

Analysis the effect of reflector (flat mirror, convex mirror, and concave mirror) on solar panel

Yahot Siahaan, Hartono Siswono

Department of Electrical Engineering, Gunadarma University, Indonesia

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ABSTRACT

At the time of the sun a straight line with solar cells may not necessarily produce the maximum output. Various ways continue to be done in order to get the maximum output. The maximum utilization of output from solar cells will accelerate the function of the solar cell. The use of reflectors is an excellent way to maximum output with effective time. The author will analyze solar cells with flat mirror, convex mirror, concave mirror, and without reflector. Each reflector is given varying treatment by calibrating the angle of the reflector to the solar cell by 60°, 90°, and 120°. After testing and data retrieval turns reflector very influential on the output of solar cells. The solar cell output power increases with each different reflector. Maximum output is obtained in a concave mirror with an angle is 90°.

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Corresponding Author:

Yahot Siahaan,
Department of Electrical Engineering,
Gunadarma University,
Depok, Indonesia.
Email: siahaany93@gmail.com

1. INTRODUCTION

Making life more simple has become the lifestyle of today's society. People are increasingly innovating in search of renewable technology. The development of technology with the utilization of natural resources is needed nowadays. One of the countries that have very prosperous natural resources is Indonesia, but Indonesia is still lacking in the utilization and facilities of natural resources. From Sabang to Merauke all are illuminated by sunlight, this is a very valuable natural asset. The solar irradiation in Indonesia is reaching 4.5 kWh/m²/day. The need for electricity is the most important thing, for it is needed a renewable technology such as solar panels. Solar energy can be utilized with solar panel technology [1]. The working principle of solar panels is when the light of the silicon cell and light will be absorbed by the silicon cell. The absorbed light energy will be transferred to silicon semiconductor properties. The energy stored inside the semiconductor will cause the electrons to loose and flow in the semiconductor. All these photovoltaic cells also have an electric field that forces the electrons loose because of the absorption of that light to flow in a particular direction.

Currently many methods have been done to get a maximum solar panel output, but it doesn't get a significant effect. One of the ways to get maximum output voltage is by adding a reflector. The addition of the reflector is very helpful and efficient for the sun exposure focused on solar panels but many reflectors do not function properly with solar cells [2]. Many types of reflectors can be used for further research but for this analysis the authors use mirrors. The mirror is an excellent reflector. The types of mirrors are flat mirror, convex mirror, and concave mirror. Each type of mirror has different reflections. The difference in angle for reflection of light on the Solar Panel determines the amount of light absorbed. The author will compare and see the effects of the three types of mirrors to get a mirror that is recommended to reflect light on solar cells with the same treatment.

2. RESEARCH METHOD

The addition of reflector in the form of flat mirror, convex and concave is expected to increase efficiency of solar panel output [3]. This research will test every mirror characteristic to the change of solar cell output. Each mirror will be compared before and after being given a reflector. As for the three types of mirrors there are several experimental circuits that we will test and compare with solar cells without reflector:

1. Solar cells circuit without using reflector.
2. Solar cells with reflector angle flat mirror value are 120°, 90°, and 60°.
3. Solar cells with reflector angle convex mirror value are 120°, 90°, and 60°.
4. Solar cells with reflector angle concave mirror value are 120°, 90°, and 60°.

Indonesia is a very good area functioned as the utilization of renewable technology that is solar panel, the more radiation received an area hence greatly affect the performance of solar panel. The sampling of this data is done at JalanKapukMargondaDepok located at position 6 ° 22'06.9 "S 106 ° 50'06.7" E. For one type of mirror reflector, a sample is needed for 3 hours in one day at 11:00-14:00 because we know that at that time the sun is very much received by radiation collectors on earth [4].

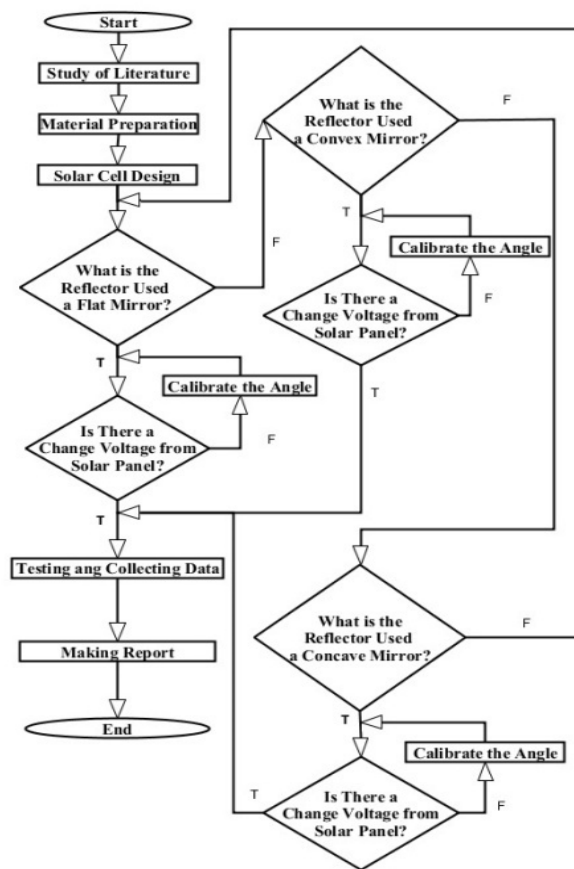


Figure 1. Flowchart

2.1. Equipment and materials for testing

a. Solar cells

This research focuses on solar cells that use the sun as an energy source. Solar cell used in this analysis is polycrystalline type [5]. Below are the pictures and specifications of the solar cell to be tested, solar cells as shown in Figure 2.



Figure 2. Solar cell

Table 1. Specification of Polycrystalline Silicon Type

Module type	P-20W
Cell type	Polycrystalline silicon
Production Tolerance	0~+3%
Maximal Voltage	18.5V
Maximal Current	1.08A
Open Circuit Voltage	22.14V
Short Circuit Current	1.16A
Max Power at STV	20W
Max System Voltage	1000VDC
Dimensions	48.5 x 36 x 2,5 cm

In accordance with the data we get from the solar cell specifications that we use, and then we can determine the Fill factor [6]:

$$FF = \frac{V_{MPP} \times I_{MPP}}{V_{OC} \times I_{SC}}$$

$$FF = \frac{18.5 \times 1.08}{22.14 \times 1.16}$$

$$FF = 0.77$$

With the equation below we can calculate the output power of solar cell that is:

$$\begin{aligned} P_{out} &= V_{oc} \times I_{sc} \times FF \\ P_{out} &= 22.14 \times 1.16 \times 0.77 \\ P_{out} &= 19.77 \text{ W} \end{aligned}$$

The next step we determine the maximum output efficiency is defined as the percentage of optimum output power to light energy [7], [8]. Because of the dimensions of solar cells that we use measuring 48.5x36 then we can determine P_{in} to 174.6W.

$$\begin{aligned} \eta &= \frac{P_{OUT}}{P_{IN}} \times 100\% \\ \eta &= \frac{19.77}{174.6} \times 100\% \\ \eta &= 11.32\% \end{aligned}$$

b. Reflector

There are three types of reflectors selected by the writer to analyze the output voltage of solar cell that is flat, convex, and concave mirror. Reflector is made of glass and aluminum. For a flat mirror the size used is 40cm x 40cm while for convex and concave mirror using a mirror with a diameter of 20cm. each reflector will be placed in contact with the solar cell with different angles for reflection that occurs between the suns against the mirror of the solar cell.

2.2. Measuring instrument

This study uses several measurements as references to get accurate results. The following are the measuring tools used by the author for data collection:

a. Protractor

Protractor is a measuring instrument to determine a degree. The degree usually denoted by $^{\circ}$, is the angular measure that can be formed on a flat plane. This tool is very important to determine the variation of the angle of the benchmark in the study.

b. Thermometer

Thermometer is used as a temperature gauge. Temperature is a very important and influential parameter for the output of solar cells

c. Lux Meter

The intensity of light is very influential in the measurement, for the authors use this tool as a parameter of how much the internality received by solar cells at the time of measurement [9]. Lux meter has a range between 0.1~20.000 Fc with resolution 0.1 Lux/0.1 Fc. Accuracy of 4% with speed 2 times / second and Operating Environment is 14 to 122F (-10 to 50C), 10% ~ 90% RH. Here's a figure of the lux meter. Lux meter as shown in Figure 3.



Figure 3. Lux meter

2.3. Schematic of research tool

Solar Sell is a major component of this research. After we get all that we need in this research, then we set the location of solar cell testing. Solar cells will be tested without a reflector and use three reflectors. Arrangements between solar cells and reflectors should also be considered. Here's a schematic of a solar cell tool without a reflector and using a reflector.

a. Schematic of the Solar Cells that Stand

The first circuit is composed of solar cells that will convert solar energy into electrical energy. The circuit of solar cells we measure using a digital multimeter that can simultaneously measure the current (I) and voltage (V). Any changes whether the current or voltage that occurs during the experiment will be recorded by taking into account some parameters of temperature and light internality received by solar cells. The circuit below shows solar cells without reflector as shown in Figure 4.



Figure 4. Solar cells circuit without reflector

b. Schematic of a solar cell with the addition of reflectors

The next series is the same as the first but that distinguishes it only by adding three different types of reflectors at different times. Its main components are solar cells and reflectors in the form of flat mirrors, convex mirrors, and concave mirrors. Each reflector will be tried differently with different test times as well so at the time of measurement will also have different light intensity and temperature. Here is a picture of the three types of reflectors and solar cells.

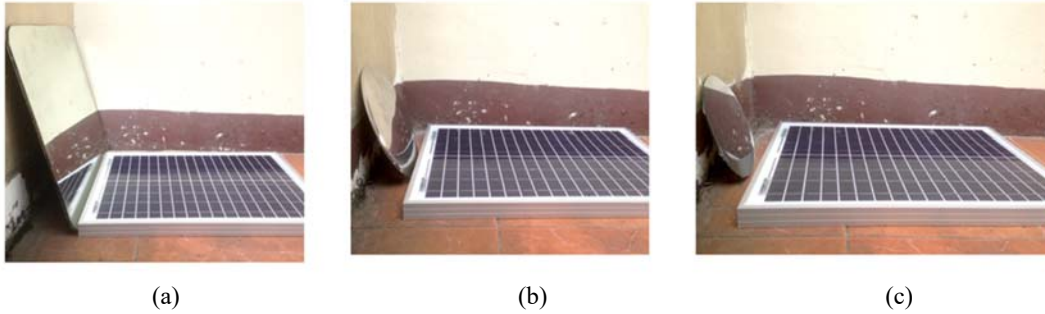


Figure 5. a) Solar cells with flat mirror reflectors, b) solar cells with convex mirror, and c) solar cell with mirror concave.

2.4. Testing variation

Each earthly region has different radiation values received depending on the location and position of the area. The slope angle of the solar cell module with the reflector greatly affects the output of the solar cells. At the time of our tests conducted at JalanMargonda, Depok, West Java then the position of solar modules directed to the north. The variation of slope angle testing between the solar cell and the reflector we arrange for the reflector to work optimally by increasing the number of solar cell outputs.

3. RESULTS AND ANALYSIS

3.1. Input radiation calculation due to reflector addition

The following calculations are useful for some parameters for solar cells with the use of reflectors with reflector angle 60° , 90° , and 120° .

a. Determining the Angle of Declination

$$\delta = 23,45 \sin \left(360 \frac{284. n}{365} \right)$$

$$n = 04 \text{ March } 2018 = 63$$

$$\delta = 23,45 \sin \left(360 \frac{284.63}{365} \right)$$

$$\delta = 17.703^\circ$$

b. Determining the Equation of Time

$$E = 9.87 \sin 2B - 7 \cos B - 1,5 \sin B$$

$$B = \frac{360(63 - 1)}{365}$$

$$B = 61.151^\circ$$

So,

$$E = 8.342 - 3.377 - 1.314$$

$$E = 3.651 \text{ minutes}$$

c. Determining the Solar Time

$$t_s = \text{standart time} + E + 4(L_{st} - L_{loc})$$

Standard Time = 12:11:12 PM (Taken from the middle hour between the initial hours of data retrieval and the final hours of data retrieval is at 10:18:03 AM – 14:05:20 PM)

$$t_s = 12:11:12 + 3.651 + 4(106 - 105)$$

$$t_s = 12:18:58 \text{ AM}$$

d. Determining the Clock Angle

$$\omega = 15^\circ(12:18:58 - 12:00:00)$$

$$\omega = 15^\circ(12:18:58 - 12:00:00)$$

$$\omega = 2.835^\circ$$

e. Determining the Zenith Angle

$$\text{Cos } \Theta_z = (\cos \delta \cos \Theta \cos \omega + \sin \delta \sin \Theta)$$

$$\text{Cos } \Theta_z = (\cos 17.703^\circ \cos 6^\circ \cos 2.835^\circ + \sin 17.703^\circ \sin 6^\circ)$$

$$\text{Cos } \Theta_z = 0.974$$

$$\Theta_z = 13.093^\circ$$

f. Determine the angle of the Sun's Altitude

$$\alpha_s = 90^\circ - \Theta_z$$

$$\alpha_s = 90^\circ - 13.093^\circ$$

$$\alpha_s = 76.907^\circ$$

g. Determining the Angle of the Sun Azimuth

$$\sin \gamma_s' = \frac{\sin \omega \cos \delta}{\sin \theta_z}$$

$$\gamma_s = 12.004^\circ$$

h. Determining the Intensity of solar radiation outside the Earth's atmosphere

$$G_{on} = G_{sc} \left(1 + 0,033 \cos \frac{360 \cdot n}{365} \right)$$

$$G_{on} = G_{sc} \left(1 + 0,033 \cos \frac{360 \cdot 63}{365} \right)$$

$$G_{on} = 1373.867$$

3.2. Solar module output calculations using the sun as a source of energy

We will test the magnitude of Voltage (V_{oc}), Current (I_{sc}) and Power (P_{out}) at each angle of the reflector. Tests are conducted within the time range 10:00 WIB-14:00 WIB.

a. Output results from solar cells without using reflector

By doing the experiment several times then obtained the results of experiments from solar cells without reflector. From this result we will be able to see the comparison of outputs produced by solar cells using and without reflector.

Table 2. The amount of solar cell output without reflecto

Hour (WIB)	Light Intensity (Lux)	Input Radiation (W/m^2)	Temperature ($^{\circ}C$)	Open Circuit Voltage / V_{oc} (V)	Short Circuit Flow / I_{sc} (A)	Output Power / P_{out} (W)	Input Power / P_{in} (W)	Efficiency (%)
10:18:03	197400	1559.46	35.7	19.60	0.467	19.153	272.90	7.018
10:21:24	195600	1545.24	39.2	19.75	0.482	19.519	270.41	7.218
10:51:43	184600	1458.34	41.9	19.38	0.499	19.670	255.20	7.707
11:30:56	191700	1514.43	38.7	19.91	0.991	19.730	265.02	7.444
11:53:20	185100	1462.29	40.4	20.49	0.625	18.806	255.90	5.004
11:56:09	171200	1352.48	43.0	19.53	0.970	18.944	236.68	8.004
12:01:10	192500	1520.75	41.7	19.90	0.904	17.989	266.13	6.759
12:13:23	186700	1474.93	40.1	19.22	0.830	15.952	258.11	6.180

b. Output results from solar cells with flat mirror reflector with angle 60° , 90° , and 120°

From the data can be seen generally: at an angle of 60° the voltage and current do not have a significant difference, an angle of 90° for the output voltage almost the same is only slightly different, and an angle of 120° the output current produced changes over time due to the temperature received by solar cells.

Table 3. The amount of solar cell output with a flat mirror at an angle of 60° , 90° , and 120°

Angle ($^{\circ}$)	Hour (WIB)	Light Intensity (Lux)	Input Radiation (W/m^2)	Temperature ($^{\circ}C$)	Open Circuit Voltage / V_{oc} (V)	Short Circuit Flow / I_{sc} (A)	Output Power / P_{out} (W)	Input Power / P_{in} (W)	Efficiency (%)
60	10:31:09	184700	1459.13	34.3	20.03	0.596	11.937	255.34	4.674
	10:45:23	195800	1546.82	37.7	20.23	0.706	14.282	270.69	5.276
	10:57:58	191900	1516.01	38.7	19.80	0.964	19.087	265.30	7.194
	11:31:18	195900	1547.61	38.8	20.35	0.943	19.190	270.83	7.085
	11:57:10	196600	1553.14	36.0	19.97	0.922	18.412	271.79	6.774
	11:58:20	198700	1569.73	39.4	20.90	0.912	19.060	274.70	6.938
	12:04:34	189700	1498.63	41.1	20.10	0.945	18.994	262.26	7.242
	12:31:44	192100	1517.59	39.3	20.32	0.890	18.084	265.57	6.809
90	10:35:56	190600	1505.74	35.6	20.14	0.530	10.674	263.50	4.050
	11:03:28	194800	1538.92	37.6	20.75	0.721	14.960	269.31	5.554
	11:33:13	190300	1503.37	39.4	20.84	0.979	20.402	263.08	7.755
	11:59:49	203900	1610.81	36.8	20.86	1.005	20.964	281.89	7.436
	12:07:11	192400	1519.96	38.8	20.04	0.985	19.739	265.99	7.420
	12:32:34	199200	1573.68	39.9	20.95	0.994	20.824	275.39	7.561
	13:15:45	192000	1516.8	38.3	20.75	0.830	17.222	265.44	6.488
	14:05:20	189900	1500.21	37.3	20.01	0.993	19.869	262.53	7.568
120	10:41:41	184800	1459.92	37.3	20.24	0.623	12.609	255.48	4.935
	11:05:04	191000	1508.9	38.5	20.36	0.727	14.801	264.05	5.605
	11:44:50	197300	1558.67	35.9	20.38	1.030	20.991	272.76	7.695
	12:09:55	192000	1516.8	37.6	20.40	0.903	18.421	265.44	6.939
	12:33:45	172300	1361.17	41.5	20.53	0.580	11.907	238.20	4.998
	13:16:40	193300	1527.07	39.9	20.19	0.894	18.049	267.23	6.754
	13:30:42	189000	1493.1	38.4	20.44	0.944	19.295	261.29	7.384
	14:01:12	192200	1518.38	39.2	20.32	0.923	18.755	265.71	7.058

c. Output results from solar cells with convex mirror reflector with Angle 60° , 90° , and 120°

At this measurement with convex mirror reflector we found that the efficiency was quite good which reached 9% even though it was unstable.

Table 4. The amount of solar cell output with a convex mirror at an angle of 60°, 90°, and 120°

Angle (°)	Hour (WIB)	Light Intensity (Lux)	Input Radiation (W/m ²)	Temperature (°C)	Open Circuit Voltage / V _{oc} (V)	Short Circuit Flow / I _{sc} (A)	Output Power / P _{out} (W)	Input Power / P _{in} (W)	Efficiency (%)
60	10:42:20	191400	1512.06	37.8	20.01	0.612	12.246	264.61	4.627
	11:07:38	185300	1463.87	38.6	20.28	0.642	13.019	256.17	5.082
	11:46:34	175600	1387.24	36.1	20.00	0.896	17.920	242.76	7.381
	12:11:12	205200	1621.08	38.5	20.08	0.910	18.272	283.68	6.441
	12:27:52	193300	1527.07	38.1	20.11	0.921	18.521	267.23	6.930
	13:18:07	194300	1534.97	39.4	20.31	0.945	19.192	268.61	7.144
	13:32:14	182000	1437.8	39.9	20.34	0.992	20.177	251.61	8.019
13:58:18	189300	1495.47	39.2	20.12	0.839	16.880	261.70	6.450	
90	10:43:01	198600	1568.94	38.1	19.93	0.667	13.293	274.56	4.841
	11:14:24	190400	1504.16	37.1	20.37	0.751	15.297	263.22	5.811
	11:48:22	178700	1411.73	36.6	19.91	1.127	22.438	247.05	9.082
	12:13:04	205600	1624.24	39.1	20.03	0.966	19.348	284.24	6.806
	12:28:43	200100	1580.79	39.2	20.32	0.859	17.454	276.63	6.309
	13:19:20	193300	1527.07	38.4	20.13	0.950	19.123	267.23	7.156
	13:34:06	187200	1478.88	39.5	20.14	0.928	18.689	258.80	7.221
13:56:32	192300	1519.17	37.5	19.44	0.834	16.212	265.85	6.098	
120	10:46:35	196700	1553.93	38.7	19.85	0.691	13.716	271.93	5.043
	11:23:03	195000	1540.5	35.2	20.59	0.824	16.966	269.58	6.293
	11:49:30	193200	1526.28	37.6	20.33	1.065	21.651	267.09	8.106
	12:14:28	198100	1564.99	39.2	20.34	0.847	17.227	273.87	6.290
	12:29:48	189200	1494.68	40.2	20.59	0.983	20.239	261.56	7.737
	13:21:18	192200	1518.38	39.4	20.78	0.904	18.785	265.71	7.069
	13:36:17	192300	1519.17	39.1	20.11	0.894	17.978	265.85	6.762
13:54:50	199300	1574.47	38.7	20.01	0.958	19.169	275.53	6.957	

d. Output results from solar cells with concave mirror reflector with Angle 60°, 90°, and 120°

The radiation received by solar cells at this angle is not too far away from the temperature of the area which is not too different from each measurement data. An angle of 90° has experienced a change in current and voltage that is quite good than the others but the measurement with an angle of 120° has a high temperature compared to the others.

Table 5. The amount of solar cell output with a concave mirror at an angle of 60°, 90°, and 120°

Angle (°)	Hour (WIB)	Light Intensity (Lux)	Input Radiation (W/m ²)	Temperature (°C)	Open Circuit Voltage / V _{oc} (V)	Short Circuit Flow / I _{sc} (A)	Output Power / P _{out} (W)	Input Power / P _{in} (W)	Efficiency (%)
60	10:47:04	198200	1565.78	39.3	19.78	0.701	13.865	274.01	5.060
	11:26:59	190500	1504.95	35.9	20.48	0.855	17.510	263.36	6.648
	11:50:35	192500	1520.75	38.9	20.33	1.053	21.407	266.13	8.043
	12:15:40	190100	1501.79	39.9	20.39	0.682	13.905	262.81	5.290
	12:30:53	190400	1504.16	40.2	20.12	0.744	14.969	263.22	5.686
	13:22:42	198900	1571.31	38.5	20.39	0.839	17.107	274.97	6.221
	13:39:30	193800	1531.02	39.0	20.45	0.899	18.384	267.92	6.861
13:52:33	194400	1535.76	38.2	20.39	0.922	18.799	268.75	6.994	
90	10:48:39	191600	1513.64	40.2	20.25	0.706	14.296	264.88	5.397
	11:28:51	198500	1568.15	38.4	20.33	0.997	20.269	274.42	7.386
	11:54:41	198700	1569.73	40.2	20.85	1.180	24.603	274.70	8.956
	12:16:50	192800	1523.12	40.2	21.02	1.020	21.440	266.54	8.043
	12:32:40	189200	1494.68	38.5	20.43	0.944	19.285	261.56	7.373
	13:23:58	192000	1516.8	39.9	20.44	0.987	20.174	265.44	7.600
	13:40:41	192200	1518.38	39.2	20.67	0.973	20.111	265.71	7.568
13:49:27	192000	1516.8	39.5	20.44	0.911	18.620	265.44	7.014	
120	10:49:59	190100	1501.79	41.1	19.67	0.715	14.064	262.81	5.351
	11:30:20	197700	1561.83	38.8	20.11	1.019	20.492	273.32	7.497
	11:55:54	197900	1563.41	41.8	20.23	1.120	22.657	273.59	8.281
	12:18:25	197800	1562.62	40.2	20.14	0.912	18.367	273.45	6.716
	12:34:18	192000	1516.8	40.1	20.33	0.829	16.853	265.44	6.349
	13:25:40	183000	1445.7	38.3	20.12	0.839	16.880	252.99	6.672
	13:42:25	192100	1517.59	39.2	20.22	0.922	18.642	265.57	7.019
13:45:16	194000	1532.6	39.4	20.16	0.892	17.982	268.20	6.704	

3.3. Research Discussion

3.3.1. Analysis of solar cell output on addition of reflector

From the data obtained during the measurement, the amount of radiation received by the Solar cell will affect the output current and voltage generated by solar cells. The greater the radiation intensity received by the solar cell then the resulting voltage and current are also weakened. Generally the voltage drop is smaller than the current. Testing has been done that the uses of concave mirror reflectors get the best input radiation rays. This can be shown in the picture below.

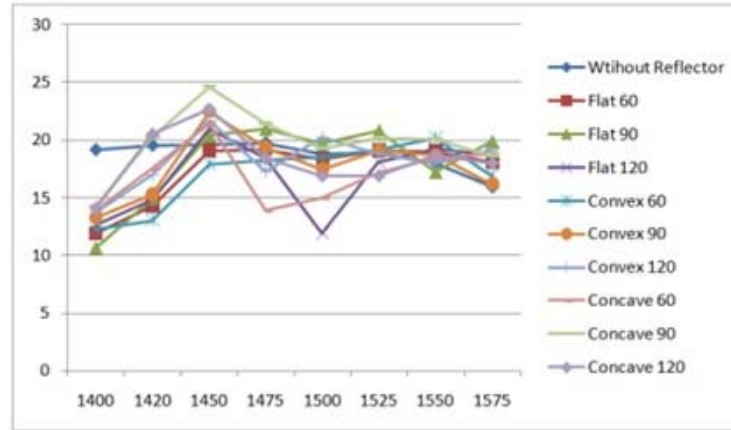


Figure 6. Relation of output power to radiation input

With the addition of Reflector, a solar cell will get the maximum output. In the data obtained the addition of mirror reflector concave with a 90° inclination angle to get the maximum output of such as Current, Voltage, Output Power and Efficiency.

3.3.2. Analysis of the influence of reflector on the temperature of solar cells

Temperature of solar cells also affects the performance of the solar cell. The voltage and current of the Solar cells are affected by the temperature. The greater the temperature received the voltage slightly reduced and inversely proportional to the electric current. Temperatures value of the solar cell is influenced by the radiation received by the solar cell itself. So the greater the radiation received is the greater the temperature of a solar cell. Here is a picture of the effect of radiation on temperature.

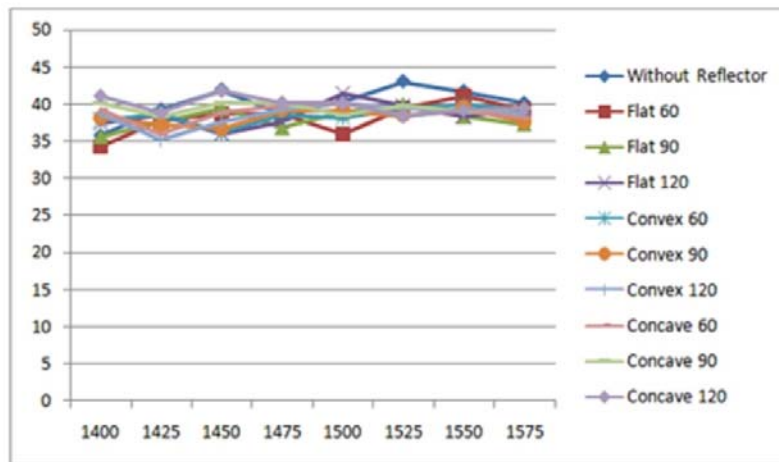


Figure 7. Tendency of solar cell temperature to radiation

4. CONCLUSIONS

The data obtained in the form of solar radiation and temperature received by solar cells depends on the condition of data collection where each time is different. The greater the radiation received by solar cells is the effect on the large temperature solar cells so that will get different outputs. The most widely accepted experiment of radiation is on a concave mirror reflector. For the solar cell output, the maximum average maximum voltage produced is 20.553 V and the average of the maximum electric current generated is 0.964 A which is produced by the addition of a concave mirror reflector with inclination angle is 90°. The maximum voltage generated by the solar cell is 21.02 V which is produced by the addition of a concave mirror reflector with a 90° inclination angle and for the maximum electric current generated is 1.180A ie by the addition of a concave mirror also with an angle of 90°. Solar Cells that have been tested can produce maximum output when added reflector with angle is 90°

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BIOGRAPHIES OF AUTHORS



Yahot Siahaan is a graduate student at Gunadarma University majoring in electrical engineering. Graduated from Gunadarma University in 2016 with an engineering degree. Interested in the field of Embedded systems, Microcontrollers, Telecommunications, Renewable Technology, and Electronics.



Hartono Siswono, Graduated from Indiana Institute of Technology, Indiana, USA in January 1988, With the degree of Bachelor of Science in Engineering. In July 2000, graduated with the degree of Master of Science in Electrical Engineering from University of Indonesia. Got the Doctoral degree in Electrical Engineering from University of Indonesia in January 2006. Started as an instructor in University of Gunadarmasince 1993, and since June 2011 as Head of Electrical Engineering Department University of Gunadarma. When studying in the United States of America, also work as an assistant for Electrical Engineering Department Indiana Institute of Technology, and also as the President of Indonesian Students Association in the United States of America for two periods. Also as an author of four books, which are: "Digital System Design by using XILINX (PerancanganSistemDigital Simulator XILINX)", "Signal Processing System (SistemPemrosesanSinyal)", "Control System (DasarSistemKontrol)", and "Digital Signal Processing (PengolahanSinyal Digital)".