

Genetic Algorithm Technique for Optimizing the Maximum Supplied Power of a Photovoltaic Module under Various Atmospheric Conditions

Dj. Bellala

Laboratoire d'Automatique et de Productique
L.A.P. Université de Batna

M. Chaabane

Département d'électrotechnique
Université de Batna

Abstract—Due to the fact of daily climatic changes and their impact on the solar modules (photovoltaic modules), the maximum of power generated from them is of a big importance, for this reason we have to follow this maximum whatever the climatic conditions in which the module is situated are. Genetic Algorithms, considered as heuristic techniques, is used to optimize this maximum generated power in terms of both current and voltage from one side and the maximum power operating point MPOP from the other side.

Index Terms-- Genetic Algorithm (GA), Photovoltaic System, MPOP, Optimization Technique, Insulation, Temperature.

1. INTRODUCTION

Because of their usefulness, heuristic techniques are being progressively applied to many engineering fields, so their application to a wide variety of problems become more and more attractive. the increased availability of powerful computational platforms helped too much the use of such techniques. Genetic algorithms based on numerical techniques are considered by their widely spread applications famous in optimization problems especially when the fluctuating character is clearly seen within the model of the problem to be solved, so and according to many references, this technique gives more rigorous results compared to the analytical ones [1]-[2].

photovoltaic energy is a technique, which converts directly the sunlight into electricity. it is modular, quiet, non-polluting, and requires very little maintenance, for this reason a powerful attraction to photovoltaic systems is noticed. 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. [3].

In this paper, an application of a genetic algorithm (GA) to optimize the MPOP of a photovoltaic module is presented, either in terms of current and voltage from the I - V characteristics or in term of the maximum power from the P - V characteristics. The MPOP is instantaneously changing with radiation and temperature changing, 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 that both I - V and P - V characteristics are not only non linear because of the non-linearity of the photovoltaic systems, but also because of the fluctuations caused by the

instantaneous change of both insulation and temperature. In fact the following two figures are really fluctuating not smooth as it is the case of the simulated ones.

The adoption of this novel adaptive GA 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 BP SOLAR, BP 4160S with the characteristics shown in the index.

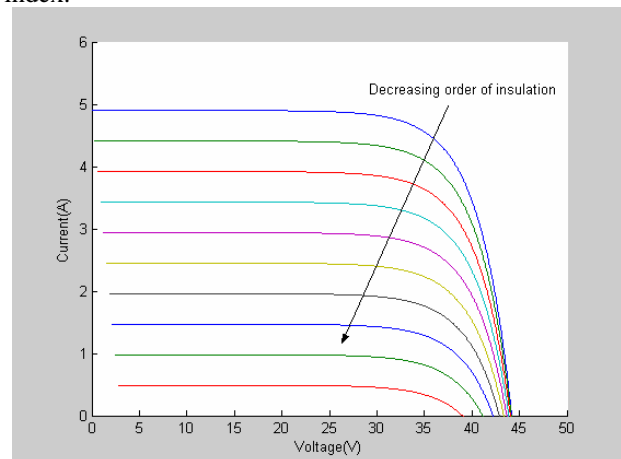


Fig. 1. I - V characteristics when insulation is changing

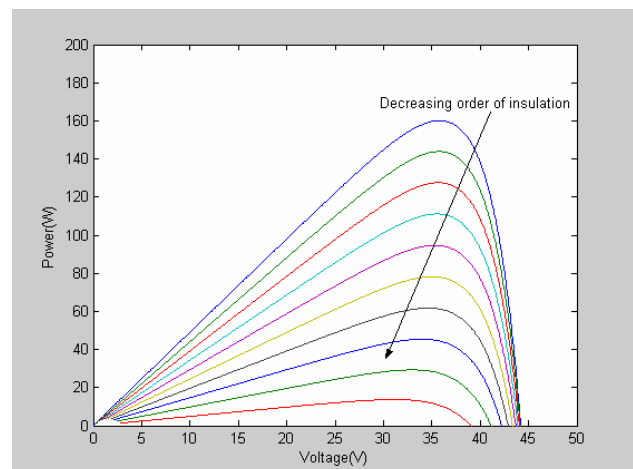


Fig. 2. P - V characteristics when insulation is changing

2. MODELING OF THE PHOTOVOLTAIC MODULE

The I-V Characteristic of the module can be expressed roughly by the equations (1) to (9). The model (one diode model) requires three points to be measured to define this curve: [4]

- The voltage of the open circuit V_{oc} .
- The current of short-circuit I_{sc} .
- The point of optimum power (I_{opt}, V_{opt})

$$I = I_{cc} [1 - C1 (\exp(\frac{V}{C_2 \cdot V_{oc}}) - 1)] \quad (1)$$

$$C_2 = \frac{\frac{V_{opt}}{V_{oc}} - 1}{\ln\left(1 - \frac{I_{opt}}{I_{sc}}\right)} \quad (2)$$

$$C_1 = \left(1 - \frac{I_{opt}}{I_{sc}}\right) \cdot \exp\left(\frac{-V_{opt}}{C_2 \cdot V_{oc}}\right) \quad (3)$$

The adaptation of the equation (1) to other levels of radiation and temperatures gives:

$$I_n = I_{ref} + \Delta I \quad (4)$$

$$V_n = V_{ref} + \Delta V \quad (5)$$

Where

$$\Delta I = \alpha \left(\frac{E}{E_{ref}}\right) \Delta T + \left(\frac{E}{E_{ref}} - 1\right) I_{sc} \quad (6)$$

$$\Delta V = -\beta \Delta T - R_s \cdot \Delta I \quad (7)$$

With:

α is the coefficient of variation of the current with the temperature

β is the coefficient of variation of the voltage

with the temperature

$$\Delta T = T - T_{ref} \quad (8)$$

Where

T is the temperature of the module

T_{ref} is the reference temperature

The temperature of the module is related to the ambient temperature by the following relation:

$$T_m = T_a + K \cdot E \quad (9)$$

Where K is the temperature factor of the module measured in m^2/w^2 .

3. GENETIC ALGORITHM APPROACH [5]

Genetic algorithms offer an alternative approach and are gaining popularity in optimization problem solving. Being inspired by the biological evolutionary process, the basic idea of genetic algorithms for optimization problems is that solutions to a problem can be reproduced from a population of candidate solutions. Repeated reproduction and survival of the fittest creates successive generations of offspring which converge toward an optimum set of characteristics

The problem with genetic algorithms lies firstly with the way to encode the variables of a problem in a meaningful way that can be used to develop a new set of values for the variables. This set of encoded variables is called a *chromosome*, this latter is comprised of *genes*, and genes represent the encoded variables for the problem.

4. PROCEDURE OF THE GA

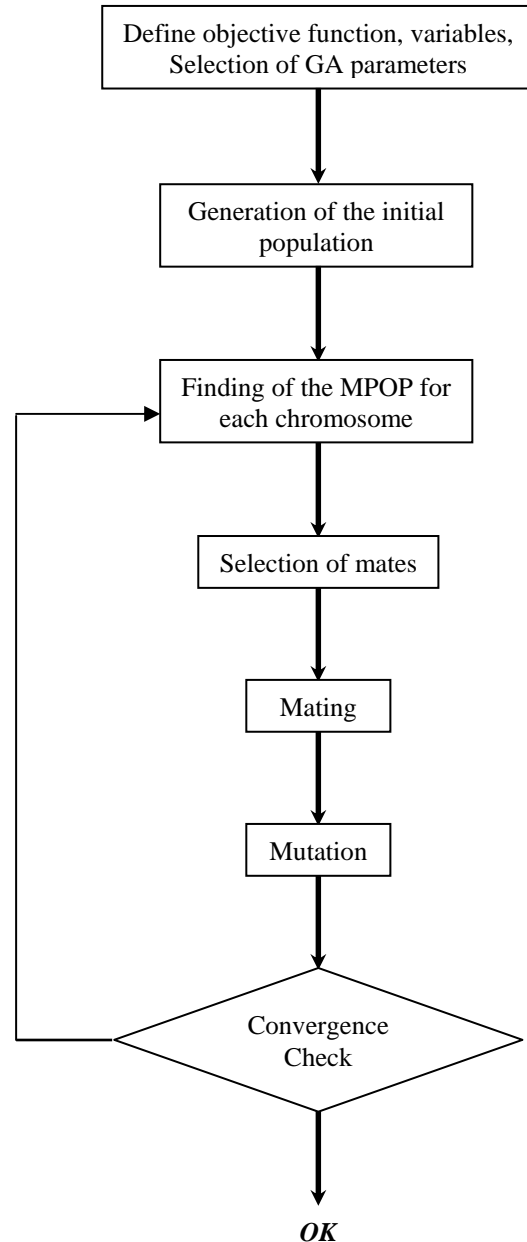


Fig. 3. Flowchart of the adopted GA.

The goal is to solve an optimization problem where we seek 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 a chromosome in the form of an array of variable values to be optimized.

Since our equation to be optimized is a function only of current and voltage, so the chromosome variables are very clear.

$$\text{chromosome} = [I, V] \quad (10)$$

Our goal is to find the global maximum value of $f(I, V)$.

To start the GA, we have to define an initial population of N_{pop} which is a matrix that represents the population with each row in the matrix being a $1 \times N_{var}$ array (chromosome) of continuous values. Given an initial population of N_{pop} chromosomes, the full matrix of $N_{pop} \times N_{var}$ random values is generated by the following statement:

$$\text{pop} = \text{rand}(N_{pop}, N_{var}) \quad (11)$$

We start solving equation (1) by filling the $N_{pop} \times N_{var}$ matrix with uniform random values ranging from zero to the value of the open circuit voltage on one axis and from zero to the short circuit current on the other axis. In our case $N_{pop} = 8$.

The process of natural selection occurs at each iteration of the algorithm. Of the N_{pop} chromosome of any generation, only the top N_{keep} are kept for mating and the rest are discarded to make room for new offspring. In our case $N_{keep} = 4$ most fit chromosomes from mating pool. Two mothers and fathers pair in some random fashion. Each pair produces two offspring that contain traits from each parent. The parents survive to be part of the next generation. The process described previously is iterated until an acceptable solution is found.

After the run, the algorithm gives the real maximum value of the fitness function (1) according to the tables and the plots shown next.

5. RESULT ANALYSIS & DISCUSSION

The program has been developed and executed under MATLAB system. The resulted values of this optimization problem are reported in Tables I, II and III.

TABLE I
OPTIMIZATION RESULTS WHEN INSULATION IS VARYING AT
TEMPERATURE OF 25°C

Insulation [W/m ²]	V _{max} [V]	I _{max} [A]	MPOP [W]
1000	35.8020	4.4729	160.1399
900	35.7571	4.0246	143.9091
800	35.6680	3.5767	127.5736
700	35.5347	3.1281	111.1551
600	35.3572	2.6778	94.6813
500	35.0471	2.2310	78.1897
400	34.6486	1.7817	61.7324
300	33.9849	1.3356	45.3891
200	33.0118	0.8874	29.2937
100	31.1105	0.4413	13.7280

TABLE II
OPTIMIZATION RESULTS WHEN TEMPERATURE IS VARYING AT
INSULATION OF 1000 W/m²

Temperature [°C]	V _{max} [V]	I _{max} [A]	MPOP [W]
0	39.6006	4.1263	163.4032
15	37.3214	4.3343	161.7613
20	36.5617	4.4036	161.0033
25	35.8020	4.4729	160.1399
30	35.0857	4.5367	159.1716
35	34.3251	4.6059	158.0981

TABLE III
OPTIMIZATION RESULTS WHEN TEMPERATURE AND INSULATION ARE
VARYING SIMULTANEOUSLY

Temperature [°C]	Insulation [W/m ²]	V _{max} [V]	I _{max} [A]	MPOP [W]
8	350	39.0063	1.3773	53.7235
16	500	38.3143	2.0603	78.9384
24	650	37.1338	2.7943	103.7637
32	800	35.5575	3.5852	127.4798
40	950	33.7946	4.4217	149.4303

These tables consider simulation results of many sample runs of the GA technique. We see clearly the variation of the MPOP with respect to either insulation or temperature and both of them with great accuracy.

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

In order to see clearly the results of this optimization study, the following figures plot the multiple variation of both current with respect to voltage and power with respect to voltage.

The maximum power operating point MPOP of each curve is represented by "o" and it shows the maximum value of power (current and voltage) that the module can supply instantaneously under different climatic conditions.

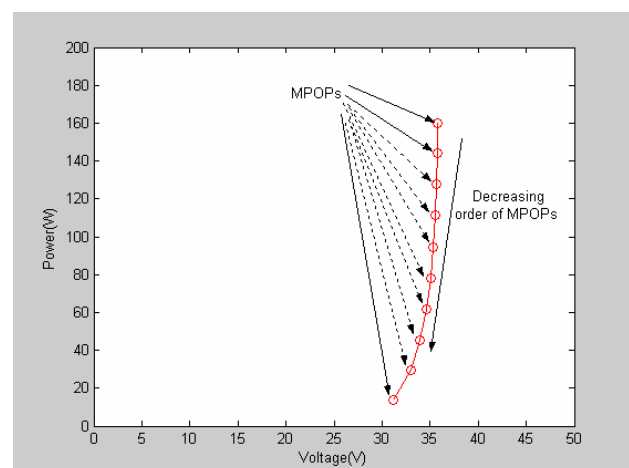


Fig. 4. MPOPs: variation with insulation from P-V characteristics.

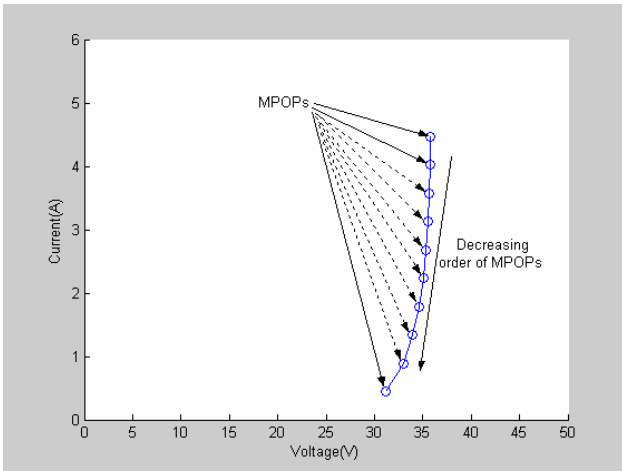


Fig. 5. MPOPs: variation with insulation from I-V characteristics.

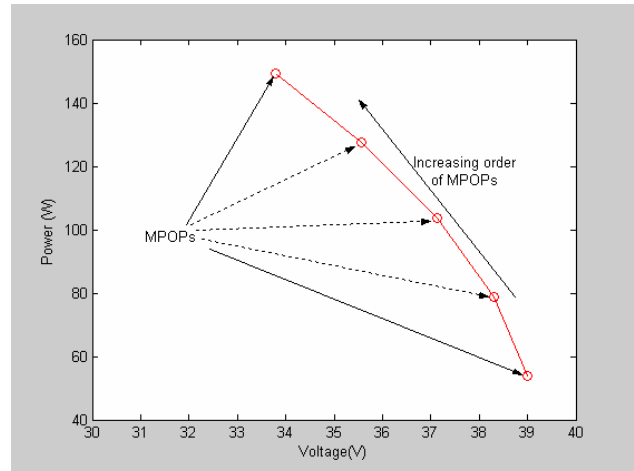


Fig. 8. MPOPs: variation with insulation and temperature at the same time from P-V

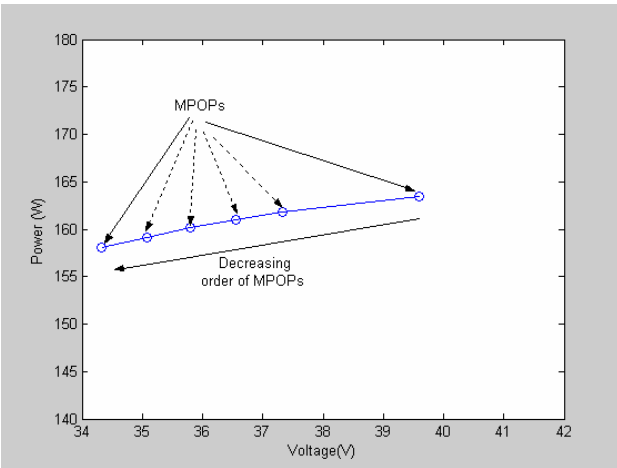


Fig. 6. MPOPs: variation with temperature from P-V characteristics.

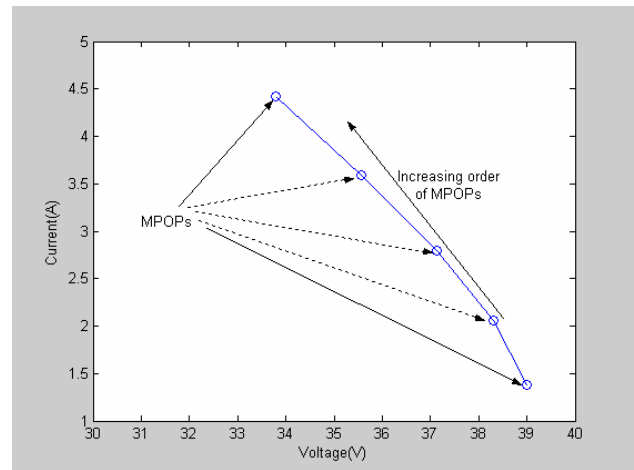


Fig. 9. MPOPs: variation with insulation and temperature at the same time from I-V characteristics

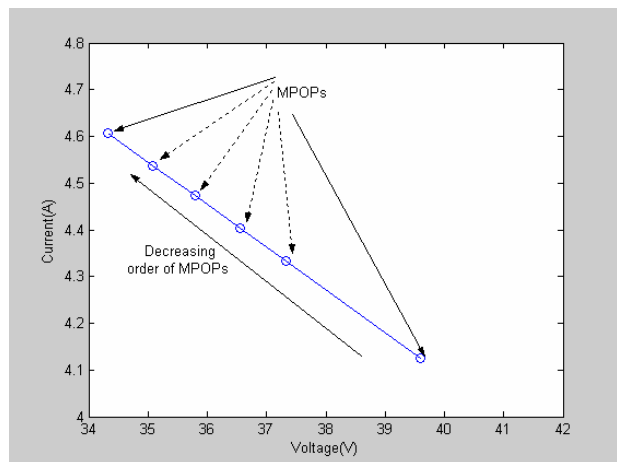


Fig.7. MPOPs: variation with temperature from I-V characteristics.

6. CONCLUSION

This study presents a genetic algorithm, which calculates instantaneously the maximum power operating point (MPOP) of a PV module in order to maximize the profit in terms of the power issued from the PV module. Because of the instantaneous changing character of both the I-V and the P-V characteristics, this heuristic method is used to seek the real maximum power and to avoid the wrong values of local maxima. In fact, the implementation of this technique reduces considerably the time of the computing process and yields to more results which are precise to a great extent.

The obtained results of this investigation are reported in Tables I, II and III and depicted in Fig. 4 to 9.

It is worth to note that, this powerful stochastic identification approach can find its application within many other models like the simplified model and the two diodes model. From the presented study, we can say with confidence that the GA approach is a promoting tool that

is useful for optimization of multi-dimensional engineering systems even with multi-objective functions.

APPENDIX

This appendix contains the electrical characteristics of The BP 4160S photovoltaic module.

Electrical Characteristics BP 4160S

Maximum power (Pmax)	160W
Voltage at Pmax (Vmp)	35.4V
Current at Pmax (Imp)	4.52A
Warranted minimum Pmax	152W
Short-circuit current (Isc)	4.9A
Open-circuit voltage (Voc)	44.2V
Temperature coefficient of Isc	$(0.065 \pm 0.015)\% / ^\circ\text{C}$
Temperature coefficient of voltage	$-(160 \pm 20)\text{mV}/^\circ\text{C}$
Temperature coefficient of power	$-(0.5 \pm 0.05)\% / ^\circ\text{C}$
NOCT	$47 \pm 2^\circ\text{C}$
Maximum series fuse rating	20A (H version) 15A (S,L versions)
Maximum system voltage	600V (U.S. NEC rating) 1000V (TÜV Rheinland rating)

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