INVESTIGATION OF SUITABLE TIME FOR THE PERFORMANCE MEASUREMENT AND EVALUATION OF MONO-CRYSTALLINE PHOTOVOLTAIC PANELS AT FEDERAL UNIVERSITY OF AGRICULTURE, ABEOKUTA (FUNAAB), ALABATA, OGUN STATE, NIGERIA

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Abstract

Human existence relies on solar energy either directly or indirectly and the world at large cannot continue to exist, remain or live without the solar energy. Solar power in Nigeria can serve as a source of sustainable energy if fully utilized due to abundant availability all year round energy and its regular appearance on daily basis in the sky under a friendly environment. The maximum output current and power of solar panel used in harvesting solar energy are obtained at solar noon. The time of solar noon differs from place to place. The study investigated suitable time for the performance measurement and evaluation of mono-crystalline photovoltaic panels at Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The main materials used for work consists of six 80 W (480 W) solar panels of sunshine product made in Germany, CM 5024 PWM 40 A digital intelligent solar charge controller 12/24 V and two 200 AH (400 AH) solar batteries. The output current and cumulative charges were read and recorded for a period of 21 days between 6: 30 am to 7: 30 pm for each day. The sunshine hour for each day was estimated from the cumulative charge and the peak current for each day. The average output current from the panels had a value of zero at 6:30 am which increases to a peak value of 21.4 A at 1: 00 pm (solar noon) then dropped gradually to zero at 7: 00 pm. The study demonstrates that the sunshine hours vary from day to day and the estimated average sunshine hour obtained for the period of the 21 days was 6.4 hours. The results of the investigation indicated that the time of maximum output current obtained changes from day to day which may be due to change in time of the solar noon but was between the periods of 1: 30 pm and 2: 30 pm. The time obtained would be the best period to carry out performance measurement and evaluation on the solar panel for the location (Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria) in other to obtain accurate estimation of the maximum power output.

Keyword: Solar noon; Sunshine hour; Solar powered system; Output current; Output power; Solar panel.

1. Introduction

Energy is the lifeblood of economies around the world and global economic growth depends on adequate, reliable and affordable supplies of energy. One year of the Sun's output that the earth receives is equivalent to 42, 000 times the World's total annual energy consumption [1]. The extraterrestrial radiation received on earth was determined to be $1.729\times 10^{14}\ kW/m^2$ in which 47 % of this radiation reaches the earth's surface [7]. Nigeria is located on Lat 4°16 N and 13°52 N within the Equator and the Tropic of Cancer and longitude between 3 °E and 15 °W [25] which is endowed with abundant sunshine all year round. The terrestrial radiation on Nigeria is 2.079×10^{15} kWh/year, average annual consumption of all forms of

energy in Nigeria is $2.4026\times 10^{11}\ kWh$ and the electrical energy consumption in the year 2001 was $15\times 10^{6}\ kWh$ [22]. This implies that the solar energy on Nigeria's land area is about 9, 000 times the average annual consumption of all form of energy and 139 million times the electrical energy consumption. Nigeria receives abundant solar energy that can be usefully harnessed with an annual average daily solar radiation of about 5.25 kW h/m^2/day. This varies between 3.5 kW h/m^2/day at the coastal areas and 7 kW h/m^2/day at the northern boundary [6, 11]. Use of solar energy in Nigeria is very favourable. To enhance the developmental trend in the country, there is every need to support the existing unreliable energy sector with a sustainable source of power supply through solar energy.

Furthermore, renewable energy has an important role to play in meeting the future energy needs in both rural and urban area [10, 21]. The development and utilization of renewable energy should be given a high priority, especially in the light of increased awareness of the adverse environmental impacts of fossil-based generation. The need for sustainable energy is rapidly increasing in the world [26]. A widespread use of renewable energy is important for achieving sustainability in the energy sectors in both developing and industrialized countries. They generally cause less environmental impact than other energy sources.

Human existence relies on solar energy either directly or indirectly and the world at large cannot continue to exist, remain or live without the solar energy. Solar power in Nigeria can serve as a source of sustainable energy if fully utilized due to abundant availability all year round energy and its regular appearance on daily basis in the sky under a friendly environment. Knowledge of the quantity and quality of solar energy available at a specific location is of prime importance for the design of any solar power system [9, 14] . Although, the solar radiation (insolation) is relatively constant outside the earth's atmosphere, local climate influences can cause wide variation in available insolation on the earth's surface from installation site to another. In addition, the relative motion of the sun with respect to the earth will allow surfaces with different orientation to intercept different amount of solar energy [4, 17, 19, 28]. The impression of the sun's movement is a result of the Earth's own rotation [38] around the sun in an elliptical orbit which cause the consequence variation of day and night [37], and seasonality (raining and drying season). The quantity of solar energy received at any given point on the surface of the earth depends on its geographical location, time of the year, time of the day and local weather conditions [20], position and altitude angle of the sun in the sky and angle of sun's rays. Earth's atmosphere also affects the amount of solar radiation received. Heavy cloud cover keeps more solar radiation from reaching Earth's surface than a clear sky.

When the sun appears high in the sky, the sun's rays hit Earth more directly and spread out less. The sun intensity is tensed at that particular time. But when the sun appear low in the sky, its rays spread out over a much wider area becoming less effective at heating the ground. A particular place would received its greatest solar radiation (solar intensity) at solar noon when the sun reached its zenith, or highest point in the sky, for that day. The length between the sunrise and sunset is called the length of the daytime [18]. A titled surface such as solar panels receives more energy as the sun's ray is perpendicular to its surface. A location of the earth receives maximum radiation when the radiation is incident at perpendicular to earth surface. The amount of radiation decreases with increases of atmosphere thickness which cross it. The height of the sun in the sky at noon varies with the season. Parameters like latitude, longitude, season and time of a day at a given location affect the position of the sun and amount of solar energy reaching the earth's surface [27]. Zakharov and Tremblay [38] reported that day duration and maximum height of the sun above horizon depend on the latitude and longitude of the observation site.

The variation of the solar radiation and intensity leads to variation in the output current and output power of a solar panel. More so, the time every location attains it maximum solar intensity varies on daily basis, also in the same location the time of maximum solar intensity change from day to day. This time is referred to as solar noon which is defined as the time of the day when the sun is at its highest point in the sky where the shadows point directly north in the northern hemisphere or directly south in the southern hemisphere [30]. At the time of solar noon the sun appears the highest above the horizon and shadows appear shortest. Solar noon changes from day to day throughout the year [38].

Osanyinpeju *et al.* [23] carried out a study on the performance evaluation on six 80 W (480 W) mono-crystalline photovoltaic panels which was done on the field using the six 80 W solar panels with set of resistors approach. The I-V and P-V curves were plotted to estimate the maximum power output from the solar panels. The value obtained from their result was 335 W (69.8 %). Osanyinpeju *et al.* [24] also worked on output voltage and output power-time characteristics of the six 80 W (480 W) mono-crystalline photovoltaic solar panels which was established in the laboratory during the working condition of the solar panels. The maximum output power from the six 80 W (480 W) solar panels obtained in the laboratory (under working condition when the six 80 W solar panels including the 40 W charge controller, 400 AH solar battery and 2000 W solar inverter was used to power a machine) for each day for the period of the 21 days ranged from 302 to 339 W. Also, the average maximum output power gotten for the period of the 21 days was 323 W which represents 67.3 % of the output power stated by the manufacturer. Their study clearly shows that the estimate maximum power output derived from the I-V and P-V curves carried out on the field would give accurate measurement of the maximum power output that would be obtained during the working condition of the solar panels with the other solar powered system (solar controller, solar battery and inverter). The issue that may arise using the field approach (solar panels with set of power resistors approach) to estimate accurately the maximum power output that can be obtained from a solar panel is that there is variation in sun intensity during the daytime. Suitable time during the day to carry out the performance evaluation of the solar panel has to be known. More so, the variation of the intensity of the sun during the day has direct effect on the power output of the solar panel. The maximum power output that would be obtained on the field would occur when the sun intensity is at its peak which is at solar noon.

The average sunshine hour for the day in a particular place is an important parameter in designing the size of the solar panel and obtaining the wattage of the solar panel needed for powering a particular machine or equipment in that particular area. The higher the average sunshine hour for a place the less the size of solar panel needed to power a particular equipment. The average sunshine hour varies from day to day. The output current and output power of a photovoltaic panel is affected by changing weather conditions of a place [3, 5], it is important to characterize the response of the output of the panel to these changes with time so that the period of the maximum output during the daytime can be known. This will go a long way in assisting the Engineer to know the period of the day field performance evaluation on the solar panel could be carried out to have accurate estimation of the maximum power output the examine solar panel can produced. This research work investigated suitable time for the performance measurement and evaluation of mono-crystalline photovoltaic panels at Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria.

2. Materials and Methods

2.1 Materials

The materials used for this study are six 80 W (480 W) panels of sunshine product made in Germany, two 200 AH (400 AH) solar batteries, stop watch and 40 W digital controller. The manufacturer's specification of each of the six 80 W (480 W) solar panel used were P_{max} of 80 W, solar irradiance of 1000 W/m^2, cell temperature of 25 ^oC, current at maximum power point, I_{max} as 4.57 A, voltage at maximum power point, V_{max} as 22.05 V, short circuit current, I_{sc} as 5.12 A, open circuit voltage, V_{oc} as 22.05 V and output tolerance as 15 %.

2.2 Methods

The carry out investigation on the suitable time for the performance measurement and evaluation of mono-crystalline photovoltaic panels at Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria the six 80 W (480 W) panels were installed on the roof of the Agricultural and Bio-Resources Engineering processing laboratory while the CM 5024 PWM 40 A digital intelligent solar charge controller 12/24 V and two 200 AH (400 AH) solar batteries were installed inside the laboratory. The CM 5024 PWM 40 A digital solar charge controller 12/24 V was used to monitor the output current and cumulative charges from the solar panels.

2.2.1 Investigation on the Maximization of Output Current from the Solar Panels Using Different Connection

The solar panels were subjected to test to investigate which of the connection (series or parallel) would maximize the output current from the solar panels. This verification of the connection of the solar panels that would maximize the output current was carried out on the field. The site used for the field investigation is located at the back of the Agricultural and Bio-Resources Engineering laboratory of Agricultural Engineering department at Federal University of Agriculture, Abeokuta (70^0N, 30^0E). FUNAAB is situated on a land area of about 97 ha between Latitude 7° 13’ and 7° 14' North of the equator and between Longitude 3° 24¹ and 3° 26' East of the Green wish meridian. It covers a geographical extent of about 150 square kilometres [31].

The panels were connected in series then parallel and comparison of the connection were made. The open circuit voltage and short circuit current were measured and recorded for the series and parallel connections. Maximum of two panels were connected at a time because the multimeter available can only measure current not more than 10Amps. The solar battery is to store charge therefore the current to be supplied by the solar panel need to be maximized.

2.2.2 Examination of the Output current and output cumulative charge of the solar panels due to the variation of the solar intensity

The six 80 W (480 W) solar panels were connected in parallel during installation to maximize current. The examination of the output current of the solar panel due to the effect of the solar intensity was monitor in the laboratory for a period of 21 days (from 24/12/2105 to 13/01/2016) between 6:30 am and 7: 30 pm using the 40 W digital solar charge controller. The cumulative charges supplied by the solar panels to the battery for each day were also read and recorded. The average output current and output cumulative charges across a period of the 21 days were evaluated.

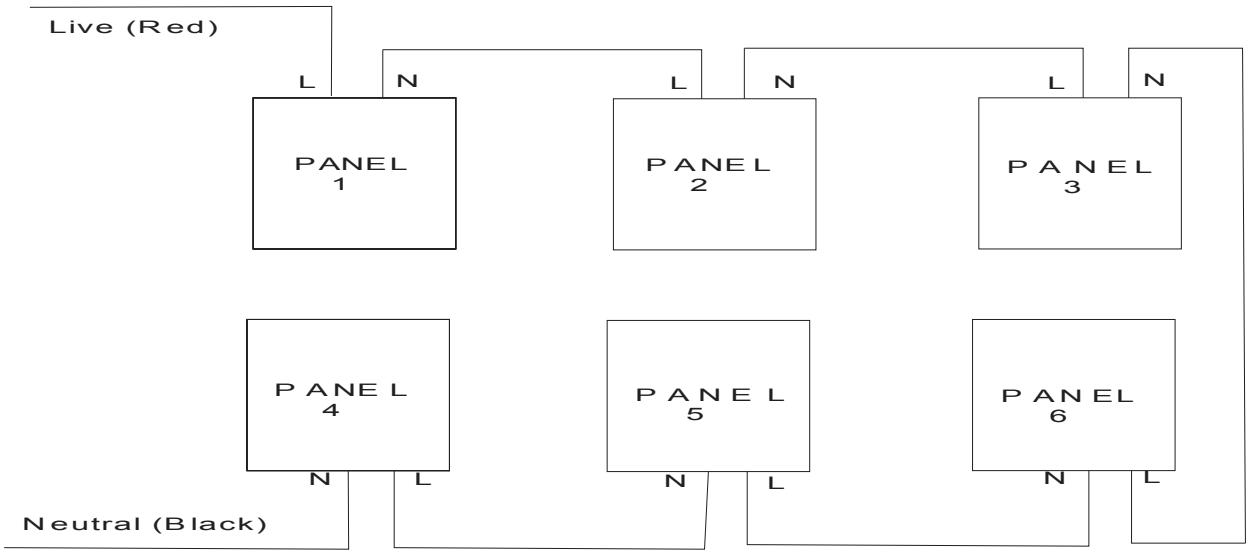

Figure 1: Circuit diagram of the series connection of the six (480 W) solar panels

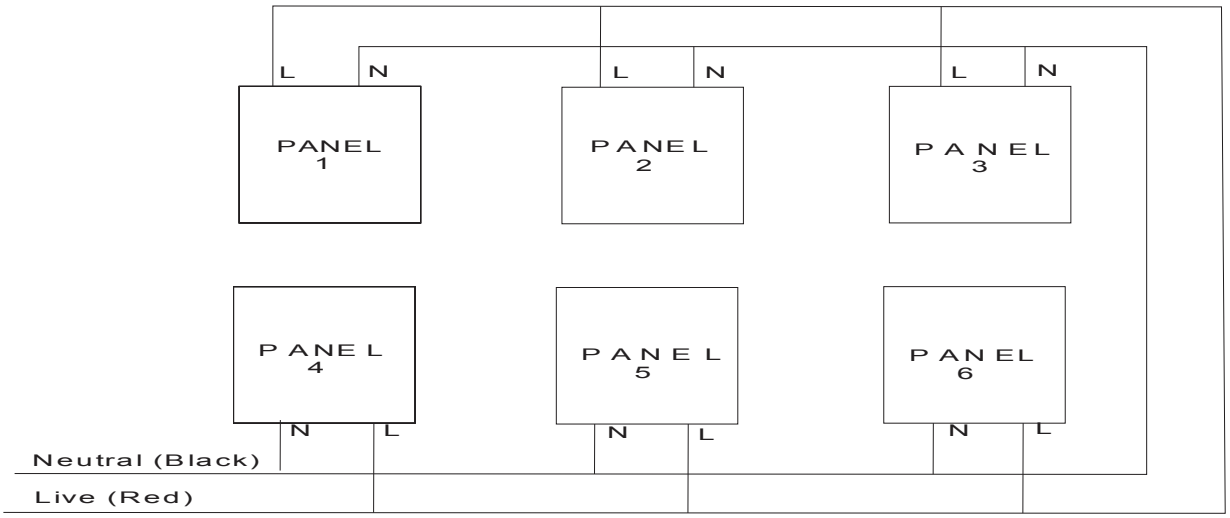

Figure 2 Circuit diagram of the parallel of the six (480 W) solar panels

Since the output current of the solar panel is approximately proportional to the solar intensity [2, 13, 15, 16, 29, 34]. The peak sunshine hours could be obtained from the values recorded for the output current of the solar panel throughout the period of sunshine. The peak sunshine hours were determined from the cumulative charge and current against daytime of sunshine curve using the formula as follow:

$$\textit{The estimate peak sun shine hour}$$

$$= \frac{\text{output cumulative charge of the panel for the period of sun shine during the daytime}}{\textit{peak current during the period of sun shine}}$$

3. Results and Discussion

Table 1 shows the open circuit voltage and short circuit current of series and parallel connections of the solar panels 1 with 3 and 5 with 6 recorded on Tuesday, 15/12/2015. From the table, the open circuit voltages, V_{oc} of the mono-crystalline PV panel 1 with solar panel 3 connected in series and parallel were 42.8 and 21.3 Volts, respectively, while for solar panel 5 with solar panel 6, the values obtained for series and parallel connection were 42.9 and 21.3 Volts, respectively. It was observed that the open circuit voltages, V_{oc} of the mono-crystalline PV panels were maximized under the series connection for both series connection of solar panels 1 with 3 and 5 with 6. This indicates that solar panels should be connected in series to maximized voltage which would be relevant in area where the electricity or power generated is to be transmitted over long distance before utilization or used with the grid system. This will prevent lost of current during transmission.

More so, for the short circuit current, I_{sc} of the mono-crystalline PV panel 1 with solar panel 3 connected in series and parallel were 4.32 and 8.99 Amps, respectively, while for solar panel 5 with solar panel 6, the values obtained for series and parallel connection were 4.37 and 9.06 Amps, respectively. It was found that the short circuits current, Isc of the mono-crystalline PV panels were maximized under the parallel connection for both parallel connection of solar panels 1 with 3 and 5 with 6.

Since the solar battery is to store electric charges the solar panels were connected together to maximize current that were delivered to the solar battery. Moreover, the power store by the battery was obtained by multiplying the output current from the solar panel by the norminal voltage of the solar battery. Based on the observation, the six mono-crystalline solar panels were connected together in parallel during the installation of the solar powered system. This result revealed that to obtained maximum output current from the solar panel, the panels should be connected in parallel. The parallel connection of the solar panel to maximized current which would be relevant in area where the electricity or power generated would be stored by a solar battery or used in an off grid system. Since solar battery stores electric charge which is a product of current and time.

Table 1. The open circuit voltage and short circuit current of series and parallel connections of the solar panels 1 with 3 and 5 with 6.

Solar Panels 1 with 3					Solar Panels 5 and 6				
Time	Parallel Connection		Series Connection		Time	Parallel Connection		Series Connection	
	Voc	Isc	Voc	Isc		Voc	Isc	Voc	Isc
11:37	21.3	8.99	42.8	4.32	11:55	21.3	9.06	42.9	4.37

Day of record (Tuesday, 15/12/2015)

Table 2 shows the average output current and average cumulative charges of the solar panels across a period of 21 days. The average output current was still zero at 6: 30 am while at 7: 00 am the solar panels has started pulling out current indicating the sun intensity is already having interaction with solar panels due to

the collision of the solar energy with bounded electrons in the panels. The collision and interaction of the solar energy from the sun with the solar panel lead to the interference of the atomic structure of the solar panel. As the daytime pass by the output current from the solar panel increases indicating more interaction of the solar energy with the solar panels. The increase in interaction is as a result of the increase in the intensity of the solar energy. On average of the output current the peak value was obtained between 1: 00 pm and 1:30 pm. Peak output current occurs when the sun have the greatest interaction with the solar panel. This occurs when the solar intensity is at its peak. After attaining the peak value, the value of the output current decrease gradually against daytime. At 7: 00 pm the output current is zero. Indicating no interaction between the solar energy and the solar panel. The variation of the output current of the solar panel is as a result of the rotation of the earth. It soon became evident, that the sun gets highest at certain point in time during the day which appeared to be different from clock noon.

Figures 3-4 present the average output current and average cumulative charges of the mono-crystalline PV panel against time over a period of 21 days. Figure 3 indicated that the average output current solar panels were zero at 6:30 am. It was found that the average output current varied throughout the daytime and attained the maximum value at 1: 00 pm and 1: 30 pm. The results indicated that the output current of the solar panels depends on daytime which was due to the variation in weather condition from time to time.

As the sun rises its altitude increases to a peak value which occur at solar noon. This increase in altitude of the sun at a particular location increases the solar power that falls on that location. At solar noon, the solar power that falls at a particular location on the earth surface is maximum. After the sun as attain the peak altitude during the day, its altitude start to diminish to set point which results to reduction in intensity to zero value.

Table 2. The average output current and average cumulative charges of the solar panels across period of 21 days due to the effect of solar intensity

S/N	Daytime	Average Output Current	Average Cumulative charges	S/N	Daytime	Average Output Current	Average Cumulative charges
1	6:30	0	0	15	13:30	21.4	78
2	7:00	0.5	0	16	14:00	21.3	89
3	7:30	1.3	1	17	14:30	20.3	99
4	8:00	2.7	2	18	15:00	19.2	108
5	8:30	3.9	4	19	15:30	17.7	117
6	9:00	5.2	7	20	16:00	15.6	125
7	9:30	6.6	10	21	16:30	12.9	131
8	10:00	9.3	15	22	17:00	9.1	136
9	10:30	12.5	21	23	17:30	5.1	138
10	11:00	15.3	29	24	18:00	1.9	139

11	11:30	17	37	25	18:30	0.1	139
12	12:00noon	19.2	47	26	19:00	0	139
13	12:30	20	57	27	19:30	0	139
14	13:00	21.4	68				

Day of record: A period of 21 days (from 24/12/2105 to 13/01/2016)

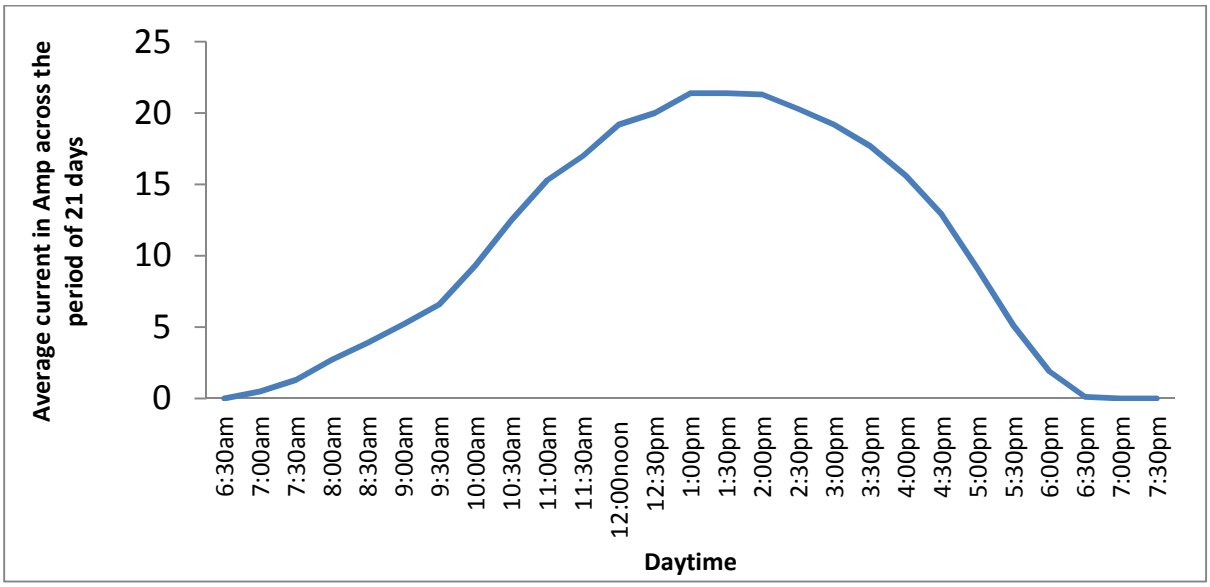

Figure 3. The average output current of the mono-crystalline PV panel against daytime over a period of 21 days.

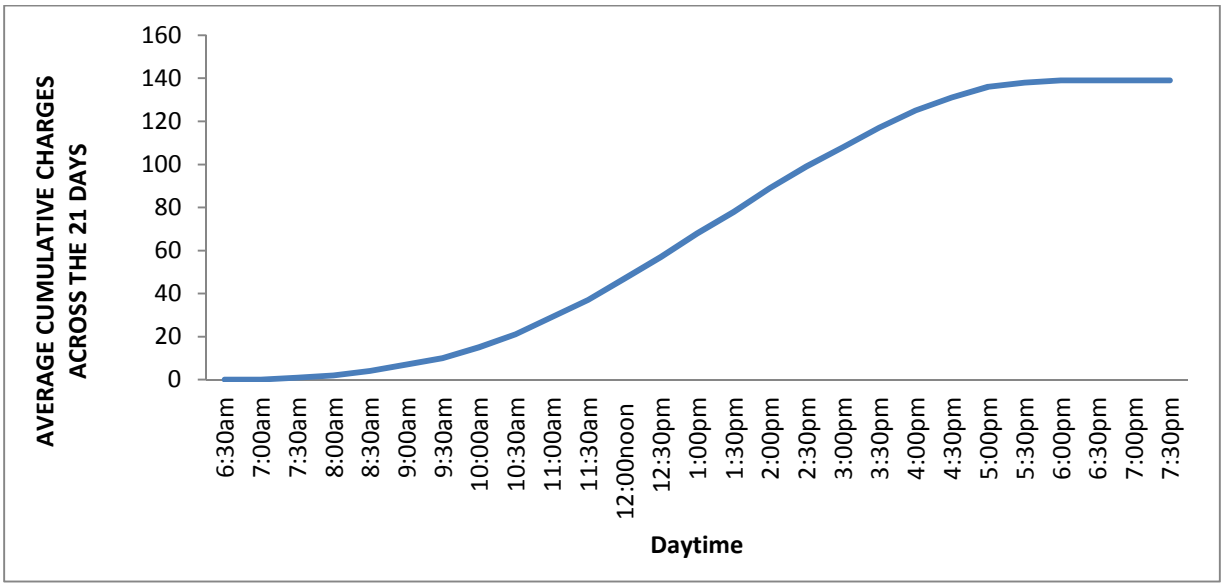

Figure 4. The average cumulative charge from the mono-crystalline PV panel against daytime over a period of 21 days

Table 3 shows the output current and cumulative charges of the solar panels for days 1 and 8 due to the effect of solar intensity. It was observed that the time of peak output current from the solar panels varied from day to day throughout the period of 21 days of investigation but was between 1:30 pm and 2:30 pm which can be seen in Table 4. For all the 21 days of investigation the output current was zero at 6:30 am and 7:30 pm. Cuce and Cuce [8]; El-Shaer *et al.* [12]; Ettah *et a'.* [13]; Tobnaghi *et al.* [35]; Tobnaghi [36] revealed that the output current of solar cells is directly proportional to the sun intensity. Stewart *et al.* [32]; Szokolay [33] analysed that the time of solar noon is never the same as clock noon where the clock noon of every place is taken as 12 pm which is at the mid day. Their analysis and observation supported why there was variation in the time of peak output current of the solar panels as obtained from the results. This indicated that the time of solar noon of FUNAAB as a locality occurs between 1:30 pm and 2:30 pm within the period of experimental study. The period would be suitable to investigate the performance of solar panel in FUNAAB area in order to get accurate measure of the particular panel.

Figures 5-8 present the output current and cumulative charges of the mono-crystalline PV panel against time on days 1 and 8. Figure 9-10 show the output current and cumulative charges of the mono-crystalline PV panels against time for day 1 to day 21. Figure 5 indicated that the output current solar panels were zero at 6:30 am and 7:00 pm. It was found that the output current varied throughout the daytime and attained the maximum value at 2:00 pm. The results indicated that the output current of the solar panels depends on daytime which was due to the variation in weather condition from time to time.

It was gathered from the investigation that the output current, and output power were affected by the climatic condition of the Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria environment. Due to this, it was important to characterize the response of the output parameters of the panel to these changes with time so that the period of the maximum output during the daytime can be known. This has gone a long way to know the period of the day the field performance measurement and evaluation on the solar panel could be carried out to be able to obtain accurate estimation of the maximum power output from the solar panels.

It was discovered that the output cumulative charges and output current from the panels for each day followed the same trend, respectively. This is as a result of the period in which the study took place which were months of December and early January. There was no rain which could have great effect on the sunshine hours and sun intensity bringing a great variation in the output current of the solar panels.

Table 3. The output current and cumulative charges of the solar panels for days 1 and 8 due to the effect of solar intensity.

Day 1 (24/12/2015)				Day 8 (31/12/2015)			
S/N	Daytime	Output Current	Cumulative charges	S/N	Daytime	Output Current	Cumulative charges
1	6:30	0	0	1	6:30	0	0
2	7:00	0.8	0	2	7:00	0.6	0
3	7:30	1.7	1	3	7:30	1.4	1

4	8:00	3	3	4	8:00	2.8	2
5	8:30	4.6	5	5	8:30	3.5	4
6	9:00	5.6	8	6	9:00	4.3	6
7	9:30	7.9	12	7	9:30	5.8	9
8	10:00	10.3	17	8	10:00	8.1	13
9	10:30	13	24	9	10:30	10.8	19
10	11:00	15.9	31	10	11:00	14.1	26
11	11:30	18.6	41	11	11:30	18.1	35
12	12:00noon	19.7	51	12	12:00noon	18.8	44
13	12:30	21	61	13	12:30	20.9	55
14	13:00	21.4	72	14	13:00	21.8	66
15	13:30	21.3	82	15	13:30	22.9	77
16	14:00	21.6	93	16	14:00	22.7	88
17	14:30	21.4	104	17	14:30	21.2	99
18	15:00	21	114	18	15:00	19.7	109
19	15:30	19.5	124	19	15:30	19.7	119
20	16:00	17.8	133	20	16:00	18.1	128
21	16:30	16.4	141	21	16:30	16.3	136
22	17:00	12.4	147	22	17:00	13.2	142
23	17:30	8.3	152	23	17:30	7.7	146
24	18:00	2.4	153	24	18:00	2.6	148
25	18:30	0.8	153	25	18:30	0	148
26	19:00	0	153	26	19:00	0	148
27	19:30	0	153	26	19:30	0	148

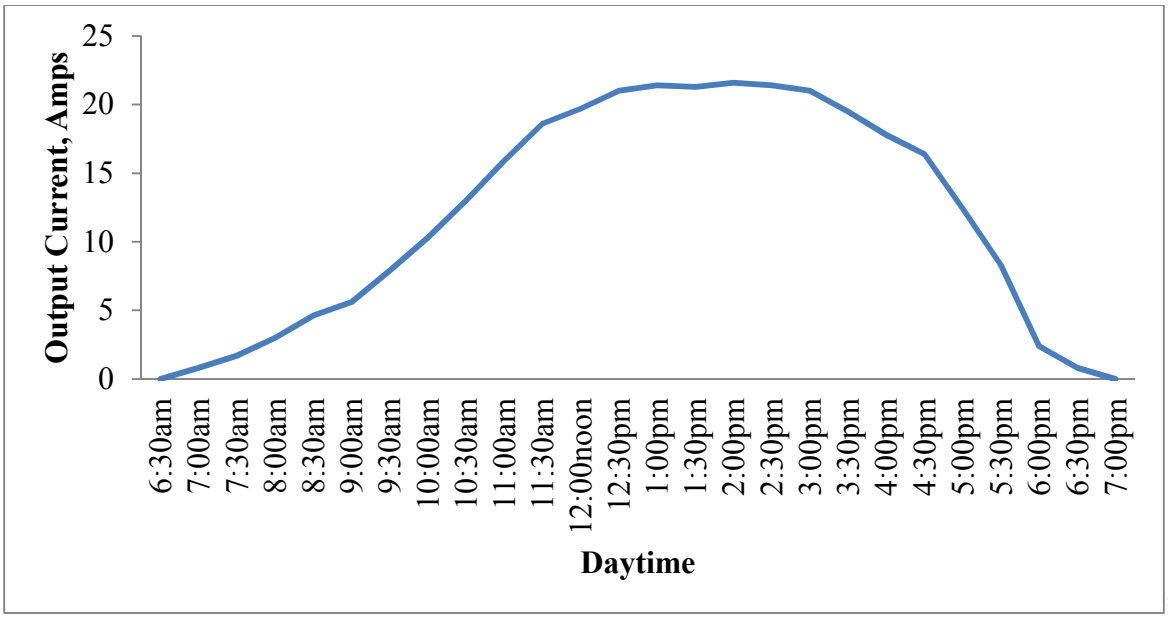

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Figure 5. The output current of the mono-crystalline PV panel against time on day 1 of incubation period

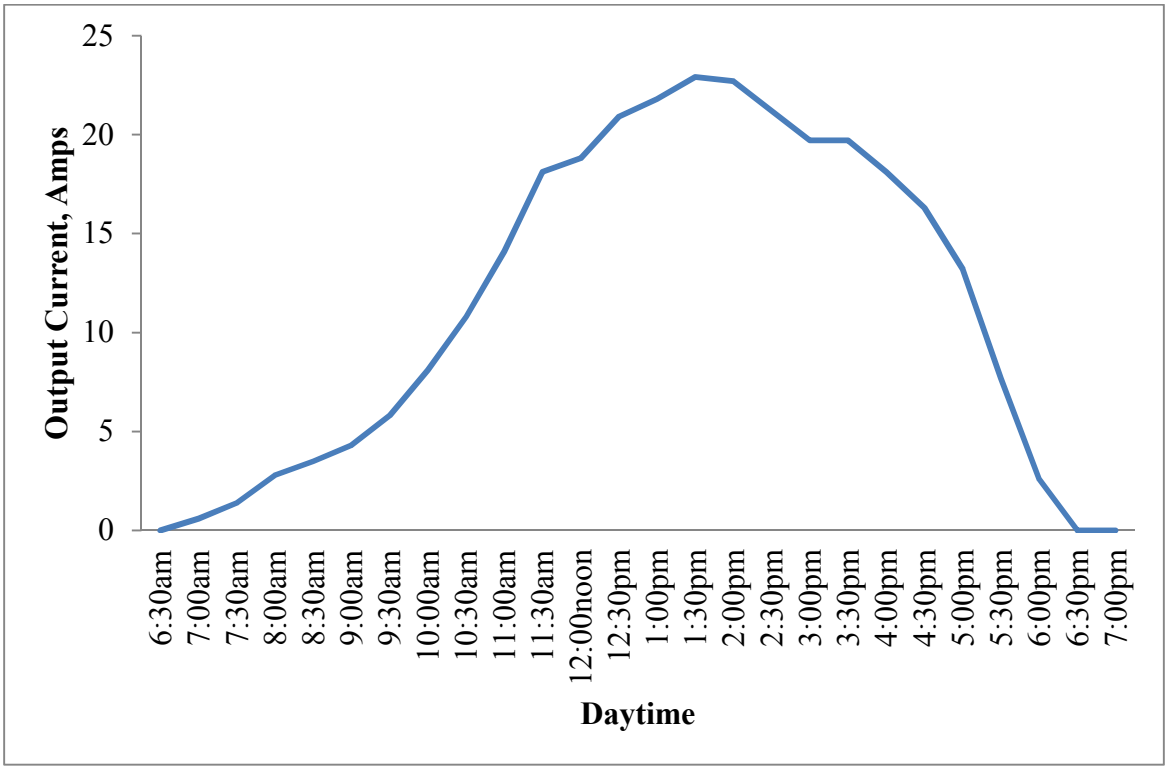

Figure 6. The output current of the mono-crystalline PV panel against time on day 8 of incubation period.

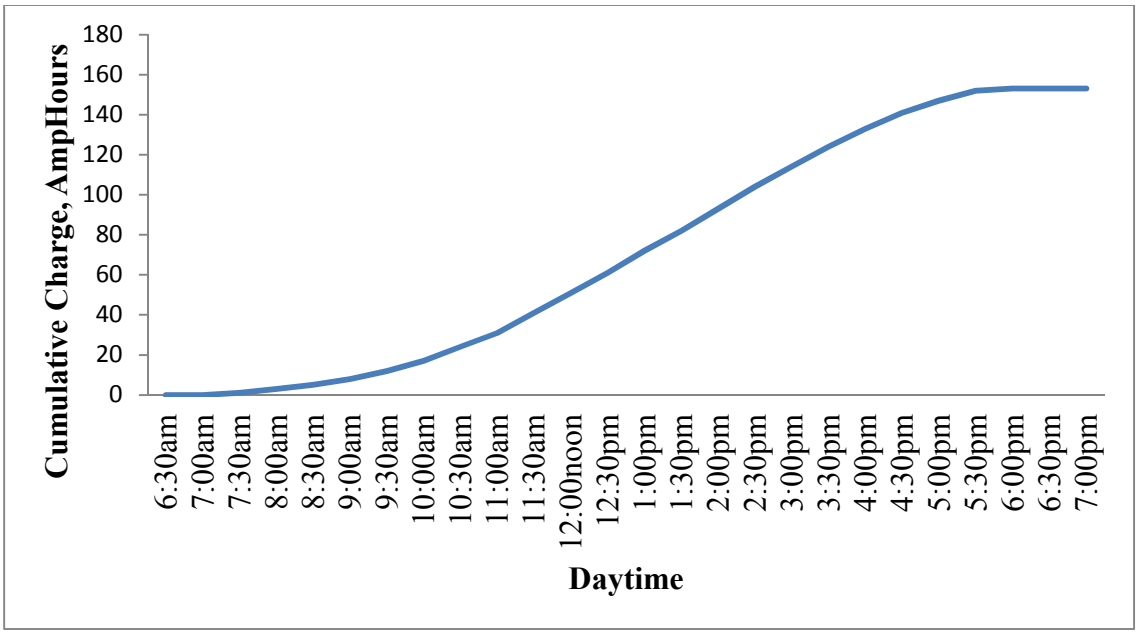

Figure 7. The cumulative charge from the mono-crystalline PV panel against daytime on day 1 of incubation period.

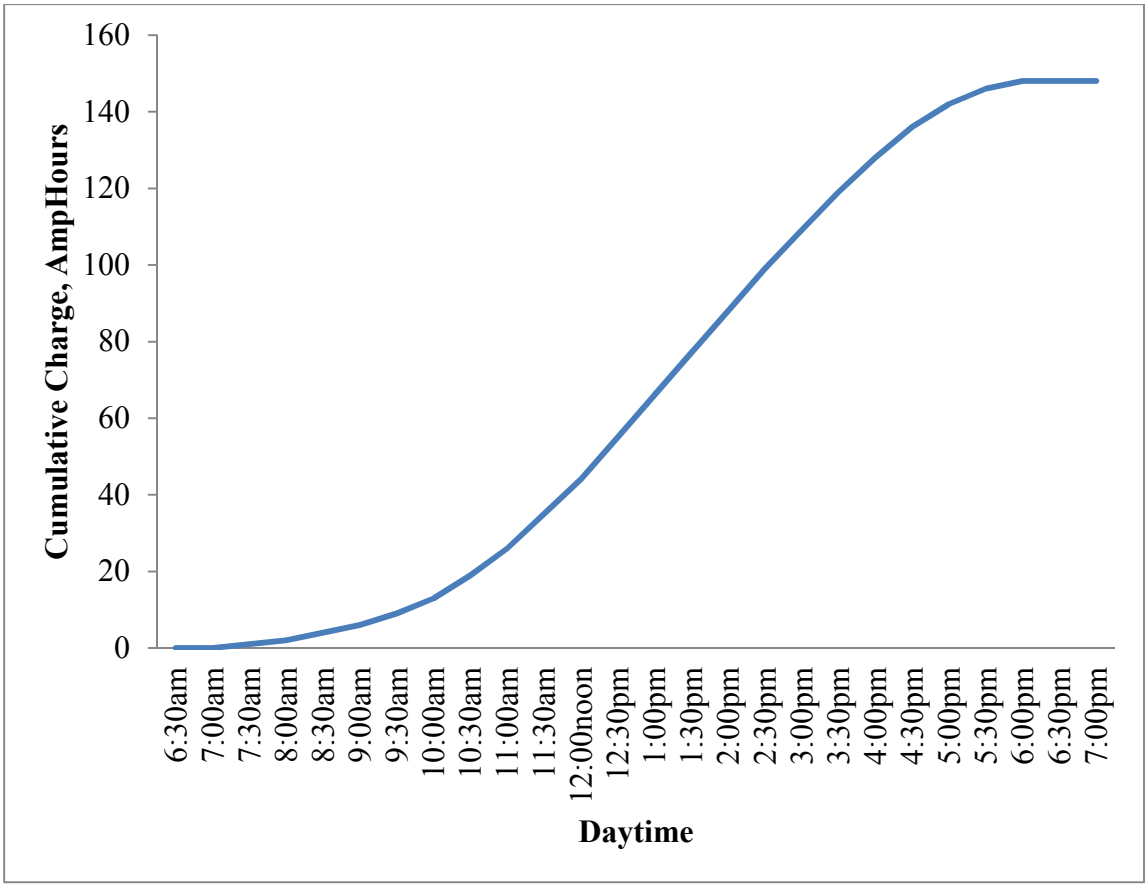

Figure 8. The cumulative charge from the mono-crystalline PV panel against daytime on day 8 of incubation period.

Figure 11 indicates the daily sunshine hour for period of 21 days. Table 4 shows the output Cumulative charges in AmpHours and peak output current in Amps of the solar panels and the estimated sun shine hours for the period of the 21 days of investigation. The result shows that the estimated peak sun shine hours ranging from 6.2 to 7.1 hours for month of December and ranging from 5.0 to 6.8 hours for month of January. The average estimated peak sun shine hour obtained for months of December and January were 6.6 and 6.3 hours respectively. More so, the evaluated estimated average peak sun shine hour for the 21 days of investigation was 6.4 hours. The results indicated that the average sunshine hours vary from day to day.

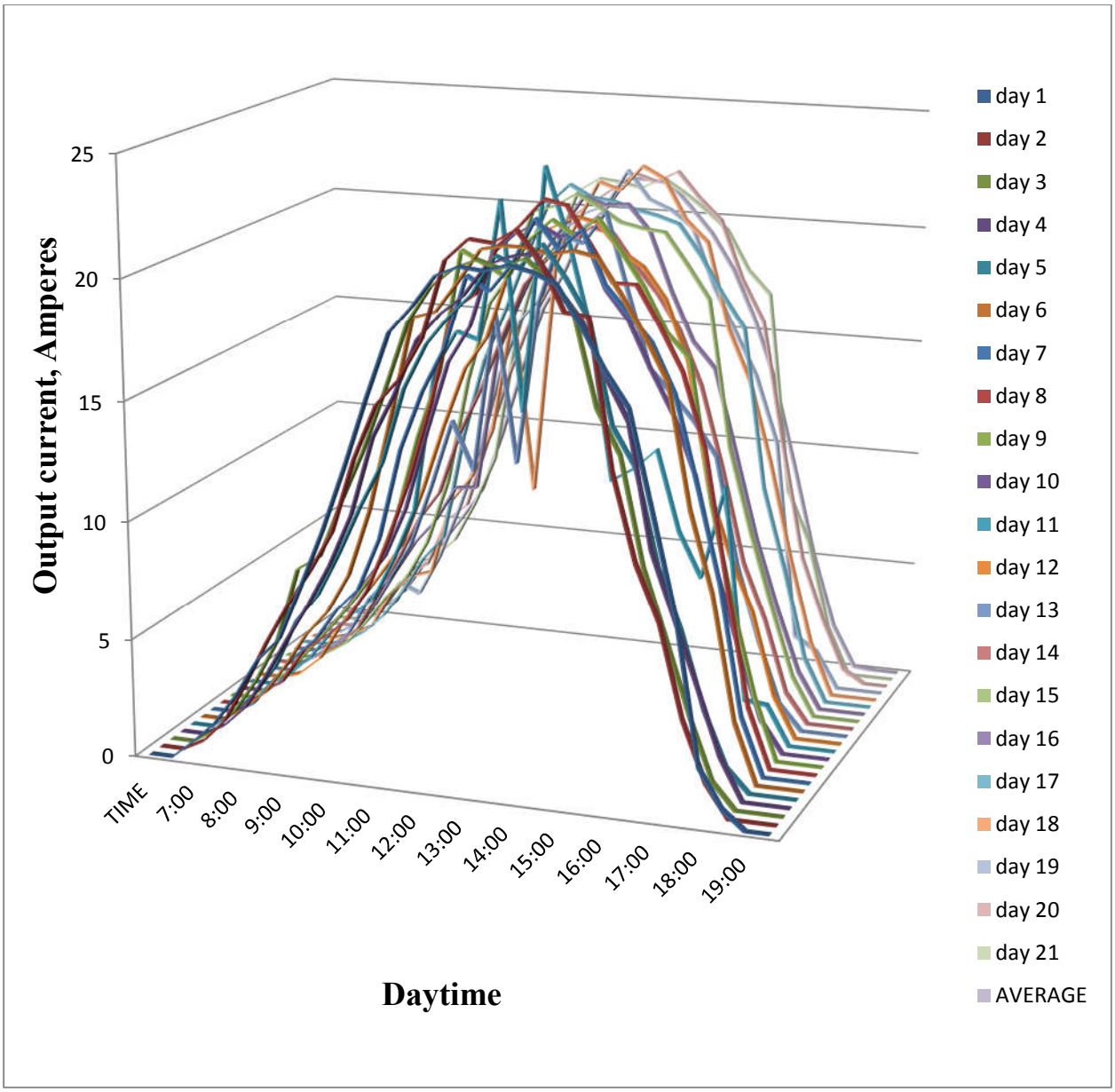

Figure 9. The output current of the mono-crystalline PV panel against time on day 1 to day 21.

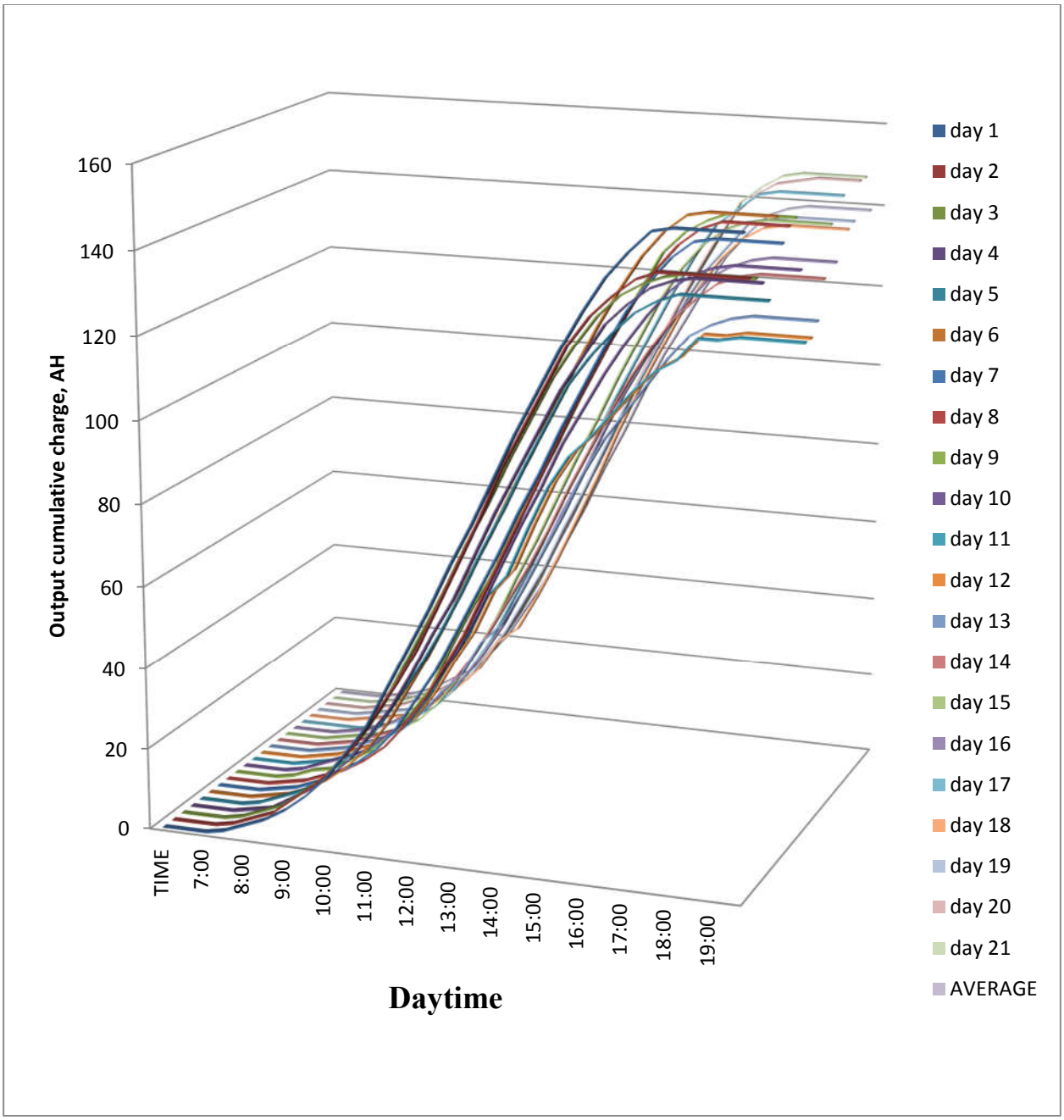

Figure 10. The cumulative charge from the mono-crystalline PV panel against daytime on day 1 to day 21 of the incubation period.

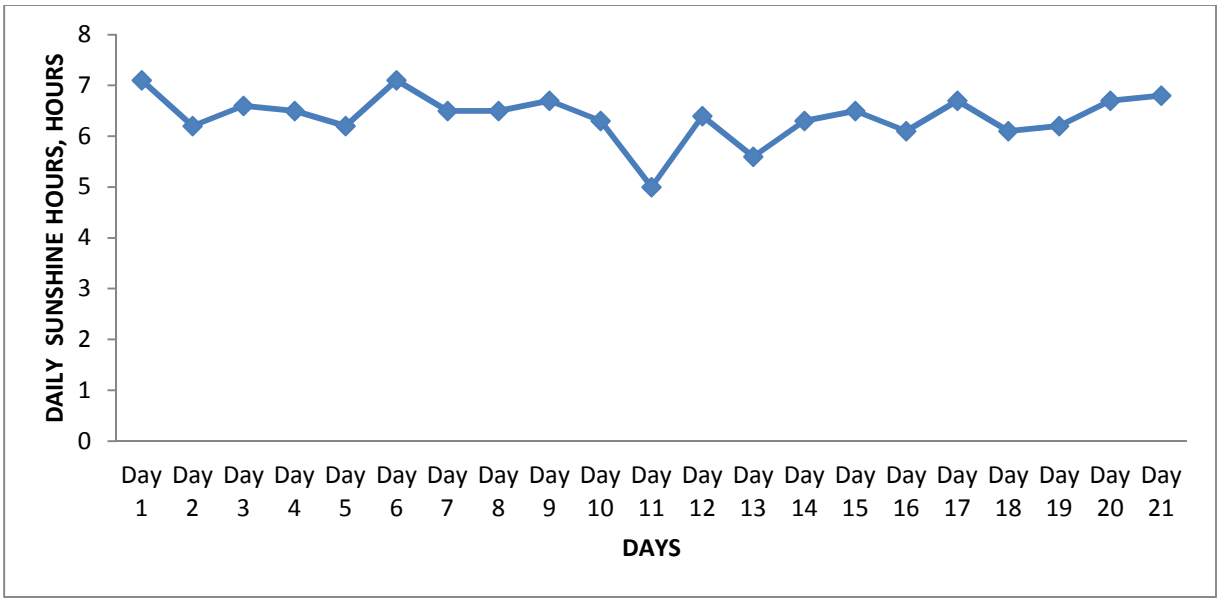

Figure 11. The daily sunshine hours for period of 21 days.

(Day of record: 24/12/2015 to 13/1/2016)

Table 4. The output Cumulative charges in AmpHours and peak output current in Amps of the solar panels and the estimated sun shine hours.

Day	Date	Cumulative charges pull out from solar panel (AH)	Peak output current (Amps)	Time of peak output current	Estimated sunshine hours
1	(24/12/2015)	153	21.6	14:00	7.1
2	(25/12/2015)	142	22.8	14:00	6.2
3	(26/12/2015)	141	21.5	14:00	6.6
4	(27/12/2015)	139	21.5	14:00	6.5
5	(28/12/2015)	134	21.7	14:00	6.2
6	(29/12/2015)	152	21.3	14:30	7.1
7	(30/12/2015)	145	22.3	13:30	6.5
8	(31/12/2015)	148	22.9	13:30	6.5
9	(1/1/2016)	149	22.1	14:30	6.7
10	(2/1/2016)	136	21.5	13:00	6.3
11	(3/1/2016)	118	23.7	13:00	5.0
12	(4/1/2016)	137	21.5	13:30	6.4
13	(5/1/2016)	121	21.6	14:00	5.6
14	(6/1/2016)	130	20.7	13:30	6.3

15	(7/1/2016)	142	21.9	13:00	6.5
16	(8/1/2016)	132	21.6	13:00	6.1
17	(9/1/2016)	147	21.9	12:30	6.7
18	(10/1/2016)	138	22.7	14:00	6.1
19	(11/1/2016)	139	22.3	13:30	6.2
20	(12/1/2016)	148	22.2	14:30	6.7
21	(13/1/2016)	148	21.7	14:00	6.8

Day of record: A period of 21 days (from 24/12/2105 to 13/01/2016)

Plate 1: The views of the six 80 W (480 W) mono-crystalline photovoltaic solar panels during field investigation and installation.

Plate 2: The view of the installed six 80 W (480W) solar panels, CM 5024 PWM 40 A digital intelligent solar charge controller 12/24V, 400 AH solar batteries and the 2000 W solar inverter used for the laboratory investigation.

Conclusion

Investigation of suitable time for the performance measurement and evaluation of mono-crystalline photovoltaic panels at Federal University of Agriculture, Abeokuta (FUNAAB), Alabata, Ogun State, Nigeria for a period of 21 days was been carried out. The solar panels were subjected to series and parallel connections to examine which of the connection would yield maximum output current. The result revealed that to obtain maximum output current from the solar panel, the panels should be connected in parallel. The estimated sun shine hours for the period of the 21 days of investigation was evaluated from the output cumulative charges in AmpHours and peak output current from the solar panels and was found that the estimated average peak sun shine hour for the 21 days of investigation was 6.4 hours in Federal University of Agriculture, Abeokuta (FUNAAB), Alabata, Ogun State, Nigeria. This indicated that the time of solar noon of FUNAAB as a locality occurs between 1:30 pm and 2:30 pm within the period of experimental study. The period would be suitable to investigate the performance of solar panel in FUNAAB area in order to get accurate measure of the particular panel. The study demonstrates that the sunshine hours vary from day to day. The results of the study also show that the output current of a solar panel depends and varies with the daytime which may be due to variation in the solar intensity during the daytime. The study reveals that the time of peak output current varies from day to day which may be due to the variation in the time of soon noon from day to day.

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