Studies of Shading Effects on the Performances of a Photovoltaic Array

[1]Mourad Talbi, [2]Nejib Hamrouni, [3]Fehri Krout, [4]Radhouane Chtourou, [5]Adnane Cherif
[1, 3, 4]Center of Research and technologies of energy of Borj Cedria, Tunis, Tunisia
mouradtalbi196@yahoo.fr

[2, 5]Innov'Com Group, Signal Processing Laboratary, Sciences Faculty of Tunis, Tunisia
hamrouni_nejib2003@yahoo.fr

Abstract **-Photovoltaic systems are vulnerable to the change of climatic conditions (temperature and irradiance). They cause a declination in power generation efficiency and reliability. The variation is commonly caused by uniform and non-uniform partial shading. The aim of this paper is to present the non-uniform partial shading impact on the performances of a photovoltaic (PV) generator. Hence, a theoretical modeling of a generator composed of a two series PV panels is presented. The first part provides literature review with mathematical model. The second section offers details of the simulation analysis under diverse partial shading conditions.**

Keywords- ***Photovoltaic; shading; modeling; MPPT;***

I. INTRODUCTION

The quick renewable development, green and clean energy technologies play a very important role in clean application particularly in electric power generation. Energy produced from renewable resources including wind, biofuels, sun and others is named renewable energy [1]. The most popular form of renewable energy is solar energy. It provides electric energy directly by employing PV modules then Maximal Power Point Tracker (MPPT) is used in order to maximize the efficiency of the PV system. The PV system has a single Maximal Power Point (MPP) at the peak values of current and voltage [2]. The power yield of PV modules is a function of different weather conditions including temperature [3], solar irradiance [4] and partial shading [2]. In this paper we will be interested in a model of a PV Module containing 36 solar cells. This model was proposed by Sanjay Lodwal and presented in mathworks [5] and we have made one modification on it by introducing the technique of the series resistance proposed in [6]. After this modification we connect in series two modified models and we study the effect of partial shading on one of them. Section 2 is dedicated to present the equivalent circuit to a PV cell. Matlab/Simulink numerical simulation of one PV module exposed to different shading effects is presented in section 4. Finally, the conclusion is given in Section 5.

II. MODEL OF THE PV GENERATOR

The PV array consists of solar cell stacks. Solar cell transforms light into electricity. In figure 1, is displayed a solar cell equivalent circuit. It is simply consists of a photo current (IPH), a diode, a shunt resistor (RSH) and an internal resistor (RS). The current at the terminal of the solar cell is expressed as follows [2]:

$$I = I_{ph} - I_S\left[exp\left(q\frac{(V+IR_S)}{KT_Cn}\right) - 1\right] - \frac{V+IR_S}{R_{sh}} \qquad (1)$$

With I_S is the saturation current, K is the constant of Boltzmann, n is an ideal factor and T_c is the Kelvin temperature.

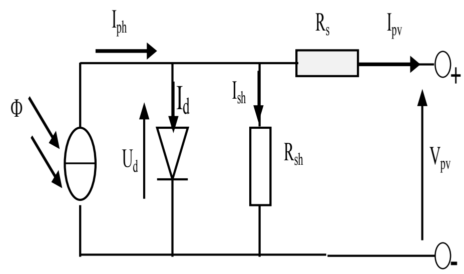


Fig.1. Equivalent circuit of a PV cell

In a simple representation of a PV cell, series resistance R_S is equal to zero and shunt resistance R_{sh} is very great [7]. This ideal case is practically impossible; though, many research works aim to reduce the effect of both the shunt and series resistances. Common PV cell yields below $2W$ at $0.5V$, which is significantly low. For larger output power values, a PV array is employed. It is it is constituted of a number of modules which are connected in series and parallel arrangements. Each of these modules is constituted of of PV cells connected in parallel and series. PV modules are simulated employing either physically using SimPower-Systems toolbox or mathematically using math function. Generally, the mathematical approach is easier to use than the physical model. On the contrary to physical model, in the mathematical one, to have a series-parallel combination for a PV cells, there is no need for block diagram repetition [7, 8]. Consequently in [7], was built the system that depends on mathematical modeling.

III. EFFECTS OF PARTIAL SHADING ON PV CHARACTERISICS

The functioning of a photovoltaic array is impacted by solar irradiance, temperature and shading and array configuration. Often, the PV arrays get shadowed, partially or wholly, by towers, trees, utility and telephone poles, adjacent buildings and the moving clouds. The situation is of special interest in case of big PV installations such as those used in distributed power generation systems. Under partly shaded conditions, the photovoltaic characteristics get more complex with more than one peak. Yet it is very crucial to understand and predict them in order to draw out the maximum possible power. Here, we present a MATLAB-based modeling and simulation scheme desirable for studying the $P-V$ and $I-V$ characteristics of a photovoltaic array. In this section is described the procedure used to simulate the $I-V$ and $P-V$ characteristics of a partially shaded PV array. It is of importance to understand how the shading pattern and the PV array structure are defined in MATLAB using the proposed scheme. The PV array is configured as a combination of six series of PV modules connected in three parallel connections. Each set of PV modules operate under different solar radiations and different cell temperatures. The first set is under solar radiation of 800 W/m^2 and cell temperature of $750°_C$, the second set is under solar radiation of 600 W/m^2 and cell temperature of $250°_C$ and the third set is under solar radiation of 700 W/m^2 and cell temperature of $500°_C$. Based on these conditions, the simulations illustrate the PV characteristics with three different multiple peaks. The maximum peak is called as global peak and the remaining two peaks are named as the local peaks. The PV output power is affected by different factors such as partial shading [9], solar radiation, temperature and the configuration of the PV arrays. In [7] Khaled Matter et al., discussed the effect of several shading condition on the PV arrays that may occur due to presence of trees, buildings and clouds. The power-voltage (P-V) characteristic curves of the PV system with full insolation exhibits nonlinearity with one MPP [7]. This complexity increases with changing insolation conditions [2, 7]. Under conditions of partial shading, some of the PV cells which collect even irradiance will work with maximum efficiency. In the series structure, a uniform current is passing in each cell. Consequently, the cells experience shading run in reverse biasing to yield equal current leading to the decrease in the MPP value. To solve this problem, a bypass diode is connected to selected cells in the series configuration [10]. The addition of bypass diodes modifies the array characteristics. Under partial shading conditions and in the presence of the bypass diodes, many local MPP emerge. The bypass diodes produce a short circuit around the shaded cells permitting the current produced from unshaded cells to flow; consequently, the array current and heating losses are reduced [10-11].

IV. SIMULATION OF THE PV MODEL UNDER DIFFERENT SHADING VALUES

In this paper, we used a Matlab/simulink for investigating the characteristics curves of a PV array subject to diverse shading circumstances. This PV array is as previously mentioned constitutes of two PV modules connected in series. Each of them is a model of PV module contains 36 solar cells. This PV array is presented in Fig. 2.

TABLE I. PARAMETERS OF THE PV GENERATOR

Parameters	***symbols***	***value***
Short circuit current	Isc	8.9A
Open circuit voltage	Vco	22.75V
Cell series resistance	Rs	0.001Ω
Cell shunt resistance	Rsh	0.05Ω
Ideal constant	n	1.2
Series cells	n_s	36
Series modules	Ns	2
Parallel module	Np	1
Boltzman constant	K	$13.807\ 10^{-23} Jk^{-1}$
Electronic charge	q	$1.6022\ 10^{-19} C$
Ambient temperature	T	25°C
Horizontal irradiance	Ir	W/m²

Where the Sub PV Module 1 or 2 is illustrated in Fig. 3 with $I_r(W/m^2)$ designates the Irradiation. For the partial shading of the Sub PV Module 2, we have chosen I_r equal to 500 W/m^2 while it is equals to 1000 W/m^2 for the Sub PV Module 2. The model of those solar cells can be determined by choosing all the parameters existent in the block parameters of each solar cell. These block parameters are presented in Table 1. Figures 4 and 5 illustrated the P-V and I-V characteristics of the PV generator in various partial shadings. I_{r1} is the irradiance of the Sub PV Module 1 and I_{r2} is the irradiance of the Sub PV Module 2.

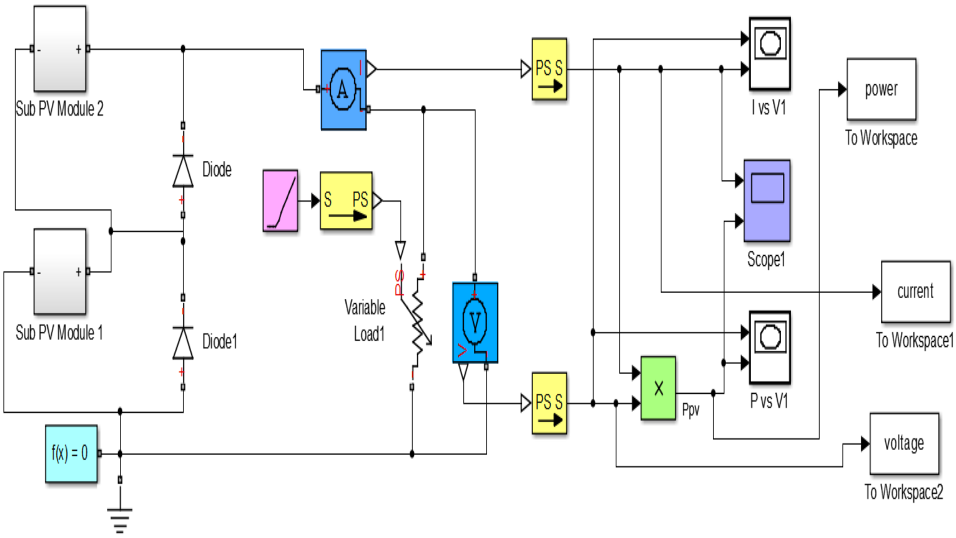


Fig. 2. The Simulation block diagram of the PV array

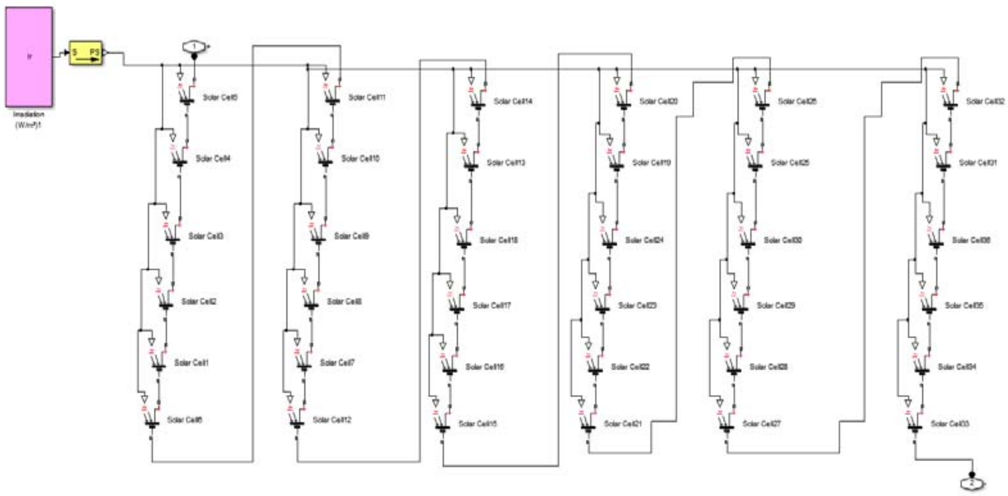


Fig. 3. The Sub PV Module 1 or 2 contains 36 solar cells connected in series.

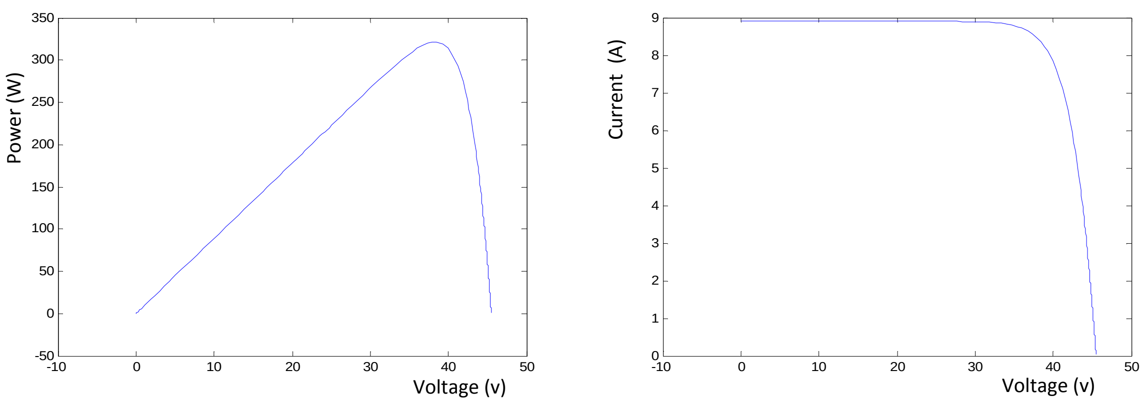
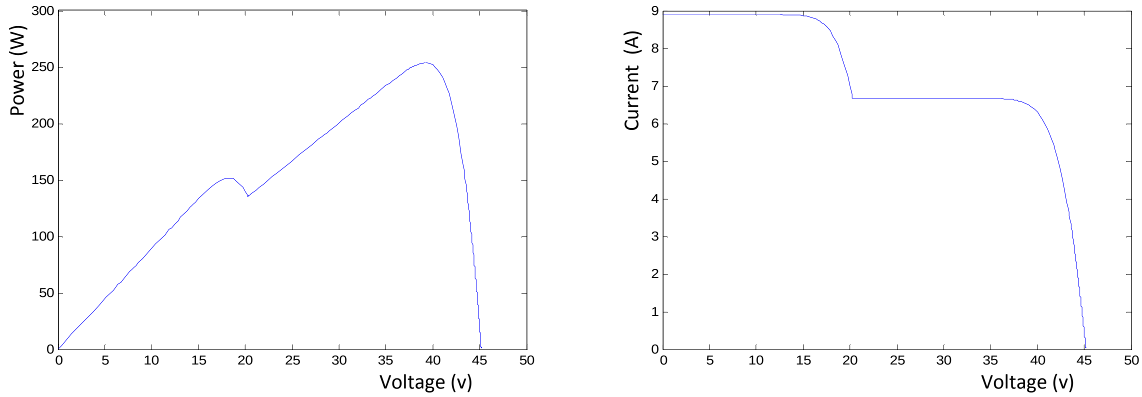
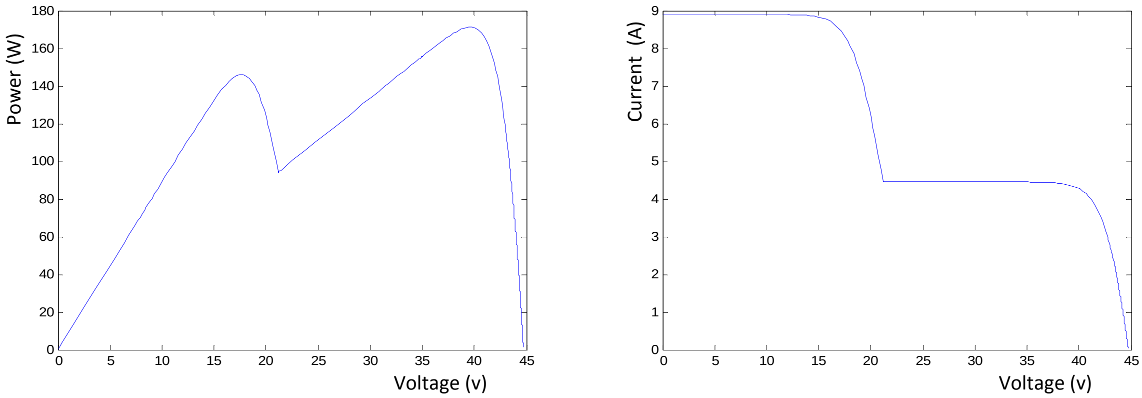


Fig.4. P-V and I-V characteristics of the PV panels for Ir1=Ir2=1000W/m²

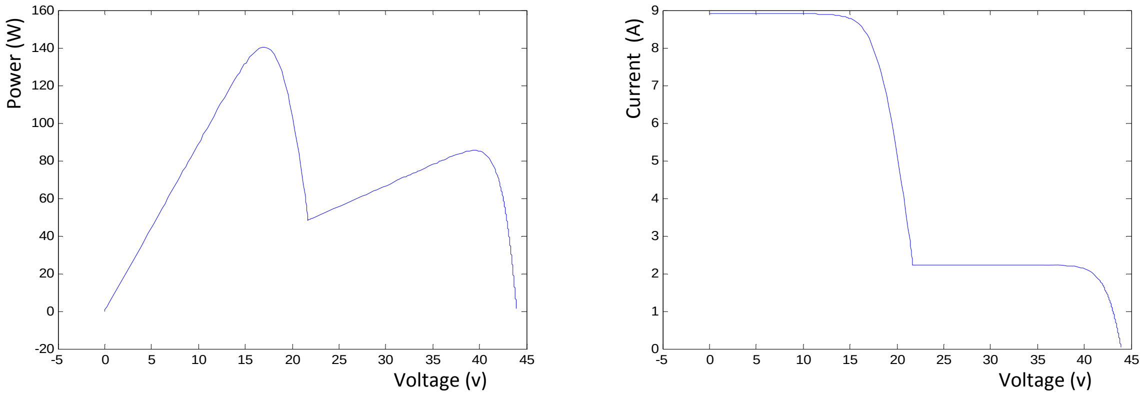
For maximum irradiances I_{r1} and I_{r2} equal to 1000W/m² and a constant ambient temperature (25°C), the maximum PV power reaches approximately 320W. The corresponding voltage and current are, respectively, 38V and 8A.



I_{r1}=750 W/m² and I_{r2}=1000W/m²



I_{r1}=500 W/m² and I_{r2}=1000W/m²



I_{r1}=250 W/m² and I_{r2}=1000W/m²

Fig.5. P-V and I-V characteristics of the PV panels for various partial shadings

In this part, we simulate a PV generator composed of two PV panels. Each panel gets exposed to different irradiance I_{r1} and I_{r2}. We supposed that I_{r2} remain constant and I_{r1}varies. The obtained results show that the maximum PV power is affected by the partial shading. Two local peaks appear on the P-V and I-V characteristics. These peaks vary with the level of the partial shading. During partial shading, each module is exposed to different irradiances. Thus, each panel has its own maximum (peak) power.

Fig. 5 presents the output (I-V and P-V) curves of the PV generator composed of two panels. It shows, for various i_{r1}, the array characteristics exhibiting two power peaks, for each case of level partial shading. For i_{r1}=250W/m² and I_{r2}=1000W/m², the peaks of the PV power are 150W and 250W.

V. CONCLUSION

This paper presents a study of a partial shading impact on the PV panel characteristics. We demonstrate that partial shading results a substantial degradation in the output power causing global and local maximum peaks in the P-V characteristic curves. For this reason, appropriately rated bypass diodes are commonly employed to preserve solar array power. Moreover, the use of a maximum power point tracking algorithm to extract the global PV power is not an efficient solution. We suggest a unified controller which makes each panel to operate at its maximum power.

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