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PHOTOVOLTAIC SHADING UNDER MAIDUGURI WEATHER CONDITIONS USING POWER SYSTEM COMPUTER AIDED DESIGN

Modu A.G., Adam B. and I. Mustapha.

Department of Electrical and Electronics Engineering, University of Maiduguri, Borno, Nigeria

ABSTRACT

A solar module is constructed by connecting a number of cells in series to get a practically usable voltage. Partial shading of a Solar Photovoltaic Module is one of the main causes of overheating of shaded cells and reduced energy yield of the module. This work is a study of effects of partial shading on the performance of a PV module. A PSCAD simulation model that represents 36 cells PV module under partial shaded conditions has been used to test several shading profiles and results are presented. From the results obtained during the study conducted on solar panels under normal condition, Maiduguri weather condition and partial shading level of 25%, 50% and 75% it can be concluded that the output power produced by solar panels under normal conditions and various shading levels are 110, 65 and 15 Watts. The result has shown that partial shading can reduce the value of the output power produced by solar panels from normal conditions

Keywords: PSCAD, PV Model, PV Shading, I – V and P – V curves

1. INTRODUCTION

The performance of series connected solar photovoltaic module is adversely affected if all its cells are not equally illuminated. All the cells in a series array are forced to carry the same current even though a few cells under shade produce less photon current [1]. The shaded cells may get reverse biased, acting as loads, draining power from fully illuminated cells. If the system is not appropriately protected, hot-spot problem can arise and, in several cases, the system can be irreversibly damaged. In the new trend of integrated PV arrays, it is difficult to avoid partial shading of array due to neighboring buildings and trees throughout the day in all the seasons [2].

In view of the above, study of partial shading of modules becomes imperative. With a physical Solar PV module, it is difficult to study the effects of partial shading. Hence, a PSCAD model of a PV module consisting of 36 cells in series has been developed to carry out this study. The model is used to study the effect of shade on the varying number of cells on the power output of the modules on the shaded illuminated cells under various illumination levels under Maiduguri, Borno State, Nigeria weather condition.

1.2 *Some Important Solar Parameters*

Irradiance (s): This is the amount of solar energy reaching the cell given in watts per meter square (W/m2). It is an input parameter which is varied from 1000 W/m2 to 200 W/m^2.

The Nominal Operating Cell Temperature: This is defined as the temperature reached by open-circuited cells in a module under STC.

Open Circuit Voltage (VOC): This is the maximum voltage available from a solar cell and this occurs at zero current. The Open Circuit Voltage corresponds to the amount of forwarding bias on the solar cell due to the bias of the solar junction with the light generated current. This value depends on solar radiation and operating Temperature Short Circuit Current (Isc): This is the current through the solar cell when the voltage across the solar cell is zero, (i.e when the cell is short-circuited). The values also depend on solar radiation and operating Temperature [3] - [5].

The Maximum Voltage (Vmax): This is the voltage generated by the solar panel when the power output is highest. It is the actual amperage which the panel should read when it is connected to solar equipment under STC.

The Maximum Current (Imax): This is the current generated by the solar panel when the power output is maximum. It is the actual amperage that the panel should read when connected to solar equipment under STC.

The Maximum Power (Pmax): This is the highest power output of the solar panel under STC. It is derived from the product of current and voltage at the maximum point.

1.3 *Equivalent Circuit of SPV Module*

The adopted method is based on PSCAD platform and simulation of the photovoltaic cell of module type of PS-P310-36. This program depends on the fundamental circuit equations of a solar PV cell considering the effects of physical and environmental parameters such as the solar radiation and cell temperature. The performance of photovoltaic systems (solar cell/panels), that is, the output current/voltage curve (IV curve) and Power/Voltage (P-V curve) are studied using an equivalent circuit model. This equivalent circuit consists of a current source with two resistors, one connected in parallel and the other in series. Based on these electronic components, equations (15) were used for the photovoltaic systems [6]. Figure

1 shows an equivalent circuit of a Photovoltaic with one diode.

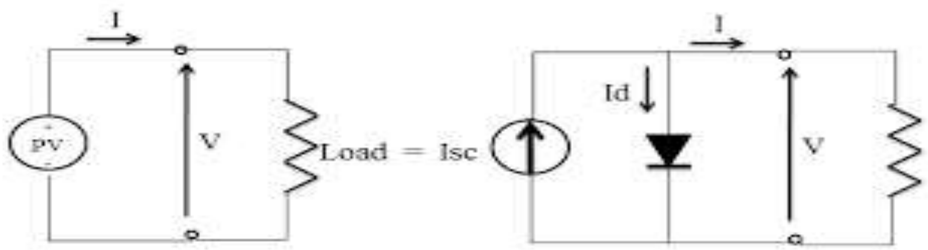

Figure 1. PSCAD equivalent circuit of SPV Module

The output current *I* through the load resistance is given by (1)

$$I = I_L - I_d(\mathrm{A} - 1) - \mathrm{B} \quad (1)$$

$$Where\ A = e^{\frac{V+IR_{se}}{V_t}}$$

$$B = \frac{V+IR_{se}}{R_{sh}}$$

1.4 *Effect of Shadow on the Module*

A shadow falling on a group of cells will reduce the total output by two mechanisms:1) by reducing the energy input to the cell, and 2) by increasing energy losses in the shaded cells. Problems become more serious when shaded cells get reverse biased. In Fig.2, a group of cells under full illumination is connected in series with another group of cells under shaded illumination. The photon current of fully illuminated cells I_{Li} is high compared with that of the shaded illuminated cells I_{Ls}. If the module currents $I < I_{Ls}$, diode D_s is forward biased and there is no risk for the shaded cells. But if $I > I_{Ls}$, then the diode current $I_{Ds} = I_{Ls}-I$ flow through the diode in the reverse direction. Reverse biased diode D_s offers high resistance will consume power and will significantly reduce the load current *I* itself. The point B will assume negative potential. If the difference in illumination levels is high, D_s may get damaged due to overheating. [7] - [9]

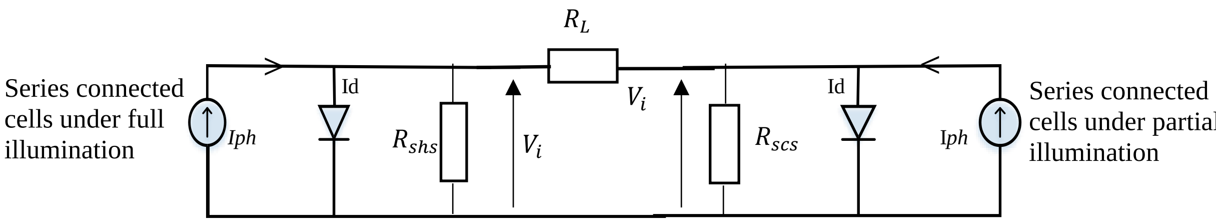

Figure 2. PSCAD equivalent circuit of SPV module consists of 36 cells in series with non-uniform illumination

1.5 *Factors Affecting the Performance of SPV Module Under Partial Shading*

The photo current generated by the shaded illuminated cell is FI_L, where F is the ratio of photo current generated by the shaded cell to that of the fully illuminated cell. F=0 means, fully shaded and F=1 means fully illuminated. When a solar cell in a series array is under shadow, its current output is given by equation 2.

$$I_s = FI_L - I_{Di}(\mathrm{As} - 1) - \mathrm{Bs} \qquad (2)$$

$$Where\ As = e^{\frac{V_{DS}}{V_t}}$$

$$Bs = \frac{V_{DS}}{R_{shs}}$$

$$V_{DS} = v_S + I_S\, R_{ScS} \qquad (3)$$

Similarly, the current through the illuminated cells is given by equation,

$$I_i = FI_L - I_{Di}(\mathrm{Ai} - 1) - \mathrm{Bi} \qquad (4)$$

$$\text{Where Ai} = e^{\frac{V_{Di}}{V_t}}$$

$$\text{Bi} = \frac{V_{Di}}{R_{shi}}$$

$$V_{Di} = v_i + I_i\, R_{Sci} \qquad (5)$$

As the shaded and illuminated cells are connected in series, the same current is forced to flow through both. So, in the equations (1), (2), (3) and (4), I_i and I_s replaced by the same current I. Therefore,

$$I = FI_L - I_{Di}(As - 1) - \mathrm{Bs} \qquad (6)$$

$$I = FI_L - I_{Di}(Ai - 1) - \text{Bi} \tag{7}$$

As the value of F decreases from 1 to 0, $e^{\frac{V_{Di}}{V_t}}$ tends to zero. Therefore (4) can be simplified as,

$$I = FI_L + I_{Di} - \frac{V_{s'} + IR_{scs}}{R_{shs}} \tag{8}$$

Rearranging (8), the expression for the voltage across the shaded cell v_s can be obtained as,

$$V_s = (FI_L - I)R_{shs} - IR_{scs} \tag{9}$$

In the above equation I_oR_{shs} is neglected in comparison with larger terms. The total module output voltage is the sum of voltages across each cell operating at the same current I. So the module consists of 36 identical series connected cells, the output voltage can be expressed as,

$$V = \sum_{j=0}^{a} V_{ij} + \sum_{k=0}^{b} V_{sk} \tag{10}$$

Where, $a + b = 36$

The power dissipated by the shaded cell is obtained by using (11) as

$$P_{Ds} = I \times v_s = I\ \{(FI_L - I)\ R_{shs} - IR_{ses}\} \tag{11}$$

Power dissipation in the shaded cell may be substantial leading to increase in its temperature. Due to increased temperature, the cell current gets concentrated in an increasingly small region of the cell, producing the hot spot. This can damage the cell encapsulation and eventually produce module failure. [10].

2. MATERIALS AND METHOD

The model of the PV module was created in PSCAD platform and the manufacturers cell datasheet of monocrystalline photovoltaic module type of PS-P310-36 under STC was used for the analysis with environmental conditions such as temperature, 25 ^{0}C to 45 ^{0}C, radiation, 200W/m^2 to 1000 W/m^2 of irradiance level, and 1.5 of the air mass. (AM). The Technical characteristics of the photovoltaic modules used for this model are shown in Table 1 [11].

Table.1: Technical specifications of the solar cell and solar module used

S/No.	Parameters	Single Cell	Module
1.	Rated Power	1.03W	37.08W
2.	Voltage at maximum Power (V_{mp})	0.46V	16.56V
3.	Current at maximum power (I_{mp})	2.25A	2.25A
4.	Open circuit voltage (V_{oc})	0.59V	21.24V

5.	Short circuit current (I_{sc})	2.55A	2.55A

All the cells of the module are assumed to be identical. Temperature differences between shaded and unshaded cells and reverse breakdown effects in shaded cells are neglected. Values of R_{ses} and R_{shs} have been assumed to be constant for a particular value of F. These assumptions will not substantially affect the conclusions drawn [12].

In this study firstly, the standard module was simulated, secondly the module under Maiduguri weather condition was equally simulated. And finally, to study the effect of shading 25%, 50% and 75% of the module in the PV array of 36 cells was carried out by adopting the following scenario cases.

Scenario case one:
The radiation and cell temperature values of all the arrays were set to be 1000 W/m^2 and 25 ^{0}C respectively being the standard test condition and simulated to observe the I-V curve.
The radiation and cell temperature values of all the arrays were set to be 266 W/m^2 and 42 ^{0}C respectively being Maiduguri weather condition and simulated to observe the I-V curve.
Reduce the radiation of PVarray1, PVarray1 & PVarray2 and PVarray1, PVarray2 & PVarray3 using the sliders to emulate shading of the cells by 25%, 50% and 75% and observe the new I-V curve.

Scenario Case two:
The breaker switch was closed (i.e. the by-pass diodes)
To investigate the shading effect, the radiation and cell temperature values of both arrays were set to be 1000 W/m^2 and 25 ^{0}C) for different shading levels and simulation was carried to observe the I-V curve.

Reduce the radiation of PVarray1, PVarray1 & PVarray2 and PVarray1, PVarray2 & PVarray3 using the sliders to emulate shading of the cells by 25%, 50% and 75% and observe the new I-V curve.

If bypass diodes are not provided, the available power drops drastically even when a single module experiences shading.

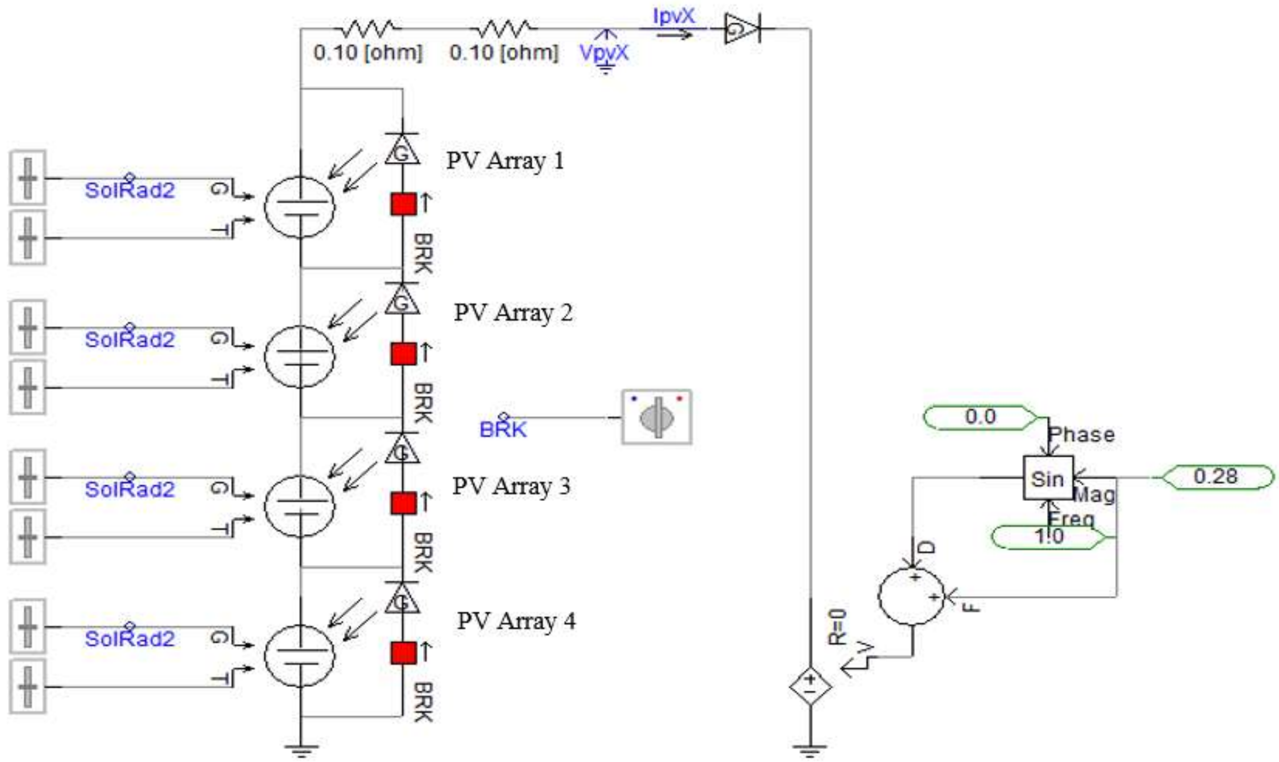

Fig 3: PV Module and Array model in PSCAD.

3. RESULT AND DISCUSSION

To study the effect of shading on the performance of the PV module, first, the out current and voltage of the module under standard test condition and Maiduguri weather condition were obtained by simulating the model of the Module created in PSCAD. The results obtained are presented in the form of I-V, P -V characteristic curves in Figures 4 & 5.

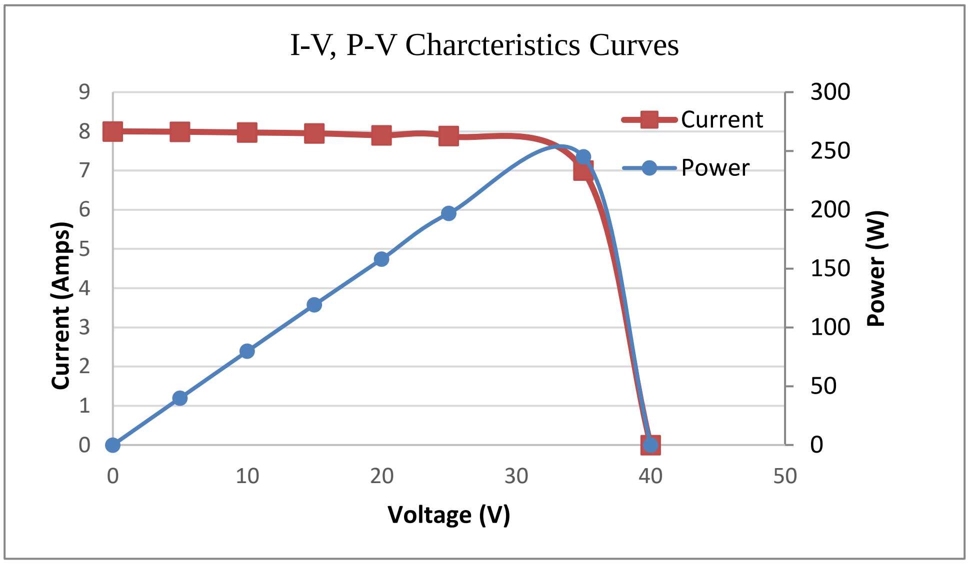

Figure 4 Characteristic Curve I-V, P-V characteristics under standard test condition

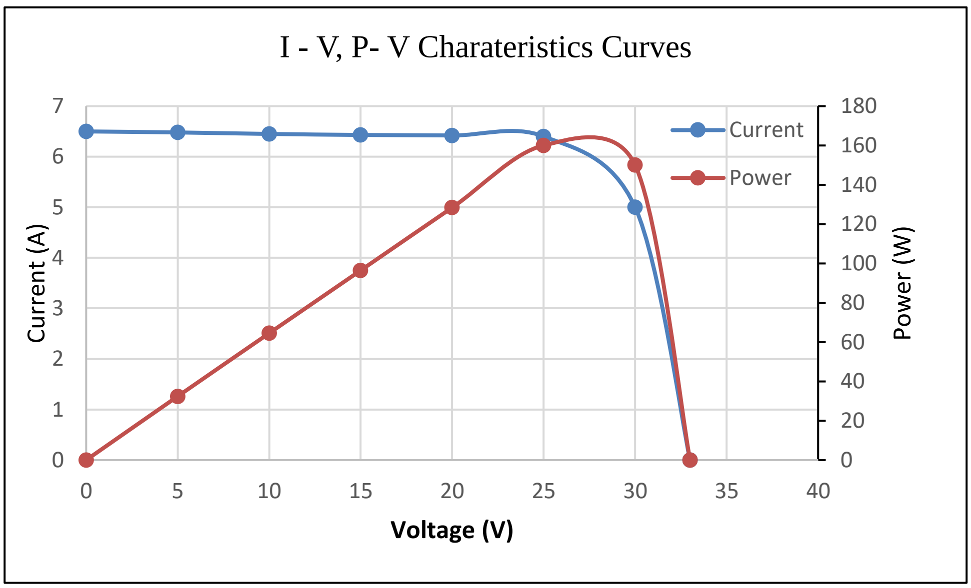

Figure 5 Characteristic Curve I-V, P-V characteristics under Maiduguri Weather condition

As a result of the influence of the solar radiation that the solar panel are exposed to there are changes in the characteristic curve of I -V in Figures 4 & 5. The output current as shown in Figure 4 has decreased significantly based on insolation reaching the surface area of the solar panel. This decrease affects the value of the output power produced by solar panels.

To study the impact of shading the surface area of the panel, the radiation reaching 25%, 50% and 75% were reduced to 150 W/m^2 and the output current and voltage were recorded and plotted in figures 6, 7

& 8.

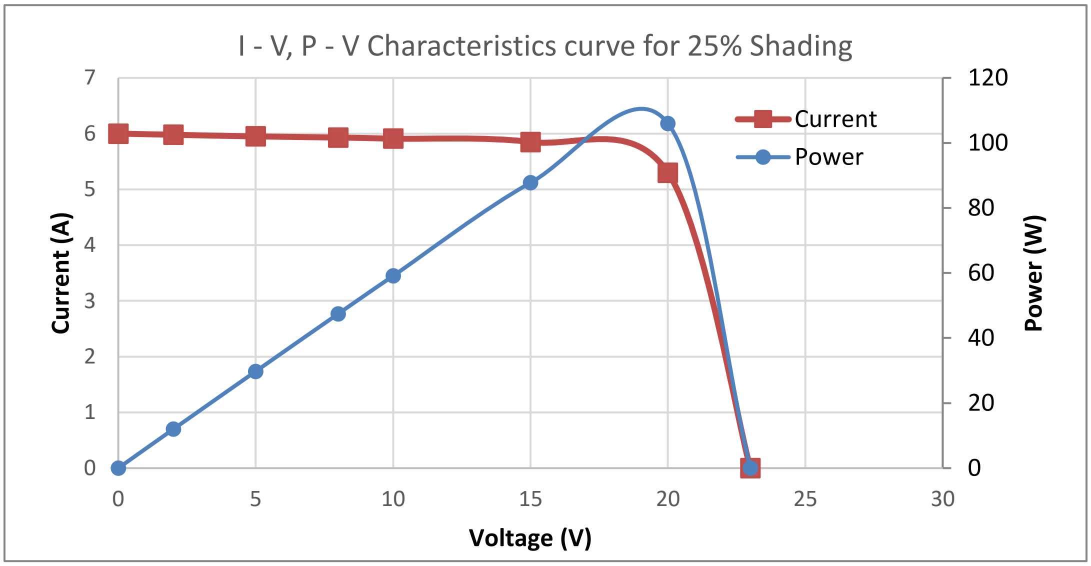

Figure 6 Characteristic Curve I-V, P-V characteristics under 25 % Shading condition

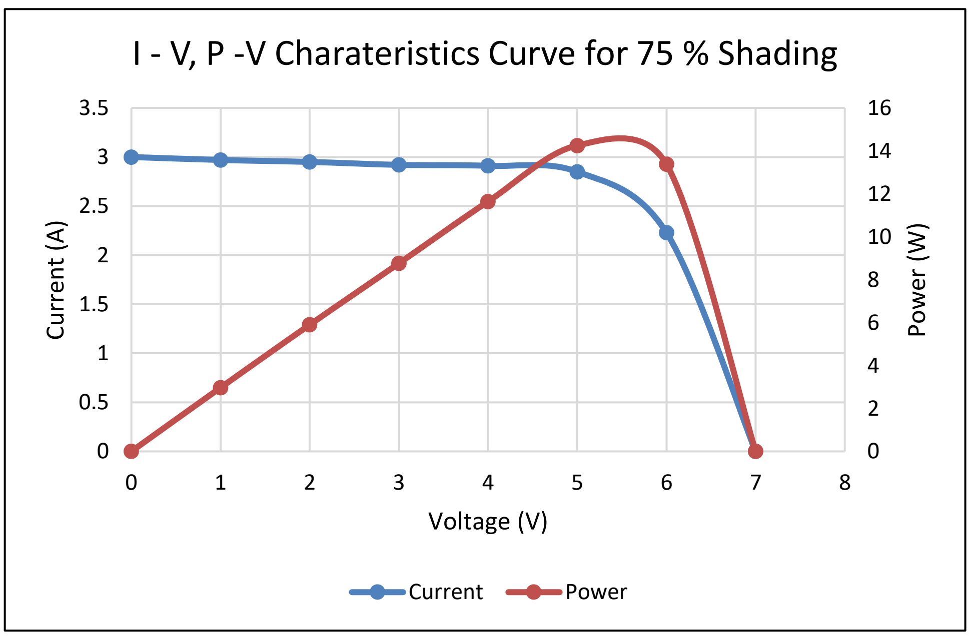

Figure 7 Characteristic Curve I-V, P-V characteristics under 50 % Shading condition

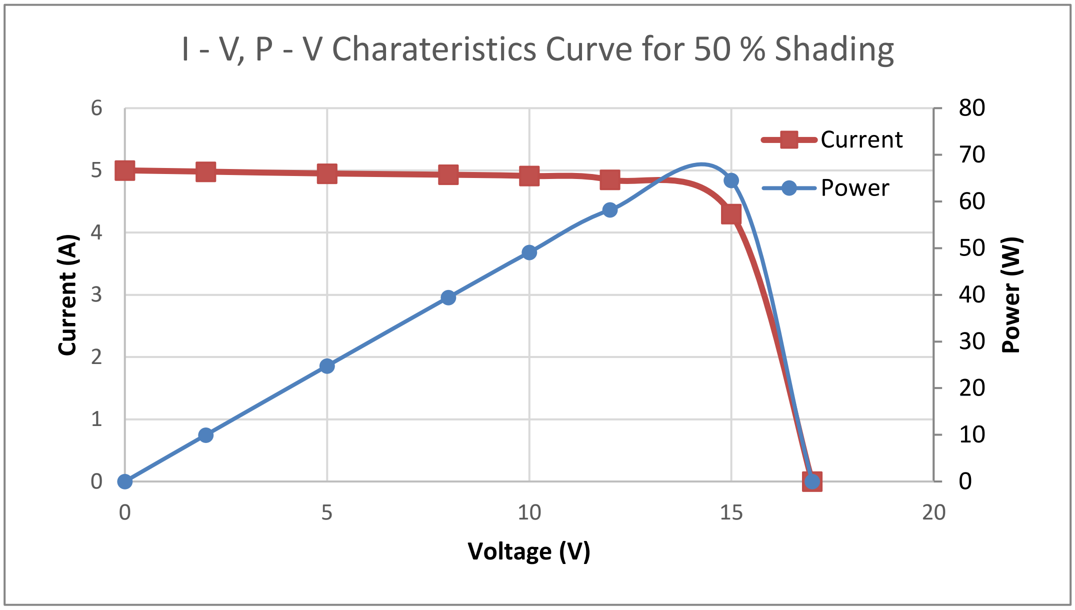

Figure 8 Characteristic Curve I-V, P-V characteristics under 75 % Shading condition

4. CONCLUSIONS

From the results obtained during the study conducted on solar panels under normal condition, Maiduguri weather condition and partial shading level of 25%, 50% and 75% it can be concluded that the output power produced by solar panels under normal conditions and various shading levels are 110, 65 and 15 Watts. The result has shown that partial shading can reduce the value of the output power produced by solar panels from normal conditions.

REFERENCES

[1] H. Gunerhan, A. Hepbasli, and U. Giresunlu, "Environmental Impacts from the Solar Energy Systems," Energy Sources, Part A Recover. Util. Environ. Eff., vol. 31, no. 2, pp. 131–138, Dec. 2008, doi: 10.1080/15567030701512733.

[2] M. Kaltschmitt, W. Streicher, and A. Wiese, Renewable energy: Technology, and environment economics. Berlin: Springer, 2007.

[3] M. Hankins, Stand-Alone Solar Electric Systems: The Earthscan Expert Handbook for Planning, Design and Installation. Washington: Earthscan, 2010.

[3] M. C. Alonso-Garc´ıa, J.M. Ruiz, and F. Chenlo, "Experimental study of mismatch and shading effects in the I-V characteristic of a photovoltaic module," Solar Energy Materials and Solar Cells, vol. 90, no. 3, pp. 329–340, 2006.

[4] N. Femia, G. Lisi, G. Petrone, G. Spagnuolo, and M. Vitelli, "Distributed maximum power point tracking of photovoltaic arrays: novel approach and system analysis," IEEE Transactions on Industrial Electronics, vol. 55, no. 7, pp. 2610–2621, 2008.

[5] H. A. Kazem, T. Khatib, and K. Sopian, "Sizing of a standalone photovoltaic/battery system at minimum cost for remote housing electrification in Sohar, Oman," ELSEVIER, Energy Build., vol. 61, pp. 108–115, 2013.
[6] T. Khatib and W. Elmenreich, Modeling of Photovoltaic Systems Using {MATLAB}®. John Wiley & Sons, Inc., 2016.
[7] M. Drif, P. J. Pérez, J. Aguilera, and J. D. Aguilar, "A new estimation method of irradiance on a partially shaded PV generator in grid-connected photovoltaic systems," Renewable Energy, vol. 33, no. 9, pp. 2048–2056, 2008.
[8] Y. Wang, H. Yang, Y. Liu et al., "The use of Ti meshes with self-organized TiO2 nanotubes as photoanodes of all-Ti dye-sensitized solar cells," Progress in Photovoltaics, vol. 18, no. 4, pp. 285–290, 2010.
[9] De Lima L. C., Ferreira L. D. A., Hedler F., & De Lima B. (2017) Development Performance analysis of a grid connected photovoltaic system in northeastern Brazil, Energy Sustainability Development, 37, 79–85.
[10] R. Ramaprabha, "Effect of shading on series and parallel connected solar PV modules," Modern Applied Science, vol. 3, no. 10, pp. 32–41, 2009.
[11] Teo J. C., Tan R. H. G., & Tan C. (2018) Impact of Partial Shading on the P-V Characteristics and the Maximum Power of a Photovoltaic String, Energies, 11 (1860), 1-22.
[12] S. Kumar, A. Selvakumar, International Conference on Innovative and Power Advance Computing Technology. 5 (2017)