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Impact of a dual-axis solar tracker and reflector glass on the performance of a 100Wp photovoltaic panel

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Abstract

Solar radiation varies by region, and photovoltaic (PV) panels typically achieve a maximum efficiency of 21%. This study examines the impact of a dual-axis solar tracker and 5mm reflector glass on the performance of a 100Wp photovoltaic system. The experiment was conducted for three days in September and involved placing reflector glass perpendicular to incoming sunlight to enhance light capture and thermal efficiency. Results showed that the system achieved a maximum efficiency of 19.31% at 10:00 AM on Day 2, with a peak power output of 31.08 W under an irradiance of 595.26 W/m². The lowest efficiency of 4.26% occurred at 8:15 AM on Day 3. The highest recorded temperature was 36.6°C, while the lowest was 30.4°C. The findings suggest that using a dual-axis tracker with reflector glass can improve PV panel efficiency and power generation by optimizing incident radiation and heat distribution.

Keywords:
Solar panel, energy, efficiency, reflector glass.

1 Introduction

The need for energy is vital for human survival, and its use and price are becoming increasingly expensive. These factors create an urgent demand to seek renewable energy sources that can be replenished quickly and have minimal environmental impact. [1], [2]. Among the new renewable energy sources that are very rapid and abundant we get only solar energy. Earth gets 16x1018 J from the sun per year, which is equivalent to 20,000 times the needs of all humanity on Earth [3]. Indonesia is a country whose position is on the equator and obtains solar energy as much as 4.7-6.0 kWh/m^2 annually [4]. Indonesia's solar energy potential is almost 207,898 MW, but only about 78.5 MW is used [5]. Solar energy can be converted into electricity in several ways, one of the most common being the use of photovoltaics (PV) or solar panels. There is a major obstacle to PV which is still low efficiency but until now Photovoltaic is still relatively easy to convert solar radiation into electrical energy. The level of efficiency that is not yet maximum when using photovoltaics makes researchers and energy observers look for solutions so that it can become even more efficient. One solution to overcome these obstacles is to use a solar tracker [6]. Solar trackers are devices that can help solar panels maximize the absorption of solar radiation by making solar panels always face (perpendicular to) the sun, [6]–[8]. In static or fixed-axis solar panels, the maximum solar radiation capture can be achieved by manually and automatically optimizing the direction and tilt of the panel itself.. The optimal direction and tilt of the panel are influenced by several factors, including the location and season [9]–[11]. The results of studies related to solar trackers, both single and dual axis, show a tendency to increase the output of solar panels, the value of which certainly varies [12]–[14]. The maximum output power generated by the Canadian Solar CS6K-270 Wp Photovoltaic model is directly proportional to solar irradiation; the higher the solar intensity, the higher the output power generated [15].

This study aims to determine the performance of the solar tracker in producing an outgoing current due to radiation around the solar panel. A dual-axis solar tracker was chosen concerning the output produced by the solar panel. From the search or existing literature, no one has ever examined the use of reflector glass that leads to better heat gain by using 5mm reflector glass in the Medan city area around Medan Perjuangan. In addition, Indonesia's location on the equator causes less significant solar movement than countries outside the tropical ring. The output of this solar tracker using a 100 Wp solar panel can get the highest energy in terms of efficiency so it is expected to provide recommendations for users, especially in the Medan City area.

2 Research methods

2.1 Research location

The research location of the dual axis Solar Tracker testing took place in April-September 2022 conducted in the laboratory of the Work Shop Development and Alternative Energy of HKBP Nommensen University Medan. The coordinate position of the research location is located at 3035'49.5 ‘LU 980 40'52.5 ’BT.

2.2 Tools and materials

A component sketch of the double-axis solar tracker used in this study is shown in Fig. 1. Description in Fig. 1 are, 1. *Photovoltaic* 100 Wp, 2. Controller, 3. Support Pole, 4. Axis, 5. Hydraulic Axis, 6. Foundation. Sketches of the panels and reflectors used in this study are shown in Fig. 2.

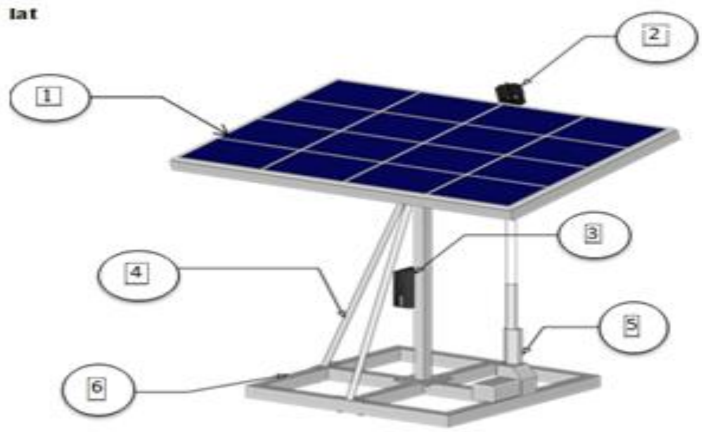

Fig. 1. Sketch of dual-axis sun tracker.

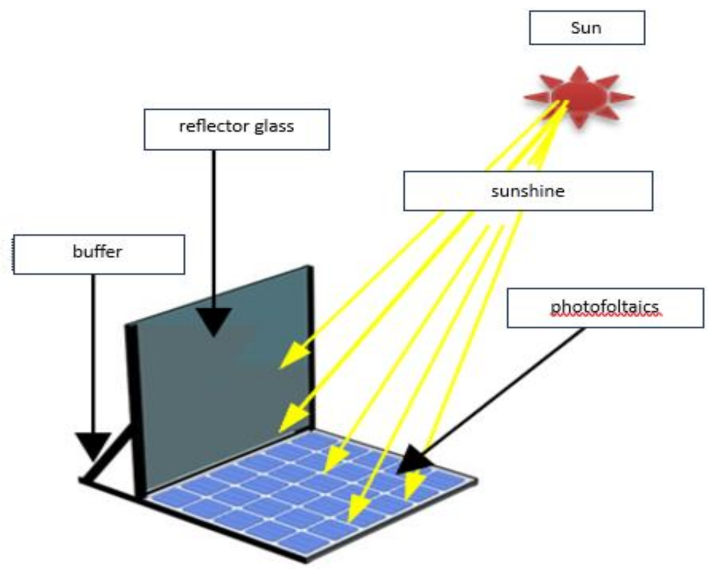

Fig. 2. Panel and reflector sketches.

Solar radiation radiates radiant energy in all directions in accordance with the solar energy theory. Solar energy is emitted and absorbed by the solar panel, and some is emitted to the reflector glass. The reflector glass reflects solar radiation to the solar panel, so it is expected to increase the energy that can be absorbed by the solar panel.

A solar tracker that absorbs solar radiation energy is connected to the controller so that the incoming and outgoing power can be acquired using a laptop and solar tracker Graphical User Interface (GUI). In this study, a grinder was used as a load to utilize the power generated by the solar tracker. An anemometer was used to measure the wind speed during testing.

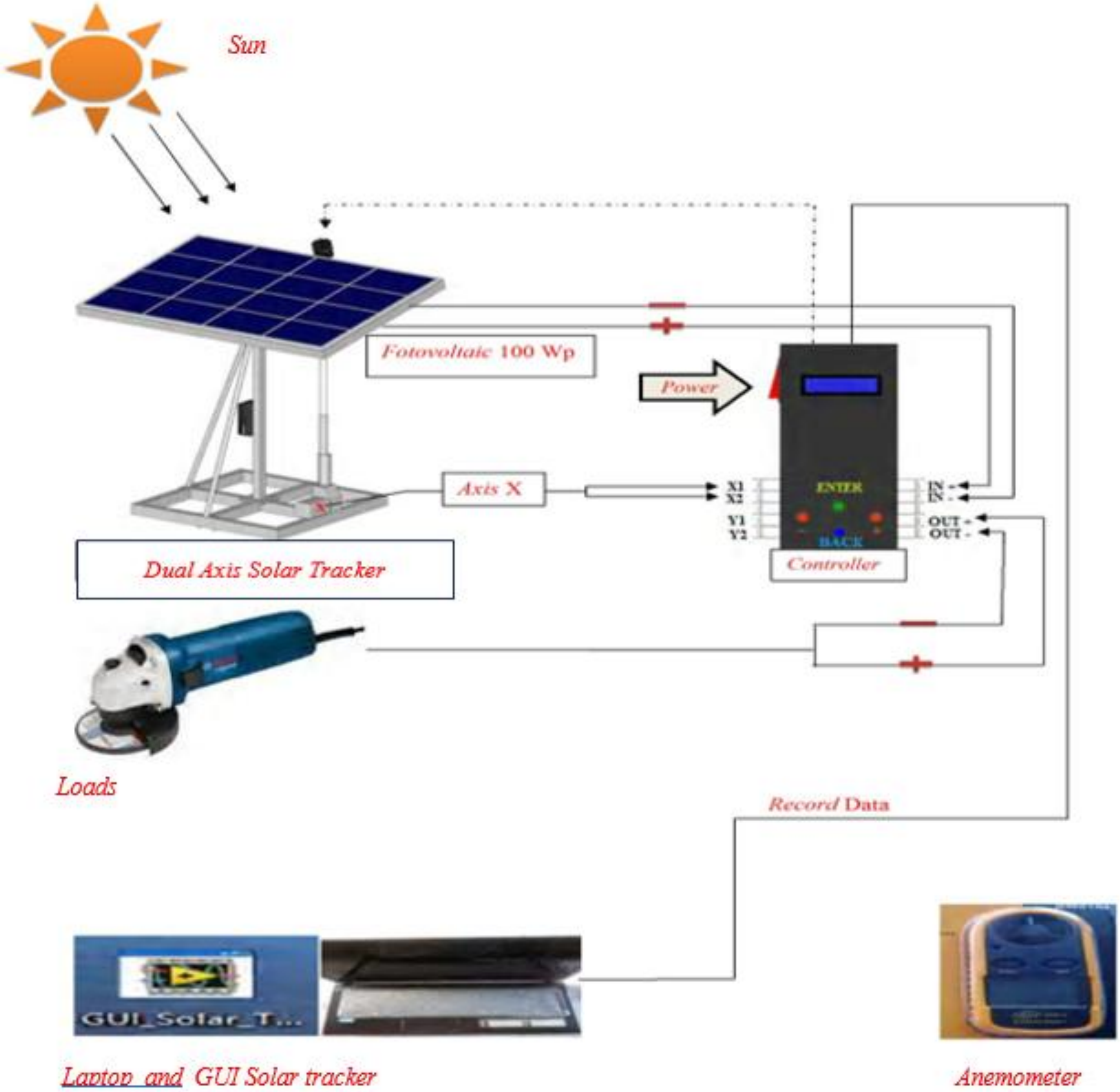

Fig. 3. Testing sketch

3 Results and discussion

3.1 Incoming power, outgoing power, and efficiency on 1st day

In the test at 08:00-17:00 WIB every 15 minutes on test on the 1st day using Eqs (1-3).

$$P_{in} = I.A_{panel} \quad (1)$$

$$P_{out} = V.I \quad (2)$$

where I is 216.09 W/m^2, A_{panel} is 0.6683 m^2, then, $P_{in} = 216.09\ W/m^2\ .0.6683\ m^2 = 144.41\ W$. V is 19.45 V, I is 0.4491 A, then $P_{out} = 15.4\ V \times 1.2188\ A = 18.66\ W$. Result for hours shown in Table. 1.

$$Eff = \frac{P_{out}}{P_{in}} \times 100\% \quad (3)$$

$$Eff = \frac{18{,}66\ W}{144{,}41\ W} \times 100\% = 12.92\%$$

Table 1. 1st day testing (per hour) 08/09/2023

No	Waktu	I (W/m^2)	Volt (V)	Current (A)	P_{in} (W)	P_{out} (W)	V (m/s)	Temp. (^{0}C)	Eff. (%)
1	8.00	216.09	15.4	12.118	144.41	18.66	0.6	29.7	12.92
2	9.00	202.83	12.69	15.219	135.55	19.31	0.4	30.4	14.24
3	10.00	252.78	17.55	1.733	168.93	30.41	0.9	31.2	18
4	11.00	208.95	14.86	14.421	139.64	21.42	0.6	33.6	15.34
5	12.00	215.07	19.29	12.112	143.73	23.36	0.9	34	16.25
6	13.00	419.94	19.47	1.593	280.64	31.01	0.5	34.6	11.05
7	14.00	315.98	17.67	13.624	211.16	24.07	0.4	35	11.40
8	15.00	209.97	14.36	12.918	140.32	18.55	0.6	35.6	13.21
9	16.00	252.78	17.9	15.928	168.93	28.51	0.9	34.8	16.87
10	16.15	277.24	17.9	15.227	185.27	27.25	0.4	34.2	14.71
11	17.00	177.36	17.83	0.927	118.52	16.52	0.9	33.7	13.94
12	rata-rata	273.99	16.97	13.993	183.1	23.94	0.6	33.2	13.71

3.2 Incoming power, outgoing power, and efficiency on 2nd days

Using Eqs (1-3), P_{in} namely I is 134.62 W/m², A_{panel} is 0.6683 m², $P_{in} = 134.18\ W$. P_{out}, V is 15.88 *Volt*, I is 0.925 *Ampere*, then $P_{out} = 14.68\ W$, The efficiency is 10.94%. Table 2 shows results in hours.

Table 2. Data testing on 2nd days (Per Hour) 09/09/2023

No	Time	I (W/m2)	Volt. (V)	Current (A)	Pin (W)	Pout (W)	v (m/s)	Temp. (°C)	Eff. (%)
1	08.00	200.79	15.88	0.925	134.1	14.68	0.4	31	10.94
2	09.00	203.85	17.46	0.925	136.2	16.15	0.6	32	11.85
3	10.00	210.96	16.01	1.217	140.9	19.48	0.6	33	13.82
4	11.00	318.01	18.2	1.5227	212.5	27.71	0.4	33.4	13.03
5	12.00	521.87	19.44	1.8229	348.7	35.43	0.4	34	10.16
6	13.00	644.19	21.39	2.1626	430.5	46.25	0.4	34.2	10.74
7	14.00	499.45	21.92	1.8835	333.7	41.28	0.4	34.5	12.36
8	15.00	623.8	21.87	1.9531	416.8	42.71	0.8	34.7	10.24
9	16.00	279.65	18.35	1.4426	186.8	26.47	0.9	33.2	14.16
10	17.00	270.79	18.27	1.3624	180.9	24.89	0.4	33.7	13.75

3.3 Incoming power, outgoing power, and efficiency on 3rd days

Using Eqs (1-3), Pin: I = 195,85 W/m², A_{panel} = 0,6683 m², $P_{in}\,130.88\ W$. $P_{out} = 8.0244\ W$. Using Efficiency is 12.1311%. The test results for three days are tabulated in Tables 3, 4, and 5.

Table 3. 3rd days testing Data (Per Hour) 10/09/2023

No	Time	I (W/m²)	Volt (V)	Current (A)	P_{in} (W)	P_{out} (W)	V (m/s)	Temp. (°C)	Effs. (%)
1	08.00	175.32	19.39	1.1333	117.16	21.97	0.5	31	10.94
2	09.00	240.55	19.87	1.4426	160.75	28.66	0.6	32	11.85
3	10.00	196.72	19.59	1.2332	131.46	24.15	0.6	33	13.82
4	11.00	313.94	20.19	1.4424	209.80	29.12	0.4	33.4	13.03
5	12.00	360.23	20.19	1.2115	241.13	24.46	0.4	34	10.16
6	13.00	430.14	19.94	1.6922	287.46	33.74	0.4	34.2	10.74
7	14.00	251.76	18.72	1.2919	168.25	24.18	0.4	34.5	12.36
8	15.00	226.28	19.39	1.2916	151.22	25.04	0.4	34.7	10.24
9	16.00	434.22	20.19	1.5224	290.18	30.73	0.4	33.2	14.16
10	17.00	129.45	15.9	0.9231	86.51	28.51	0.5	33.7	13.75

Table 4. Tabulation of test data

Time	I (W/m2)	Volt (V)	Current (A)	Pin (w)	Pout (w)	V wind (m/s)	Temp (0c)	Eff. (%)
day-1	273.99	16.97	1.3993	183.1	23.94	0.6	33.2	13.71
day-2	407.61	19.1	1.5927	272.41	31.08	0.6	33.4	11.87
day-3	283.11	19.59	1.3835	189.2	26.73	0.6	32.2	14.9
Average	321.57	18.55	1.458	214.9	27.25	0.6	32.9	13.49

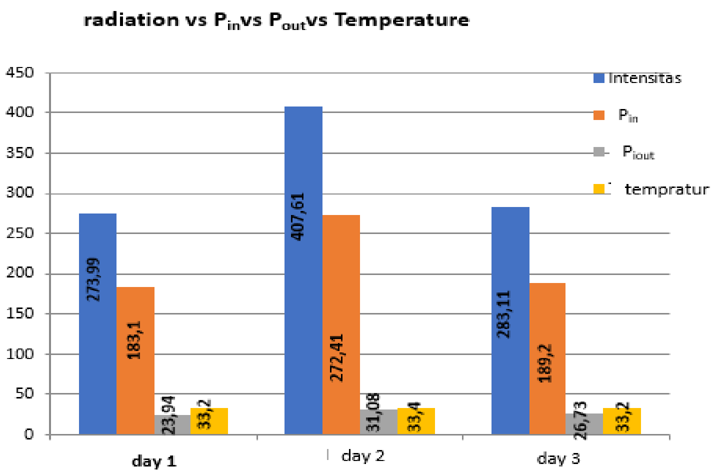

Fig. 4. Radiation, power in, power out, and temperature

The variation of testing per day is different, as low and high solar intensity will be followed by an increasing trend of power output as well as increasing voltage (Fig. 4). The voltage is directly proportional to the current strength and inversely proportional to the wind speed (Fig. 5). The intensity increases as the power or heat absorbed is high; therefore, the output power also increases (Fig. 6). The intensity increases but the wind weakens; however, as the power or heat absorbed is high, the output power also increases, and the efficiency increases.

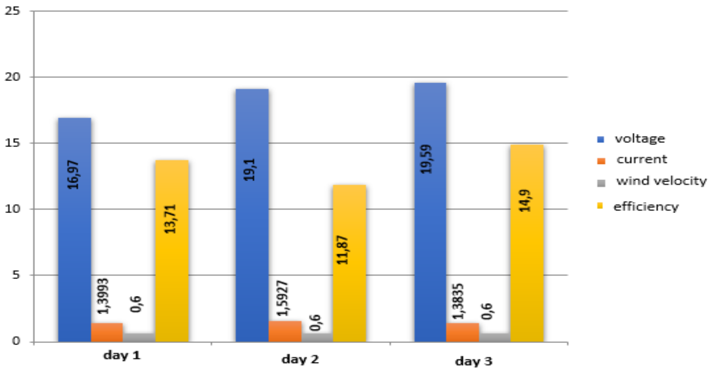

Fig. 5. Voltage, current, wind speed, and efficiency.

Table 5. Tabulation of test data

Day	I (W/m²)	Volt (V)	current (A)	P in (w)	P out (w)	V wind (m/s)	Temp (°C)	Eff. (%)
Day-1	299.25	14.25	1.60	199.99	23.00	0.56	30.41	11.23
day-2	308.76	13.68	1.81	206.34	24.88	0.51	32.87	11.53
day-3	315.62	11.86	1.92	210.93	23.53	0.56	36.36	10.79
Average	307.88	13.26	1.78	205.75	23.80	0.54	33.21	11.18

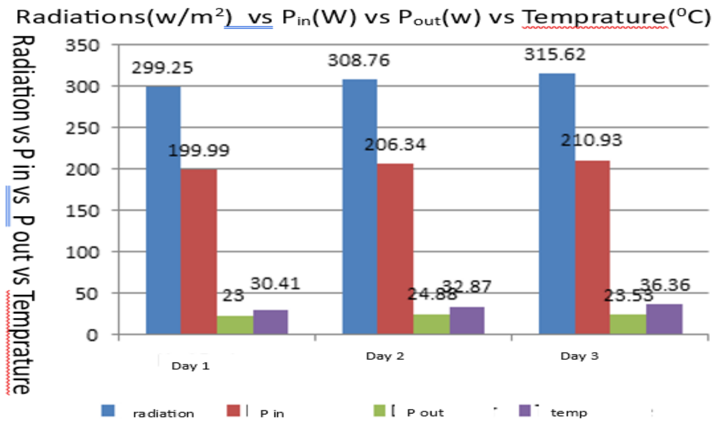

Fig. 6. Radiation, incoming power, outgoing power and temperature.

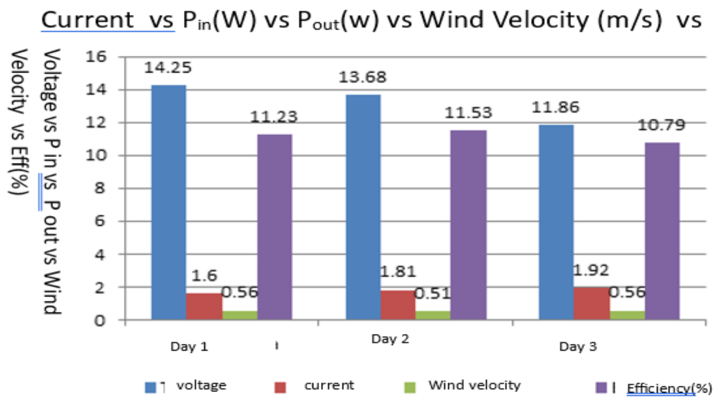

Fig. 7. Voltage, current, wind speed and temperature

This research still has shortcomings; namely, the coordinate point of the solar tracker position must always be perpendicular to the incoming rays, while the advantage is a higher heat increase owing to the reflector glass as an additional instrument.

4 Conclusion

The experimental results confirm that adding reflector glass and a dual-axis tracker enhances the efficiency of a 100Wp photovoltaic system. The highest recorded efficiency was 19.31%, with an average of 13.49%. The highest power output was 31.08 W, while the lowest efficiency was 4.26%. The system's temperature ranged from 30.4°C to 36.6°C, indicating the thermal influence of the reflector glass. The results demonstrate that optimizing solar tracking and light reflection can significantly improve energy output. Future research could explore advanced tracking algorithms and alternative reflector materials to further enhance PV performance.

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