Comparative Study Between MPPT Control By Incremental Conductance And Perturb And Observe Under Different Climatic Conditions.

Houda RHILANE, Insaf EL IDRISSI, Abdelhadi EL MOUDDEN

Abstract: The aim of this paper is to study and analyze the ability of the MPPT control designed for a photovoltaic system to ensure the search and continuity of the maximum power point at the output of a photovoltaic generator, under standard test conditions as well as during climatic changes (Illumination and temperature). For comparison, we have dealt with two different methods, the incremental conductance and the perturbation and observe. Both methods allowed the system to maintain its maximum power point in each case of study but with some differences. For this, we chose MATLAB/Simulink as the platform used to perform simulations of all the study cases.The emphasis was put on obtaining a system that presents a better adaptation between its different components: photovoltaic generator (GPV) and load. The PV system used in this study consists of a photovoltaic array that - under standard test conditions (T=25°C and G=1000W/m²) - is characterized by a peak power of 59.5 W, an optimal voltage of 17.5V and a current of 3.4A.

Index Terms: MPPT, GPV, Incremental conductance, Perturb & Observe, Matlab-Simulink.

1 Introduction

When the photons forming the sunlight arrive on the surface of the photovoltaic cell, they create a displacement of charges (electrons), thus a potential difference, so the photovoltaic cell transforms the light energy into electrical energy in the form of continuous current (DC), in turn, the current flow creates an electromotive force at the terminals of the cell, which corresponds to the photovoltaic effect. The quality of energy produced depends on the material that forms the photovoltaic cell and its properties.

2 Materials and Methods

2.1 Schematic diagram of PV System with MPPT

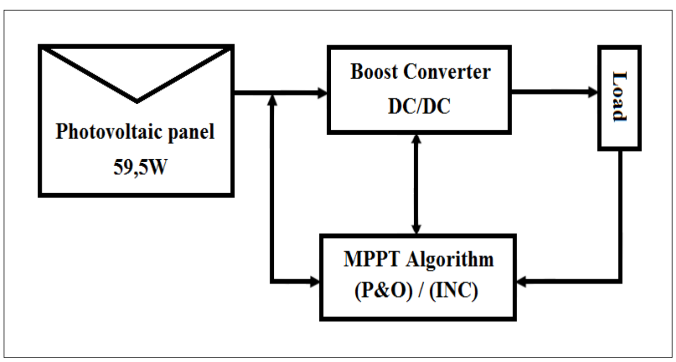

Figure 1: *PV system with MPPT*

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2.2 Photovoltaïc system

A photovoltaic panel made of a semiconductor material absorbs the energy of the photons coming from the solar rays and transforms it into electrical energy, because when they arrive on the surface of the panel, they move the electrons which in turn create a potential difference and thus a direct current (DC), the latter depends on the material that forms the photovoltaic cells [1][2][3][4][5].

2.3 Equivalent diagram of the photovoltaic cell

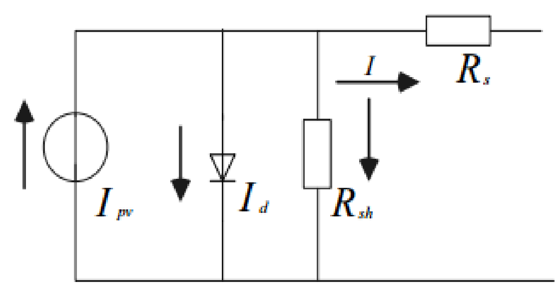

Figure 2: *equivalent circuit of a pv cell*

The equivalent model of a photovoltaic cell [6] is formed by a current generator $\mathbf{I_{ph}}$, a diode, a resistance $\mathbf{R_s}$ corresponding to the losses by Joule effect, as well as a shunt resistance $\mathbf{R_{sh}}$ which represents a leakage current between the upper grid and the back contact [7][8].

$$I = I_{pv} - I_0\left[e^{\frac{q(V+IR_S)}{AKT}} - 1\right] - \frac{V+IR_S}{R_{sh}} \qquad (1)$$

I_{pv}: The PV short-circuit current
I_0: Saturation current of the diode.
R_{sh}: The PV battery parallel resistance.
q : Elementary charge, = 1.60217646×10 - 19 C.
V: Cell Output Voltage (V).
k : Boltzmann constant, = 1.3806503×10 - 23 J/K.
R_s , R_{sh}: Cell Series and Shunt Resistance (Ohms).

2.4 MPPT technique

It serves to improve the efficiency of the photovoltaic system by pushing it to seek the optimal operating point, regardless of the weather conditions. This is done by adapting the photovoltaic source to the load for all the conditions mentioned in order to obtain maximum energy production.MPPT control is often used in photovoltaic systems to help the system to deliver maximum power when variations in temperature and irradiance occur. Since the conversion efficiency of the PV system remains low, MPPT control is important for optimal and efficient production. There are several techniques for monitoring the maximum power point, such as the technique, “Fuzzy logic”, “Perturb and observe” and “incremental conductance” [9].

Incremental conductance

Incremental conductance is one of the methods used to help PV systems find the maximum power point by perturbing the operating point until the maximum power point (MPP) is reached, once the MPP is found, the perturbation stops, otherwise when the latter is not reached, the operating point must be disturbed in the direction that can be calculated with the help of the relation between dI/dV and -I/V, which comes from the fact that the ratio dP/dV is negative when the MPP is on the left side of the MPPT and is positive on its right side [10][11][12][13].

$$\frac{dI}{dV} = -\frac{I}{V} \quad \text{at the MPP} \quad (2)$$

$$\frac{dI}{dV} > -\frac{I}{V} \quad \text{left of the MPP} \quad (3)$$

$$\frac{dI}{dV} < -\frac{I}{V} \quad \text{right of the MPP} \quad (4)$$

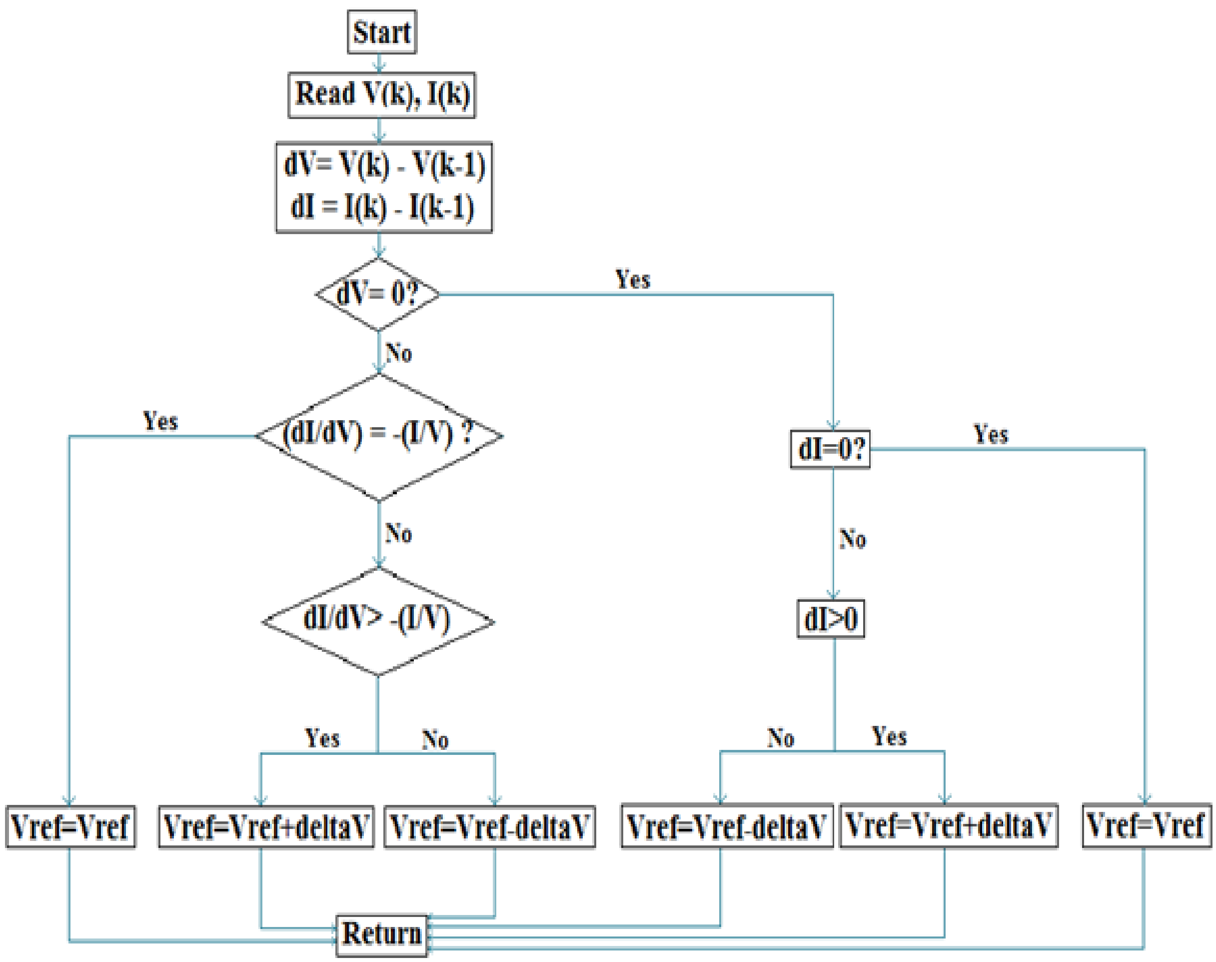

Figure 3: *Incremental conductance algorithm flowchart*

Perturb and Observe

There are many algorithms, of which the “P&O” is one, its simplicity and generic nature makes it probably the most used. As its name indicates, this method is based on the perturbation of the operating point in order to obtain the MPP. This is directly related to the variation of the power dP. For a given point, we consider two cases: if this point is

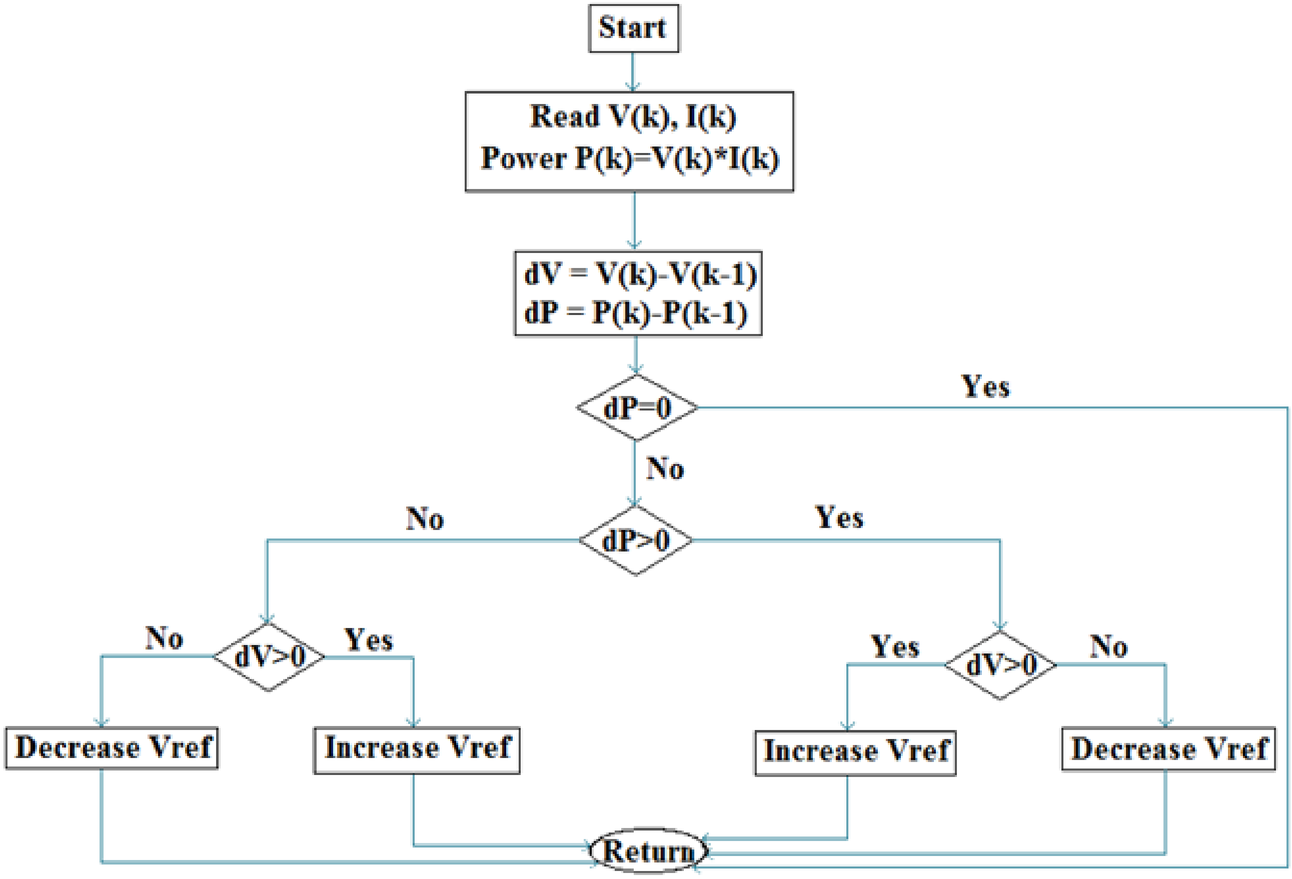

***Figure 4:** Perturb and Observe algorithm flowchart*

3 RESULTS AND DISCUSSION

3.1 Variations in the characteristics (P/V) and (I/V)

Perturbed in any direction and dP>0, we know that the operating point is moving towards the MPP, otherwise if dP<0, we know that the operating point is moving away from the MPP, something that requires the algorithm to reverse the direction of the perturbation. The following figure shows the "P&O" algorithm [14,15,16].

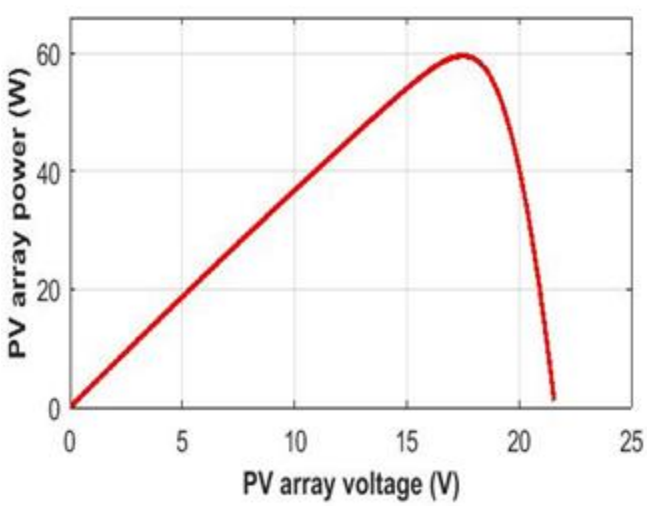

Figure 5: Characteristic P/V

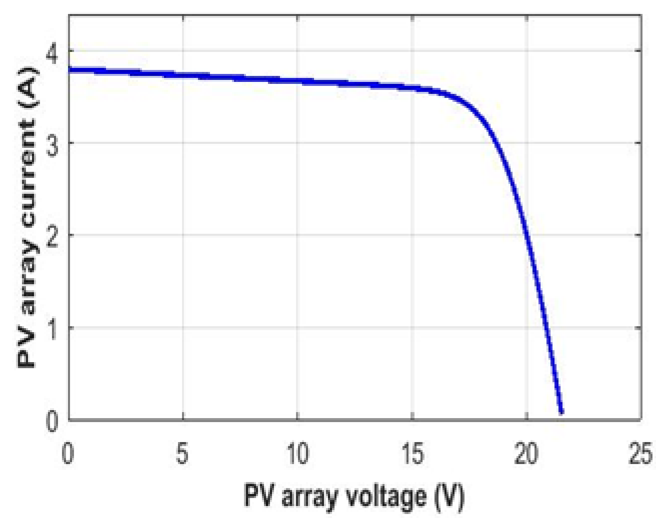

Figure 6: Characteristic I/V

The curve P(V) shows the maximum power point that the MPPT control can reach, which in our case is P=59,5W. The curve (I/V) shows the current and voltage corresponding to the maximum power point I_{mpp} = 3,4A and V_{mpp} =17,5V.

3.2 Variations in the characteristics (P/V) and (I/V) based on climate change

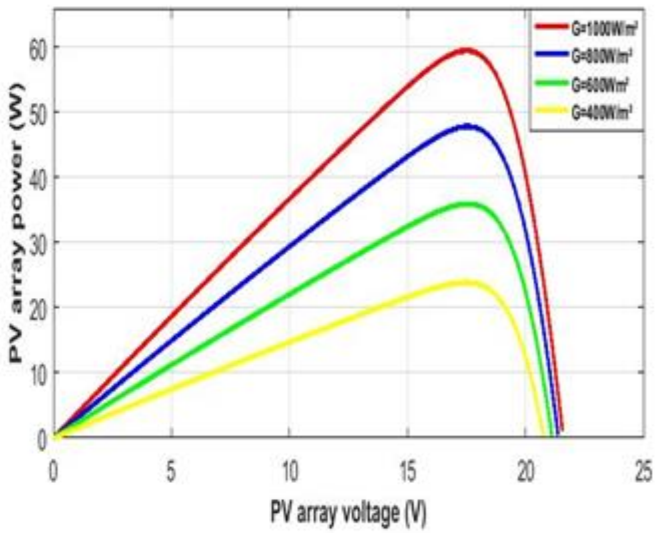

Figure 7: The P/V characteristic for different irradiations

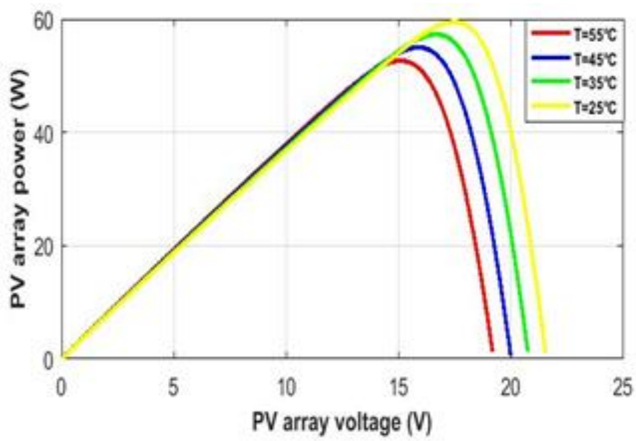

Figure 8: The P/V characteristic for different temperatures

The figure 7 shows the power of the photovoltaic panel as a function of voltage for different values of irradiation, we note the great influence of the latter on the production of the photovoltaic panel such that the power decreases proportionally with the decrease in irradiation. The maximum power P_{mpp} corresponding to the irradiation G=1000W/m² is P=59,5W, equal to P=47,85W for G= 800W/m², is of P=36,97W for G=600W/m² and equal to P=23,9W for G=400W/m². The voltage corresponding to the MPP for all irradiation values remains the same $V_{MPP=}$17,5V. Contrary to the results obtained for the figure illustrating the P/V characteristic for different irradiations, figure 8 shows us that when the temperature increases the output of the PV generator decreases, so by increasing the temperature the output power of the PV panel decreases. For the temperature values shown in figure 8, for T=25°C the maximum power P_{mpp} =59,5W, for T=50°C the maximum GPV output power P_{mpp} =53,81W, for T=75°C the maximum GPV output power P_{mpp} =47,73W, and for T=100°C the maximum GPV output power P_{mpp} =41,32W. Besides the power, the output voltage of the GPV also decreases when the temperature increases.

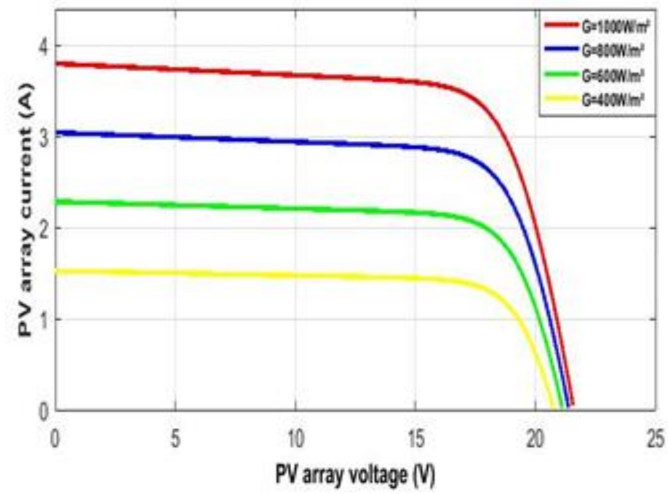

Figure 9: The I/V characteristic for different irradiations

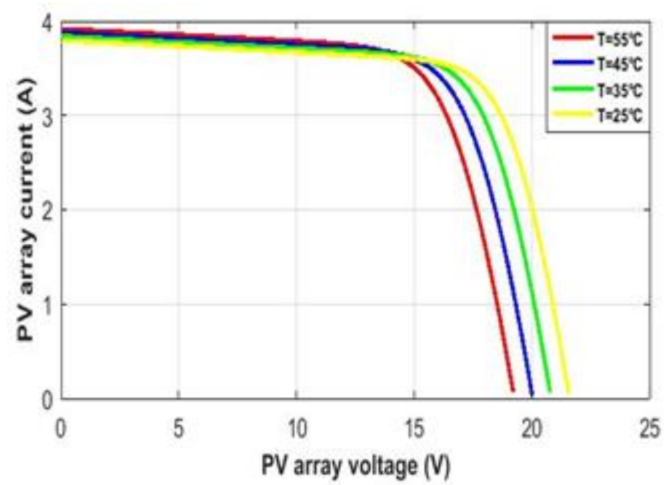

Figure 10: The I/V characteristic for different temperatures

As for the impact of the change of the irradiation on the output power of the photovoltaic panel, the I/V characteristic for different irradiations above shows that the output current decreases when the irradiation decreases. For our PV generator the current is equal to I_{MPP}=3,4A for G=1000W/m², I_{MPP}= 2,77A for G=800W/m², I_{MPP}=2,08A for G= 600W/m² and I_{MPP}=1,37A for an irradiation of G=400W/m². The current is also impacted by the temperature change, like the GPV output power, it also decreases with increasing temperature. The current corresponding to the maximum power point is I_{MPP}=3,4A for T=25°C, I_{MPP}=3,47A for T=50°C, I_{MPP}=3,52A for T=75°C and I_{MPP}=3,55A for T=100°C. On the other hand the voltage of the photovoltaic panel decreases as the irradiation decreases [17][18][19][20]. This following part represents the results of simulations with the application of the MPPT using a setup created by the Matlab/simulink tool. This assembly is formed by:

- A photovoltaic panel of 59.5W
- A boost converter DC/DC
- A MPPT based on incremental conductance
- A 10 Ω resistor

3.3 Simulation results

1. The following figures were obtained under standard conditions (1000W/m² and 25°C). These simulation results represent the characteristics at the output of the photovoltaic panel and at the output of the boost converter controlled by the MPPT Incremental conductance, for:

$$C_e = 1\text{mF} \quad C_s = 3{,}227\mu\text{F} \quad L = 1{,}45\text{mH} \quad R_s = 10\Omega$$

-Characteristic curves of the voltage, current and power at the output of the GPV by the “INC” and “P&O”:

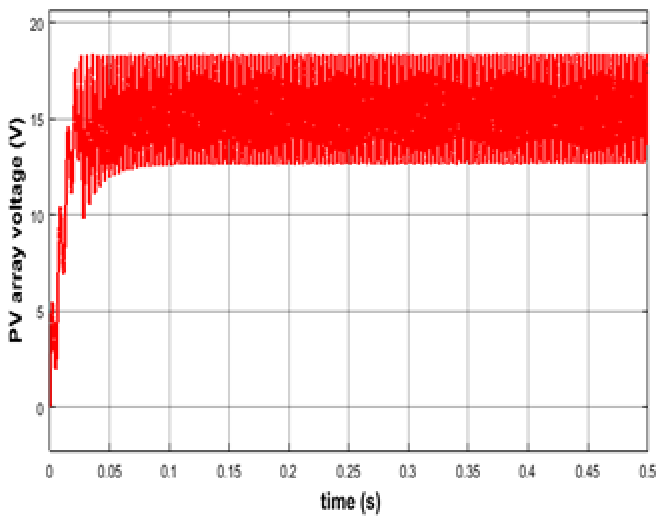

***Figure 11:** V_{pv} (Inc) voltage result (V) according to time(s)*

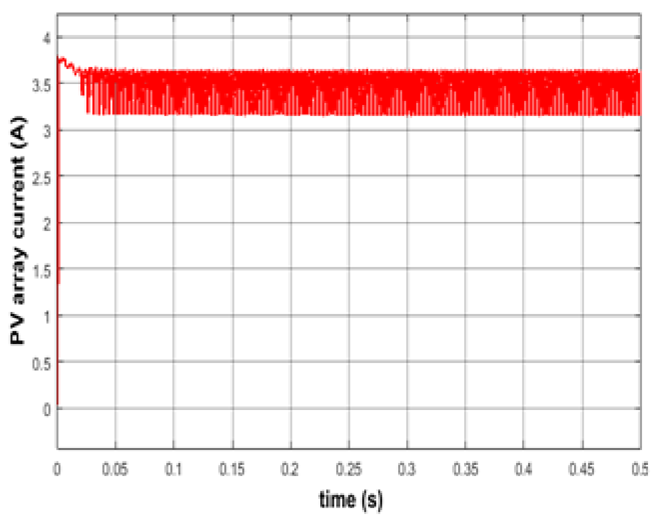

***Figure 12:** I_{pv} (Inc) current result (A) according to time(s)*

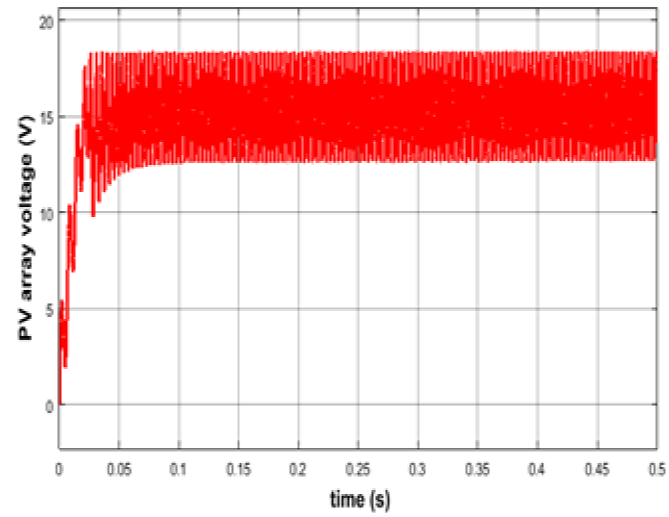

***Figure 13:** P_{pv} (Inc) power result (W) according to time(s)*

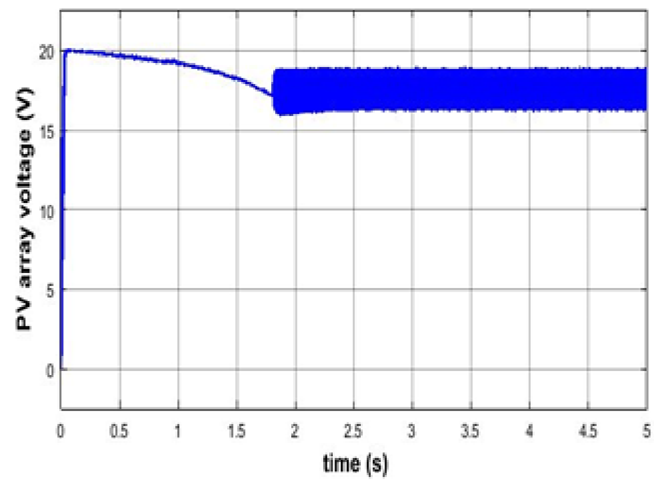

***Figure 14:** V_{pv} (P&O) voltage result (V) according to time(s)*

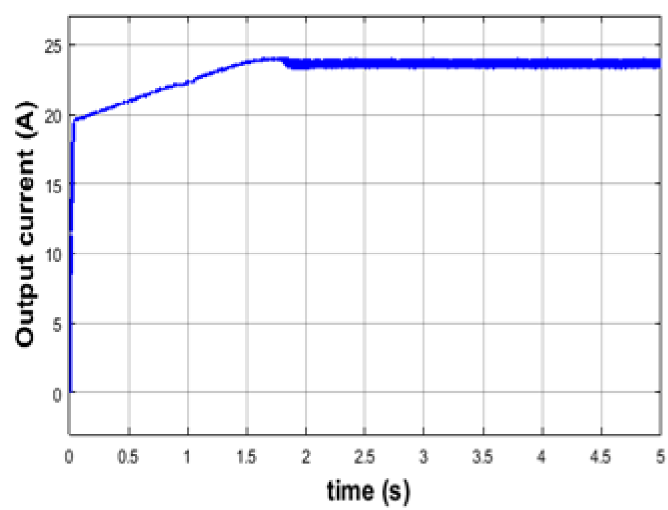

***Figure 15:** I_{pv} (P&O) current result (A) according to time(s)*

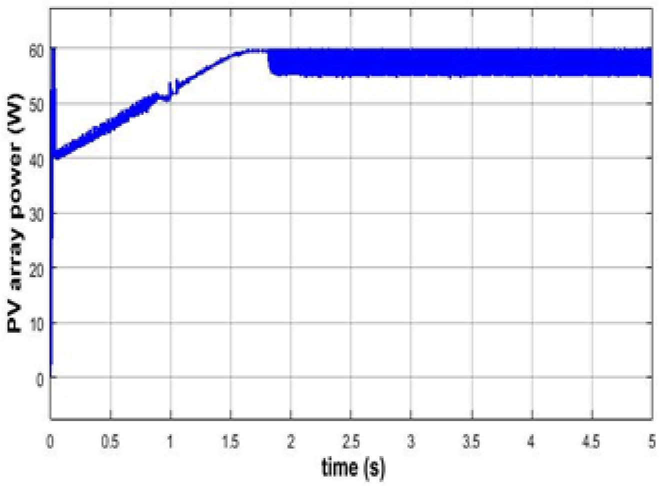

Figure 16: ***P_{pv} (P&O) power result (W) according to time(s)***

3.4 Characteristic curves of the voltage, current at the output of the boost converter by the "INC" and "P&O".

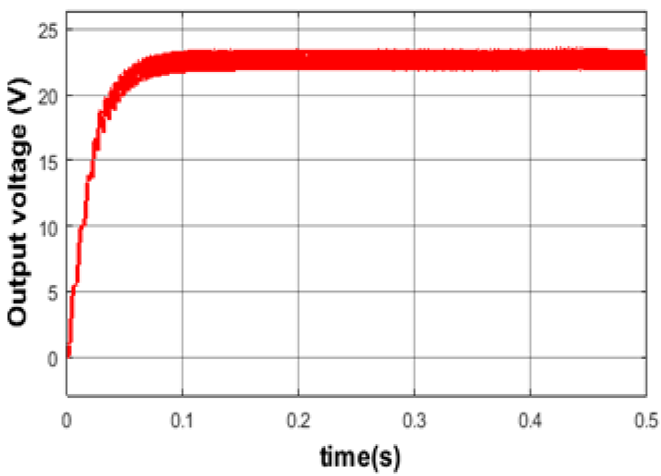

Figure 17: ***V_s (Inc) voltage result (V) according to time (s)***

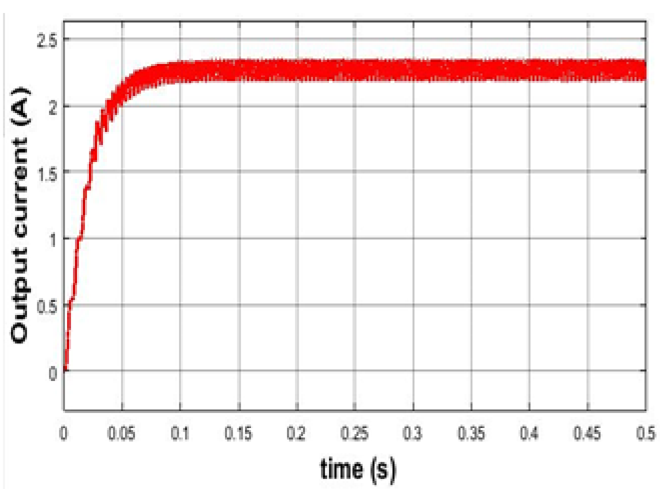

Figure 18: ***I_s (Inc) current result (A) according to time (s)***

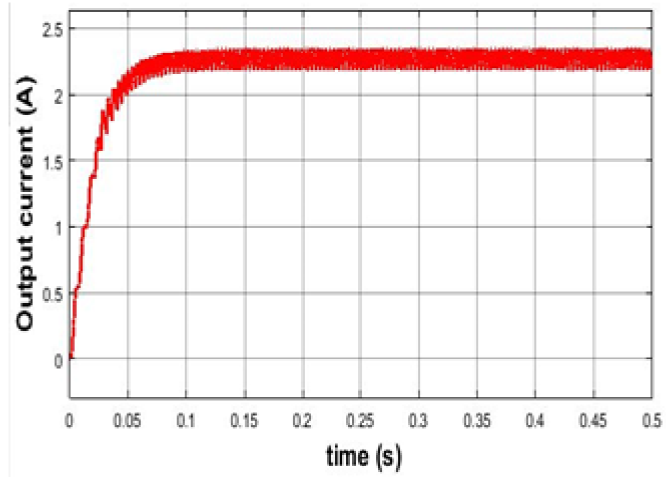

Figure 19: ***V_s (P&O) voltage result (V) according to time (s)***

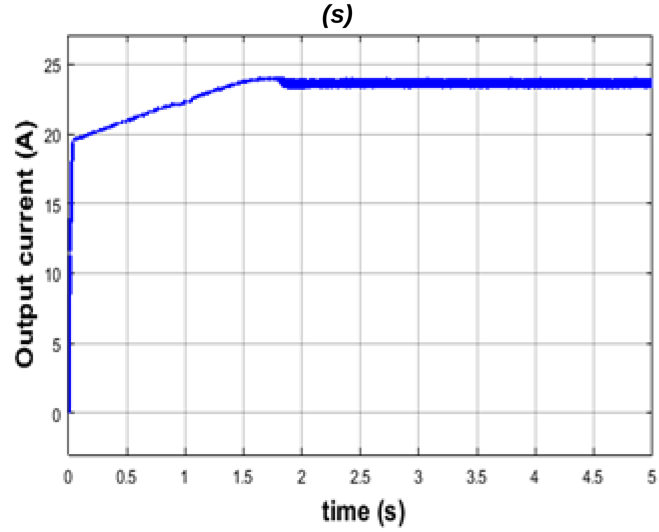

Figure 20: ***I_s (Inc) current result (A) according to time (s)***

All the curves corresponding to the simulation of the system in the presence of the "INC" show that all the characteristics of voltage, current and power at the output of the GPV as well as at the output of the boost converter with MPPT control based on the "INC after the very first moments, at (t=0,031s) form a band that oscillates around a value, and we notice that:

- the output curves of the GPV have reached values of (V=18.35V, I=3.63A and P=60W) which are approximately equal to the values of the MPP corresponding to (G=1000W/m² and T=25°C) that we have already quoted in the previous part and which are (V=17.5V, I=3.4A and P=59.5W),
- and the voltage and current at the output of the boost converter have reached maximums of (V=23.44V and I=2.34A).

The characteristic curves of the same variables in the case of the simulation of the system controlled by the MPPT based on the "P&O" command clearly show that the system took much longer to reach its MPP, since it reaches it only at the time (t=1,82s). As the "INC", the "P&O" also led the system to reach the MPP that the GPV reaches in the

(STC). The current, voltage and power reached values are:

-at the output of the GPV, (I=3,55A, V=18,86V and P=59,7W),

-at the output of the boost converter, (I=2,39A and V=23,92V).

2. This last part will contain three simulations that studied the impact of MPPT control by incremental conductance on the convergence of the GPV output characteristics at the maximum power point for two cases:

- keeping the temperature fixed and varying the irradiance,
- then keeping the irradiance fixed and varying the temperature,

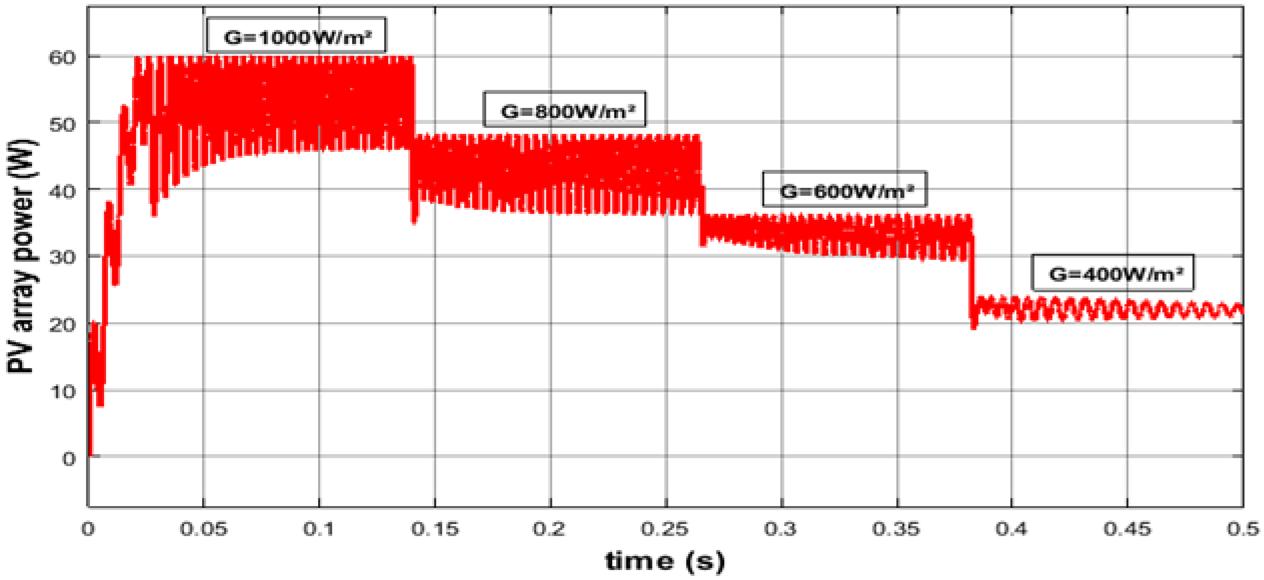

Figure 21: ***P_{pv} (Inc) power result (W) according to time (s) for different values of illumination.***

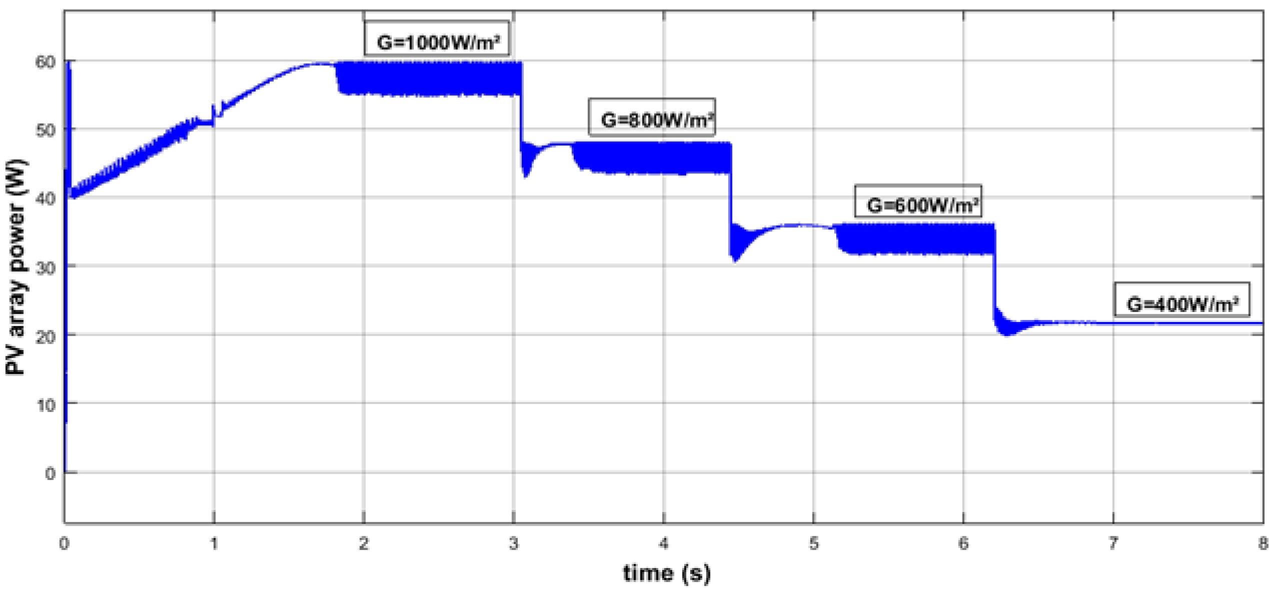

Figure 22: ***P_{pv} (Inc) power result (W) according to time (s) for different values of illumination.***

For both methods, in the figures representing the impact of the change in irradiation on the output power of the GPV (figure 21 and figure 22), it is remarkable that the power increases to the MPP corresponding to the first irradiation value, then every time we change the irradiation value, we visualize a new MPP.

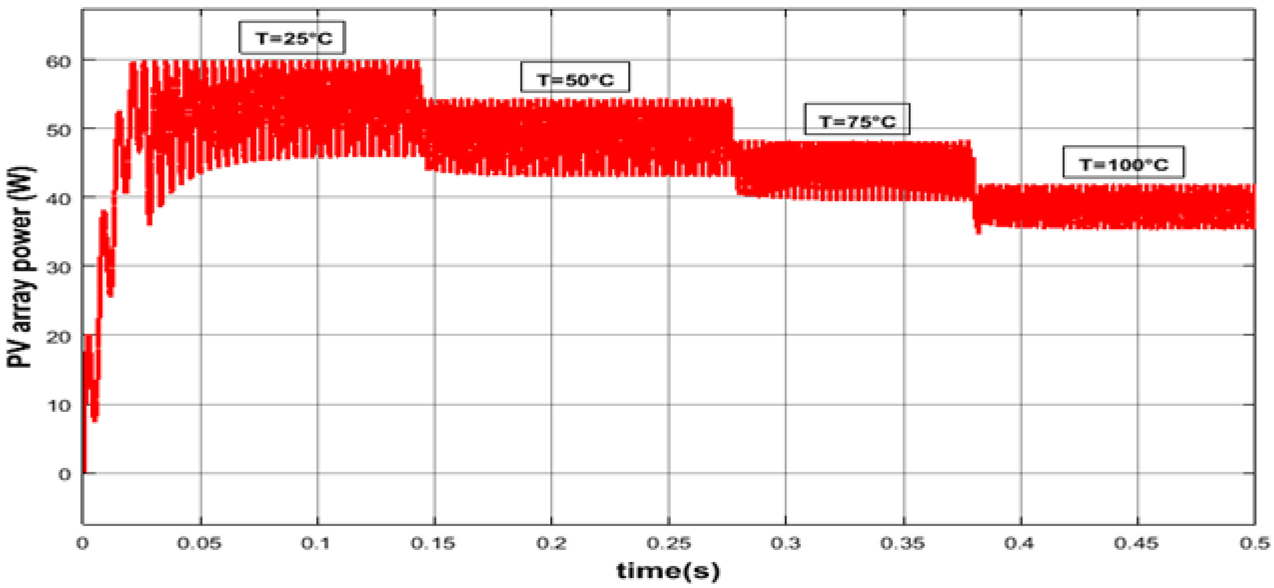

Figure 23:** P_{pv} **(Inc) power result (W) according to time (s) for different values of illumination.

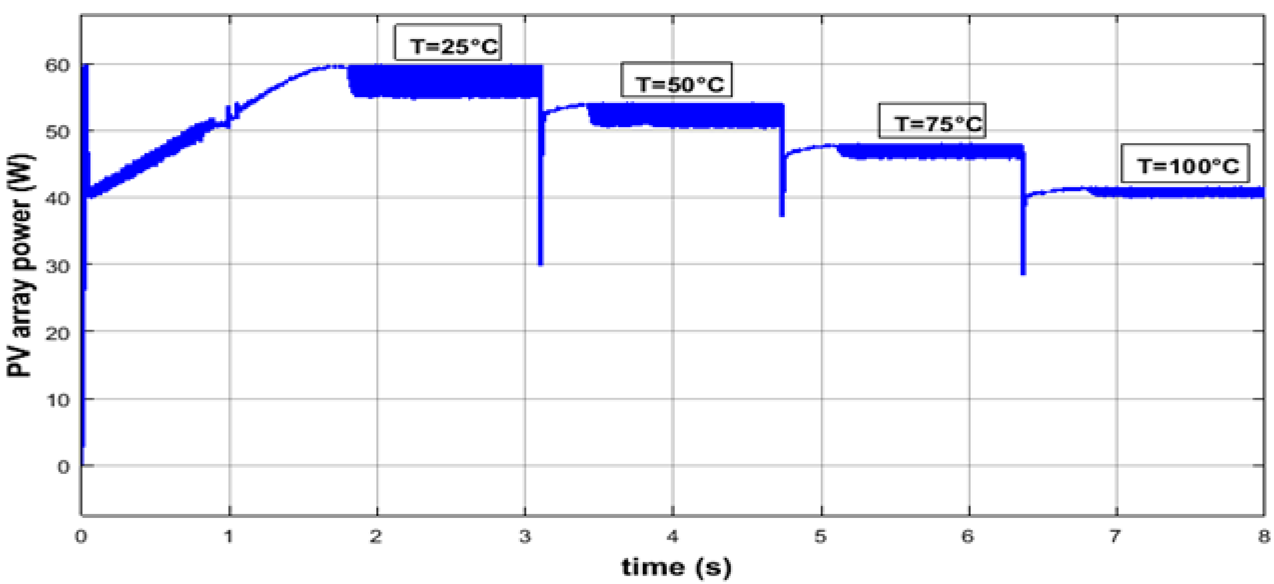

Figure 24:** P_{pv} **(P&O) power result (W) according to time (s) for different values of temperature.

Similarly is the impact of the temperature change on the GPV output power for both methods (“INC” and “P&O”) (figure 23 and figure 24), except that on the one hand the difference is always that the power increases by increasing the irradiation and decreases by increasing the temperature. And on the other hand, the difference between the two methods “INC” and “P&O” is the fact that in the case of “INC” the command finds the new MPP quickly when one passes from one irradiation or temperature value to another while the method of “P&O” takes time to search for and find the new MPP each time you change the value of these variables (G and T).

4 Conclusions

This study showed the capability and efficiency of the photovoltaic system equipped with MPPT control based on once incremental conductance algorithm and second time perturbation and observation algorithm to provide maximum poweroutput to the system for different temperature and irradiance values. The model is simulated using MATLAB/Simulink. The resulting curves from the simulation show that the change in climate clearly influenced the performance of the GPV, such that the maximum power point. Furthermore, comparing the simulation results obtained in the presence of the “INC” based MPPT control with those resulting from the “P&O”, it is concluded that both methods served to achieve the MPP except that the “INC” found the MPP in a much shorter time compared to the “P&O” based MPPT control.

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