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PARTICLE SWARM OPTIMIZATION BASED OF THE MAXIMUM PHOTOVOLTAIC POWER TRACTIOQG UNDER DIFFERENT CONDITIONS

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ABSTRACT

Photovoltaic electricity is seen as an important source of renewable energy. The photovoltaic array is an unstable source of power since the peak power point depends on the temperature and the irradiation level. A maximum peak power point tracking is then necessary for maximum efficiency.

In this work, a Particle Swarm Optimization (PSO) is proposed for maximum power point tracker for photovoltaic panel, are used to generate the optimal MPP, such that solar panel maximum power is generated under different operating conditions. A photovoltaic system including a solar panel and PSO MPP tracker is modelled and simulated, it has been has been carried out which has shown the effectiveness of PSO to draw much energy and fast response against change in working conditions.

Keywords: Particle Swarm Optimization (PSO), photovoltaic system, MPOP, optimization technique.

1. INTRODUCTION

Photovoltaic energy is a technique, which coverts directly the sunlight into electricity. It is modular, quit, non-polluting and requires very little maintenance, for this reason a powerful attraction to photovoltaic systems is noticed.

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By having a quick glance on both the current-voltage and the power-voltage characteristics of PV arrays, we see clearly the dependence of the generating power of a PV system on both insulation and temperature. [2].

In this study, we present an application of a Particle Swarm Optimization (PSO) on a photovoltaic system, which helps to catch the Maximum Power Operating Point (MPOP). This latter change instantaneously with changing radiation and temperature, what implies a continuous adjustment of the output voltage to achieve the transfer of the maximum power to the load. The justification of this application lies in the fact the I-V and P-V characteristics are non linear because of the nonlinearity of the photovoltaic systems from one hand and because of the instantaneous change of both insulation and temperature from the other hand, what makes the two previous plot in fact fluctuating instead of the simulated smooth ones (Figure 1 and 2). [4]

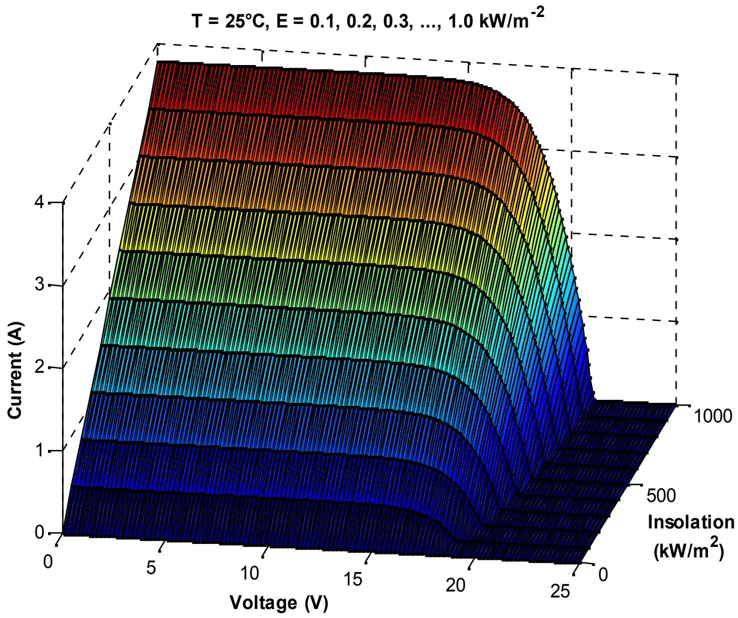

Fig.1. I-V characteristics when insulation is changing.

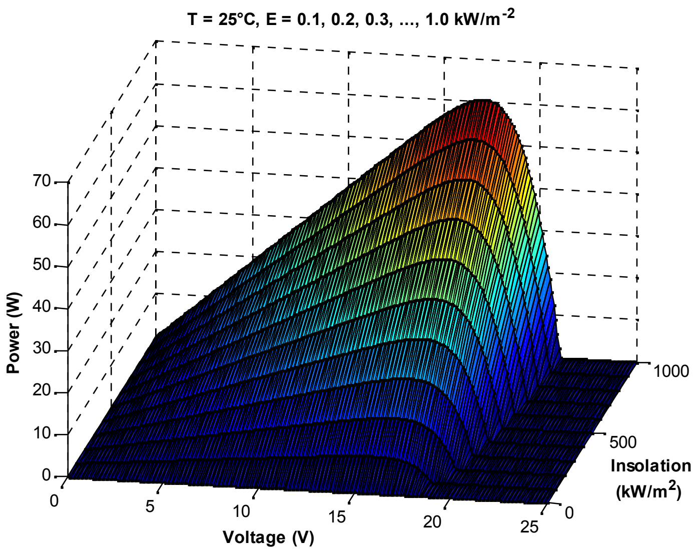

Fig.2. P-V characteristics when insulation is changing.

Therefore, the adoption of this novel adaptive PSO technique offers the possibility of dealing accurately with these optimization problems and to overcome the incapacities of the traditional numerical techniques. The proposed approach is employed in fitting both the I-V and P-V characteristics of a solar module referenced as Solarex MSX 60 with the characteristics shown in the index.

Modeling of the photovoltaic generator

Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode. The output of the current source is directly proportional to the light falling on the cell (photocurrent I_{ph}). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates a current I_D, called diode (D) current or dark current. The diode determines the I-V characteristics of the cell.

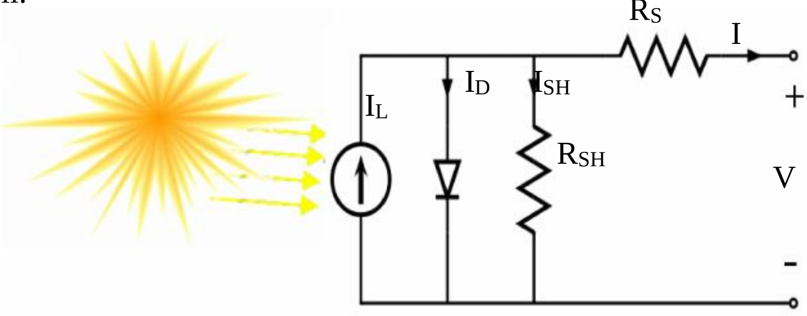

Fig.3. Circuit diagram of the PV model.

Increasing sophistication, accuracy and complexity can be introduced to the model by adding in turn [7]:

- Temperature dependence of the diode saturation current I_0.
- Temperature dependence of the photo current I_L.
- Series resistance R_S, which gives a more accurate shape between the maximum power point and the open circuit voltage. This represents the internal losses due to the current flow.
- Shunt resistance R_{sh}, in parallel with the diode, this corresponds to the leakage current to the ground and it is commonly neglected
- Either allowing the diode quality factor n to become a variable parameter (instead of being fixed at either 1 or 2) or introducing two parallel diodes with independently set saturation currents.

In an ideal cell $R_s = R_{sh} = 0$, which is a relatively common assumption [5]. For this paper, a model of moderate complexity was used. The net current of the cell is the difference of the photocurrent, I_L and the normal diode current I_0:

$$I = I_L - I_o\left(e^{\frac{q(V+IR_S)}{nkT}} - 1\right) \tag{1}$$

The model included temperature dependence of the photo-current I_L and the saturation current of the diode I_0.

$$I_L = I_L(T_1) + K_o(T - T_1) \tag{2}$$

$$I_L(T_1) = I_{SC}(T_{1,nom})\frac{G}{G(_{nom})} \tag{3}$$

$$K_o = \frac{I_{SC}(T_2) - I_{SC}(T_1)}{(T_2 - T_1)} \tag{4}$$

$$I_o = I_o(T_1)\times\left(\frac{T}{T_1}\right)^{\frac{3}{n}} e^{\frac{qVq(T1)}{nk\left(\frac{1}{T}-\frac{1}{T_1}\right)}} \tag{5}$$

$$I_o(T_1) = \frac{I_{SC}(T_1)}{\left(e^{\frac{qVoc(T1)}{nkT_1}} - 1\right)} \tag{6}$$

A series resistance R_S was included; witch represents the resistance inside each cell in the connection between cells.

$$R_S = -\frac{dV}{dI_{V_{oc}}} - \frac{1}{X_V} \tag{7}$$

$$X_V = I_o(T_1) \times \frac{q}{nkT_1} e^{\frac{qV_{OC}(T1)}{nkT_1}} - \frac{1}{X_V} \tag{8}$$

The shunt resistance R_{sh} is neglected. A single shunt diode was used with the diode quality factor set to achieve the best curve match. This model is a simplified version of the two diode model presented by Gow and Manning [6]. The circuit diagram for the solar cell is shown in Figure 3.

The I-V characteristics of the module can be expressed roughly by the Eq. 1-8. the model requires three point to be measured to define this curve: [3].

- The voltage of the open circuit Voc.
- The current of short-circuit Isc.
- The point of optimum power (Iopt, Vopt).

Particle swarm optimization approach

Particle swarm optimization (PSO) is a population-based optimization method first proposed by Kennedy and Eberhart in 1995, inspired by social behavior of bird flocking or fish schooling. The PSO as an optimization tool provides a population-based search procedure in which individuals called particles change their position (state) with time. In a PSO system ,particles fly around in a multidimensional search space .

During flight, each particle adjusts its position according to its own experience (This value is called pbest), and according to the experience of a neighboring particle (This value is called gbest), made use of the best position encountered by itself and its neighbor (Figure 4)

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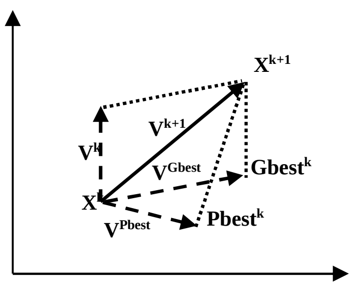

Fig.4. Concept of a searching point by PSO.

This modification can be represented by the concept of velocity. Velocity of each agent can be modified by the following equation:

$$v_{k+1} = w.v_k + c_1 rand*(pbest - x^k) + c_2 rand*(gbest - x^k) \quad (9)$$

Using the above equation, a certain velocity, which gradually gets close to pbest and gbest can be calculated .

The current position (searching point in the solution space) can be modified by the following equation:

$$x^{k+1} = x^k + v_{k+1} \ , k = 1,2,...,n \quad (10)$$

Where x^k is current searching point , x^{k+1} is modified searching point , v_k is current velocity , v_{k+1} is modified velocity of agent Vpbest is velocity based on pbest ,Vgbest is velocity based on gbest, n is number of particles in a group, m is number of members in a particle, $pbest_i$ is pbest of agent k, $gbest_i$ is gbest of the group, w is weight function for velocity of agent k, c_i is weight coefficients for each term .

c1 and c2 are two positive constants. r1 and r2 are two randomly generated numbers with a range of [0,1]. w is the inertia weight and it is defined as a function of iteration index k as follows:

$$w(k) = w_{\max} - (\frac{w_{\max} - w_{\min}}{Max.Iter.}) * k. \quad (11)$$

Where $Max.Iter$, k is maximum number of iterations and the current number of iterations, respectively. To insure uniform velocity through all dimensions, the maximum velocity is as.

$$v^{\max} = (x^{\max} - x^{\min}) / N. \quad (12)$$

Where N is a chosen number of iterations.

Application of PSO to MPOP

The goal is to solve some optimization problem where we search for an optimal solution in terms of the variables of the problem (current and voltage) by imposing the constraints on the current and the voltage which should be both bigger than zero. Consequently, we have to find particles in the form of an array of variable values to be optimized.

To minimize F is equivalent to getting a maximum fitness value in the searching process. The objective of OPF has to be changed to the maximization of fitness to be used as follows:

$$fitness = \begin{cases} P(V,I)/P_{\max}; & if \quad P_{\max} < P \\ 0 \ ; & otherwise \end{cases} \quad (13)$$

The PSO-based approach to find the global maximum value of f(I,V) (Figure 5).the following steps:

Step 1: randomly generated initial population.

Step 2: For each particle, the construction operators are applied.

Step 3: fitness function evaluation.

Step 4: compare particles fitness function and determine pbest and gbest.

Step 5: change of particles velocity and position according to (9) and (10) respectively.

Step 6: If the iteration number reaches the maximum limit, go to Step 8. Otherwise, set iteration index k = k + 1, and go back to Step 2.

Step 7: Print out the optimal solution to the target problem.

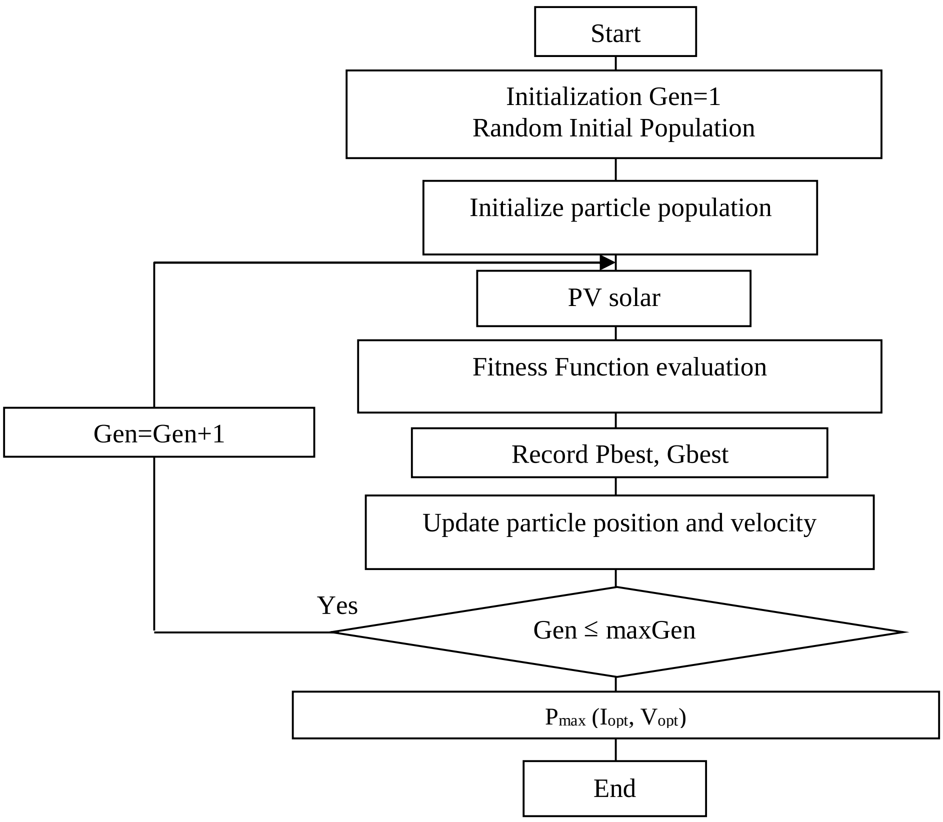

Fig.5. PSO computational procedure.

2. RESULTS AND DISCUSSIONS

The program has been developed and executed under MATLAB system.The program was written and executed on Pentium 4 having 2.4 GHZ 1GB DDR RAM.

The optimal setting of the PSO control parameters are:

c1=0.5, c2=0.5, numbers of particles is 50 and number of generations is 30. The Inertia weight was kept between 0.4 and 0.9.

The resulted values of this optimization problem are reported in Table 1-3. These tables consider simulation results of many sample runs of the PSO technique. We see clearly the variation of the MPOP with respect to either insulation or temperature and both of them with great accuracy (Figures 6-11).

Tableau 1. Optimization results when insulation is varying at temperature of 25 °C.

Insulation [Wm^{-2}]	V_{max} [V]	I_{max} [A]	M_{pop} [W]
100	15.4354	0.3538	5.4604
200	15.9016	0.7162	11.3889
300	16.3891	1.0657	17.4666
400	16.6170	1.4202	23.5997
500	16.7480	1.7770	29.7618
600	16.8680	2.1301	35.9307
800	17.0305	2.8325	48.2388
900	17.0297	3.1927	54.3711
1000	17.0173	3.5536	60.4728

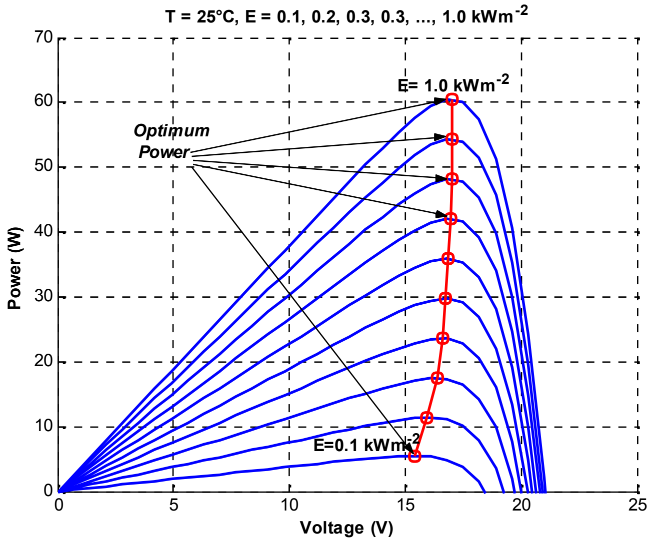

Fig.6. MPOPs variation with insulation from P-V characteristics.

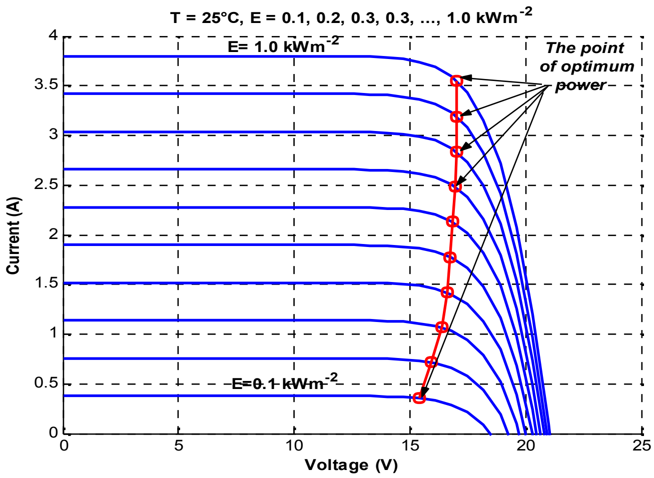

Fig.7. MPOPs variation with insulation from I-V characteristics.

Tableau 2. Optimization results when temperature is varying at insulation of 1000Wm^{-2}

Temperature [°C]	***V_{max} [V]***	***I_{max} [A]***	**M_{pop} [W]**
0	18.9437	3.5322	66.9123
25	17.0594	3.5447	60.4699
50	15.1356	3.5609	53.8962
75	13.3214	3.5447	47.2205
100	11.4335	3.5406	40.4809

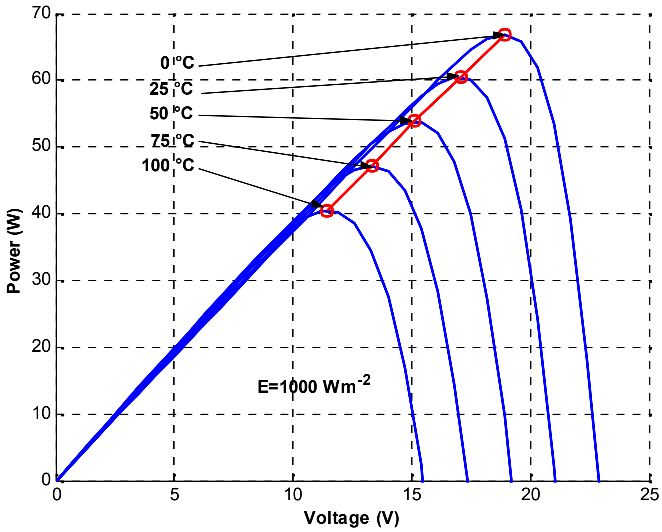

Fig.8. MPOPs variation with temperature from P-V characteristics.

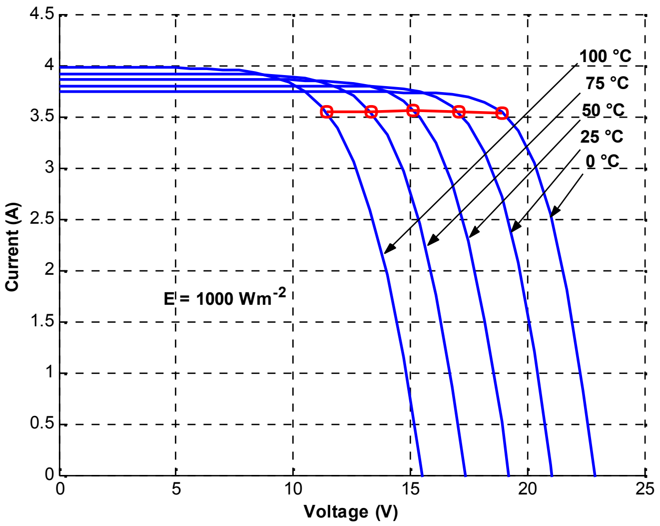

Fig.9. MPOPs variation with temperature from I-V characteristics.

Tableau 3. Optimization results when temperature is varying at insulation of 1000Wm^{-2}

Temperature [°C]	***Insulation [Wm^{-2}]***	V_{max} **[V]**	I_{max} **[A]**	M_{pop} **[W]**
0	**100**	17.3580	0.3022	5.2454
25	**250**	16.2762	0.8859	14.4195
50	**500**	14.8163	1.8080	26.7885
75	**750**	13.2337	2.6796	35.4606
100	**1000**	11.3587	3.5618	40.4571

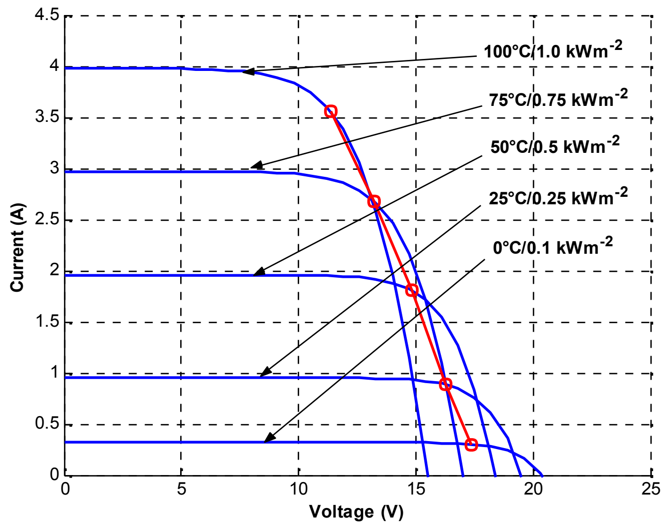

Fig.10. MPOPs variation with insulation and temperature at the same time from I-V characteristics.

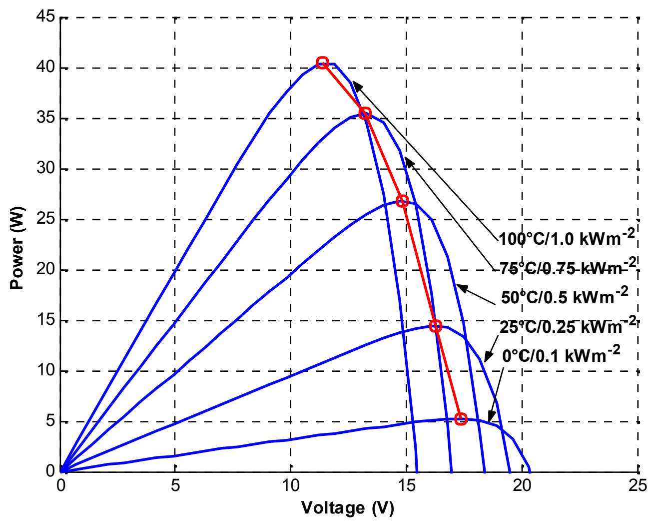

Fig.11. MPOPs variation with insulation and temperature at the same time from P-V characteristics.

In summary, the presented results demonstrate noticeably the interests and benefits of suggested procedure and how accurate it is.

In order to see clearly the results of this optimization study, the Figures 6-11 plot the multiple variation of both current with respect to voltage and power respect to voltage. The maximum power operating point MPOP of each curve is represented either by "o" and it shows the maximum value of power (current and voltage) that the module can supply instantaneously under different climatic conditions.

3. CONCLUSION

This study present a PSO, which calculates instantaneously the MPOP of a PV module in order to maximize the profits in terms of the power issued from the PV module. Because of the P-V characteristics this heuristic method is used to seek the real maximize power and to avoid the wrong values of local maxima. The obtained results of this investigation are reported in Table 1-3 and depicted in Figures 6-11.

The results show that the optimal Power solutions determined by PSO is well capable of determining the global or near global maximum power operating point.

Major drawback of PSO, like in other heuristic optimization techniques, is that it lacks somewhat a solid mathematical foundation for analysis to be overcome in the future, development of relevant theories. Also, it can have some limitations for real-time applications since the PSO is also a variant of stochastic optimization techniques requiring relatively a longer computation time than mathematical approaches

Appendix

Appendix 1 : Solarex MSX 60 Specifications (1kW/m^2, 25°C)

Characteristics	SPEC.
Typical peak power (P_m)	60W
Voltage at peak power (V_m)	17.1V
Current at peak power (I_m)	3.5A
Short-circuit current (I_{SC})	3.8A
Open-circuit voltage (V_{OC})	21.1V
Temperature coefficient of open-circuit voltage (α)	-73 mV/°C
Temperature coefficient of short-circuit current (β)	3 mA/°C
Approximate effect of temperature on power	-0.38W/°C
Nominal operating cell temperature (NOCT^2)	49°C

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