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Advanced PSO For MPPT Algorithm Under partial Shading Conditions

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Abstract

Most often the PV panels are exposed to partial shading due to cloud, buildings and trees causing multiple peaks on the power-voltage (P-V) characteristic curve. Under these conditions the conventional Maximum Power Point Tracking methods cannot track the global maximum power point GMPP, where it is trapped at the first local maximum power point. That is why this paper proposes a particle swarm optimization (PSO) method based on maximum power point tracking (MPPT) algorithm to track global maximum power point (MPP) of photovoltaic (PV) generation under partial shading conditions. To show his efficiency and its advantages, it has been compared with P&O algorithms. Experimental results show that the PSO method is effective in terms of high reliability and high accuracy in tracking the global MPP.

Keywords: Solar energy, MPPT algorithms, Partial shading, PSO, P&O.

1. Introduction

Earth is the planet that provides us with the energy to live in. We have always used natural resources such as wood, carbon, petroleum and gas but all of these resources are limited, and with a lot of exploitation we have affected our health and the environment. Right now, we have found several ways to get energy. We have found new sources that allow us to live and preserve the environment at the same time [1]. These sources are renewable energy sources such as: Solar Energy. Photovoltaic technology is used to describe the hardware made of semiconductor materials, which converts sunlight into electrical power, however, their high dependence to weather conditions (temperature and irradiance) and relatively low conversion efficiency are their main drawbacks [2-3]. Under such conditions, PV panels are exposed to partial shading due to cloud, buildings and trees. Because this effect in turn reduces the PV panel output significantly and multiple peaks on the power-voltage (P-V) characteristic curve are created. For this reason, the maximum power point controllers are adapted. because there is a necessity to operate PV at Global maximum power point to utilize the maximum available power [4]. Improving the efficiencies of the PV panel or the converter is not an easy task due to the available technology limitations. Instead, improving the tracking of the (MPP) with more reliable control algorithms is possible, not expensive and can be applied even in plants which are already in service just by updating their MPPT control algorithms [5]. In fact, several MPPT methods which vary in complexity, convergence speed, cost, range of effectiveness and implementation hardware have been proposed. Most of them are DC/DC chopper circuits based such as: perturb and observe (P&O) and particle and swarm (PSO) methods [6].

2. PV array under partial shading conditions

When PV cells are connected in series, the current flowing through them is limited by the current generated from the least efficient cell (the shaded cell). Thus, a cell that would not receive the same amount of light as the rest of the set would produce a weaker current, this is called partial shading. The shadowing of a single cell in string leads to reverse bias of the shadowed cell. The cell acts as load instead of generator for overcoming this dilemma, bypass diodes have been connected in parallel, but with opposite polarity [7]. Therefore, multiple peak-power points (MPPPs) are observed in the PV curve, where there is only one global MPP (GMPP) and the rest are local MPPs (LMPP).

As shown in "Fig. 1", the PV array consists of three PV panels (Suntech 85W divided into three equal parts)) connected in series.

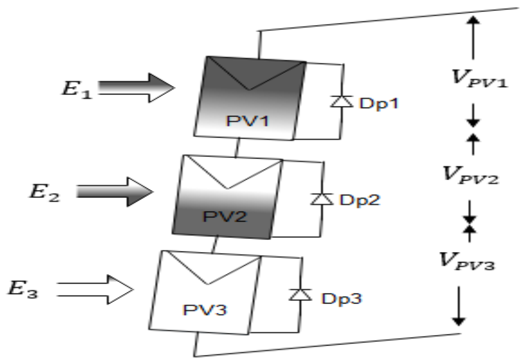

Fig.1. Electrical schema of the 3 PV modules connected in series under partial shading.

Therefore, there are three possible types of multiple peak P–V curves, depending on the type and ratio of the shadow of each PV panel. The GMPP is situated at the middle, in another case is located either on the left or the right of the PV curve as shown in "Fig. 2" [8-9].

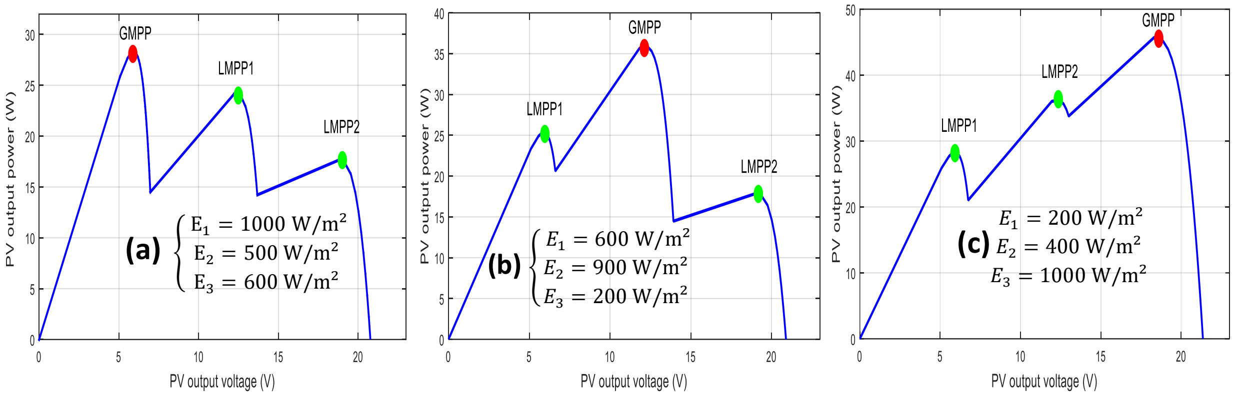

Fig. 2. P-V curves of three panels connected in series under partial shading.
a- GMPP in the left b- GMPP in the middle c- GMPP in the right**.**

3. Particle swarm optimization

Particle swarm optimization (PSO) algorithm is a population-based search method, proposed in 1995 by James Kennedy and Russell Eberhard to optimize nonlinear functions [10]. It is inspired by the social behavior of organism such as: birds flocking, fish schooling and bee swarming while searching for food that individuals communicate in such a way which the entire population migrates toward the same target along the same direction.

Particle swarm optimization (PSO) algorithm consists of "n" particles, where each particle represents a candidate solution. Particles follow a simple behavior: emulate the success of neighboring particles and achieve their own successes. The position of a particle is, therefore, influenced by the best particle solution in a neighborhood, as well as its best solution.

Each particle can be shown by its instantaneous speed and position, the most optimist position of each individual and the most optimist position of the surrounding. In PSO, the speed and position of each particle change according to the following equality [11-12].

$$V_i(k+1) = WV_i(k) + c_1r_1\big(P_{best} - X_i(k)\big) + c_2r_2\big(G_{best} - X_i(k)\big) \quad (1)$$

$$X_i(k+1) = X_i(k) + V_i(k+1) \quad (2)$$

i: is the ordinal number of particle.
k: presents the number of iteration.
$X_i(k)$: is the position of the i^{th} particle at current moment.
$X_i(k+1)$: is the position of the i^{th} particle at current moment.
$V_i(k)$: is the velocity of the i^{th} particle at current moment.
$V_i(k+1)$: is the velocity of the i^{th}particle at the next moment
$P_{best,i}$: is the individual best position of the i^{th} particle.
G_{best}: is the global best position.
W : is the inertia weight.
r_1, r_2: are two independent random numbers in [0, 1].
c_1, c_2: are acceleration factor

4. Using the PSO in MPPT

In order to track the MPP quickly in PV applications, and to overcome the problems posed by conventional MPPT algorithms in terms of, speed, stability and accuracy. A novel maximum power point tracking controller based on Particle swarm optimization has been developed .

Since partially shaded P–V curve exhibits multi peaks characteristics, PSO method is very effective to track the global point (GMPP) rapidly under climatic and load variables conditions and under partial shading.

So it is possible to take the duty cycle $D_i(k)$ (which defines the control signal of the DC / DC converter) instead of the position of the particle ($X_i(k)$), the change of the duty cycle ($\Delta D_i(k)$) as being the velocity ($V_i(k)$), and the objective function being the power corresponding to each duty cycle, in summary [13-14].

$$\begin{cases} X_i = D_i \\ V_i = \Delta D_i \\ P_{best,i} = D_{best,i} \\ G_{best} = D_{best,G} \\ F(X) = P(D) \end{cases} \quad (3)$$

Therefore, the PSO method for MPPT can be expressed by the equations "(4)" and "(5)":

$$\Delta D_i(k+1) = W\Delta D_i(k) + c_1r_1\big(P_{best} - D_i(k)\big) + c_2r_2\big(G_{best} - D_i(k)\big) \quad (4)$$

$$D_i(k+1) = D_i(k) + \Delta D_i(k+1) \quad (5)$$

$D_i(k+1)$:is the duty cycle of the i^{th}particle at the next moment.
$D_i(k)$: is the duty cycle of the i^{th}particle at current moment (k).
$\Delta D_i(k+1)$: is the change of the duty cycle of the i^{th} particle at the next moment.
$\Delta D_i(k)$: is the change of the duty cycle of the i^{th} particle at current moment.
$D_{best,i}$: is the individual best duty cycle of the i^{th} particle.
$D_{best,G}$: is the global best duty cycle.

At each iteration, we determine the power corresponding to the position of each particle of the swarm (duty cycle), then we define the objective function "power" which gives the weight of each duty cycle (position of a particle), the duty cycle is better if the power corresponding is superior.

The different steps of PSO [15]

Step 01: (Initialization of the algorithm) the number of particles is four. The particles are placed on fixed positions. The first particle is set as 0.1, the fourth particle is set as 0.9. The first and fourth particles defined the PSO search space. The second and the third particles are randomly set between 0.1 and 0.9.
The Optimization constants (w, c_1, c_2, r_1, r_2) are also defined in this step; these constants define the behaviour of the evolution of the algorithm and require a good knowledge of the system.
Step 02: (Particle evaluation): each duty cycle is applied to the converter, the corresponding voltage and current will be recovered and the power of each particle is calculated. This power is greater for an optimal duty cycle.
Step 03: update the best individual and global position
If the duty cycle of a particle gives the best power of its course then this duty cycle will be recorded as the individual best duty cycle $D_{best,i}$, and if it gives the greatest power than those obtained by the other particles then it becomes the global best duty cycle $D_{best,G}$,
Step 04: (Update D_i and ΔD_i): if the convergence criteria is satisfied then the global best duty cycle $D_{best,G}$ is used, otherwise an optimization of D_i and ΔD_i of all the particles is applied using “(4)” and “(5)”.

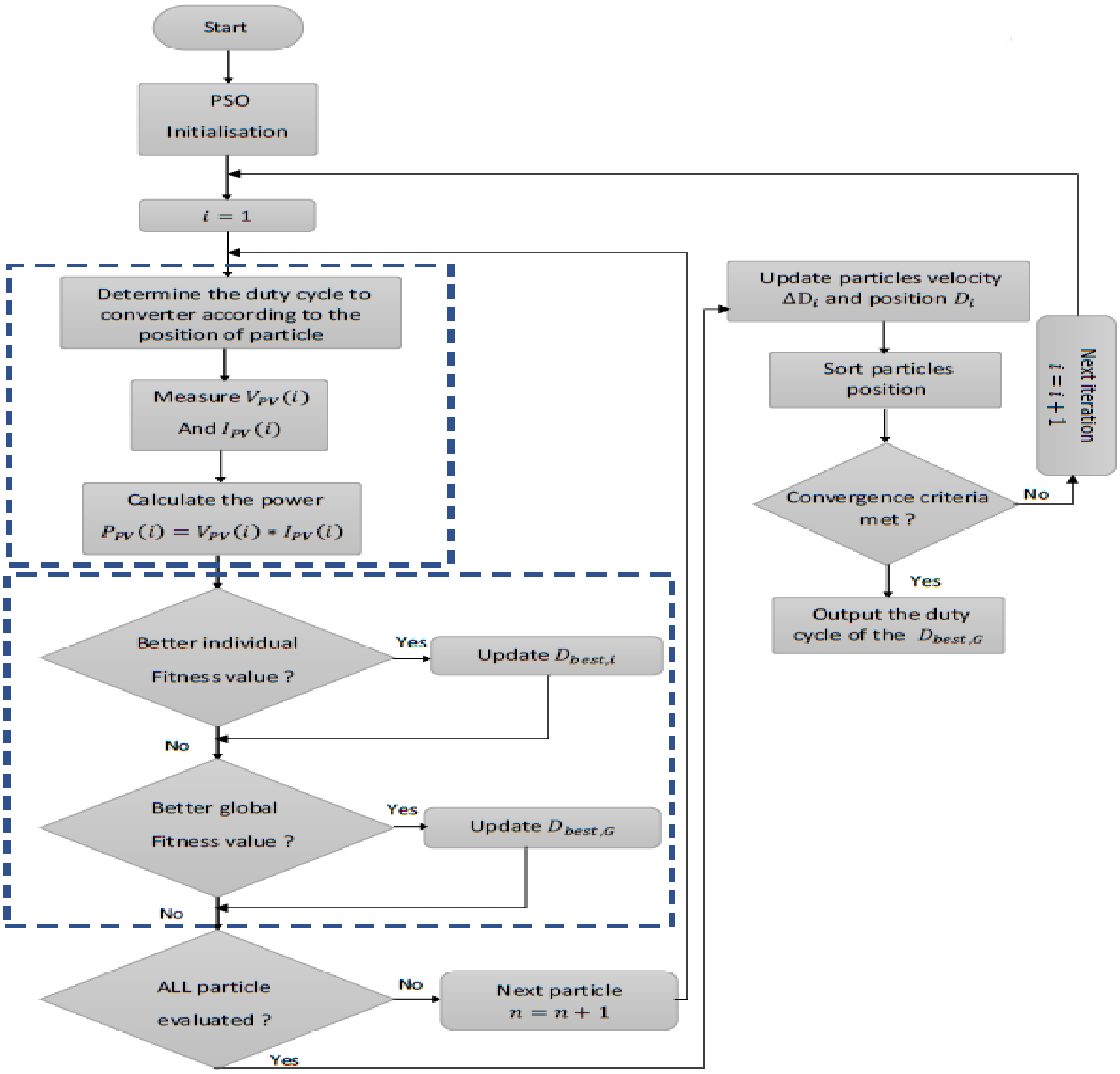

Fig. 3. Flowchart of the PSO algorithm

5. Description of the photovoltaic chain

A photovoltaic chain consists of four blocks. The first block represents the energy source (photovoltaic panel), it is built from three modules connected in series where each one consists of 12 cells. The parameters of the PV panel are shown in table1. The second block is a BOOST converter and the third block represents the load and the fourth block represents the control system.

Table 1. ***Parameters of the Photovoltaic Panel***

Type	Suntech 85W
Number of cells in series	36
Maximum power (W)	85.2 W
Maximum power voltage (V)	17.60 V
Maximum power current (A)	4.83 A
Open circuit voltage (V)	21.9 V
Short circuit current (A)	5.15 A
Series resistance of PV model (ohms)	0.145Ω
Parallel resistance of PV model (ohms)	300 Ω

The conversion chain of a photovoltaic system is powered by a PV generator through a DC-DC converter controlled by an MPPT control. The latter varies the duty ratio of the converter so that the power supplied by the GPV is the maximum power available at its terminals.

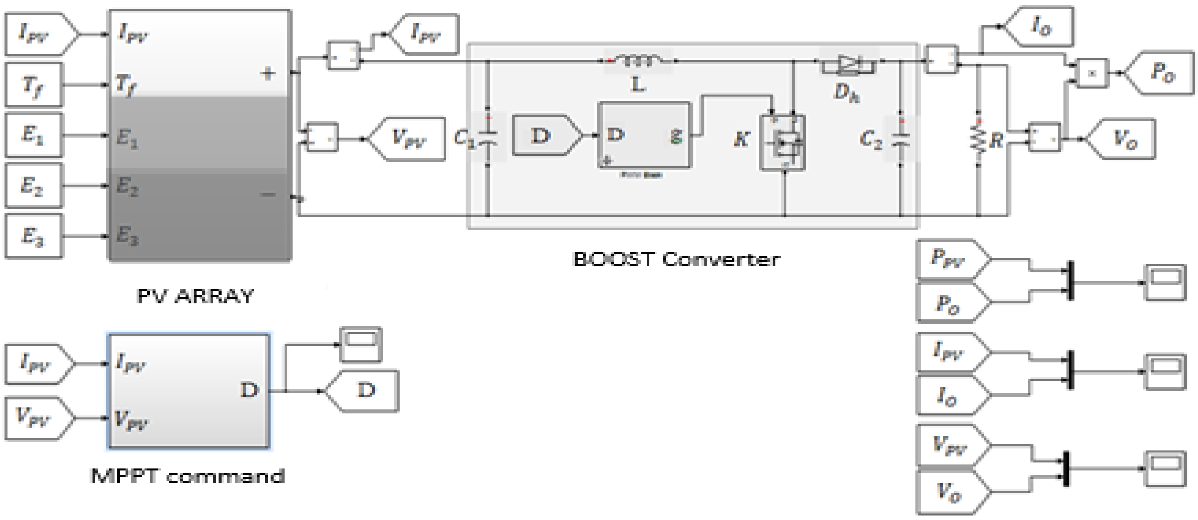

Fig. 4. Simulation model of a photovoltaic chain with MATLAB / Simulink software.

Table 2. ***Parameters of the DC-DC Converter***

Input Voltage (V_{in})	17.6 V
Output Voltage (V_o)	30 V
Power Operation (P)	85.2 W
Inductor (L)	1 mH
Capacitor (C_1)	450µF
Capacitor (C_2)	450µF
Load (R)	10 Ω
Switching Frequency (f_s)	1.5 Khz

6. Simulation of MPPT technique under partial shading

To show the efficiency and advantages of the intelligent PSO method, a comparison with the classical P & O method was performed. Both methods are implemented under partial shading, each part of PV module is exposed to different levels of radiation. As mentioned above, there are three models of P-V curves depending on the pattern of partial shading.

A. The GMPP is in the left

In the first test, the simulation was done with irradiation of $1000 W/m^2$ in the first module, 500 W/m^2 in the second and 600 W/m^2 in the third module. The simulation results of the PV output power, for the PSO and P&O methods are shown in figure 5 and 6 respectively.

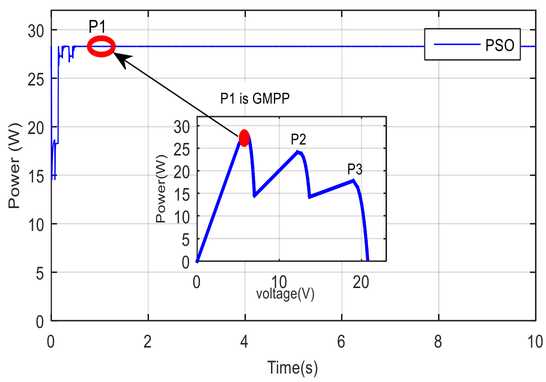

Fig.5. Variation of the power of the PV panel of the PSO control, under partial shading.

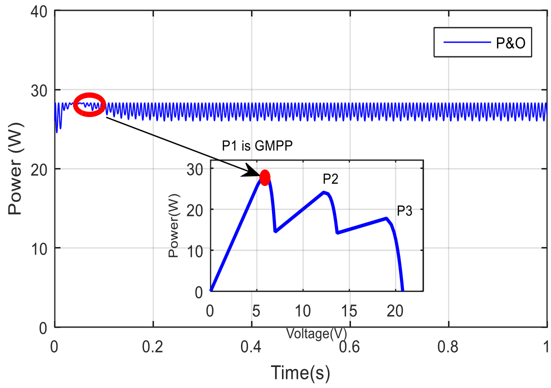

Fig. 6. Variation of the power of the PV panel of the P&O control, under partial shading.

B. The GMPP is in the middle

In the second test, the simulation was done with irradiation of $600 W/m^2$ in the first module, $900\ W/m^2$ in the second and $200\ W/m^2$ in the third module. The simulation results of the PV output power, for the PSO and P&O methods are shown in figure 7 and 8 respectively.

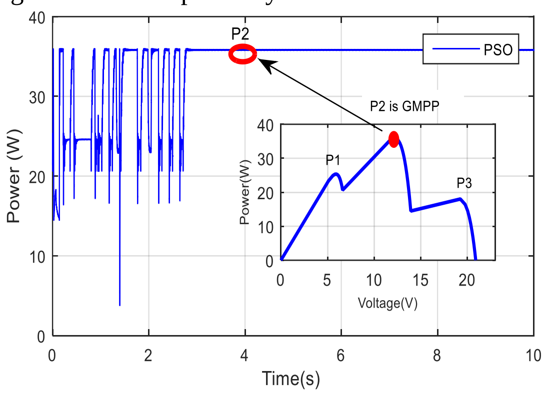

Fig.7. Variation of the power of the PV panel of the PSO control, under partial shading.

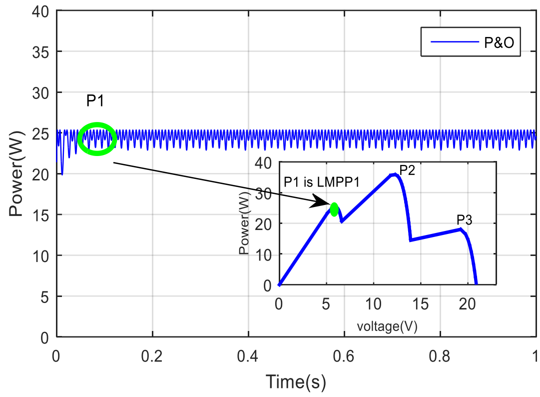

Fig. 8. Variation of the power of the PV panel of the P&O control, under partial shading.

C. The GMPP is in the right

In the third test, the simulation was done with irradiation of $200 W/m^2$ in the first module, $400\ W/m^2$ in the second and $1000\ W/m^2$ in the third module. The simulation results of the PV output power, for the PSO and P&O methods are shown in figure 9 and 10 respectively.

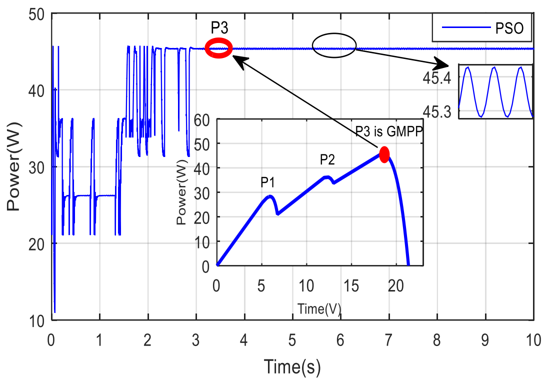

Fig.9. Variation of the power of the PV panel of the PSO control, under partial shading.

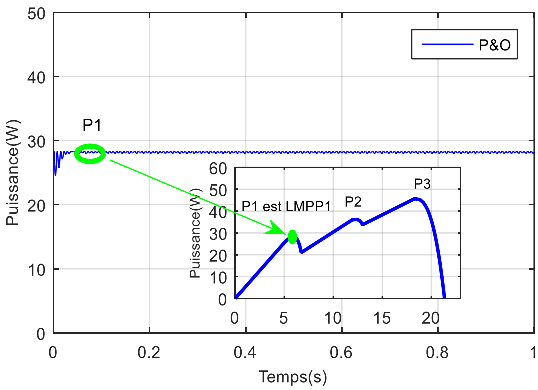

Fig. 10. Variation of the power of the PV panel of the P&O control, under partial shading.

7. Interpretation of results and comparison

From the results obtained, we observe the effect of the algorithms applied on the point of maximum power. Once the maximum power is reached, the system stabilizes at this value.

For the P&O, there will be an oscillation around this value due to the disturbance of the duty cycle, as shown in "Fig.5" while for PSO, there is no oscillation because after several iterations, the speed goes to zero.

Under partial shading, most conventional MPPTs cannot find the global maximum power point (GMPP). As can be seen in "Fig. 6, 8 and 10", P&O is trapped at the first local maximum power (LMPP), causing significant power loss.

This makes it totally unable to handling partial shading conditions. While the PSO algorithm shows a great ability to distinguish local and global peaks, as shown in "Fig. 5, 7 and 9".

Table 3. ***Comparative Results***

Radiation W/m^2	GMPP (W)	PSO Power (W)	P&O Power (W)	Tracking PSO/P&O (S)	Efficiency PSO/P&O%
600-900-200	28.31	28.28	28.30	0.470/ 0.030	99.89/99.96
1000-500-600	35.87	35.79	25.34	2.79/0.05	99.77/70.64
200-400-1000	45.69	45.32	28.27	2.88/0.03	99.19/61.87

Analysing the results presented in Table 3. it is possible to observe the efficiency and convergence speed of the PSO optimization technique in the search of the GMPPT point despite of the partial shading condition.

8. Conclusion

In this paper the problem of the partial shading of the PV arrays was discussed. Then, to demonstrate that the classical algorithms were unable to truck the maximum point, a comparison with the intelligent PSO method was performed and concluded that P & O is trapping to the first LMPP. However, the PSO command shows a great ability to distinguish the GMPP with very low oscillations in the steady state.

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