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Changes in Electrical Parameters Due to Partial Shading of PV Solar Cell

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Abstract

The shadowing effect of photovoltaics modules has a devastating impact on their performances since any shadow is able to keep down the electricity production. Therefore in the recent years new technologies and devices have come up in the photovoltaics field in order to improve the performance. However, in order to know how these electronic products work when the shadows take place on the solar panels further investigations have to be done. The aim of this paper is to use the change in electrical parameters with partial shading of PV solar cell. The experimental results show that the electrical parameter, such as the open circuit voltage (V_{OC}), short circuit (I_{SC}), maximum power (P_{max}) and fill factor decreases when the shading area increases. These relationships between these parameters and shadow level can be utilized as measuring the irradiation of the Sun (Solar irradiance).

Keywords

Shadowing, Photovoltaics, Parameters

1. Introduction

Solar cells are devices in which sunlight releases electric charges so they can move freely in a semiconductor and ultimately flow through an electric load, such as a light bulb or a motor. The phenomenon of producing voltages and currents in this way is known as the photovoltaic effect. The fuel for solar cells—sunlight—is free and abundant. The intensity of sunlight at the surface of the earth is at most about one thousand watts per square meter. Thus the area occupied by the cells in a photovoltaic power system may be relatively large, and its cost must be considered in calculating the cost of the electricity produced. The primary factor that determines whether solar cells will be used to supply electricity in a given situation is the cost per unit output, relative to that of alternative power sources, of acquiring, and operating the photovoltaic system [1].

The photovoltaic (PV) industry is experiencing rapid growth due to improving technology, lower cost, government subsidies, standardized interconnection to the electric utility grid, and public enthusiasm for an environmentally benign energy source [2], [3]. More precisely, PV usage worldwide has grown between 15% and 40% for each of the past 10 years, while the inflation adjusted cost of PV energy has declined by roughly by a factor of 2 over the same time period [4]. PV system sizes vary from the MW range, in utility applications, down to the kW range in residential applications. In the latter systems, the PV array is typically installed on the roof of a house, and partial shading of the cells from neighboring structures or trees is often inevitable. Then impact of partial shading on PV system performance has been studied at great length in the past [5], [6]. Some past studies assume that the decrease in power production is proportional to their viewed. This is followed by the impact of partial shading on the I-V and P-V curves of a circuit containing two cells with and without bypass diodes. The concept is extended to the circuits with series and parallel sub modules.

Finally, the impact of shading is illustrated by measurements on a commercial PV panel and a large PV array. The shaded area and reduction in solar irradiance, thus introducing the concept of shading factor [8]. While this concept is true for a single cell, the decrease in power at the module or array level is often far from linearity with the shaded portion. Other past studies tend to be rather complicated and difficult to follow by someone with limited knowledge on electronic/solid-state physics.

The objective of this study is to clarify the impact of shading on a solar panel performance in relatively simple terms that can be followed by a power engineer or PV system designer without difficulty. First, the circuit model of a PV cell and its I-V curve are reviewed.

This is followed by the impact of partial shading on the I-V and P-V curves of a circuit containing two cells with and without bypass diodes. The concept is extended to the circuits with series and parallel sub modules. Finally, the impact of shading is illustrated by measurements on a commercial PV panel and a large PV array.

2. Experimental Work

In this work the effect of shading on solar cell efficiency which has been carried out of using the following procedure.

2.1. Apparatus

Two digital AVO-meter Bel MERIT DX405, Rheostat, conducting wires, solar cells, holders, sunlight.

2.2. Theory

Solar cell efficiency is the ratio of the electrical output of a solar cell to the incident energy in the form of sunlight. The energy conversion efficiency (η) of a solar cell is the percentage of the solar energy to which the cell is exposed that is converted into electrical energy [9, 10]. This is calculated by dividing a cell's power output (in watts) at its maximum power point (P) by the input light (E, in W/m^2) and the surface area of the solar cell (A in m^2). Solar cell's power output is found by multiplying the cell's current and the cell's voltage By convention, solar cell efficiencies are measured under standard test conditions (STC) unless stated otherwise. STC specifies a temperature of 25°C and an irradiance of 1000 W/m2 with air mass 1.5 spectrums. These conditions correspond to a clear day with sunlight incident upon a sun-facing 37°-tilted surface with the sun at an angle of 41.81° above the horizon. In this experiment, we are going to use a 100 W desk lamp to simulate the solar radiation. In an ideal case the irradiance of a 100 W light bulb at a distance of 0.15 m is around E= 350 W/m^2. We are going to use this value in our solar cell efficiency calculations [11]. First we should get familiar with the equipment we are going to use in this experiment.

$$P\,max\ = V\,max\ \times I\,max \tag{1}$$

$$P_O = V_{OC} \times I_{SC} \tag{2}$$

Where P_O is power in, V_{oc} is Open –circuit voltage and I_{sc} is Short –circuit current.

$$FF = \frac{P\,max}{P\,o} \tag{3}$$

Fill –factor (FF): The FF is defined as the maximum power from actual solar cell to the maximum power from ideal solar cell.

P_{max} is power out.

$$\eta = \frac{p\,max}{G \times A} \tag{4}$$

Efficiency (η): Efficiency is defined as ratio of energy output from solar cell to input energy from sun [12].

The efficiency of energy conversion is still low, thus requiring large areas for sufficient insulation and raising concern about unfavorable ratios of energies required for cell production versus energy collected.

Where η is Efficiency, G is solar irradiance, A is cells space Radiology intensity fallen in cell on area unity (G).

2.3. Carrying Out the Experiment

The solar cell was connected as shown in the figure 1 in series with ammeter and rheostat and voltmeter in parallel with them then subjected to the light. then shaded one cell and current – voltage pairs are recorded then two cell are shaded again and the procedure were followed and soon until the hall cell is shaded and this result were compared with that one without shaded. Results were tabulated, graph of I-V was drawn and the fill factor, efficiency was calculated as shown in table 1.

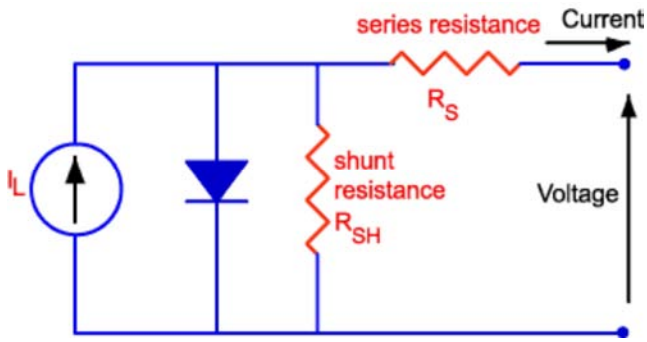

Figure 1. *Shows how to connect devices and tools with solar cell [12].*

3. Result and Dissection

The experiment was carried out in physics lab in Omdurman University, Omdurman, Sudan. In this experiment five samples of solar cell were shaded. The results of experiment were compared with the unshaded cell.

Table 1. *Shows Results for Relationship between Shading Area, P max, Fill Factors and Efficiency.*

Cell No.	Shading Area in m^2	Fill Factor	Efficiency	P max
Without shade	0.00	9.62	58%	3750
1Array shaded	0.0053	0.522	38.7%	499
2cell shaded	0.0106	0.352	28.8%	441
3cell shaded	0.0159	0.344	24.5%	434
4cell shaded	0.0212	0.310	20.5%	293.32
5cell shaded	0.0265	0.218	16.6%	290
Withfull shade	0.06466	0.123	7.71%	205

Figure 2 show the voltage virus current curves for different values of shading array area of solar cell. The shapes of the different curves in figure 2 show that the voltage is large for before and after shading array of PV solar cell, while null for large for different values of shading aero of PV solar cell. the open circuit voltage (v $_{oc}$) decreases slightly while the area of shading increases. The behavior of open circuit voltage is the reduction charge of carrier across the solar cell junction with different area of shading [13]. it appears through the shading effect ion solar cell in short circuit and open circuit conditions that the solar cell has résistance behavior under shading area thus the solar cell behave like resistance that increases with the shading area, resulting in a reduction in the current and voltage due to than slow.

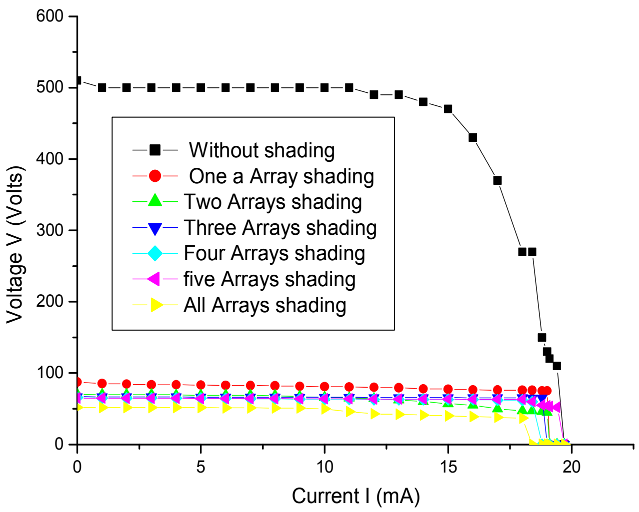

Figure 2. *Shows the relationship between voltage and current for different shading area.*

Different parameter of solar cell can responds different to shading area. In general, the influence of shading on this parameter of for PV solar cell such as efficiency, Fill Factor and power maximum, as shown in table 1 in view of fig.3 and fig. 4 it cleave that the fill factor and p $_{max}$ decreases when the total shading area increases. This decrease in fill factor and power maximums due to reduction in the photo current and photo voltage, in accordance to Basim et al.[14].

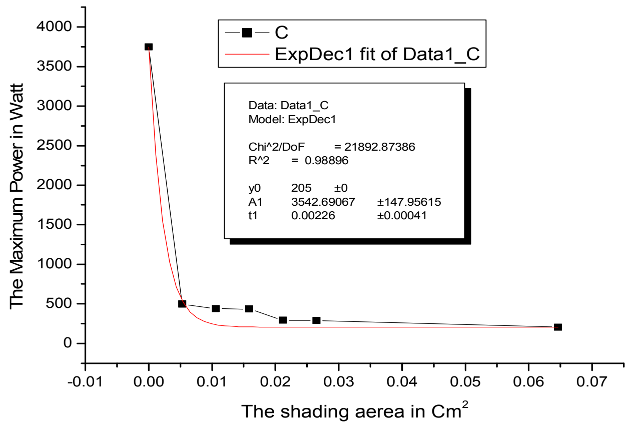

Figure 3. *Shows the relationship between the great power and space shaded.*

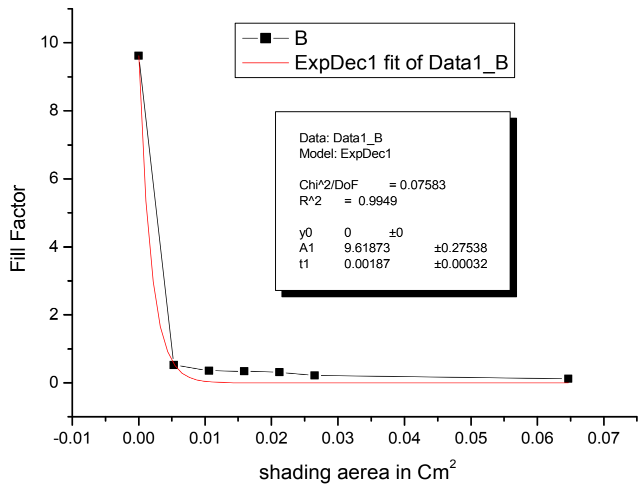

Figure 4. *Show the relationship between the solar cell shaded area and Fill Factor (FF).*

From mathematical models we can predict to the open current voltage (V $_{OC}$) by rate 5 time for PV solar cell as compared to (V oc) after shading area for PV solar cell by using the origin 61 program on Fig. 3 and Fig 4 shows the relation between the Fill factor of PV solar cell and shading area in Cm^2.

For maximum power:-

$$P_{max} = 205 + 3542.69e^{\frac{-x}{0.0026}} \quad (5)$$

And for Fill Factor

$$FF = 9.61873e^{\frac{-x}{0.00187}} \quad (6)$$

Where P_{max} is maximum power, *FF* is Fill Factor and shading area, x is shading area.

Then subtracted equation (5) into equation (4) we get:-

$$G = \frac{P_{max}}{A\eta} = \frac{205+3542.69e^{\frac{-x}{0.0026}}}{0.06466\eta} \quad (7)$$

Where G is G is solar irradiance, x is shading area.

4. Conclusion

The operating shading plays a central role in the photovoltaic conversion process.

Analysis of the change in parameter of PV solar cell such as (V_{OC}), I_{OC}, FF and P_{max} due to different values of shading area show that:

- The open circuit and the short circuit were decreased for all values of shading area increase.
- Fill factor and Maximum power are decrease when shading area increases.
- The depending on change different shading area, the equation (4.1) and (4.2) reflect the relationship between p max and FF with change shading area respectively.

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