Global optimum operating point tracker of PV system, under partial shading, using parallel searching

Slimane HADJI
Laboratoire de technologie industrielle et de l'information, Université de Béjaia Bejaia, Algeria
mail.hadji@gmail.com

Lylia LARBI
Laboratoire de technologie industrielle et de l'information, Université de Béjaia Bejaia, Algeria
lylia.larbi06@gmail.com

Abdelhakim BELKAID
Laboratoire de technologie industrielle et de l'information, Université de Béjaia Bejaia, Algeria
belaid08@yahoo.fr

Ilhami COLAK
Department of Electrical & Electronics Engineering Nisantasi University Istanbul, Turkey
ilhcol@gmail.com

Ramazan BAYINDIR
Department of Electrical & Electronics Engineering Gazi University Ankara, *Turkey*
bayindir@gazi.edu.tr

***Abstract*— Photovoltaic (PV) panels, sources of renewable energy, are widely integrated into smart grids. the main challenge of photovoltaic systems is the phenomenon of partial shading. In partial shading, more than one optimum point can be found in the P-V curve of a PV array. Tracking the global optimum becomes difficult, because almost methods converge to the first optimum which is not necessary the global one. In this paper, a global optimum operating point tracker is given, by dividing the searching space into more than one and compare between the maximum power of each one. The famous Perturb and Observe (PO) and Incremental conductance (IC) are used to find the optimum of each area searching, and simulation results are given.**

Keywords*— *Smart grid; Photovoltaic; partial shading; global maximum power point; Incremental Conductance.

I. Introduction

The photovoltaic generator is constantly subjected to variable operating conditions. Therefore, the ability to extract the maximum available power from PV modules regardless of generator temperature, solar irradiance, shade conditions and aging of PV cells plays a critical role [1].

When a PV generator composed of identical PV cells, is under a uniform illumination, then its power-voltage characteristic admits one peak. But, when one of its cells is shaded, the latter reduces the current flowing in the unshaded cells, causing what is called hot spot heating and therefore the cracking of the shaded cell [2].

This drawback is overcome by using an externally conductive bypass diode whenever the solar cell is reverse biased, allowing current from the unshaded cells to flow outside the shaded cell, thus preventing hot spot damage. Although the impact of shaded cells can be mitigated by inserting bypass diodes, partial shading still significantly alters the energy produced by the PV system for two reasons: The P-V curve has multiple peaks and the position and amplitude of the global maximum point changes with changing shading conditions.

To extract the maximum power available on the photovoltaic generator, appropriate control methods called Maximum Power Point Tracking (MPPT) algorithms are required. The latter are implemented into the control units of the static converters utilized as interface between the PV source and the electrical loads or the network.

The MPPT approach that is generally more used is the Perturb and Observe (P&O) algorithm [3-6]. But the latter can only perform well under normal operating conditions and they often fail to trap maximum power in partial shade conditions. Thus, enormous power can be lost [7].

In order to remedy to these limitations, substantial research labours have been devoted to the implementation of more sophisticated algorithms capable of identifying the Global Maximum Power Point (GMPP) in order to cutting the maximum offered power from the PV system regardless of the shading pattern [8-9].

The research work proposed in this document is definitely focused on the solution provided to PV installations to overcome the disadvantage of partial shading. The solution consists on P&O method by dividing the domain of variation of the duty cycle into three subsets.

1. Modelling of a PV array

A photovoltaic generator is obtained by combining solar cells in series and in parallel. It can be represented analytically by its current-voltage characteristic and electrically by its equivalent circuit known as the one-diode model. The one diode model can be signified as [10]:

$$I_{PV} = n_p\left(I_{ph} - I_0\left[e^{\frac{q(V_{PV}+R_s I_{PV})}{AkTn_s}} - 1\right] - \frac{(V_{PV}+R_s I_{PV})}{n_s R_{sh}}\right) \quad (1)$$

$$I_{ph} = I_{ph\_STC} + K_I(T - T_{STC})\frac{G}{G_{STC}} \quad (2)$$

$$I_0 = \frac{I_{SC\_STC} + K_I(T - T_{STC})}{e^{(V_{oc\_STC} + K_V(T - T_{STC})/V_T - 1)}} \quad (3)$$

Different quantities cited in (1)-(3) relations are described in Table 1.

Table 1. PV Array specifications

V_{PV}, I_{PV}	output voltage and output current of the PV array
R_s	series resistance
R_{sh}	shunt resistance
q	electron charge
I_{ph_STC}, I_{ph}	photo-generated current in STC conditions photo-generated current in operating conditions
I_o	dark saturation current in STC
T_{STC}, T	temperature at STC and operating conditions
$I_{SC\ STC}$	short circuit current at STC
A	diode ideality factor
k	Boltzmann's constant
n_p, n_s	number of cells connected in parallel and series
V_{oc_STC}, V_{oc}	open circuit voltage at STC open circuit voltage at operating condition
G_{STC}, G	irradiance at STC and operating condition
V_T	thermal voltage
K_I K_V	temperature coefficient of I_{SC} temperature coefficient of V_{oc}

2. P&O-GMPPT Algorithm

Both conventional P&O and IC techniques are unable to differentiate the global maximum power point among multiple maximums. The principle of these two techniques consists in varying the initial duty cycle Di over a search interval [Dmin, Dmax], where Dmin and Dmax respectively represent the minimum and maximum duty cycle, to recover the closest maximum power point that either local or global. To ensure a better convergence towards the global maximum power, it is necessary to choose a good initial duty cycle. Starting from this idea, the proposed structure consists of dividing the domain of variation of the duty cycle [Dmin, Dmax] into three subsets, and each subset is associated with its own initial duty cycle.

Subsequently, the P&O method is applied to each sub-interval, a selection will be made to derive the duty cycle corresponding to the PPMG, all these steps have been summarized in the flowchart of the figure 3. The offered technique is talented to extract the GMPP from a PV panel often exposed to fast varying partial shading situations; such a technique does not require the measurement of irradiance or temperature.

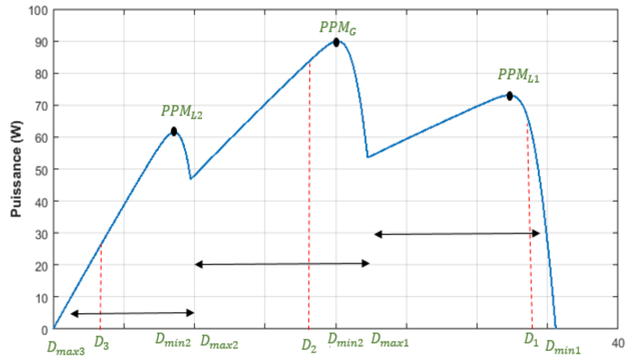

Fig. 1. Division of the duty cycle variation interval D

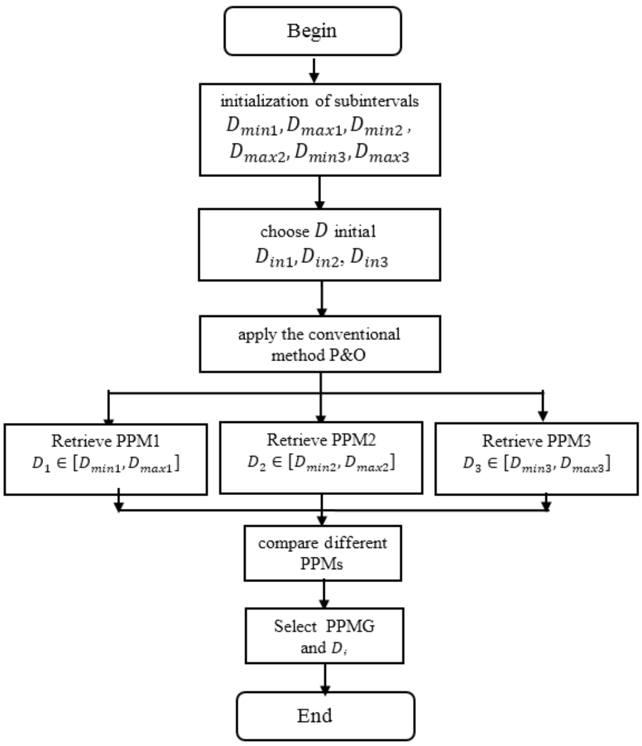

Fig. 2. The P&O organization chart with the breakdown of the duty cycle variation interval D.

3. Simulation results

In order to validate the proposed algorithm, it was assumed that the studied module is subjected to three different uniform illuminations. The technical specifications of the studied module are reported in Table 2.

Table 2. Specification of PV modules (Advanced Power API-P215)

Parameter	Value
V_{oc}	36.4 V
I_{sc}	7.97 A
Current at P_{max} (I_{MPP})	7.24 A
Voltage at P_{max} (V_{MPP})	29.7 V
Maximum Power (P_{MPP})	215.028 W
V_{oc} coeff. of temperature (K_V)	-0.325 %/°C
I_{sc} coeff. of temperature (K_I)	0.055 %/°C

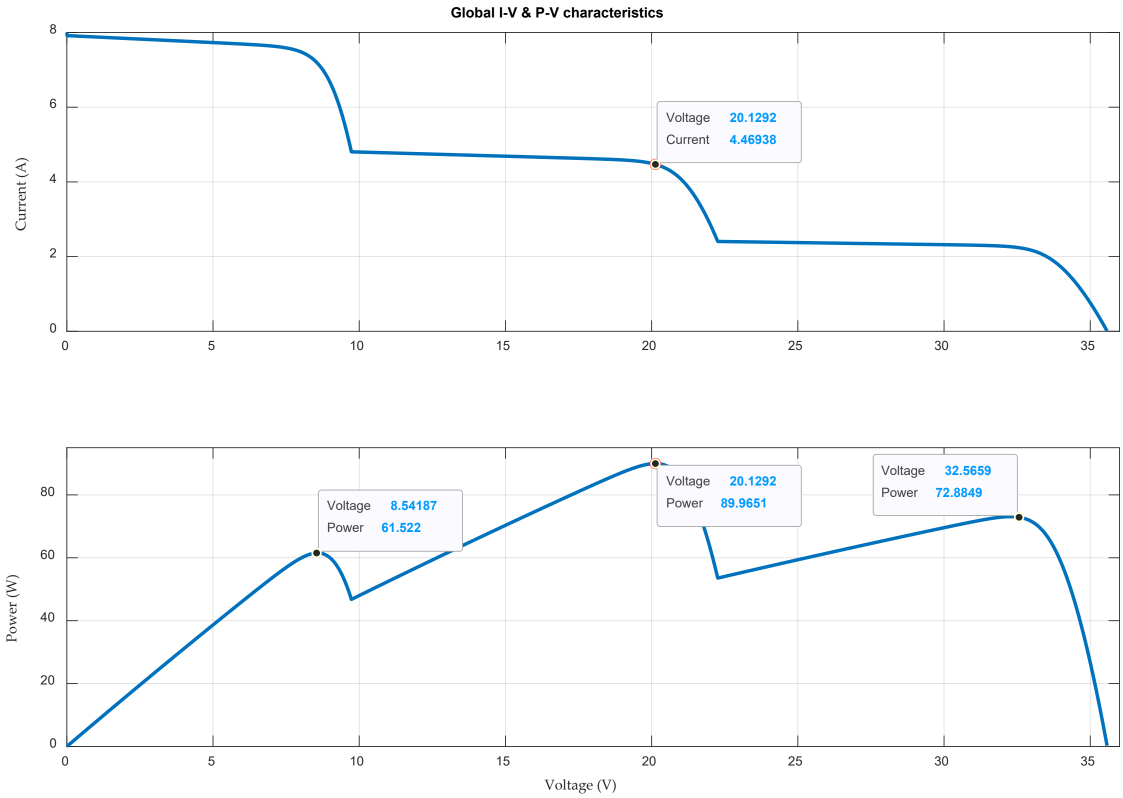

Fig. 3. P-V and I-V curves under partial shading.

In partial shading conditions, the PV cells receive different levels of temperature and irradiance. Consequently, the P-V and I-V characteristics curves of the PV panel admit more than one peak, several local optima LMPPs and one global optimum GMPP, as shown in Fig. 3. Thereby, tracking the real maximum power under these non uniform conditions is a very difficult task that needs more sophisticated MPPT methods.

Fig. 4 shows that the PV panel attain its local optimum because the MPPT method used is the conventional P&O.

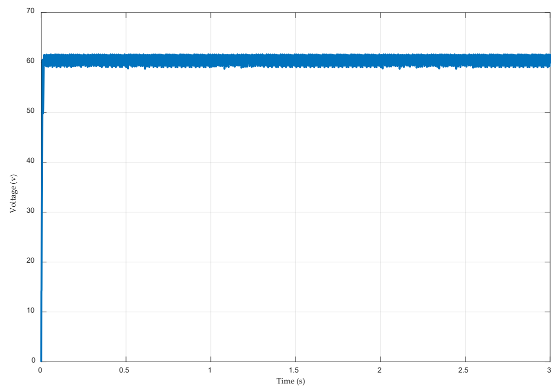

Fig. 4. Power evolution using the conventional method

By applying the proposed method, the PV system obtain the global maximum as depicted in Fig. 5. The maximum power, the voltage and the current corresponding to the GMMP are illustrated respectively.

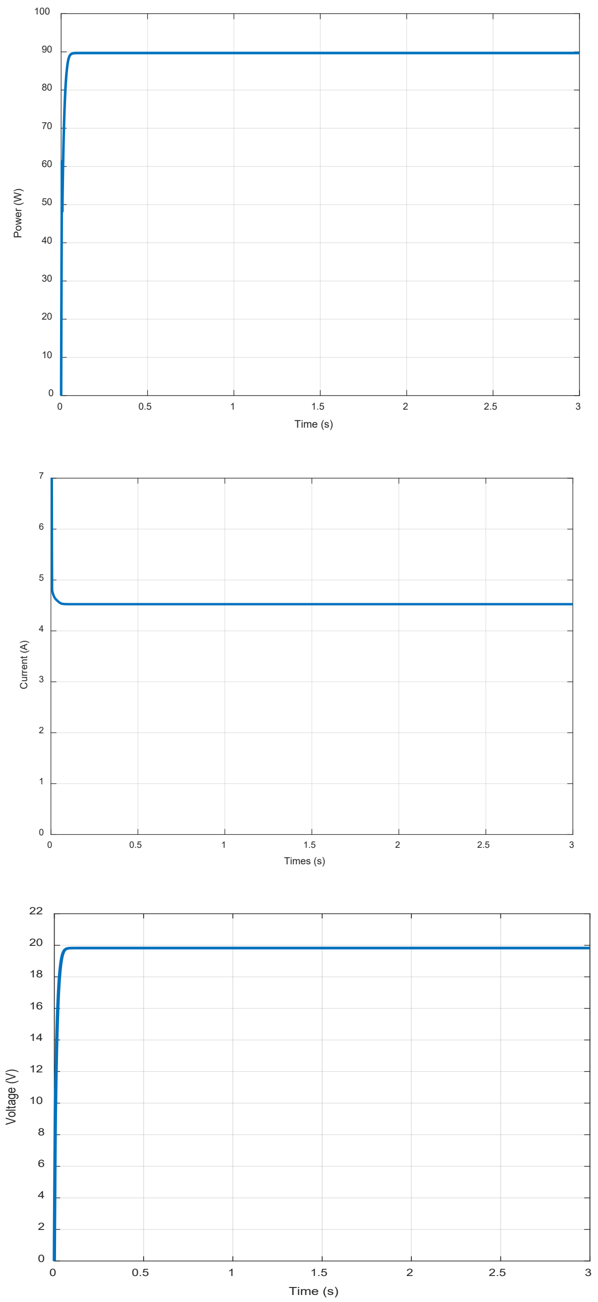

Fig. 5. Power, voltage and current under the partial shading conditions

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II. CONCLUSION

In this document, an Improved Perturb and Observe algorithm is proposed to design an MPP tracker for PV systems more efficient under Partial Shading Conditions. To ensure a better convergence towards the global maximum power, the proposed structure consists of dividing the domain of variation of the duty cycle [Dmin, Dmax] into three subsets, and each subset is associated with its own initial duty cycle. The drawback of the local minima trapping, very troublesome in PV panels under partial shading conditions, is efficiently surmounted thanks to the proposed method..

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