PSO Control under Partial Shading Conditions

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ABSTRACT

The change observed in new habits and traditions of human beings has significantly influenced the way of their current life especially in their needs for electrical energy. This has consequently increased the demand for energy, which has forced the researchers and the industrials to focus their efforts in the development of electricity production systems based on renewable energies, such as photovoltaic (PV), thermal, hydraulic, etc.
In the case of the photovoltaic installations, the random change in climatic conditions is considered as a challenge for the engineers in the field. Moreover, the phenomenon of partial shading prompts scientists to suggest practical solutions to overcome it while ensuring the desired performance of the installation.
The Maximum Power Point Tracking technique is considered to improve the dynamic performance of the photovoltaic system.
Our contribution deals the research of a point of maximum power for a photovoltaic system, under conditions of partial shade using particle swarm optimization algorithm (PSO).
The simulation of this structure under the Matlab/ Simulink environment shows that the system ensures better performance and good efficiency.

I. Introduction

In the recent years, the demand for energy is increased through the world, which has forced the researchers and the industrials to invest themselves for the development of renewable energies such as solar, wind, geothermal, biomass [1].
Solar energy is nowadays the most popular energy in the production of electric power. However, its short coming is the phenomenon of partial shading due to the passage of clouds. Our work consists on a contribution to the study and remediation of the consequences of above problems related to the photovoltaic module [2]. Indeed, the capacity of the photovoltaic panel depends on its area exposed to the sunlight, which explains the main problems of photovoltaic systems.
Consequently, the electricity produced by photovoltaic (PV) solar modules largely depends on weather conditions: Irradiation (E) and Temperature (T). On the other hand, partial shading distorts the shape of the nonlinear characteristic P = f (V) of the photovoltaic system by showing several local maximums of maximum power points on this characteristic [3]. To overcome these inevitable natural phenomena, maximum power monitoring techniques have been developed to ensure the extraction of maximum power using optimization methods under varying weather conditions [4, 5].

In the literature, many optimization methods are developed such as perturbation and observation (P&O), conductance incremental (IC), Fuzzy Logic (FL), particle swarm optimization (PSO), ect… [6].
For practical consideration, the PSO algorithm is shown more suitable and very effective for extracting maximum power from a PV system [7]. This performance depends on how quickly to reach the point of maximum power (MPP) of how to oscillate around this point and the robustness in the face of sudden atmospheric changes such as partial shading (PS), mainly in terms of ability to quickly track the global maximum power point during operation. The aim of this work is to perform the maximum power point tracking (MPPT) control of the DC / DC stage under partial shading conditions using a particle swarm optimization algorithm.
The rest of the paper is organized according to the following sections: the second section deals with the PV conversion chain, the mathematical model of the system and the PSO algorithm. The third section is dedicated to the simulation of the system and the performance evaluation of the proposed algorithm. The discussions and the concluding remarks are given in the last section.

II. Modelization

We consider the conversion chain of three elements: the PV panel, the Boost converter with the PSO control and the DC- load. The photovoltaic system is shown in figure 1.

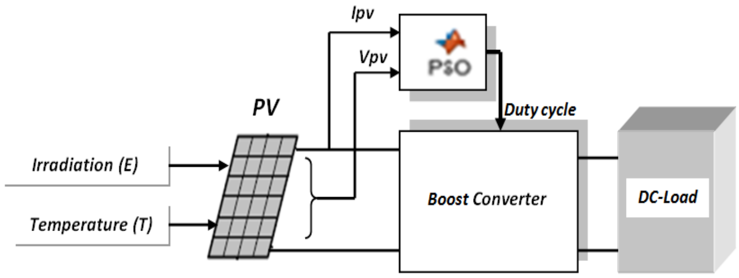


Figure 1. Conversion chain

II.1. Photovoltaic cell

The figure 1 shows the single diode-equivalent electrical circuit of a photovoltaic cell [8-10].

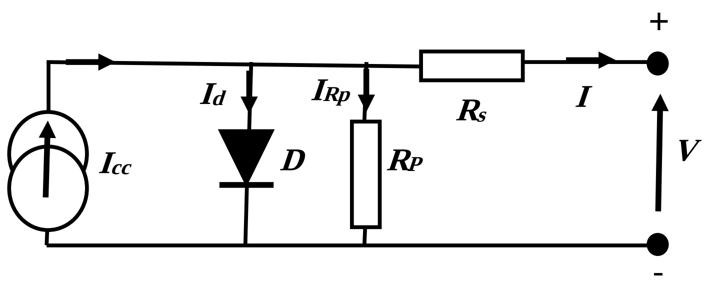


Figure 2. PV cell equivalent electrical circuit model [10]

With,
I_{CC}(A): short-circuit current of the cell depending on the irradiation and the temperature;
I(A): cell current;
V(V): cell voltage;
I_d(A): diode Current;
I_{Rp}(A): current of parallel resistor;
R_P(Ω): parallel resistance which characterizes the junction currents;
R_s(Ω): series resistance which characterizes the various resistances of the contacts and connection.

Then we can deduce:

$$I = I_{cc} - I_d - I_{R_p} \tag{1}$$

The short-circuit current for any temperature (T) is expressed by the following relation:

$$I_{cc_{(T)}} = I_{cc_{(Tref)}}.(1 + k_i(T_c - T_{ref})) \tag{2}$$

$I_{cc(ref)}$: short-circuit current for a reference temperature measured under sunshine of 1000W/m^2;
T_{ref}: reference cell temperature expressed in Kelvin (° K) corresponding to the standard temperature 25°C;
T_{ref} (° K) = 25 + 273.15 ° K;
k_i: temperature coefficient of I_{ph} expressed in (%);

I_{cc} is expressed by the following relation:

$$I_{cc}(E) = I_{cc}(E_0).\frac{E}{E_0} \tag{3}$$

Where,
E_0: standard nominal sunshine equal to 1000W/m^2.

Equation (1) can be written:

$$I = I_{cc} - I_d - \frac{V + I.R_s}{R_p} \tag{4}$$

With,

$$I_d = I_0(e^{\frac{q}{nkT_c}(V + I.R_s)} - 1) \tag{5}$$

Considering that the photovoltaic cell is of good quality, the current-voltage equation of the cell is written:

$$I = I_{cc} - I_0 e^{\frac{q}{nkT_c}(V + I.R_s)} \tag{6}$$

With,
I_0 (A): diode saturation current; q = (1.602×10-19 C): electron load; n: non-ideality factor of the diode junction;
K: $1.381{*}10^{-23} J/K$, Boltzmann constant; T_c (K) : effective cell temperature; T(K)=273=T (°C) .

II.2. Effect of partial shading on the operation of the PV module

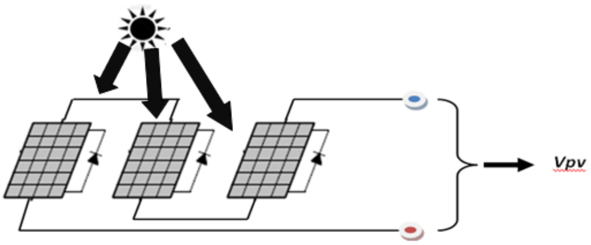


Figure 3. PV array under partial shading condition

The phenomenon of partial shading is a problem affecting the proper functioning of the PV. It is a non-uniform distribution of illumination. This phenomenon hinders the extraction of the maximum power point because of the appearance of several local maximum power points.
Under this phenomenon, all or the most parts of the PV could be shaded which results in a reduction of the energy consumption and the maximum power of the partially shaded PV modules [11-14].

II.3. Maximum Power Point Tracking Techniques

In this work, the maximum power point tracking (MPPT) is obtained using Particle Swarm Optimization (PSO) algorithm. This algorithm was proposed in 1995 by Kennedy and Eberhart.It is inspired by the behavior of animals such as birds. This technique is based on the rules of progressive displacement of the random positions of these particles to reach an optimal local position [15-17].
A flowchart of the conventional PSO algorithm is shown in Figure 4. This algorithm is executed according to the following equations:

$$V_i(t+1) = w.(V_i(t) + c_1.rand_1.(PBest_i(t) - D\_fitness_i(t)) + c_2.rand_2.(GBest_i(t) - P_i(t))) \quad (7)$$

Where,

$$P_i(t+1) = P_i(t) + V_i(t+1) \quad (8)$$

And,

$$D = PSO(V, I) \quad (9)$$

With,

P: gear position; V: speed; P_{Best}: best position of the particle that matches $Local\_D_{Best}$; G_{Best}: best position of the particle group that corresponds to $Global\_D_{Best}$; *rand*: random variable; D: duty cycle; c_1: weight of local information; c_2: weight of global information; w: weight of inertia.

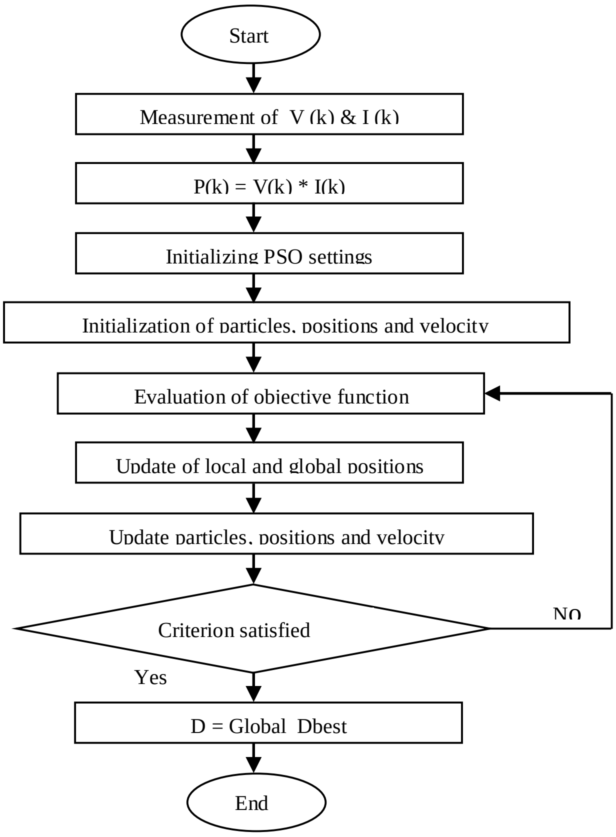


Figure 4. PSO Algorithm [6]

The algorithm steps are described below:

Step 1: Initializing the PSO Settings.
Step 2: Initialization of particles, positions and speed.

- Particle initialization is equivalent to assigning the value of zero to the previous and new components of the P_{PV} vectors:

$$P_{PV}\_Old = zero(1, swarms) \tag{10}$$
$$P_{PV}\_New = zero(1, swarms) \tag{11}$$

- Initializing positions amounts to assigning random values between 0 and 1 to the components of the position vector which are those of the duty cycles:

$$D\_Cur = 0.3.\,rand(1, swarms) \tag{12}$$

- The random initialization of the velocity according to the Eq (13):

$$Vel= 0.5.\,(rand(1, swarms)\,).(V_{max}-V_{in}) + V_{min}) \tag{13}$$

Step 3: The evaluation of the objective function in this algorithm consists in comparing the previous power with the new power:

$$P_{PV}\_Old = P_{PV}\_New \tag{14}$$

For a given iteration and for each position we calculate P_{PV} *_New* starting from the values of *D_Cur* and we determine the new GMPP. So, we define the best local duty cycle, then we compare the new GMPP with the previous GMPP according to equation (15):

$$GMPP\_Old = GMPP\_New \tag{15}$$

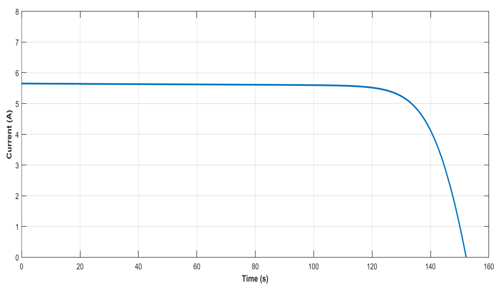
Step 4:

- The first stop criterion to be satisfied is based on the equation (15). If the *GMPP_New* is equal to the *GMPP_Old,* then the operating point has reached the *GMPP* and the duty cycle which corresponds to it *(D)* is equal to the best global duty cycle *(Global_Dbest)*.
- The second condition for the PSO algorithm to stop is to reach the numberof stretches without satisfying the equation (15).

Step 5: The updating of positions and velocity is based on equation (7) and equation (8).

III. Simulation Results and Discussion

The first part of this section consists on analyzing the behavior of the photovoltaic system, first under standard weather conditions then in the presence of partial shade. The second part consists on validating the contribution of the PSO technique to extract the maximum power (global optimum).
The figures 5 and 6 show the current and the power, respectively, of the photovoltaic generator as a function of the voltage under the standard values of irradiation *(E=1000W/m^2)* and temperature *(T=25°C)*. Thus, the maximum power developed is equal to 682W.



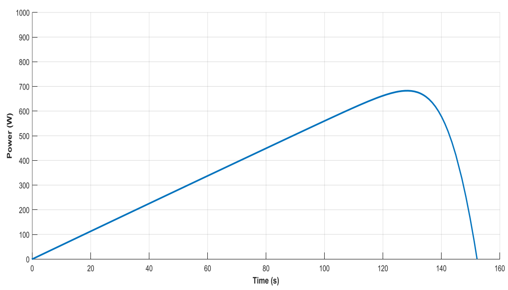


Figure 5. Characteristics $I_{pv}=f(V_{pv})$ Figure 6. Characteristics $P_{pv}=f(V_{pv})$

The temporal magnitudes of voltage, current, duty cycle and power are respectively illustrated by figure 7. We notice that the extracted power is that corresponding to the point of the global optimal.

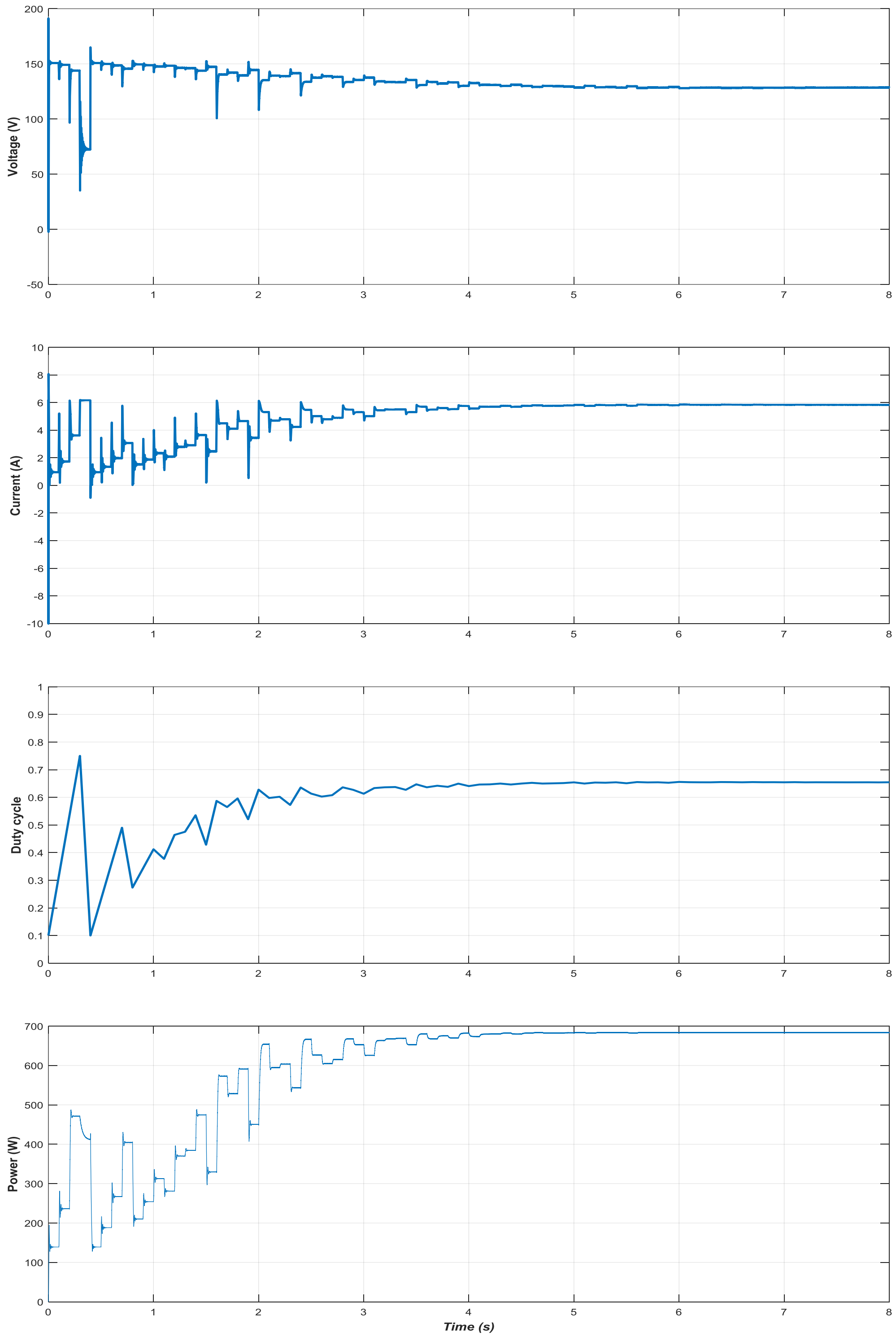


Figure 7. Evaluation of quantities under standard conditions

Moreover, we have performed simulations concerning the behavior analysis of the photovoltaic system under the partial shading effect . For this purpose, two (02) scenarios were considered. The data relating to these scenarios are given in table 1. The characteristics$I_{pv}=f(V_{pv})$ and $P_{pv}=f(V_{pv})$are represented by the figure8 and the figure 9.

Table 1. Partial shading scenarios data

Case No	Partial shading scenario : E(W/m^2)	V_m (V)	I_m (A)	GMPP (W)
1	[950 700 550]	138	3.5	442
2	[750 400 250]	90	3	237.5

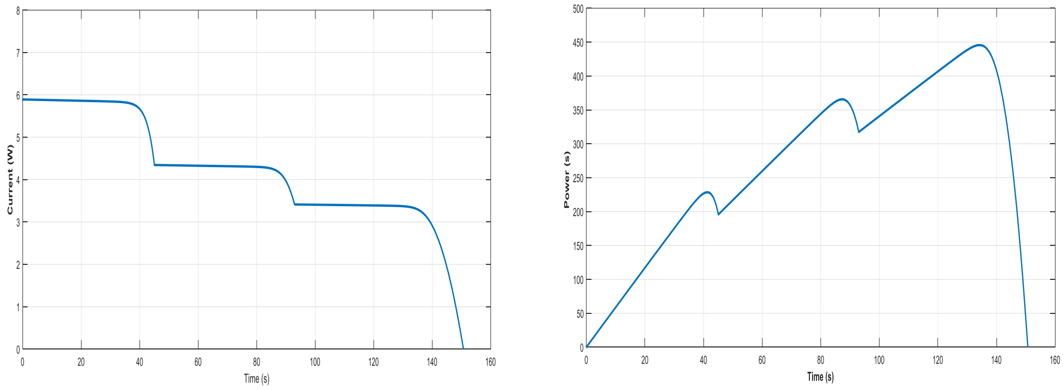


Figure 8. $I_{pv}=f(V_{pv})$ and $P_{pv}=f(V_{pv})$ characteristics under partial shading condition (Scenario 01)

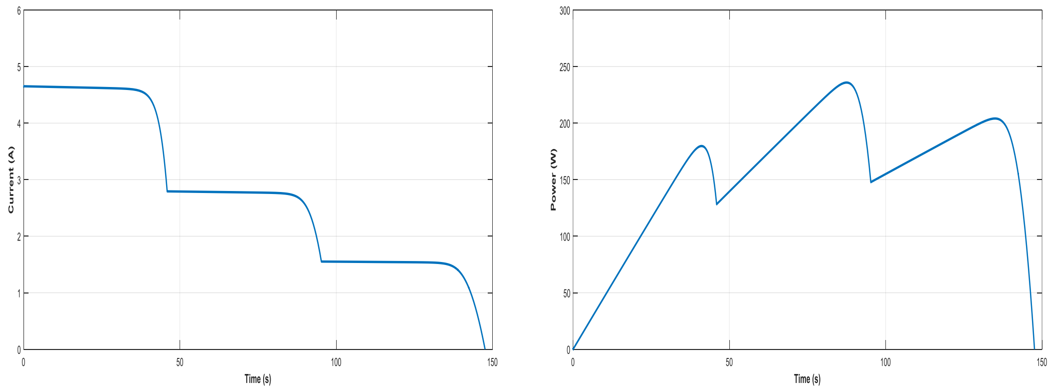


Figure 9. $I_{pv}=f(V_{pv})$ and $P_{pv}=f(V_{pv})$ characteristics under partial shading condition (Scenario 02)

Considering, the two (02) shading scenarios discussed previously, the figures 10 and 11 present the corresponding temporal behaviors. We notice that for the two (02) cases, the powers stabilize on the optimal values (P = 442W for the first test) and (P = 237.5W for the second one).

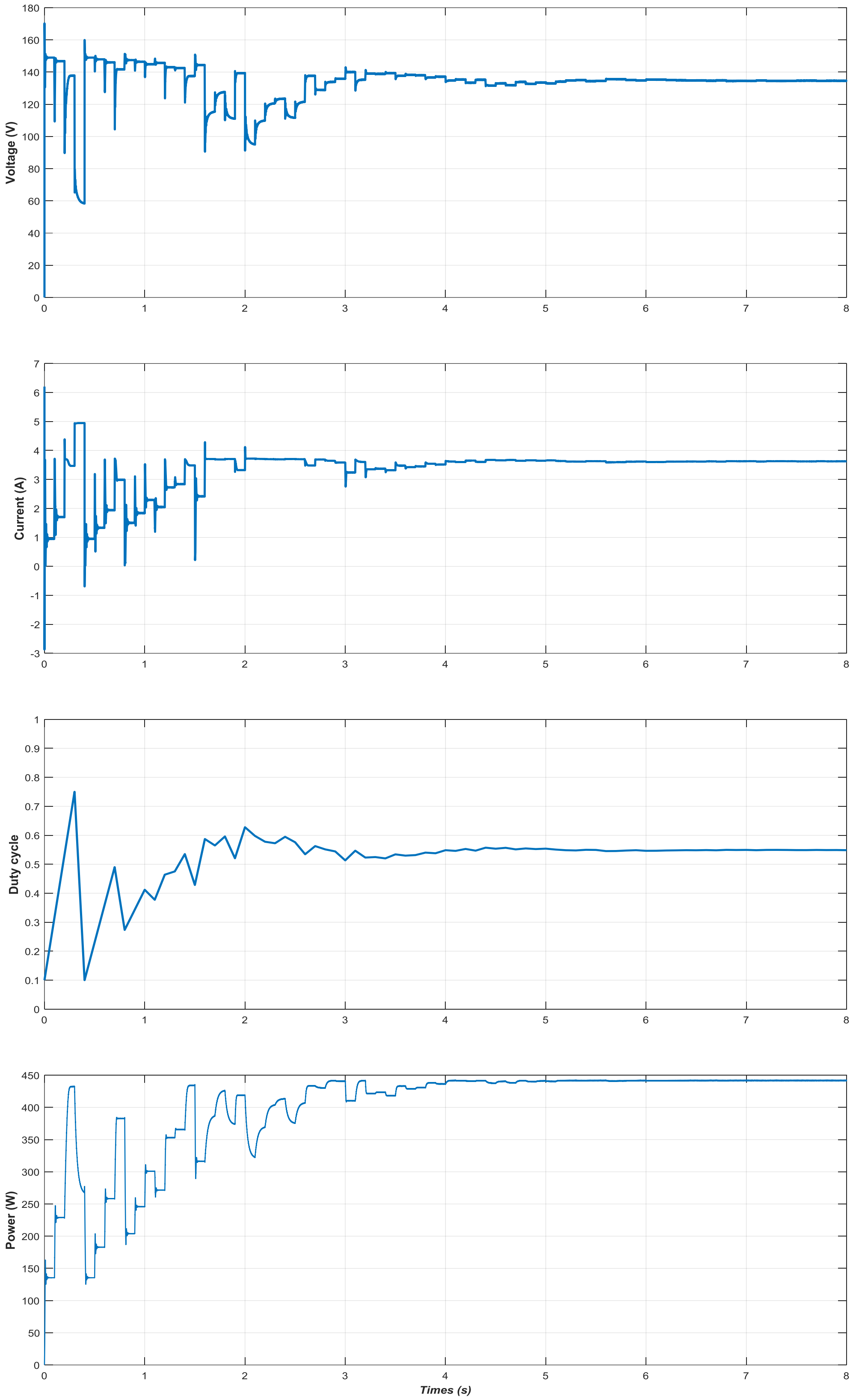


Figure 10. Evaluation of quantities under the first case of the partial shading conditions

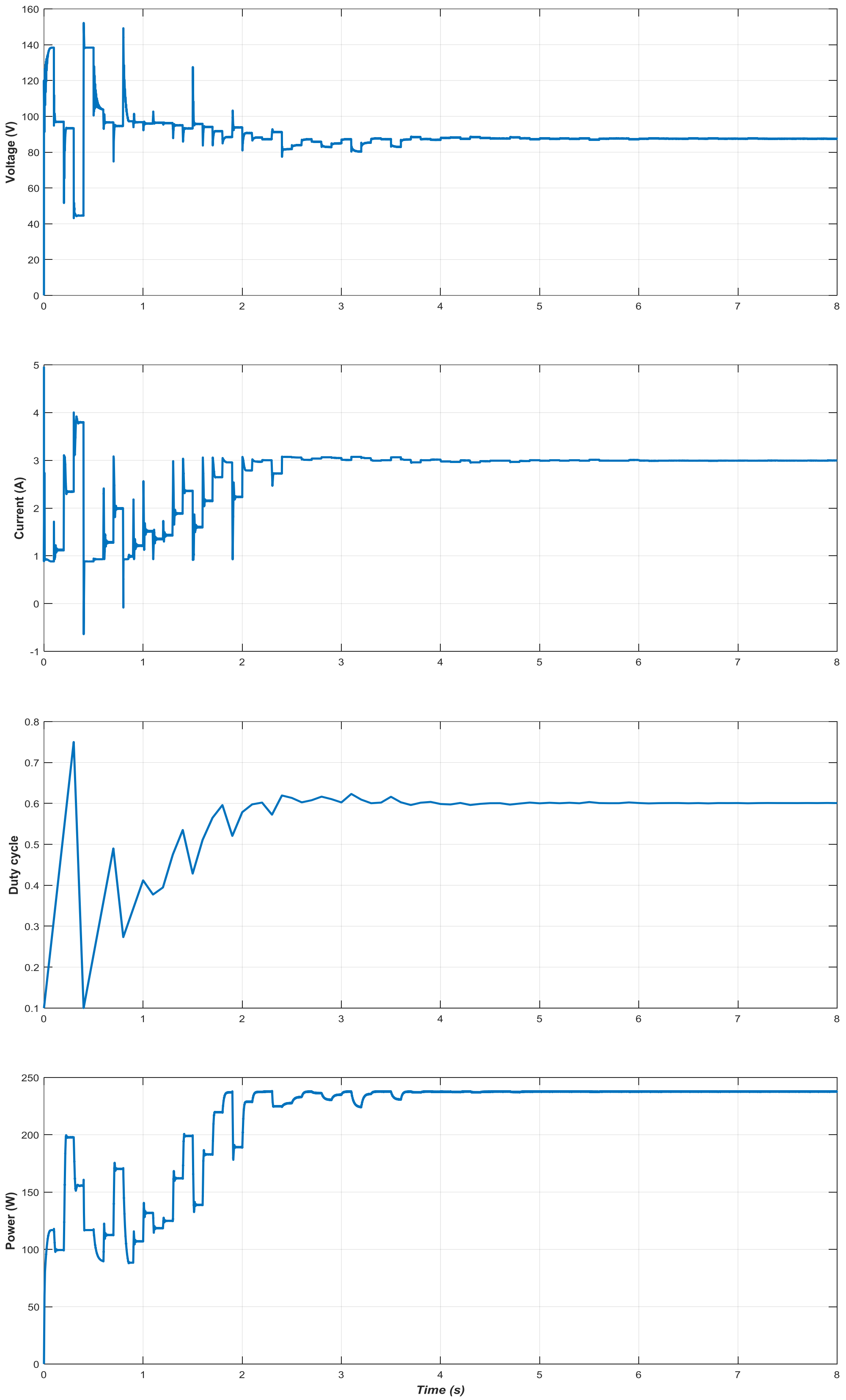


Figure 11. Evaluation of quantities under the second case of the partial shading conditions

IV. Conclusion

In this work we have studied of the behavior and characteristics of the photovoltaic solar system under the partial shading. The goal of using the PSO technique has proven to be very effective in finding the overall maximum power point. Starting from the problem that under shading the nonlinear characteristic of the power as a function of the voltage presents partial optimums and a single global optimum, the technique adopted was tested by simulation and it was validated efficient to operate at the point maximum power.

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