Study of Partial Shading Effects on Photovoltaic Arrays with Comprehensive Simulator for Global MPPT Control

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Abstract- The partial shading is one of the major problems that exist in the photovoltaic farm installations. This is due to the presence of multi peaks in the power curves characteristics where the conventional methods of maximum power point tracking were not able to solve the problem. To overcome this shortcoming, in the present contribution we suggest a simulator based on a tracker algorithm which is able to track the global maximum GP in three cases , namely uniform irradiance ,sudden irradiance , and the partial shade conditions. The obtained results are compared to the data reported in the literature and showed good agreement. Thus, our simulator has been extended to include not only uniform irradiance case, but also the other mentioned cases.

Keywords Shaded conditions; maximum power point tracking; global maximum GP; PV system; simulator.

1.Introduction

Nowadays, the increase in global energy demand and the pursuit of most countries to ensure their energy security through the development of alternative energies, come in the forefront the solar energy. Photovoltaic system represents one of the best alternative resources in the field of electricity generation due to its increasing use. Moreover, the use of such kind of energy is not only economical and inexhaustible, but also its maintenance is low, noiseless, and lesser hazardous for environment in comparison to other types of energy. it is "green energy" by excellence.

The total installed capacity of photovoltaic (PV) is over 31 GW in 2012, as a tangible target increase to 84 GW by 2017 according to the aggressive projections following the technical reports of the European Photovoltaic Industry Association (EPIA) [2]. Photovoltaic effect is the production of electricity by conversation of solar photons into electricity by semiconductors such as silicon. Among the factors that have a significant impact on the operation of photovoltaic system the most notable are ;temperature, solar intensity, partial shade, and configuration of PV strings. Therefore, the MPPT method is required to guarantee the generation of the highest power from PV modules. In recent years, various methods have been proposed for tracking MPPT, such as perturb and observe (P&O) [3], the linear reoriented coordinates (LRC) method [4], neural network [5] and fuzzy logic [4].

Normally the maximum power point MPP of the PV array under uniform insolation is only the single power peak. However, frequently the PV arrays get shadowed partially and the p–v characteristic exhibits multiple local maxima, only one of them corresponds to the global MPP (GMPP), whereas the MPPT methods mentioned above may fail to track the GMPP. In order to overcome this problem, it is necessary to develop a special GMPPT method able to track the global MPP under partial shading conditions (PSC). During last years, some researchers work with MPP under partial shading conditions. [6]. Choudhury and Rout [7] proposed a Fuzzy Logic MPPT under PSC for the control of a photovoltaic power generator that produce 104 kilowatts , Miyatake et al [8] have been detailed a GMPPT method using a sequence of Fibonacci to track the GP under partially shaded conditions. Recently, the PSO or the Particle swarm optimization algorithm is among the effective methods for GMPP tracking under partially shaded. This technique is based on stochastic optimization population and it was created by Eberhart and Kennedy in 1995 [9], stimulated by social behavioural action of bird group or fish swarm. PSO is based on a search optimization where a population of random solutions is employed to initialize the system and seeking for optima by updating generations. The exceptional characteristic of particle swarm optimization is that .it can be worked in continuous number space and in real time [10]. A significant number of investigators are interested by this approach [12].The key advantage of this technique in [11], is using direct control of the duty cycle method to eliminate the complexity of control loops. In [13] authors can give successfully study that is the modified PSO-based MPPT method. This study is a novel algorithm based on conventional PSO is presented.

The major drawbacks of the PV generation system are low efficiency of energy conversion and very high installation investment cost [14,15].Besides, the possibility of evaluating the behavior of the PV system in existence of shading conditions is included in some commercial programs, for example PVSyst [16]. However, these programs work only by approximate data, in very limited positions and with expensive nature. Hence, It is very important to develop a simulator for techno economic purposes in design and conception of photovoltaic systems, because it will provide an ideal vision before the installations, where it will reduce to a considerable extent of the cost installation and the augmentation of generators PV efficiency. For this reason, the present article proposes a simplified soft simulator that can achieve this operation. Additionally, the Value-added in this research paper is a developed Matlab/Simulink PV simulator using an improved global power peak tracking method under partially shaded conditions using PV cell model of two diodes, founded on an analytical study of PV panels under no uniform weather conditions. A different simulation cases are presented with results to test the accuracy and consistency of this simulator, in the context to improve the performance of proposed model; these results are tested by the comparison method of the simulation and experimental results of P–V Characteristics under partial shaded conditions of PSO MPPT proposed in [11].

The present paper is organized as follows:

Section 2 introduces the PV system under normally conditions with the impact of various temperatures and irradiations. Then, In Section 3 the study of PV array's responses in partial shading weather is shown and the effect of these conditions is simulated. Sections 4 and 5 describe the algorithm and the response of the proposed application. In order to prove the performance of the proposed model, the section 6 offers a comparative study with literature work presented in [11]. Finally, our work is achieved by a conclusion.

2. PV Array Mathematical Model Design and Their Characteristics under Uniform Conditions

The electrical model can represent the solar cell with two diodes exposed in" Figure 1"[1]. Its current-voltage properties is calculated by the next formulas (1):

$$I = Iph - Id1 - Id2 - Ish \tag{1}$$

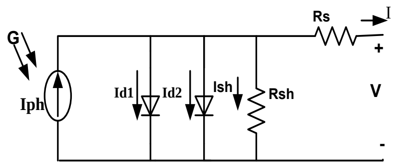

Fig.1. The circuit model of a photovoltaic cell.

When the photocurrent is calculated by expression (2), the current diodes are calculated by the following expressions (3) and (4) successively:

$$Iph = (Iph,n + KiDT)\frac{G}{Gn} \tag{2}$$

$$Id1 = I01\left[\exp\left(\frac{V + IRs}{a1VT1}\right) - 1\right] \tag{3}$$

$$Id2 = I02\left[\exp\left(\frac{V + IRs}{a2VT2}\right) - 1\right] \tag{4}$$

$$I01 = I02 - \frac{Iscn + KiDT}{\exp\left[Vocn + \frac{KvDT}{Vt}\right] - 1} \tag{5}$$

To calculate the shunt current and the panel voltage the formulas (6) and (7) are used:

$$Ish = \frac{V + RsI}{Rsh} \tag{6}$$

$$Vm = Ns * V \tag{7}$$

"Figure 2" shows the I-V and P−V curves obtained at various temperatures , while "Figure 3" shows the I-V and P−V curves obtained at divers irradiations.

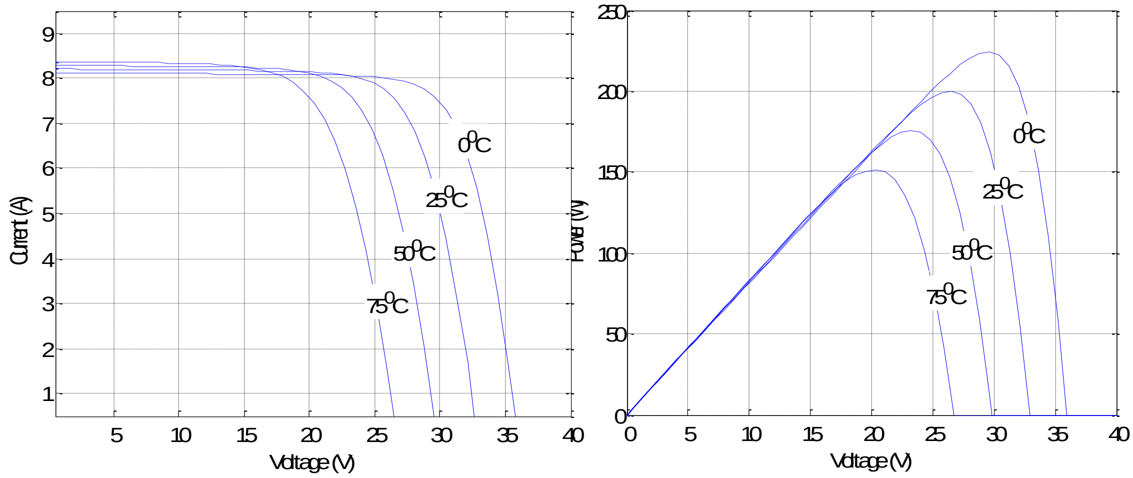

Fig.2. I-V and P-V characteristics under diverse temperatures.

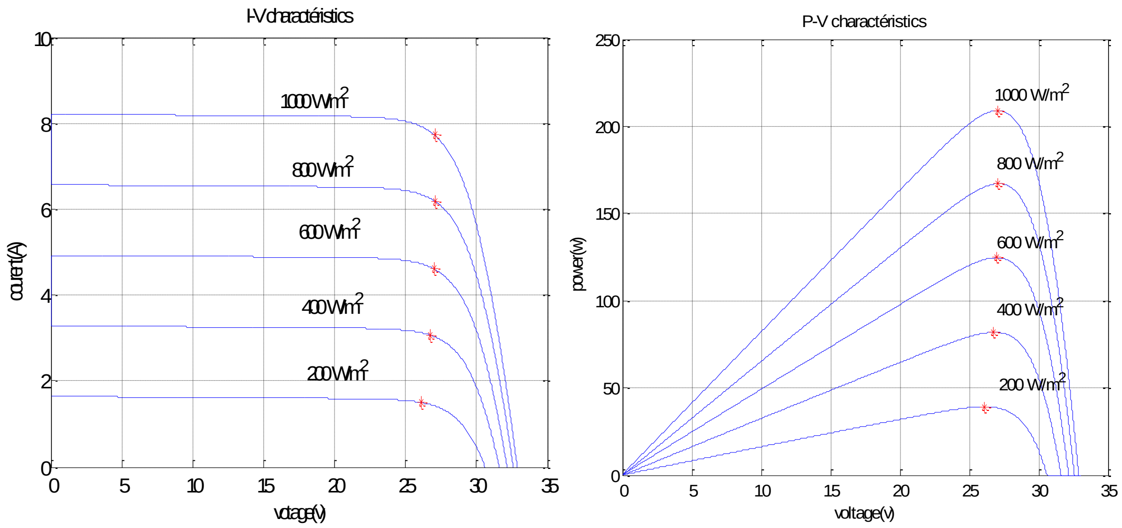

Fig.3. I-V and P-V curves under diverse irradiations.

3.PV Array Properties under the Impact of Partial Shade

The significant improvement of our study is to cover the diverse behaviour of PV power characteristics under both ordinary and mismatching weather conditions without diving in the physical and internal analysis of semiconductors characteristics of solar cells [18]. The hot-spot is a physical phenomenon appears when one of panel string is shaded; it can then act as an electric load. The shaded photovoltaic cells absorb an important quantity of electrical energy generated by other photovoltaic cells receiving high irradiation and converting it to heat. Further, the addition of a bypass diode between specific numbers of cells in the series circuit is given as a good solution in this case [19].

In the case of the shaded cells, the anti parallel connection of bypass diodes with each chain of cells lets the current flows through the bypass diode in a single direction. [20].

In the present paper, the string of photovoltaic panels connected with non-uniform irradiation has been measured and "Figure 4", shows the series connection of modules with three bypasses diodes where Matlab / Simulink is employed for the simulation. Figure 5, shows the I-V and P-V responses under uniform conditions and under shaded conditions, where 3 peaks are created, with GP is the global maximum peak and are local maximum peaks.

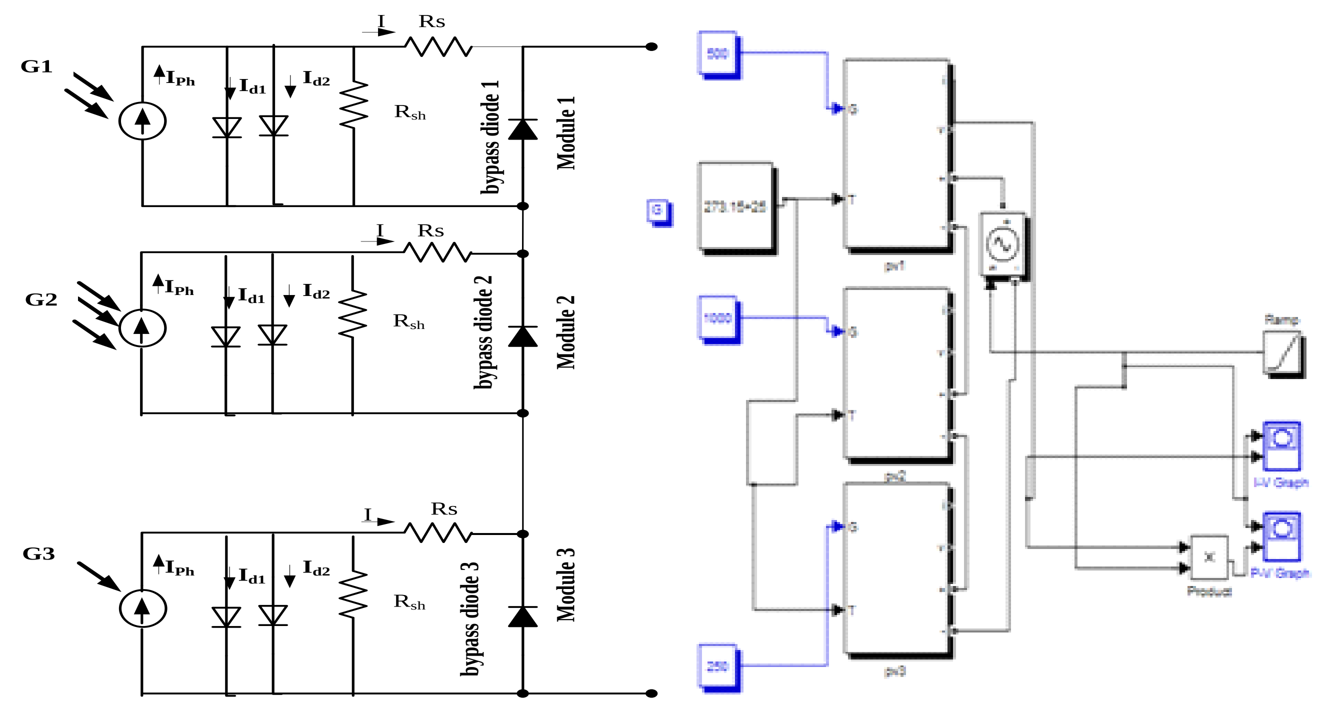

Fig.4. Simulation of 3 serial PV panels under partial shading conditions with bypass diodes using Matlab / Simulink.

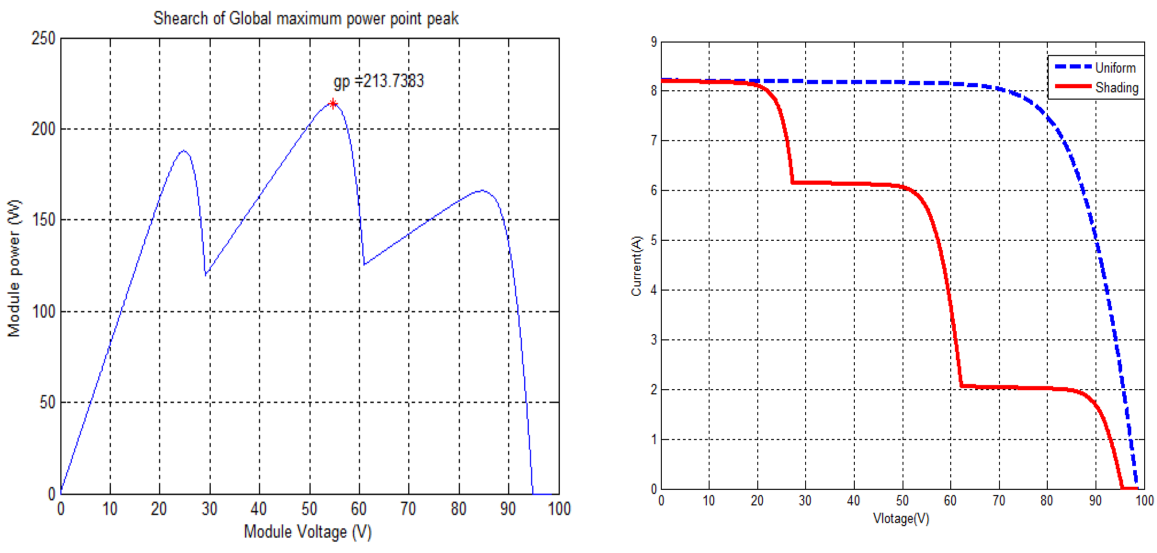

Fig.5. The resulting simulation of power-voltage and current-voltage curves.

The multiple peaks established in the characteristic curves I--V and P-V in partially shaded conditions are caused by bypass diodes as given in "Figure 5" .

4.Proposed Simulator

The basic idea is to create a congruent PV simulator for all kinds with the possibility of testing different types of thin-film, multi-crystalline and mono-crystalline. One of the most advantages of this algorithm is that it is capable to track the MPP in all cases, under uniform conditions and under shaded conditions. That is to say, it has the possibility to track the MPP and to keep track of the maximum power point (GMPP). The offered simulator is based on proposed global maximum tracking algorithm, where the use of current and voltage is the main idea to find the power local maximum peaks in function of feedback method (P=V*I and dV/dI=0) Then, we calculate the number of peaks (pi).If this number equal to 1 the switch 1 is activated which is the case of uniform conditions irradiations. Where the incremental conductance method presented in [1] is used .If pi > 1 the

Switch 2 is activated; In this case the algorithm detects that the PV panels are under partially shaded conditions. In this respect, the peaks are compared in order to find the global maximum power peak GMPP. The steps of our algorithm are presented in the organizational chart, Figure 6.

The user can communicate with the proposed simulator through a graphical interface that allows the possibility to load data sheet parameters of selected PV modules directly, (Voc, Isc, Vmp, Imp, Kv, Ki and Ns).This step would be by calculating Rs and Rsh using the method presented in [20] as shown in Figure 7.Then the user clicks the button "run" to simulate the adjusting power peak. Following the user click the button "Next" then input the different proposed irradiations.

3.1.The simulator user interface

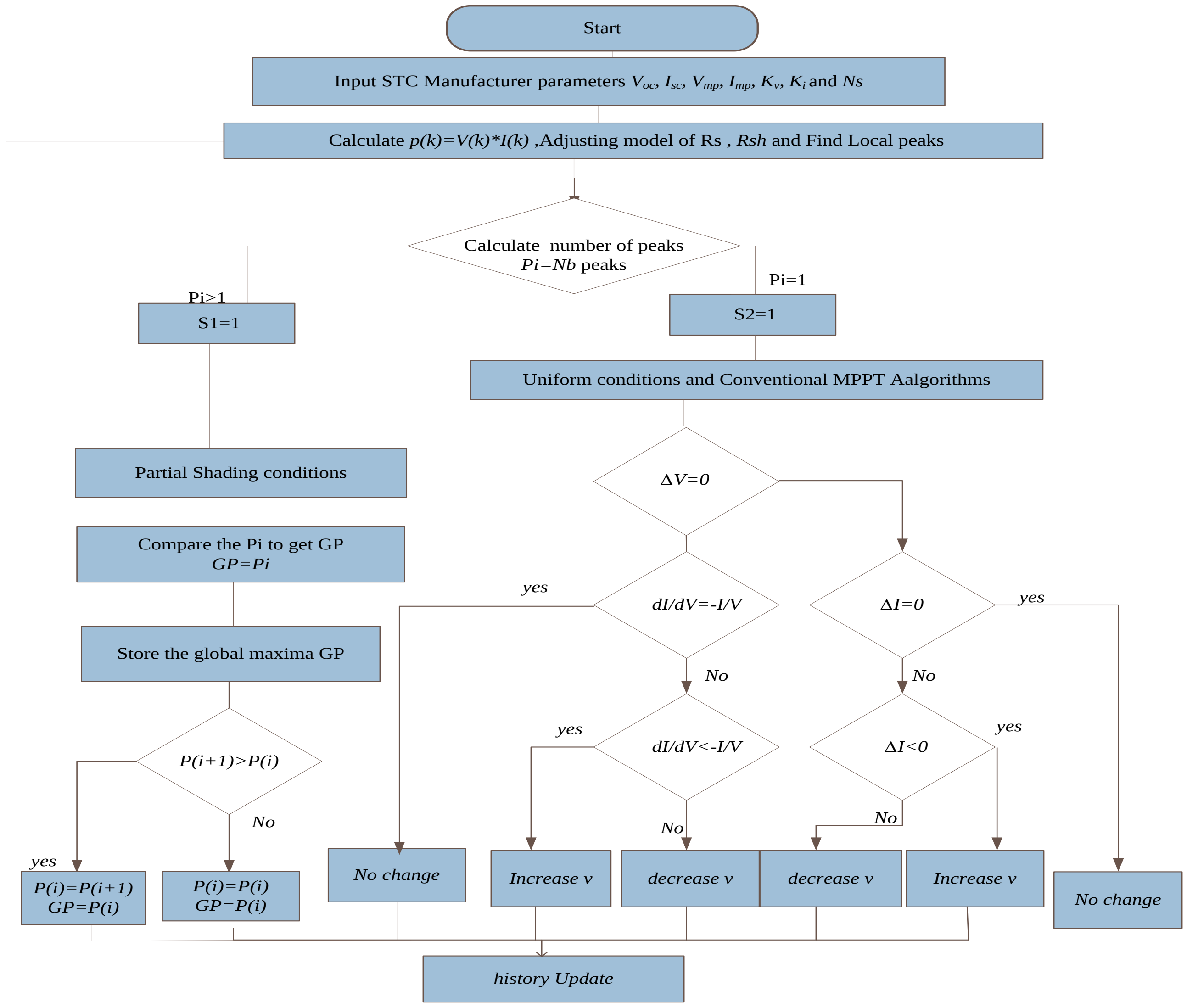

Fig.6. Flowchart for the GMPPT algorithm.

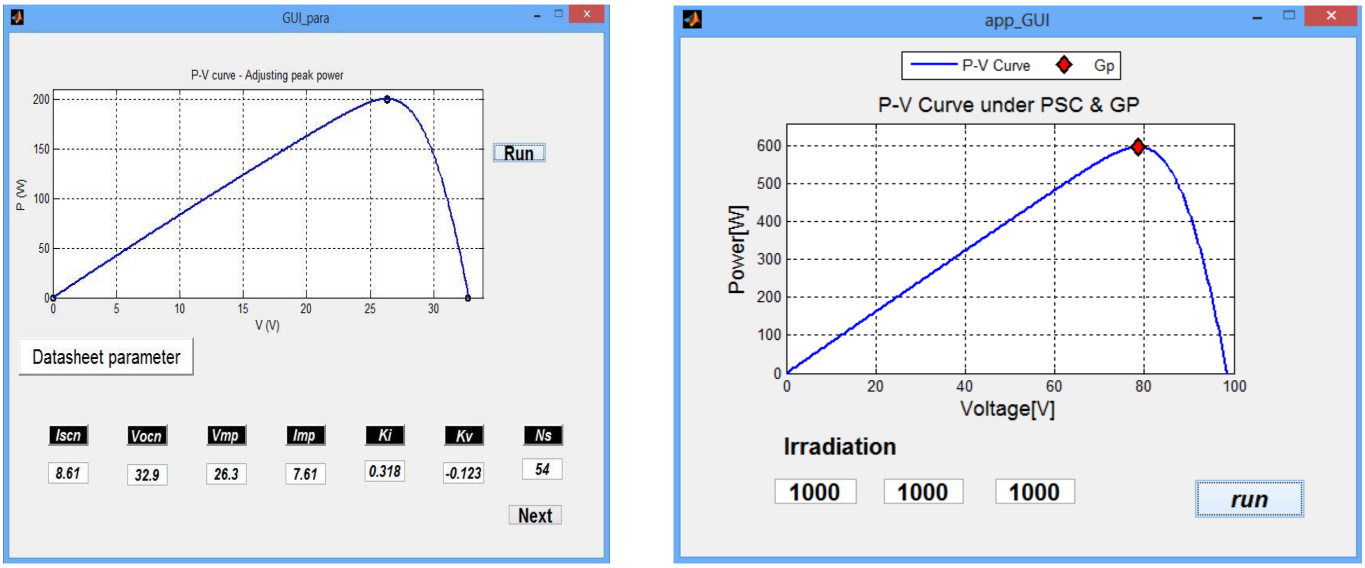

Fig.7. Adjusting of parameter values.

5.Results and Discussion

This section is intended to simulate the characteristic The next action is the track of global maximum power in 2 parts, firstly check the local peaks, in which the system scanned the power values in real time to find all peaks, then, the algorithm selects the GMPP between the maximum local peaks. The obtained parameter will be called the global peak; the simulation result is shown in Figure 8.

The response of 3 KC200GT modules connected in series during PSC conditions, where the chosen parameters for testing are, G1= 1 kw/m^2 for first panel, which is under uniform irradiation, G2=0. 25 k/wm^2 for the second and G3=0.5 kw/m^2 for the third panels.

The most advantage of proposed simulator provides the possibility to execute a sequential simulation with only initialization parameters, which allowing to give the opportunity to see the different energy levels produced in function of level shading panels.

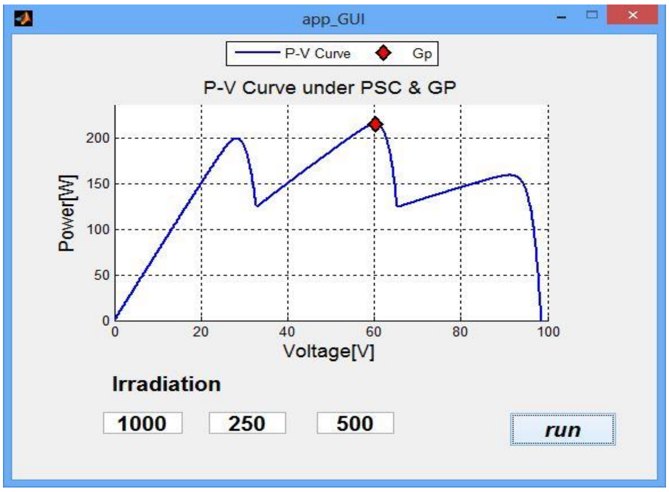

Fig.8. Search of maximum global power peak.

This clears the impact of partial shading and it provides a predictive study before doing the practical installation of solar panels. Figure 9 explains this advantage when the following test parameters are successively used: G1= [100 500 250], G2= [750 600 1000], G3= [750 300 800], and G4= [100 300 800] (w/m^2).

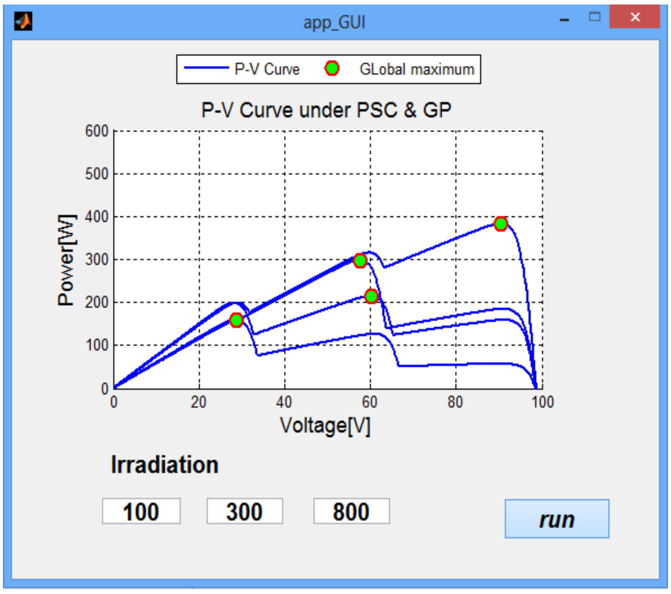

Fig.9. Search of maximum global power peak in different cases of irradiance.

6.A Comparative Search of Maximum Global Peak Power Simulation

To prove the program efficiency and accuracy in the calculation process of GP, we compared its responses with the simulation and experimental results P–V Characteristics under partially shaded conditions in comparison with the same initialization parameters of PV systems has been made. The generator consists of 8 panels KC200GT which are connected by the following connection method shown in "Figure 10".

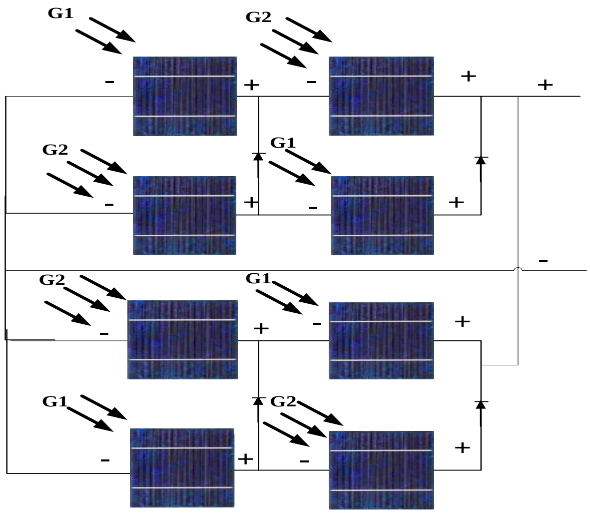

Fig.10. Schematic of 8 panels with bypass diodes in mismatching conditions.

Results in figure 11 shows the comparison of voltage-power characteristics of PV system at constant temperature T = 25°C and irradiance, G1= 500 w/m^2 and G2= 800 w/m \1a\. The obtained results from this study confirm that the proposed method can avoid the negative consequences of the partial shading problem successfully, without complexity. And the table 1 summarizes the positive points of the proposed method compared to method of literature.

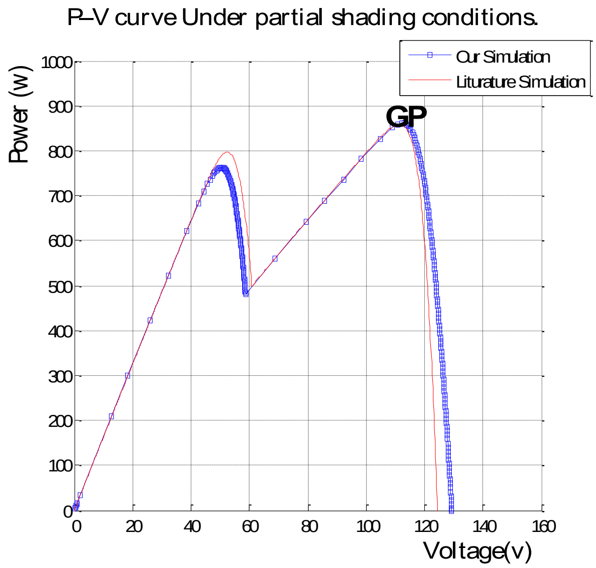

Fig.11. Simulation results of P–V curve at shading conditions.

Table 1. Comparison of MPPT our method and literature method.

Comparison operators	PSO MPPT proposed in [11],	Our method
Initialization parameters	Reset for each test.	One initialization for several tests.
Adjusting of Rs and Rsh model	Reset for each test.	One step using datasheet parameters.
Complexity	High (based on stochastic optimization population).	Low (based on an algorithmic method).
Reliability	High	High
Specialization use	Limited use (partially shaded conditions only).	Uniform irradiance, sudden irradiance , and the partial shade conditions.

7.Conclusions

In the present research work an adaptable and flexible simulator with simple techniques to track the global maximum power under mismatching conditions using Matlab/Simulink was developed. The mathematical model and output characteristics of the PV panels were analyzed, and the effects of partial shaded phenomena in PV arrays were examined in detail. The simulation results confirm the efficiency and the feasibility of the proposed simulator under influence of this condition and it was proven that the system is capable to track the GMPP with simple and fast response. As a conclusion, the proposed work can be an appropriate field for simulator developers and it is able to validate the effectiveness of existing and new MPPT techniques.

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Nomenclature

Symbol	Description	Symbol	Description
I, V	Current & Voltage	G	Irradiation on the device surface[w/m2]
Iph	Photovoltaic Current	Gn	Nominal irradiation [w/m2]
q	Charge of an electron	I01 , I02	Reverse saturation currents of diode 1 & diode 2
N	Diode ideality factor	VT1 , VT2	Thermal voltages of respective diodes
Rs, Rsh	Series , Shunt resistors	a1 , a2	Diode ideality constants
Id1 ,Id2	Currents of diode 1 & diode 2	Isc	Short circuit current [A]
Ish	Shunt resistor current	Voc	Open circuit voltage
k	Boltzmann constant	Ki ,Kv	Cell's short-circuit current , Cell's open circuit voltage Temperature coefficients
T , Tn	Actual & Nominal temperatures [K]	A	Ideal factor

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