Study of optimization methods for monitoring the maximum power of a solar system

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ABSTRACT

Electricity generation systems based on renewable energy sources require the tracking of the maximum power point using optimization algorithms because the photovoltaic systems are characterized by their linear nature and their efficiency depends on the level of solar irradiation and temperature, which decreases the efficiency of operation efficiency photovoltaic generators**.** These algorithms allow tracking the maximum power produced by solar panels under different temperature and illumination levels. This paper considers three optimization algorithms namely, the Perturb and Observe optimization, the Incremental Conductance approach and the Genetic Algorithm in order to analyze their performance under varying irradiation conditions.

Keywords: Solar system, Optimization algorithms, MPPT, Performance, Simulation.

I. Introduction

Nowadays, the demand for electrical energy is increasing all over the world. Indeed, it even seems that the trend of energy consumption will continue to increase, mainly due to economic growth and per capita electricity consumption [1].

So, to meet this demand for energy, the use and installation of renewable resources has been considerably encouraged in order to overcome, on the one hand, the disadvantages recorded from the use of fossil fuels and on the other hand thanks to their advantages, including their low cost, their non-polluting operation and their low cost maintenance [2, 3].

One of the most efficient renewable energy sources is solar energy because it is suitable for many different applications. However, photovoltaic (PV) cells are characterized by their linear nature and their efficiency depends on the level of solar irradiation (E) and temperature (T), which decreases the efficiency of operation efficiency GPV generators [4]. Therefore, a maximum power point tracking (MPPT) controller is provided in the installations in order to extract the maximum power and improve the lifetime of the photovoltaic systems [5, 6]. However, several conventional, modern and metaheuristic MPPT control strategies have been developed using only the measurement of current and voltage at the output of the GPV in order to improve the operating efficiency and optimize the energy production of photovoltaic conversion systems [7-12].

Among all these methods, three have been considered in this work and the performance of each of them has been analyzed and discussed under the effect of the change in irradiation.

The rest of this paper is organized as follows. In section 2, the details of the MPPT problem formulation are described. In section 3, the theory of each method considered is also presented. The simulation results are presented and discussed in Section 4. Finally, a conclusion is presented before the reference section.

II. Modelling of PV module and MPPT méthodes

The studied system shows by Fig.1 consists of a photovoltaic generator, which operates at its maximum power thanks to a boost inverter equipped with a follower (MPPT).

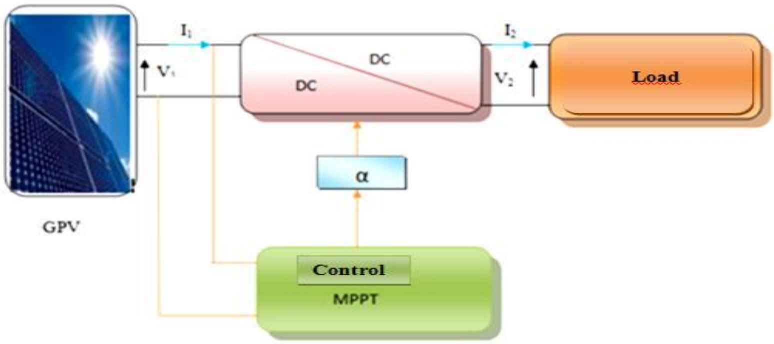


Figure 1. Bloc circuit of studied configuration

II.1. Modeling of the PV module

A photovoltaic system consists of a large number of identical solar cells connected in series and parallel to increase its voltage and power output [13, 14]. The single-diode model of the equivalent circuit that describes the photovoltaic module is shown in Figure 2 and is the most widely used] in the literature [15, 16].

The PV model contains a single diode, a current source, an equivalent series resistance RS and a shunt resistance RSH. The presence of RSH is caused by the p-n junction current leakage the cell.

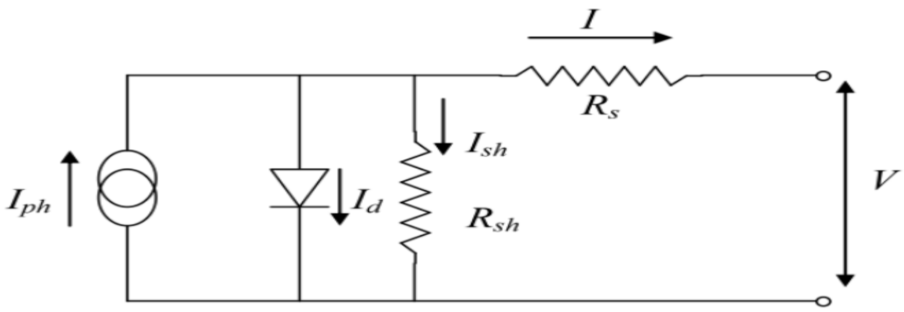


Figure 2. Equivalent circuit of photovoltaic model.

Considering the Fig.1, it is possible to write the following equation:

$$I_{ph} = I + I_d + I_{sh} \tag{1}$$

The junction current I_d is given by:

$$I_d = I_0(e^{q\left(\frac{V+R_S I}{nKT}\right)} - 1) \tag{2}$$

The current in the resistor R_{sh} is given by:

$$I_{sh} = \frac{V+IR_s}{R_{sh}} \tag{3}$$

From equation (1), we get the current expression I:

$$I = I_{ph} - I_d - I_{sh} \tag{4}$$

By replacing in (4) the currents Id and I_{sh} by their expressions respectively in (2) and (3) we obtain:

$$I = I_{ph} - I_0(e^{q\left(\frac{V+R_sI}{nKT}\right)} - 1) - \frac{V+IR_s}{R_{sh}} \tag{5}$$

Where, I is the cell current [A], V is the cell voltage [V], I_p is the photo-current of cell [A], R_s is the series resistance of the cell [Ω], R_{sh} is the shunt resistance of the cell [Ω], Tis the temperature of the cell [°K], q is the charge of the electron $e = 1.6 * 10^{-19}$[C], is I_0: the saturation current [A], K is the constant of Boltzmann ($1.3854*10^{-2}$ [JK^{-1}]) and nis the non-ideality factor of the diode.

The specialized PV module, namely the Soltech 1STH-215-P, whose parameters are shown in Table 1, is used to obtain the V-I and P-V graphs shown in Figure 2. Figure three shows that the PPM is significantly influenced by the three levels of solar irradiation identified in this work for the analysis of the system behavior: 1000W/m^2 (standard irradiation), 700W/m^2 and 500W/m^2.

Table 1. Parameters of the Soltech 1STH-215-P	Values
Maximum power (W)	213.15
Maximal voltage (V)	29
Maximal current (A)	7.35
Short circuit current (A)	7.84
Open circuit voltage (V)	36.3
Parallel strings	1
Series-connected modules per string	1

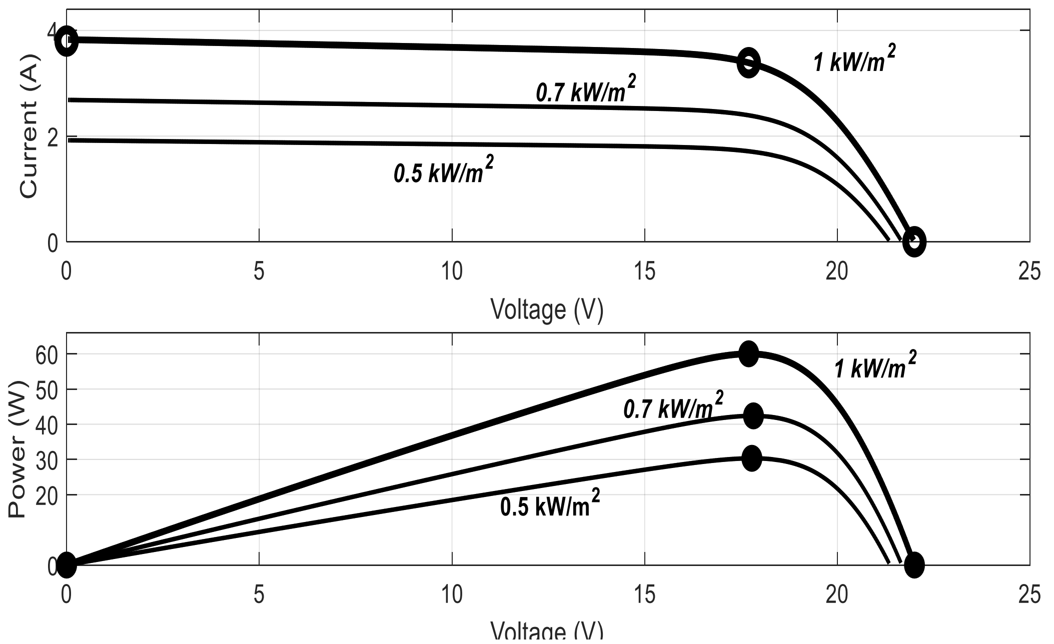


Figure 3. I=f(V) and p=f(V) characteristics.

II.2. Boost converter model

A boost converter is a switching power supply that converts a DC voltage into another DC voltage of higher value. PV-powered systems often use multiple panels in series to provide a sufficiently high voltage level [17].

A boost converter, or parallel chopper, is a switching power supply that converts one DC voltage into another DC voltage of higher value. Figure 4 shows the basic diagram of a boost converter [18].

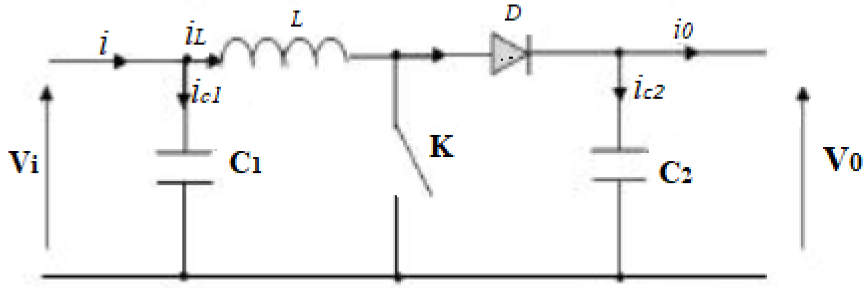


Figure 4. Model of a Boost converter.

III. MPPT methods

III.1. MPPT Perturb and Observe

The Maximum Power Point Tracking control makes it possible to search for the optimum operating point of the PV generator which depends on the weather conditions, so as to continuously maximize the power at the output of the PV array [19, 20] . The principle of Perturb and Observe (P&O) control consists in causing a disturbance of low value on the voltage, which generates a variation of the power. Fig. 5 shows the flowchart of the P&O type MPPT control. To determine the power at any time, two sensors are needed to measure the voltage and current values.

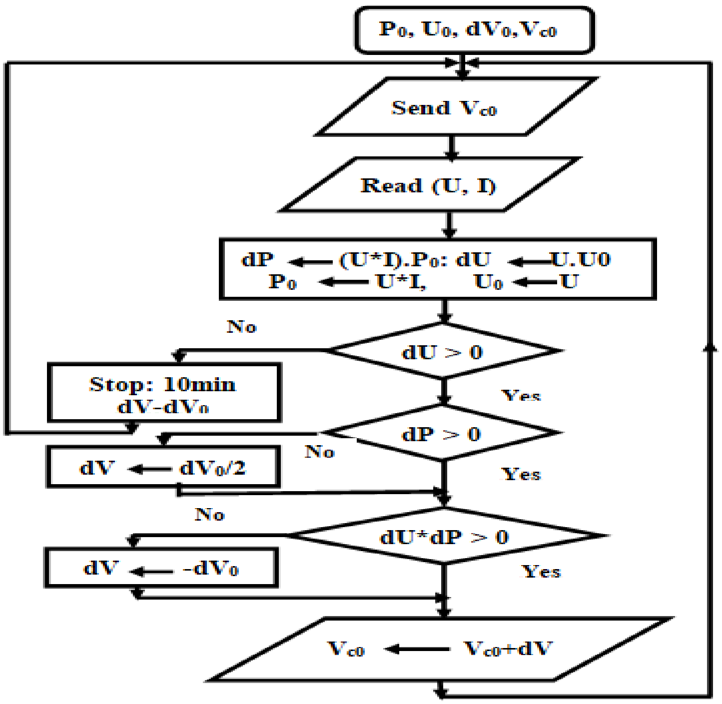


Figure 5. Organizational chart of the P&O algorithm.

III.2. Incremental conductance

This method is also widely used [21, 22]. This algorithm is based on calculating the derivative of the output power of the panel with respect to the voltage. This derivative is zero at the point of maximum power, positive left and negative right point MPPT.

$$\begin{cases} P = V * I \\ \dfrac{dP}{dV} = 0 \ldots\ldots\ldots P = P_{Max} \\ \dfrac{dP}{dV} \langle 0 \ldots\ldots\ldots\ldots P \langle P_{Max} \\ \dfrac{dP}{dV} \rangle 0 \ldots\ldots\ldots\ldots P \rangle P_{Max} \end{cases} \quad (6)$$

The partial derivative $\dfrac{dP}{dV}$ is given by:

$$\frac{dP}{dV} = I + V\frac{dI}{dV} \approx I + V\frac{\Delta I}{\Delta V} \quad (7)$$

Equation (4) can be written as follows:

$$\begin{cases} \dfrac{dI}{dV} = -\dfrac{I}{V} \ldots\ldots\ldots P = P_{Max} \\ \dfrac{dI}{dV} \langle -\dfrac{I}{V} \ldots\ldots\ldots\ldots P \langle P_{Max} \\ \dfrac{dI}{dV} \rangle -\dfrac{I}{V} \ldots\ldots\ldots\ldots P \rangle P_{Max} \end{cases} \quad (8)$$

So, to reach the point of maximum power, we compare the instantaneous conductance $(g = I / V)$ to the incrimination of the conductance $(\Delta g = \Delta I / \Delta V)$.The size of the increment determines the speed of MPPT tracking. Fast tracking can be achieved with a larger increment, but the system could not operate exactly at MPPT and oscillates around it. The algorithme is given by Fig. 6.

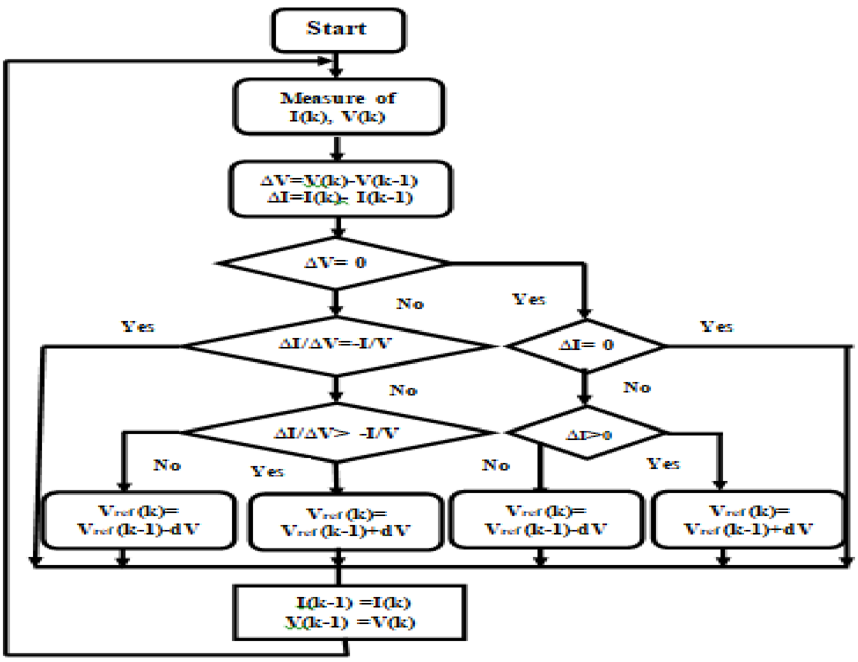


Figure 6. Algorithm of the incremental command of the conductance.

III.3. Genetic Algorithm

The genetic algorithm (GA) is a nature-inspired meta-heuristic optimization approach, which was proposed by Holland in1975 [23]. This algorithm is suitable for solving any optimization problem based on the principles of biological evolution. The algorithm starts with a randomly generated solution called chromosomes, which are recombined or mutated, puisted to define a predefined fitness function. GA finds the best solution by breeding, crossover and mutation operations [24]. The crossover factor (CF) is known as the probability of chromosome pairs to produce offspring, while the mutation factor (MF) describes the probability of changing the state of a randomly selected binary bit of a chromosome from 0 to 1 and vice versa. The individual steps of GA are as given in Algorithm [25].

Algorithm
Step 1: Select CF and MF
Step 2: Initialize population of chromosomes
Step 3: Set iteration i=1
Step 4: Calculate fitness function value of each chromosmes $F_p^i=f(X_p^i).\aleph p$ *and find the index of best chromosomes* $X_p^i=.\aleph p$.
Step 5: Pertom the three process (selection of chromosomes, crossover of parents and mutation of offsprings) to generate a new set of chromosomes $X_p^i=.\aleph p$.
Step 6:Evaluate fitness function of each particle after updating $F_p^{i+1}=f(X_p^{i+1}).\aleph p$
Step 7: if $F_p^{i+1} \langle\ F_p^i$ *then set b=b+1*
Step 8: if $i^1 \langle$ *Maxite then i=i+1 and goto step 5 eslse goto step 9*
Step 9: Print optimum solution as X_b^i

III.4. Results and Discussion

The studied MPPTs have been tested on a converter chain composed of a photovoltaic solar panel connected to load resistors via a step-up converter with MPPT controller, as it has been illustrated previously by in figure 1. The output voltage and current of the PV system are supplied to the MPPT block, and then the digital controller generates a PWM duty to control the switch of the power converter with the predefined frequency. In other words, the MPPT controller is executed according to the duty cycle generated from the MPPT block.

The test used for the validation of the study consisted in considering a variable solar irradiation profile and a constant temperature equal to its standard value as shown in figure 7. Under these conditions, the three MPPT methods have been considered in turn, which has allowed us to visualize for each case the power produced by the photovoltaic generator, the power absorbed by the load as well as the average value of the latter for the Perturb and Observe, Incremental Conductance and Genetic Algorithm optimization methods as shown in figures 8 a, b and c respectively. The analysis of these last curves shows that the Genetic Algorithm optimization method offers better performances in terms of speed and efficiency. However, the other two methods have almost the same performance. Finally, figure 9 represents the superposition of the three average powers absorbed by the load where zooming in on the essential places is shown showing the superiority of the Genetic Algorithm method over the other two.

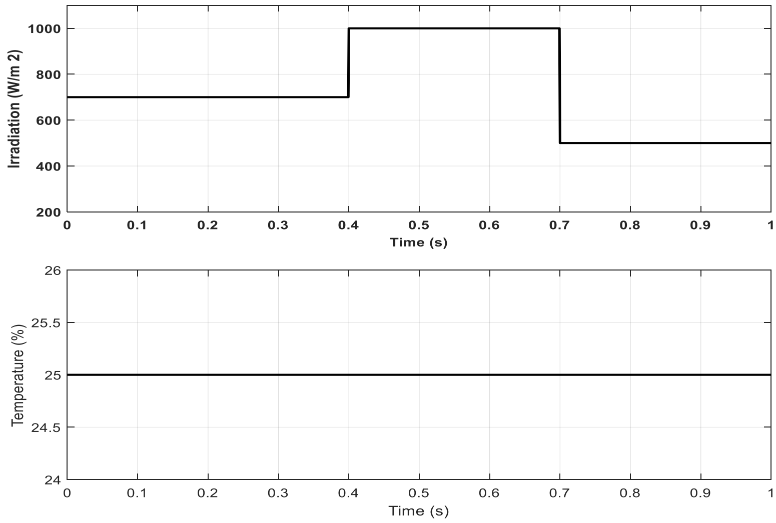
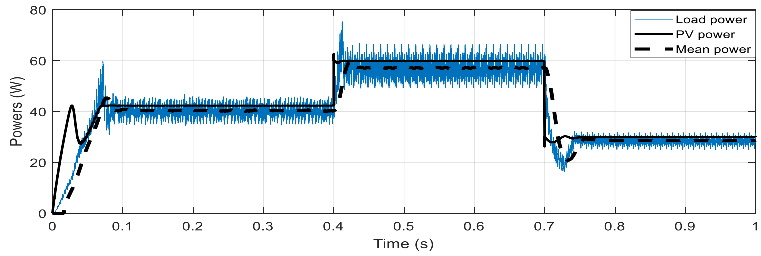
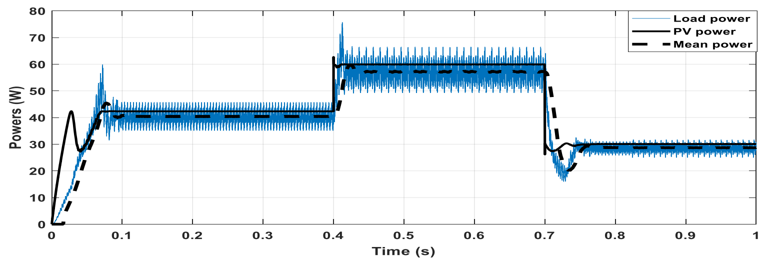


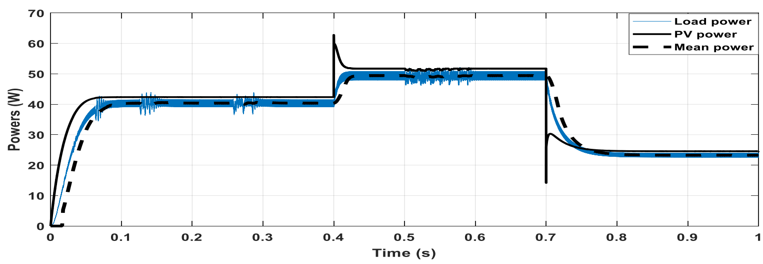
Figure 7. Irradiation and Temperature Profil.



a) Power with Perturb and Observe.



b) *Power* with Incremental Conductance.



c) Power with Genetic Algorithm.

Figure 8. Load and mean load Powers.

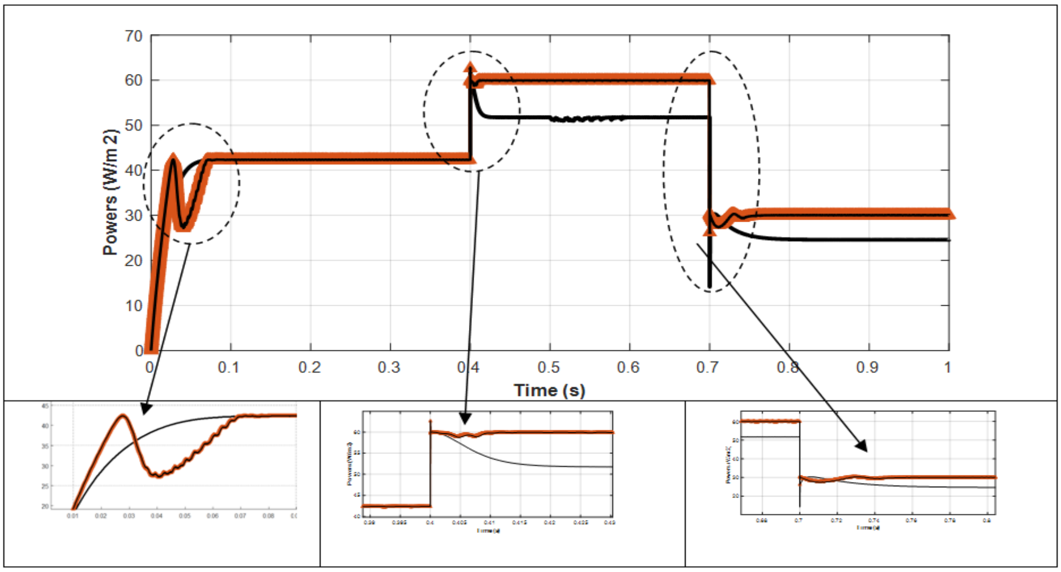


Figure 9. Superposition of the powers obtained by the three methods.

IV. Conclusion

In this paper, three maximum power tracking approaches have been studied, simulated and analyzed to evaluate the performance and operating efficiency of the photovoltaic system. For this purpose, an irradiance change profile with three distinct irradiance levels, one of which represents the standard, was considered for the comparison of the tested MPPT methods. The simulation results show that the MPPT based on genetic algorithm is exceptional in terms of response time and is better than the others are. En effet, grace au bloc suivi de puissance maximal, on constate que malgre le changement des conditions climatiques, le systeme de conversion assure l'extraction du maximum de la puissance developée par les panneaux solaires. Indeed, thanks to the block followed by maximum power, we see that despite the change in climatic conditions, the conversion system ensures the extraction of the maximum power developed by the solar panels.

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