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Comparative Performance Evaluation Of Solar Photovoltaic Module With And Without Reflective Boosters

Muhammad Haliru Ibrahim[1]; Aisha Nasir[2]; Jamilu Musa Garba[3] & Usman Abubakar[4]

[1]Department of Physics, Faculty of Science, Federal University Gusau, Zamfara State, Nigeria

[2,4]Department of Physics, Faculty of Science, Sokoto State University, Sokoto, Nigeria

[3]Umaru Ali Shinkafi Polytechnic, Sokoto, Nigeria

***Corresponding author: Hallyphysics2013@gmail.com**

Abstract

The efficiency of solar photovoltaic module cause by natural source cannot be overwhelm but can be minimized and reduced using boosters, this paper demonstrates the performance evaluation of polycrystalline (20 watts) module. The practical research was carryout with and without reflective mirror. Which was study under normal atmospheric condition (outdoor) considering peak sun shine hours, The module was set facing south direction (without mirror) and module was set facing south for the second experiment, the mirror is standing at a certain distance away facing the module on north east direction. It was observed that reflecting mirror has an effect on the performance by increases the values of various parameters studied such as short circuit current, open circuit voltage, load current, load voltage, surface temperature, power output and efficiency. The result shows that the data obtained in Table 4.1 without reflecting mirror in various parameters such as solar radiation 689, surface temperature 34.20^{0}C, ambient temperature is 28.80^{0}C, open circuit voltage 19.81Volts, short circuit current 3.24 A, load current 0.09 A, load voltage 19.35 Volts and power 1.741 Watts respectively. However, the result obtains in Table 4.6 with reflected mirror in various parameter such as solar radiation is 689, surface temperature 34.60^{0}C, ambient temperature is 28.80^{0}C,open circuit voltage 19.99 Volts, short circuit current 3.30 A, load current 0.09 A, load voltage 19.87 Volts and power 1.788A, respectively. After comparison of the result, it was concluded that the data obtained in the one with reflecting mirror is higher than the data obtained in the one without reflecting mirror due to the fact that the average of both the two test shows that the data obtained by reflected mirror is far greater than that without reflecting mirror.

Keywords: Polycrystalline Module, Reflecting mirror, Solar power meter, Digital multimeter, Infrared thermometer, Rheostat.

INTRODUCTION

Solar energy is one of the main promising clean energy sources in the world. The use of solar energy (photovoltaic) to meet residential energy needs has been promoted for some years in Nigeria by some renewable energy companies. This was due to numerous advantages that the solar energy has compared to fossil fuels. Solar energy is the energy produced directly by the sun in form of radiation and captured on earth for practical end especially for generating of electricity. Radiant light and heat from the sun harnessed using a range or ever-evolving technologies such as solar heating, Photovoltaic, Solar Thermal, Solar architecture artificial photosynthesis. Solar modules use light energy (photons) from the sun to generate electricity through the photovoltaic effect. However, the solar photovoltaic system depends on the solar radiation. It is common for a solar photovoltaic module to become illuminated partially. The sun is an average star. It has been burning for more than 4-billion years and it will burn at least that long into the future before erupting into a giant red star, engulfing the earth in the process. Some stars are enormous sources of X-rays: others mostly generate radio signals (Charbonneau, 2014). Photovoltaic (PV) is a method of generating electrical powers by converting solar radiation into direct current electricity using semiconductors that produce the photovoltaic effect. It is not the heat required from the sun but the amount of irradiation available (Aldo and Da Rosa, 2015). In recent years, renewable energy is widely vacated by many countries. PV cell is one of the most popular renewable energy products it can directly convert the solar radiation into electricity which can be utilized to power appliances. However, during the operation of PV cell only around 15% of solar radiations converted to electricity with the rest converted to heat. The electrically will increase. Photovoltaic decree is typically sold on the basic of standard test condition efficiency (David, 2014). On this paper the experiment shows the effect of reflective mirror as booster on a solar photovoltaic module and the result will show how to minimized efficiency factor on natural event such as cloudy weather.

Studied PV modules with and without a tilted plane reflector. They indicated that the planar booster reflectors can improve the yearly energy output of PV modules by about 22% (Ahmad and Hussein, 2012).Investigated the performance of photovoltaic modules with planar booster reflector with variable length and tilts for Swedish conditions. The reported that a flat stationary booster reflector can increase the annual output of the module in the order of 20-25 percent (Ronnelid *et al.*, 2012). The effects of booster reflectors on the photovoltaic water pumping system performance was investigated and it pointed outs that concentrating solar radiation on the PV cell increasing the mean PV cell consequently increasing the water pumping flow however the application booster the reflector increasing photovoltaic cells temperature. It is well known that the performance of PV panels well drop when the cell temperature increase. By increasing the cell temperature 0.4-0.5ºC, a decrease in the output power for single and multi-crystalline silicon solar cells is detected. However, the increase of cell temperature as a result of the increasing intensity of solar radiation on the PV panels is, without a doubt. The largest negative effect of using photovoltaic modules augmented with the booster reflector, therefore it is necessary to keep the temperature of the photovoltaic module at a low level to achieve satisfactory performance. Several theoretical and experimental studies are done in the passive and active PV cooling system (Tabaei and Ameri, 2012). Also, the effect of an operating head on the performance of photovoltaic water pumping systems was investigated. it showed that there is a maximum power corresponding to each lead. So when the modules power exceeds that maximum point, the remaining power is wasted. They also found that when array power corresponding to the held more weather is pumped during the day (Abdol Zadeh and ameri, 2009). Investigation on the electrical and thermal performance of a single-crystalline submerged photovoltaic solar panel. They showed that, in shallow water, an increase of 10-20% in efficiency will be achieved. Investigated the possibility of improving the performance of photovoltaic water pumping system by spraying water over the top surface of PV array, experimentally. They pointed out that the efficiency photovoltaic water pump system can be increased by spraying water over the front PV array.

The aim of this paper is to carryout comparative performance evaluation of the two module one with reflective mirror and the other without reflective mirror. Also, to compare current voltage and power characteristic of both PV module (poly-crystalline) and to determine the effect of radiation concentrators on series and parallel PV module.

Theory:

Photovoltaic Cell

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is physical and chemical phenomenon; it is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels (Aldo and Da Rosa, 2015).

Solar Photovoltaic Module

Solar panels refer to a panel designed to absorb the sun rays as a source of energy for generating electricity or heating. A PV module is a packaged connected assembly of typically 6 x 10 solar cells, solar PV panels constitute the solar array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions, and typically ranges from 100 to 365 watts. The efficiency of a modules determines the area of a module given the same rated output an 8% efficient 230Watt module will have twice the area of a 16% efficient 230Watt a singular solar module can produce only a limited amount of power. Most installation contains multiple modules. A photovoltaic system typically includes a panel or an array of solar tracker and interconnection wiring (Wikipedia, 2021).

Types of Solar PV Module

There are three main types of modules for both commercial and residential use.

i. Monocrystalline

ii. Polycrystalline

iii. Amorphous also called "thin film"

Photovoltaic System Components

Photovoltaic systems are built from several important components:

- ✓ **Array:** One or more panels (modules) wired together for a specific voltage and fastened to a mounting structure.
- ✓ **Battery:** A device that chemically stores direct current (DC) electrical energy.
- ✓ **Charge Controller:** Equipment that regulates battery voltage.
- ✓ **Inverter:** An electrical device that changes direct current (DC) to alternating current (AC).
- ✓ **DC loads:** Appliances, motors and equipment powered by direct current (DC).
- ✓ **AC loads:** Appliances, motors and equipment powered by Alternating Current (AC)

Photovoltaic Effect

Photovoltaic effect is the creation of voltage or electric current in material upon exposure to light and is a physical and chemical phenomenon. The standard and obvious photovoltaic effect is directly related to the photoelectric effect, though they are different processes. When the sunlight or any other light is incident upon a material surface, the electron presents in the valence band absorb energy and being excited, jump to conduction band and become free.

Load Line and Resistance

A load line is used in graphical analysis of non-linear electronic circuits; representing the constraint other parts of the circuit place on a non-linear device, called the device its usually drawn in a graph of the current versus the voltage is called the device's characteristic curve (Wikipedia 2021).

Efficiency of Solar Cell

Solar cell efficiency is the ratio of the output of a solar cell to the incident energy in form of sunlight. The energy conversion (n) of a solar cell is the percentage of the solar energy to which the solar cell is exposed that is converted into electrical energy. Efficiency is calculated by dividing a cell's power output (in watt) at its maximum power point (Pout) by the input in Wm^2 and the surface area of the solar cell A (in m²).

$$\eta = \frac{\text{Poutput}}{\text{Pinput}} \text{X } 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: η = Efficiency of Solar Cell , Pout = Power output , Pin = Power Input

METHODOLOGY

The study was carried out at Federal University Gusau (FUGUS), Zamfara State. The experiment set up begins with the arrangement of the materials which are as follows:

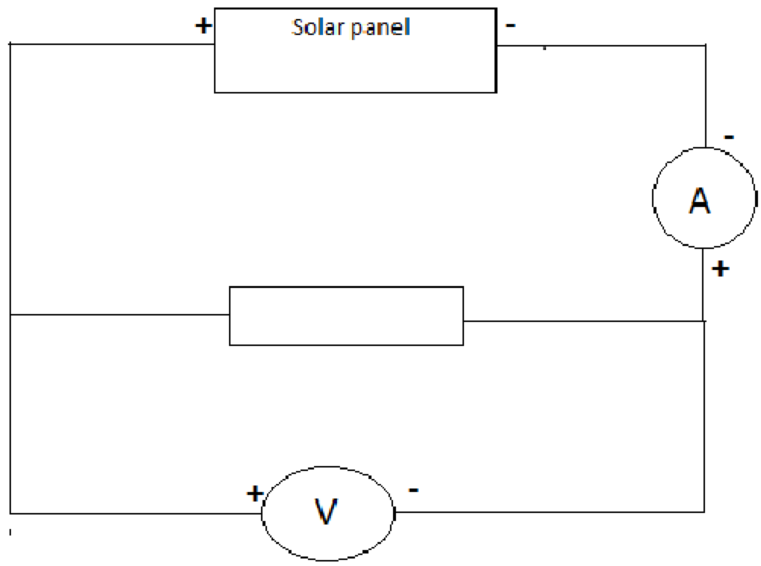

Figure 1. Experimental circuit diagram

The module was set facing south for the first experiment (without mirror). And module was set facing south for the second experiment, the mirror is standing at a certain distance away facing the module on north east direction. Secondly, we used solar power meter in watt per square meter (W/M^2), for measuring solar radiation. A digital multi-meter, directly connected on the module for measuring the short circuit current (ISC), and measuring the open circuit voltage (VOC). A digital multi-meter connected with potentiometer rheostat on the modules in series to measure the load current (IL) and also connected in parallel on measuring load voltage (VL). An infrared to thermometer on the modules to measuring their temperature. We used the multi-meter for measuring the ambient temperature, the reading was taken at every 1hour from 10:00am to 1:00pm and also take at every 30 minutes from 1:00pm to 4:00pm time interval from 10:00am to 4:00pm local time every day for a period of 5 working days in a week.

RESULT AND DISCUSSION

Selections of the data obtained in the experiment are shown in the Tables 4.1 to 4.10 below.
Where Table 4.1 to 4.5 represent data without reflecting mirror and 4.5 to 4.10 represent data with reflecting mirror.

Table 1: Data generated without reflecting mirror on day 5th July, 2021.

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	689	34.20	28.80	19.81	3.24	0.09	19.35	1.741
11:00	786	40.00	31.40	19.88	3.75	0.08	19.64	1.571
12:00	528	39.20	34.00	19.57	3.42	0.09	19.47	1.752
01:00	409	46.00	36.30	19.20	3.66	0.09	19.10	1.719
01:30	460	44.00	37.80	20.56	4.81	0.10	20.25	2.028
02:00	452	41.80	40.20	19.30	3.67	0.09	19.12	1.720
02:30	398	39.00	38.40	19.67	3.66	0.09	19.37	1.743
03:00	517	41.70	38.20	19.56	3.72	0.08	19.36	1.348
03:30	409	64.70	36.70	19.33	4.71	0.07	19.23	1.346
04:00	452	44.80	37.30	19.22	5.21	0.06	19.10	1.146

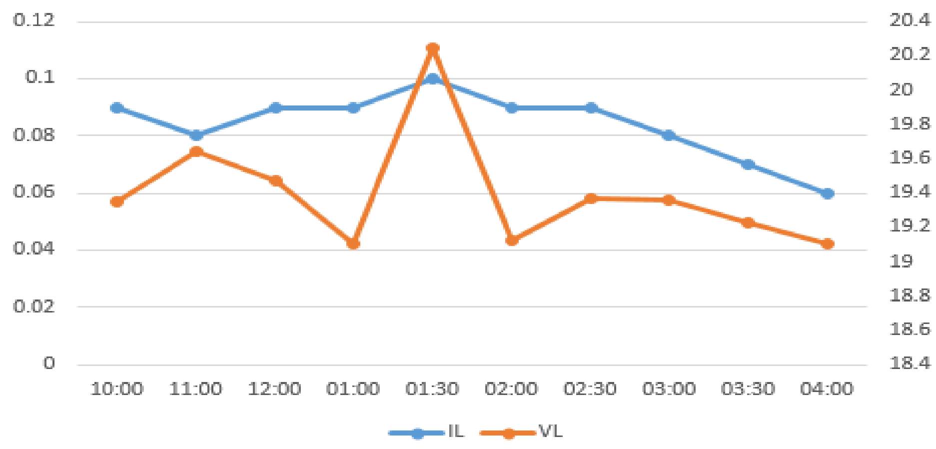

Figure 4.1 Variation of load current and load voltage against time interval

Table 2: Data generated without reflecting mirror on day 6th July, 2021.

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	479	49.30	33.20	19.20	3.88	0.06	19.10	1.146
11:00	603	61.30	33.60	19.40	3.67	0.07	19.30	1.351
12:00	980	58.00	37.00	19.70	3.92	0.08	19.60	1.568
01:00	689	66.30	34.30	19.70	3.20	0.06	19.65	1.179
01:30	818	60.40	37.60	19.89	3.79	0.08	19.79	1.583
02:00	560	56.20	39.00	19.96	4.20	0.10	19.86	1.986
02:30	377	47.60	38.20	19.30	3.10	0.05	19.20	0.960
03:00	581	46.60	37.10	19.00	3.30	0.06	18.90	1.134
03:30	517	47.60	35.80	19.10	3.10	0.07	19.00	1.330
04:00	549	49.50	36.90	19.20	3.15	0.08	19.10	1.528

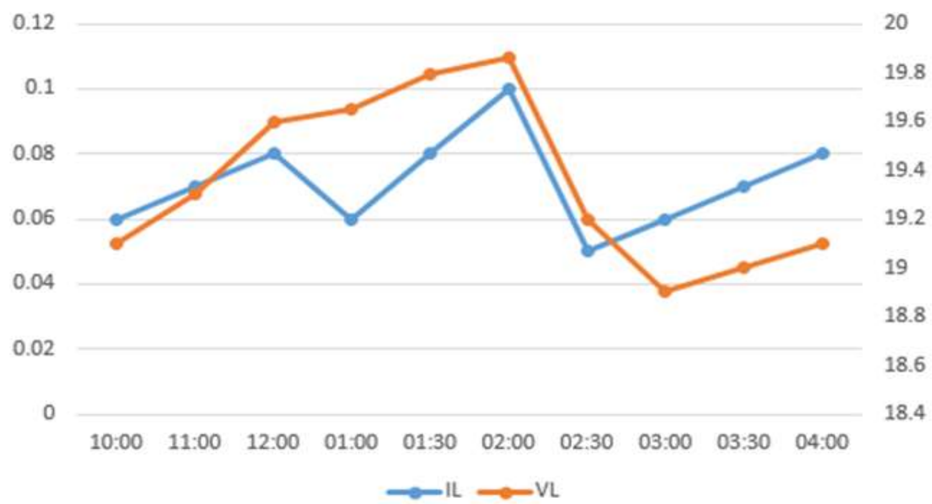

Figure 2 Variation of load current and load voltage against time interval

Table 3: Data generated without reflecting mirror on day 7th July, 2021.

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	571	53.10	34.30	18.70	3.12	0.08	18.60	1.488
11:00	495	44.40	32.40	18.60	3.10	0.06	18.50	1.110
12:00	625	54.10	30.90	18.70	3.14	0.07	18.60	1.302
01:00	743	50.90	32.50	18.80	3.25	0.08	18.70	1.496
01:30	937	55.00	34.60	19.20	3.30	0.09	19.10	1.719
02:00	360	62.40	39.60	19.91	4.58	0.10	19.80	1.980
02:30	480	49.50	39.90	20.25	4.80	0.09	20.15	1.813
03:00	450	56.30	39.80	20.19	4.60	0.09	20.10	1.809
03:30	340	52.90	39.70	20.40	4.90	0.10	20.30	2.030
04:00	948	57.70	32.90	19.30	3.39	0.09	19.20	1.728

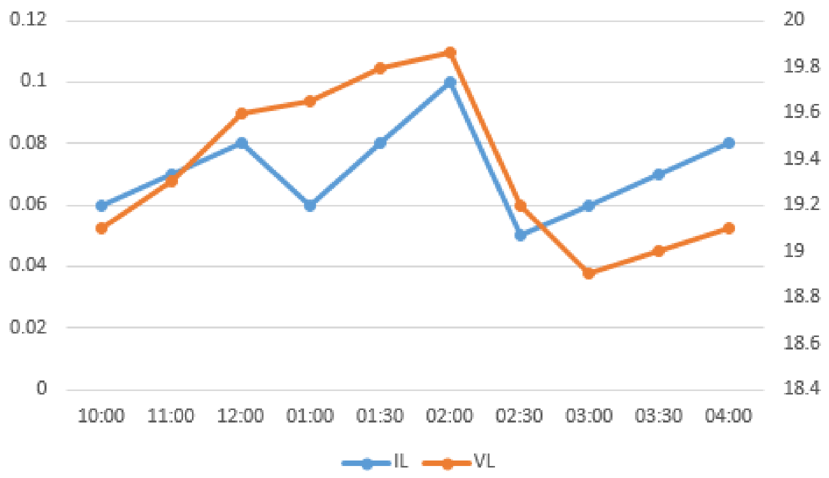

Figure 3A graph of load current and load voltage against time interval

Table 4: Data generated without reflecting mirror on day 8th July, 2021

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	334	43.30	30.00	17.10	2.64	0.07	17.00	1.190
11:00	775	53.90	35.60	18.30	3.90	0.09	18.20	1.638
12:00	387	36.80	31.80	17.00	3.70	0.06	16.90	1.014
01:00	614	56.30	36.30	18.40	3.77	0.08	18.30	1.464
01:30	463	41.30	35.50	17.10	3.00	0.08	17.00	1.360
02:00	258	38.10	34.80	17.00	3.10	0.06	16.99	1.019
02:30	668	45.20	36.50	18.30	3.90	0.08	18.20	1.456
03:00	498	50.60	36.70	17.20	3.80	0.07	17.10	1.197
03:30	571	46.80	34.00	17.90	2.90	0.06	17.80	1.068
04:00	387	42.90	34.20	17.00	2.80	0.05	16.69	0.834

Variation of Load Current and Load Voltage against Time Interval

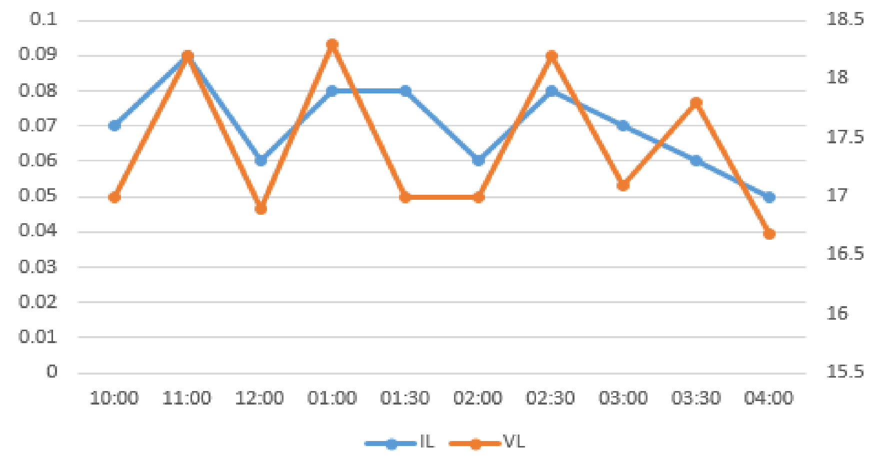

Figure 4 A graph of load current and load voltage against time interval.

Table 5: Data generated without reflecting mirror on day 9th July, 2021.

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	441	44.50	32.20	19.10	3.11	0.09	18.90	1.700
11:00	371	52.00	37.80	19.25	3.35	0.10	19.10	1.910
12:00	700	56.00	36.00	19.40	3.95	0.09	19.20	1.728
01:00	862	58.00	36.70	19.45	4.10	0.10	19.30	1.930
01:30	959	62.30	32.50	19.50	4.30	0.09	19.35	1.737
02:00	969	61.30	31.20	19.70	4.40	0.09	19.40	1.746
02:30	510	60.50	33.70	20.19	4.90	0.10	19.80	1.980
03:00	390	62.00	34.20	20.30	4.92	0.10	20.00	2.000
03:30	991	60.30	37.10	19.90	4.95	0.09	19.80	1.782
04:00	301	53.40	37.90	19.20	4.66	0.07	9.10	1.337

Variation of Load Current and Load Voltage against Time Interval

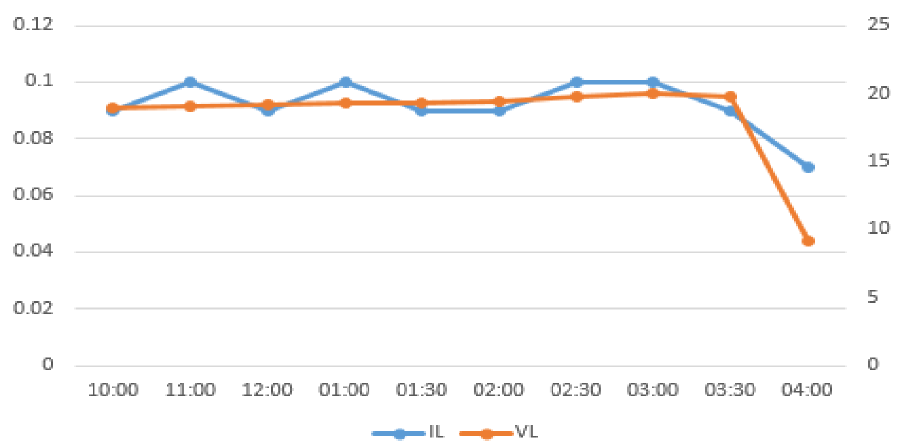

Figure .5 a graph of load current and load voltage against time interval

Table 6: Data generated with reflecting mirror on day 2nd August, 2021.

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	689	34.60	28.80	19.99	3.30	0.09	19.87	1.788
11:00	786	42.20	31.40	19.95	3.80	0.09	19.85	1.786
12:00	528	59.90	34.00	19.67	3.50	0.10	19.54	1.954
01:00	409	48.90	36.30	19.30	3.70	0.09	19.20	1.728
01:30	520	52.30	37.80	20.67	4.89	0.10	20.57	2.057
02:00	452	50.80	40.20	19.40	3.70	0.09	19.30	1.737
02:30	398	46.90	38.40	19.74	3.69	0.09	19.07	1.770
03:00	517	44.00	38.20	19.59	3.80	0.09	19.47	1.752
03:30	409	61.00	36.70	19.93	4.84	0.09	19.04	1. 786
04:00	452	50.20	37.30	19.34	5.30	0.08	19.25	1.540

Variation of Load Current and Load Voltage against Time Interval

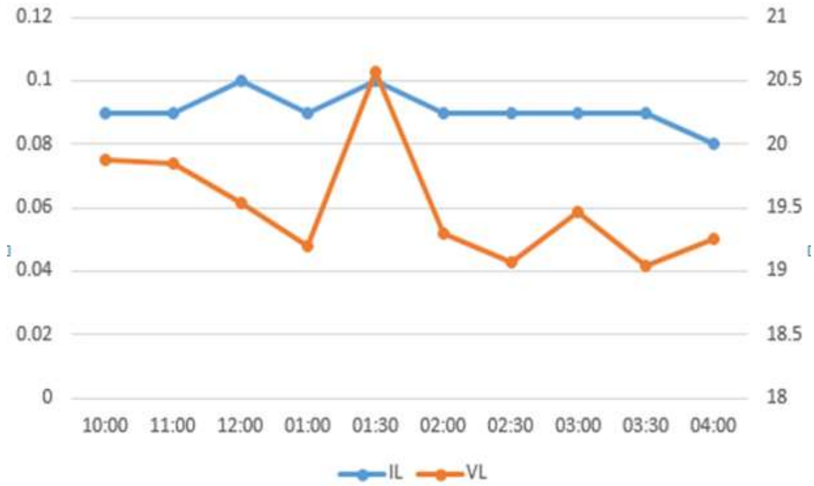

Figure 6 A graph of load current and load voltage against time interval

Table 7: Data generated with reflecting mirror on day 3rd August, 2021.

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	479	57.40	33.20	19.30	3.68	0.07	19.20	1.344
11:00	603	47.60	33.60	19.50	3.74	0.08	19.40	1.552
12:00	980	49.10	37.00	19.10	4.10	0.09	19.00	1.710
01:00	689	65.10	34.30	19.80	3.30	0.07	19.78	1.384
01:30	818	67.20	37.60	19.19	3.89	0.09	19.80	1.782
02:00	530	57.90	39.00	20.30	4.30	0.10	20.20	2.020
02:30	377	47.60	38.20	19.40	3.20	0.06	19.30	1.158
03:00	581	49.60	37.10	19.20	3.40	0.07	19.10	1.337
03:30	517	50.50	35.80	19.30	3.20	0.09	19.20	1.728
04:00	549	59.10	36.90	19..10	3.30	0.10	19.00	1.900

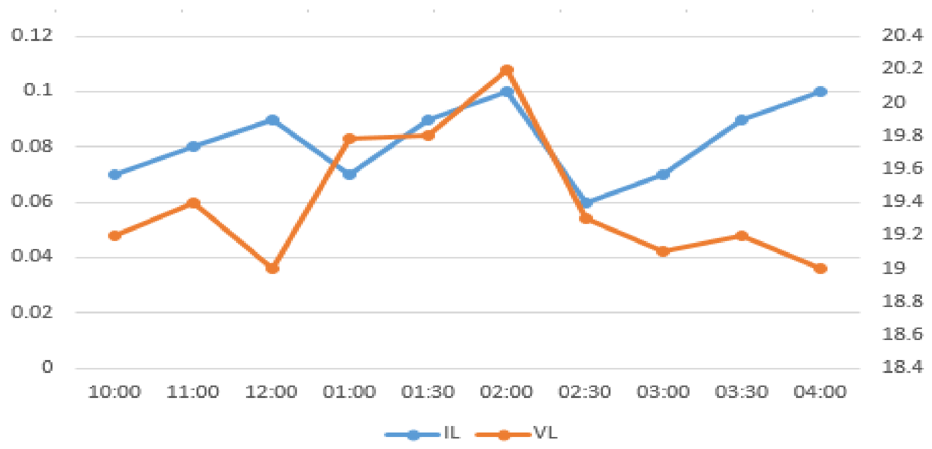

Figure 7 a graph of load current and load voltage against time interval

Table 8: Data generated with reflecting mirror on day 4th August, 2021.

T	G	T_c	T_a	V_{oc}	I_{SC}	I_L	V_L	P
10:00	571	60.10	34.30	18.809	3.19	0.09	18.70	1.683
11:00	495	54.40	32.40	18.70	3.24	0.07	18.60	1.302
12:00	625	59.10	30.90	18.90	3.30	0.08	18.70	1.496
01:00	743	60.90	32.50	19.30	3.35	0.10	19.20	1.920
01:30	937	58.00	34.60	19.95	3.40	0.10	19.90	1.990
02:00	470	69.40	39.60	20.30	4.60	0.09	19.20	1.728
02:30	610	39.50	39.90	20.29	4.80	0.10	20.19	2.019
03:00	580	60.30	39.80	20.30	4.70	0.09	20.20	1.818
03:30	520	59.90	39.70	20.50	4.99	0.17	20.40	2.040
04:00	948	67.70	32.90	19.40	3.45	0.07	19.30	1.351

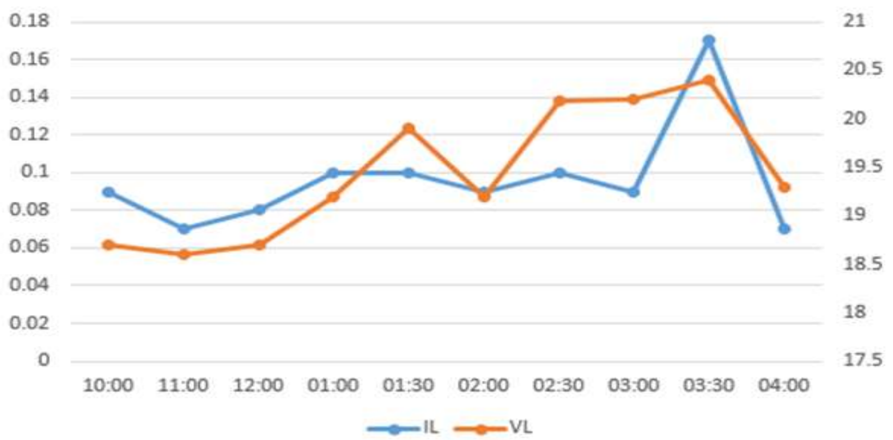

Figure 8. A graph of load current and load voltage against time interval with reflected mirror

Table 9: Data generated with reflecting mirror on day 5th August, 2021.

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	334	37.10	30.00	17.00	2.50	0.06	16.90	1.014
11:00	775	45.20	35.60	18.20	3.80	0.08	18.10	1.448
12:00	387	40.10	31.80	16.90	3.60	0.07	16.80	1.176
01:00	614	51.80	36.30	18.30	3.67	0.07	18.20	1.274
01:30	463	40.20	35.50	17.00	2.90	0.05	16.91	0.845
02:00	258	36.80	34.80	16.99	3.00	0.07	16.94	1.185
02:30	668	42.70	36.50	18.20	3.80	0.05	18.10	0.905
03:00	498	48.10	36.70	17.10	3.70	0.04	17.00	0.680
03:30	571	46.50	34.00	17.80	2.80	0.03	17.70	0.531
04:00	387	42.50	34.20	16.69	2.70	0.03	16.60	0.498

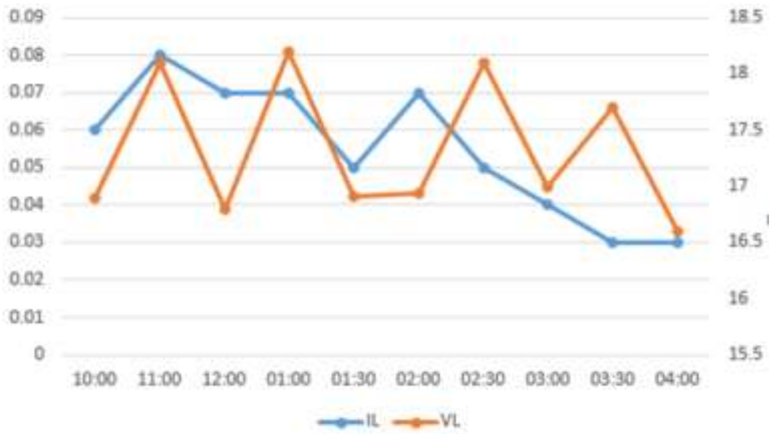

Figure 9 Variation of Load Current and Load Voltage against Time Interval

Table 10: Data generated with reflecting mirror on day 6th August, 2021.

T	G	T_c	T_a	v_{oc}	I_{SC}	I_L	V_L	P
10:00	441	47.90	32.20	19.20	3.15	0.10	19.10	1.910
11:00	371	55.00	37.80	19.30	3.40	0.08	19.25	1.536
12:00	700	60.50	36.00	19.50	4.00	0.10	19.40	1.940
01:00	862	64.50	36.70	19.60	4.20	0.09	19.45	1.755
01:30	959	62.80	32.50	19.70	4.40	0.10	19.50	1.960
02:00	969	64.10	31.20	19.76	4.50	0.09	19.70	1.773
02:30	380	64.70	33.70	20.25	4.95	0.10	20.19	1.990
03:00	680	62.90	34.20	20.40	4.98	0.10	20.30	1.999
03:30	991	61.00	37.10	19.98	4.99	0.09	19.90	1.780
04:00	301	55.30	37.90	19.30	4.80	0.09	19.20	1.732

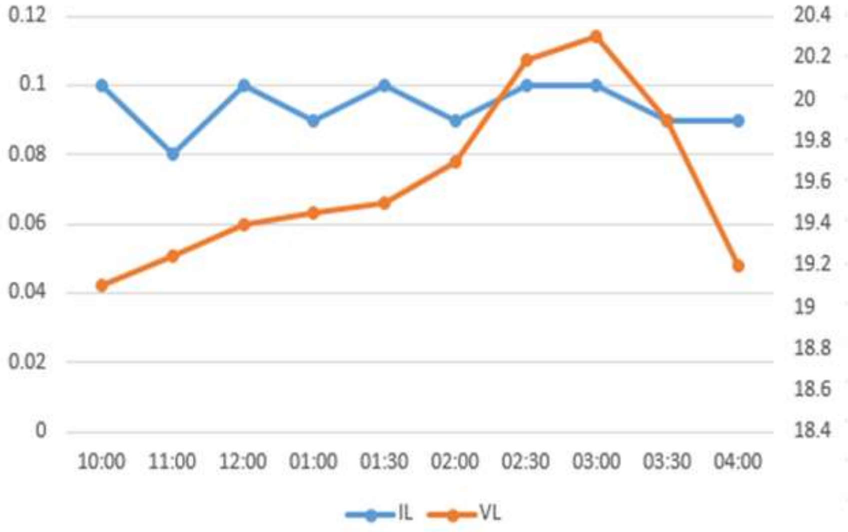

Figure 10 a graph of load current and load voltage against time interval with reflecting mirror

4.2 DISCUSSION OF THE RESULT

This research has shown that the effect of reflective mirror on the Solar Panels (Modules) was quite subjected since power output strongly depends on the weather, (seasons, the time and more factors). From the data collected, graphs were plotted and presented in Figure 4.1 to 4.10. I observed that the moment when photovoltaic (PV) module is reflected with a mirror the power output become higher than the one without reflecting mirror. Therefore, model of polycrystalline photovoltaic (PV) module (20W) has more effect when reflected by a mirror as it experienced a little increase in voltage. Solar panel (Module) was connected directly on the solar module to increase the value of various Parameters such as short circuit current and open circuit voltage. Solar panels (Modules) with a load (rheostat) decrease the voltage flow in the circuit due to the attached load. Solar panels (Modules) connected with a resistance load decrease the current flow in the circuit. The data also shows that surface temperature of the panel reflected by a mirror is higher than the one without reflecting mirror. The ambient temperature increase with increase in solar radiation, same with the voltages, currents, and power. The values obtained directly connected on the solar module are higher than the values obtained with rheostat. The result shows that the data taken when the panel is reflected by a mirror is higher than the data taken when the panel without reflected by a mirror.

CONCLUSION

The research on the performance of photovoltaic (PV) module (Polycrystalline 20W), was study under normal atmospheric condition (outdoor), shown that reflecting mirror has an effect on the performance. It increases the values of various parameters studied such as short circuit current, open circuit voltage, load current, load voltage, surface temperature, power output and efficiency. The result shows that the data was obtain in table 4.1 without reflecting mirror in various parameters such as solar radiation 689, surface temperature 34.20, ambient temperature is 28.80, open circuit voltage 19.81, short circuit current 3.24, load current 0.09, load voltage 19.35 and power 1.741 are respectively. And also the result shows that the data was obtain in Table 4.6 with reflected mirror in various parameter such as solar radiation is 689, surface temperature 34.60, ambient temperature is 28.80, open circuit voltage 19.99, short circuit current 3.30, load current 0.09, load voltage 19.87 and power 1.788 are respectively. After comparison of the result, it was concluded that the data obtained in the one with reflecting mirror is higher than the data obtained in the one without reflecting mirror due to the fact that the average of both the two test shows that the data obtained by reflected mirror is far greater than the one without reflecting mirror.

RECOMMENDATION

Based on the research carried out, the following recommendations were made.

- Extensive study should be undertaken in this research area in order to fully understand the ways in which reflecting mirror affect the modules.
- Government should train a group of individuals for an in-depth knowledge that could be used for the research and analysis on photovoltaic systems to improve power generation technology in the country.
- The effect of reflecting mirror on photovoltaic systems (monocrystalline and polycrystalline) is being a great challenge in power generation, so research in this area has become necessary.

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