voltage (v)	Charging time
09-10 WIB	257 (w/m^2)	3 km/h	11.5 v	1.8 A	17.0 V	11.7 V	1 hour
10-11 WIB	464 (w/m^2)	5 km/h	11.5 v	3.2 A	18.1 V	11.9 V	1 hour
11-12 WIB	568 (w/m^2)	6 km/h	11.5 v	4.1 A	18.6 V	12.1 V	1 hour
12-13 WIB	584.44 (w/m^2)	5 km/h	11.5 v	4.3 A	18.8 V	12.3 V	1 hour
13-14 WIB	563.28 (w/m^2)	5 km/h	11.5 v	4.0 A	18.5 V	12.2 V	1 hour
14-15 WIB	416.29 (w/m^2)	5 km/hour	11.5 v	2.9 A	17.9 V	12.0 V	1 hour

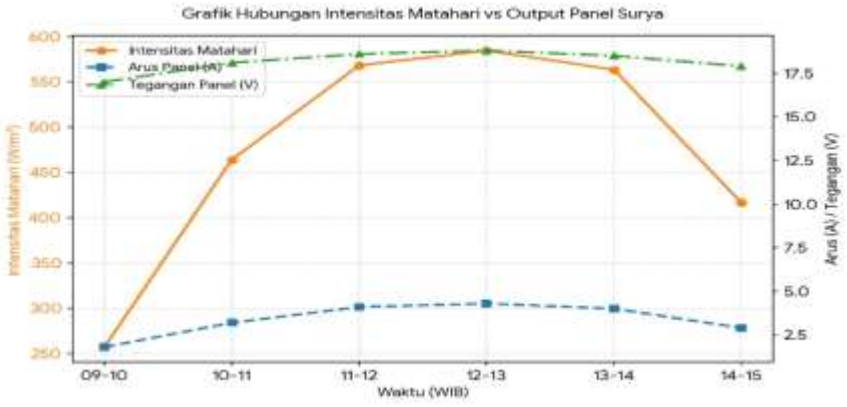


Figure 4.3 First trial test graph

Based on the test results data in Table 4.2, the performance of the 100 W solar panel at a 10° tilt angle showed optimal performance with an average solar intensity of 475.50W/m and an average wind speed of 4.83km/h. These environmental conditions were proven to be able to

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stimulate the solar panel to produce a stable electrical output with an average voltage of 18.15 V and an average current of 3.38 A, where the highest performance point was achieved at 12-13 WIB when the solar intensity was at its maximum peak of 584.44W/m. This constant electrical power supply was proven to be effective in carrying out the charging process, as indicated by the increase in the final battery voltage from the initial condition of 11.5 V to reach an overall average value of 12.03 V at the end of the test.

DISCUSSION

1. Calculation of light intensity on solar panels at 09.00-10.00 WIB

a). time range 09:00-10:00 (based on measurement data from Luxmeter)

Period I: 09:00-9:15

$$G = Lux \times 0{,}0079$$
$$G = (6386lux)(0{,}0079)$$
$$G = 50{,}45\ \mathrm{W/m2}$$

period II: 09:15-9:30

$$G = Lux \times 0{,}0079$$
$$G = (8200lux)(0{,}0079)$$
$$G = 64{,}78\ \mathrm{W/m2}$$

Period III: 09:30-9:45

$$G = Lux \times 0{,}0079$$
$$G = (8700lux)(0{,}0079)$$
$$G = 68{,}73\ \mathrm{W/m2}$$

period IV:9:45-10:00

$$G = Lux \times 0{,}0079$$
$$G = (9240lux\ )(0{,}0079)$$
$$G = 72{,}996\ \mathrm{W/m2}$$
$$= 73\ \mathrm{W/m2}$$

b). time range 10:00-11:00 (based on measurement data from Luxmeter)

Period I: 10:00-10:15

$$G = Lux \times 0{,}0079$$
$$G = (11900lux)(0{,}0079)$$
$$G = 94\ \mathrm{W/m}$$

period II: 10:15-10:30

$$G = Lux \times 0{,}0079$$
$$G = (14810lux)(0{,}0079)$$

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$$G = 116{,}99\ \mathrm{W/m2}$$
$$G = 117\ \mathrm{W/m2}$$

Period III: 10:30-10:45

$$G = Lux \times 0{,}0079$$
$$G = (15180lux)(0{,}0079)$$
$$G = 119{,}922\ \mathrm{W/m2}$$
$$G = 120\ \mathrm{W/m2}$$

period IV:10:45-11:00

$$G = Lux \times 0{,}0079$$
$$G = (16800lux\ )(0{,}0079)$$
$$G = 132{,}72\ \mathrm{W/m2}$$
$$= 133\ \mathrm{W/m2}$$

c). time range 11:00-12:00 (based on measurement data from Luxmeter)

Period I: 11:00-11:15

$$G = Lux \times 0{,}0079$$
$$G = (17810lux)(0{,}0079)$$
$$G = 140,7\mathrm{W/m2}$$
$$G = 141\ \mathrm{W/m2}$$

period II: 11:15-11:30

$$G = Lux \times 0{,}0079$$
$$G = (17840lux)(0{,}0079)$$
$$G = 140{,}936\ \mathrm{W/m2}$$
$$G = 141\ \mathrm{W/m2}$$

Period III: 11:30-11:45

$$G = Lux \times 0{,}0079$$
$$G = (17960lux)(0{,}0079)$$
$$G = 141{,}88\ \mathrm{W/m2}$$
$$G = 142\ \mathrm{W/m2}$$

period IV:11:45-12:00

$$G = Lux \times 0{,}0079$$
$$G = (18180lux\ )(0{,}0079)$$
$$G = 143{,}622\ \mathrm{W/m2}$$
$$G = 144\ \mathrm{W/m2}$$

d). time range 12:00-13:00 (based on measurement data from Luxmeter)

Period I: 12:00-12:15

$$G = Lux \times 0{,}0079$$

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$$G = (18360lux)(0{,}0079)$$
$$G = 145\ \mathrm{W/m2}$$

period II: 12:15-12:30

$$G = Lux \times 0{,}0079$$
$$G = (18410lux)(0{,}0079)$$
$$G = 145{,}44\ \mathrm{W/m2}$$

Period III: 12:30-12:45

$$G = Lux \times 0{,}0079$$
$$G = (18480lux)(0{,}0079)$$
$$G = 145{,}992\ \mathrm{W/m2}$$
$$G = 146\ \mathrm{W/m2}$$

period IV:11:45-13:00

$$G = Lux \times 0{,}0079$$
$$G = (18680lux\ )(0{,}0079)$$
$$G = 147{,}572\ \mathrm{W/m2}$$
$$G = 148\ \mathrm{W/m}$$

e). time range 13:00-14:00 (based on measurement data from Luxmeter)

Period I: 13:00-13:15

$$G = Lux \times 0{,}0079$$
$$G = (18570lux)(0{,}0079)$$
$$G = 146{,}7\ \mathrm{W/m2}$$
$$G = 147\ \mathrm{W/m2}$$

period II: 13:15-13:30

$$G = Lux \times 0{,}0079$$
$$G = (17630lux)(0{,}0079)$$
$$G = 139{,}277\ \mathrm{W/m2}$$
$$G = 139{,}3\ \mathrm{W/m2}$$

Period III: 13:30-13:45

$$G = Lux \times 0{,}0079$$
$$G = (17640lux)(0{,}0079)$$
$$G = 139{,}356\ \mathrm{W/m2}$$
$$G = 139{,}36\ \mathrm{W/m2}$$

period IV:1:45-2:00 PM

$$G = Lux \times 0{,}0079$$
$$G = (17420lux\ )(0{,}0079)$$
$$G = 137{,}618\ \mathrm{W/m2}$$

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$$G = 137{,}62\ \mathrm{W/m2}$$
$$G = 138\ \mathrm{W/m2}$$

f). time range 14:00-15:00 (based on measurement data from Luxmeter)

Period I: 14:00-14:15

$$G = Lux \times 0{,}0079$$
$$G = (15510lux)(0{,}0079)$$
$$G = 122{,}5\ \mathrm{W/m2}$$

period II: 14:15-14:30

$$G = Lux \times 0{,}0079$$
$$G = (13050lux)(0{,}0079)$$
$$G = 103{,}095\ \mathrm{W/m2}$$

Period III: 14:30-14:45

$$G = Lux \times 0{,}0079$$
$$G = (13000lux)(0{,}0079)$$
$$G = 102{,}7\ \mathrm{W/m2}$$
$$G = 103\ \mathrm{W/m2}$$

period IV:2:45-3:00 PM

$$G = Lux \times 0{,}0079$$
$$G = (11150lux\ )(0{,}0079)$$
$$G = 88\ \mathrm{W/m2}$$

2. Calculate the power generated by the solar panel during the time period 09:00-15:00

- Period I: 09:00-09:15

$S = G \times A$= $(6386lux)(0{,}0079)(0{,}536m^2)$

S_1== 27 watts $(50{,}45w/m^2)(0{,}536m^2)$

Period II: 09:15-09:30

S_2= =$G \times A(8200lux)(0{,}0079)(0{,}536m^2)$

= = 34,722 watts$(64{,}78w/m^2)(0{,}536m^2)$

Period III: 09:30-09:45

S_3= =$G \times A(8700lux)(0{,}0079)(0{,}536m^2)$

= = 36.84 watts$(68{,}73w/m^2)(0{,}536m^2)$

Period IV: 09:45-10:00

S_4= =$G \times A(9240lux)(0{,}0079)(0{,}536m^2)$

= = 39.125 watts$(72{,}99w/m^2)(0{,}536m^2)$

Total power received by the panel current during the period 09:00-10:00 WIB

$$ST = S_1 + S_2 + S_3 + S_4$$

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$ST = 27w + 34{,}72 + 36{,}84 + 39{,}125$

$= 137{,}68w$

- Period I: 10:00-10:15

$S = G \times A$= $(11900lux)(0{,}0079)(0{,}536m^2)$

S_1== 50,384 watts $(94\ w/m^2)(0{,}536m^2)$

Period II: 10:15-10:30

S_2= =$G \times A(14810lux)(0{,}0079)(0{,}536m^2)$

= = 67,712 watts$(117\ w/m^2)(0{,}536m^2)$

Period III: 10:30-10:45

S_3= =$G \times A(15180lux)(0{,}0079)(0{,}536m^2)$

= = 64.32 watts$(120w/m^2)(0{,}536m^2)$

Period IV: 10:45-11:00

S_4= =$G \times A(16800lux)(0{,}0079)(0{,}536m^2)$

= = 71.14 watts$(132{,}72w/m^2)(0{,}536m^2)$

Total power received by the panel current during the period 10:00-11:00 WIB

$ST = S_1 + S_2 + S_3 + S_4$

$ST = 50{,}384w + 67{,}712w + 64{,}32w + 71{,}14w$

$= 253{,}556w$

- Period I: 11:00-11:15

$S = G \times A$= $(17810lux)(0{,}0079)(0{,}536m^2)$

S_1== 75.42 watts $(140{,}7\ w/m^2)(0{,}536m^2)$

Period II: 11:15-11:30

S_2= =$G \times A(17840lux)(0{,}0079)(0{,}536m^2)$

= = 73.54 watts$(140{,}936\ w/m^2)(0{,}536m^2)$

Period III: 11:30-11:45

S_3= =$G \times A(17960lux)(0{,}0079)(0{,}536m^2)$

= = 76,112 watts$(142w/m^2)(0{,}536m^2)$

Period IV: 11:45-12:00

S_4= =$G \times A(18180lux)(0{,}0079)(0{,}536m^2)$

= = 76.98 watts$(143{,}622w/m^2)(0{,}536m^2)$

Total power received by the panel current during the period 11:00-12:00 WIB

$ST = S_1 + S_2 + S_3 + S_4$

$ST = 75{,}42w + 73.54w + 76{,}112w + 76{,}98w$

att= $304{,}052w$

- Period I: 12:00-12:15

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$S = G \times A$= $(18360lux)(0{,}0079)(0{,}536m^2)$

S_1== 77.72 watts $(145\ w/m^2)(0{,}536m^2)$

Period II: 12:15-12:30

S_2= =$G \times A(18410lux)(0{,}0079)(0{,}536m^2)$

= = 77.96 watts$(145{,}44\ w/m^2)(0{,}536m^2)$

Period III: 12:30-12:45

S_3= =$G \times A(18480lux)(0{,}0079)(0{,}536m^2)$

= = 78.25 watts$(145{,}992w/m^2)(0{,}536m^2)$

Period IV: 12:45-13:00

S_4= =$G \times A(18680lux)(0{,}0079)(0{,}536m^2)$

= = 79 watts$(147{,}572w/m^2)(0{,}536m^2)$

Total power received by the panel current during the period 12:00-13:00 WIB

$ST = S_1 + S_2 + S_3 + S_4$

$ST = 77{,}72w + 77{,}96w + 78{,}25w + 79w$

att= $312{,}93w$

- Period I: 13:00-13:15

$S = G \times A$= $(18570lux)(0{,}0079)(0{,}536m^2)$

S_1== 78.63 watts $(146{,}7\ w/m^2)(0{,}536m^2)$

Period II: 13:15-13:30

S_2= =$G \times A(17630lux)(0{,}0079)(0{,}536m^2)$

= = 74.65 watts$(139{,}277\ w/m^2)(0{,}536m^2)$

Period III: 13:30-13:45

S_3= =$G \times A(17640lux)(0{,}0079)(0{,}536m^2)$

= = 74.69 watts$(139{,}356w/m^2)(0{,}536m^2)$

Period IV: 13:45-14:00

S_4= =$G \times A(17420lux)(0{,}0079)(0{,}536m^2)$

= = 73.76 watts$(137{,}62w/m^2)(0{,}536m^2)$

Total power received by the panel current during the period 13:00-14:00 WIB

$ST = S_1 + S_2 + S_3 + S_4$

$ST = 78{,}63w + 74{,}65w + 74{,}69w + 73{,}76w$

att= $301{,}73w$

- Period I: 14:00-14:15

$S = G \times A$= $(15570lux)(0{,}0079)(0{,}536m^2)$

S_1== 65.68 watts $(122{,}529\ w/m^2)(0{,}536m^2)$

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Period II: 14:15-14:30

S_2= $=G \times A(13050lux)(0{,}0079)(0{,}536m^2)$

= = 55.26 watts$(103{,}095\ w/m^2)(0{,}536m^2)$

Period III: 14:30-14:45

S_3= $=G \times A(13000lux)(0{,}0079)(0{,}536m^2)$

= = 55,047 watts$(102{,}7w/m^2)(0{,}536m^2)$

Period IV: 14:45-15:00

S_4= $=G \times A(11150lux)(0{,}0079)(0{,}536m^2)$

= = 47.21 watts$(88{,}085w/m^2)(0{,}536m^2)$

Total power received by the panel current during the period 14:00-15:00 WIB

$ST = S_1 + S_2 + S_3 + S_4$

$ST = 65{,}68w + 55{,}26w + 55{,}047w + 47{,}21w$

att= $223{,}2w$

So the total power received from the 100 watt solar panel with a time span of 09:00-15:00 WIB in a 6 hour period, the power generated is: 1533.15 Watts.

3. Calculation of the rate of radiant heat transfer with a time span of 09:00-15:00

$$\boxed{Q = \mathcal{E}\sigma A(\Delta T)}$$

Period I: 09:00-10:00

$$Q = \mathcal{E}\sigma A(\Delta T)$$

$$Q_1 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(25℃ + 22℃)^4$$

$$Q_1 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(59℃ + 273k)^4$$

$$Q_1 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(322k)^4$$

$$Q_1 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(10{,}7 \times 10^9 k^4)$$

$$Q_1 = (0{,}85)(5.67\ w)(0{,}536\ m)(107)$$

$$Q_1 = 276{,}40\ watt$$

Period II: 10:00-11:00

$$Q = \mathcal{E}\sigma A(\Delta T)$$

$$Q_2 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(25℃ + 28℃)^4$$

$$Q_2 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(53℃ + 273k)^4$$

$$Q_2 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(326k)^4$$

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$$Q_2 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(11{,}93 \times 10^9 k^4)$$
$$Q_2 = (0{,}85)(5.67\ w)(0{,}536\ m)(119{,}3)$$
$$Q_2 = 308{,}2\ watt$$

Period III: 11:00-12:00

$$Q = \mathcal{E}\sigma A(\Delta \mathrm{T})$$
$$Q_3 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(26{,}5℃ + 28{,}5℃)^4$$
$$Q_3 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(55℃ + 273k)^4$$
$$Q_3 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(328k)^4$$
$$Q_3 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(11{,}57 \times 10^9 k^4)$$
$$Q_3 = (0{,}85)(5.67\ w)(0{,}536\ m)(115{,}7)$$
$$Q_3 = 299\ watt$$

Period IV: 12:00-13:00

$$Q = \mathcal{E}\sigma A(\Delta \mathrm{T})$$
$$Q_4 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(28{,}5℃ + 29{,}75℃)^4$$
$$Q_4 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(58℃ + 273k)^4$$
$$Q_4 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(331k)^4$$
$$Q_4 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(12 \times 10^9 k^4)$$
$$Q_4 = (0{,}85)(5.67\ w)(0{,}536\ m)(120)$$
$$Q_4 = 310\ watt$$

Period V: 13:00-14:00

$$Q = \mathcal{E}\sigma A(\Delta \mathrm{T})$$
$$Q_5 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(28{,}125℃ + 29{,}375℃)^4$$
$$Q_5 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(57{,}5℃ + 273k)^4$$
$$Q_5 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(330{,}5k)^4$$
$$Q_5 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(11{,}93 \times 10^9 k^4)$$
$$Q_5 = (0{,}85)(5.67\ w)(0{,}536\ m)(119{,}3)$$
$$Q_5 = 308{,}2\ wat$$

Period VI: 14:00-15:00

$$Q = \mathcal{E}\sigma A(\Delta \mathrm{T})$$

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$$Q_6 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(27{,}562℃ + 29{,}873℃)^4$$
$$Q_6 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(57{,}43℃ + 273k)^4$$
$$Q_6 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(330{,}43k)^4$$
$$Q_6 = (0{,}85)\left(5.67 \times \frac{10^{-8}w}{m^2}.k^4\right)(0{,}536m^2)(11{,}92 \times 10^9k^4)$$
$$Q_6 = (0{,}85)(5.67\ w)(0{,}536\ m)(119{,}2)$$
$$Q_6 = 308\ watt$$

So the result of the rate of radiation heat transfer at 09:00-15:00 is

$$QT = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$$
$$QT = 276{,}40w + 308{,}2w + 299w + 310w + 308{,}2w$$
$$QT = 1501{,}8watt$$

So the optimal power used is the solar panel current during operation.

$P = S_T$ - 1533.15 Watts – 1501.8 Watts$Q_T =$

32.7 watts 33 watts==

Optimal power 33 Watts at an angle$P = 0°, 10°, 20°$

$P_{T1} = (33\ watt \cos 0°)i + (33\ watt \sin 0°)j$

$P_{T1} =$ +0$(33\ watt)(1)ij$

P_{T1} =33 watt$i$

$P_T$power used angular current:10°

$P_{T2} = (33\ watt \cos 10°)i + (33\ watt \sin 10°)j$

$P_{T2} =$ +$(33\ watt)(0.98)i(33\ watt)\ (0{,}17)j$

P_{T2} =32.34 watts + 5.61ij

$P_T$power used angular current:20°

$P_{T3} = (33\ watt \cos 20°)i + (33\ watt \sin 20°)j$

$P_{T3} =$ +$(33\ watt)(0.94)i(33\ watt)\ (0{,}34)j$

P_{T3} =31.02 watts + 11.22ij

Then the power value is obtained by using the angle variation.{0°, 10°, 20°}

$+P_{Ttotal} = P_{T1}P_{T2} + P_{T3}$

++11.22= $(33\ \text{watt}i + 0j) + (32{,}34\ w)i + 5{,}61j\ (31{,}02w)ij$

$= 96{,}36w\ i + 16{,}83w\ j$

$P_{T1} = \sqrt{(96{,}36)^2 + (16{,}83w)^2}$

$P_{T1} = \sqrt{9285{,}25w^2 + 283{,}25w^2}$

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97.82 Watts$P_{T1} = \sqrt{956{,}5w^2} =$

This means that with a power capacity of 100 watts, it is suitable for use because the operational power current of the solar panel is 97.82 watts

CONCLUSION

Conclusion Based on the results of data analysis and testing of the charging system using a 100 watt solar panel on a plant sprayer, the following conclusions can be drawn:

1. Optimal Charging System: The battery charging system on the plant sprayer reaches its most optimal condition when the 100 watt solar panel is installed at an inclined angle. At this position, the solar panel is able to produce the highest average current (3,873 A) and the highest charging power (72,409 W) compared to the sloping position or the flat position.$20^\circ 10^\circ 0^\circ$
2. Power Increase Characteristics: Changes in tilt angle have been shown to affect charging power linearly and unidirectionally. Each increase in tilt angle of (up to the test limit) increases the charging output power of the sprayer battery by a constant 1.036 Watts. The difference in power efficiency is only seen to be statistically significant when the angle is changed directly from the horizontal position to the optimal angle.$1^\circ 20^\circ 0^\circ 20^\circ$
3. Charging Time Conditions: The charging time variable is not affected by changes in the tilt angle of the solar panel. This is due to the protection system in the sprayer's Solar Charge Controller (SCC), which limits the maximum current threshold for battery safety, so the charging time remains constant.

SUGGESTION

Field Test Suggestion on Sprayer: Further research is recommended to test the charging performance directly while the crop sprayer is in active use in the field (on-the-go charging) to see the real charging efficiency under shock.

1. Optimization of Controller Equipment (SCC): It is recommended to replace or modify the type of Solar Charge Controller (SCC) to a more adaptive MPPT type so that the increase in current from the solar panel at an angle) can be converted into a faster battery charging time duration.20^∘
2. Battery Capacity Development: It is recommended that future research try using varying battery capacities for the sprayer so that the charging efficiency measurement limits of this 100 watt solar panel can be seen in more detail.

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