Fixed or variable step size PV MPPT?

Comparative study between P&O and IC

Abdelghani Harrag, Abbes Remita, Ahmed Oussama Bouzaher

Abstract—**In this paper we investigate two MPPT commands (P&O and IC) for PV systems. The two algorithms were firstly evaluated independently using fixed and variable step size. In second time, a comparaison between the two methods is carried out. For this, the whole system composed of a PV MSX60 module connected to resistive load via a DC-DC boost converter driver using both proposed MPPTs algorithms are implemented under Matlab/Simulink environment. we were interested in the study and modeling of a photovoltaic system. The obtained results using Matlab/Simulink environment show that the accuracy with the P&O method in the case of high irradiation is less than with the IC method; On the other hand, the precision with the IC method for low irradiation is much less than with the P&O method. As for the response time, the IC method exhibits a better convergence time irrespective of the level of irradiation.**

Keywords- PV, DC-DC boost converter, MPPT, P&O, IC, Fixed step size, Varible step size.

I. Introduction

Energy is the motor of the world. Today, the most widely used energies in the world such fossil energy are polluting and will eventually be depleted. It is necessary to find another solution to take an non-polluting energy as environmental protection has become an important issue. These energies, known as renewable such solar energy which is an interesting alternative among renewable energy[1].

Photovoltaic energy is, involving several fields such as mechanics, optics, power electronics, control theory, and other fields, The discovery of the photovoltaic effect allows to transform solar light directly into electrical energy Based photovoltaic cell to create a photovoltaic effect we need a photovoltaic system. Photovoltaic systems has a problem is influenced by changing climatic conditions; Such as irradiation and temperature, which makes it possible to produce electrical energy varies as a non-linear voltage-current characteristic with a maximum power point (MPP), which depends on environmental factors[2].

There are various methods for controlling optimum electrical power: method on the physicochemical properties of cells, method on mechanical followers of automatic orientation of solar panels, and method on the interface of power electronics that connects the generator PV with its load. This last method is commonly known as the electrical control of PV systems. One of the systems in the development of topologies of static converters and controlled by MPPT (Maximum Power Point Tracking) control for the best capture of maximum power. Therefore, a MPPT search technique of the maximum power point (MPP) to control the duty cycle of the DC/DC converter is necessary to ensure optimal operation of the PV chain under different operating conditions. Electricity is the most important for lighting, heating, cooking, distraction, communication and information, and so on. And for this the direct conversion of solar radiation into electricity is known as photovoltaic effect and to create a photovoltaic effect we need a photovoltaic system [3-5].

In this work we were interested in the study and modeling of a photovoltaic system. To optimize the electrical production of solar panels to produce maximum power regardless of weather conditions, one solution is the use of a d Adaptation This allows the maximum power point to be tracked by controlling the PV voltage or current.

II. Photovoltaic Conversion Chain

A. Equivalent circuit of the photovoltaic cell

A photovoltaic cell can be described in a simple manner as an ideal current source which produces an I_{ph} current proportional to the incident light power, in parallel with a diode. This model does not take into account all the phenomena present during the conversion of light energy neglecting voltage and current losses exist[6].

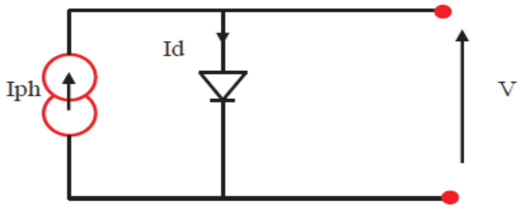

Fig.1 Ideal model of PV cell [6].

The addition of serial resistance R_s for the losses of voltage and a parallel resistance R_p for the losses of current lead to the circuit presented by Fig. 2.

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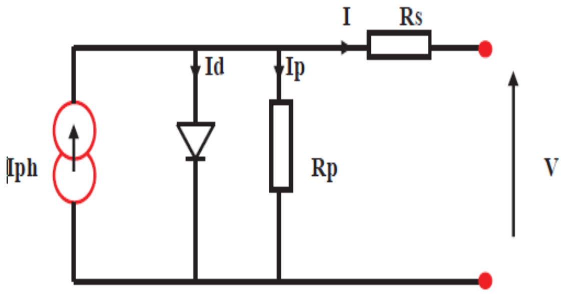


Fig.2 Single Diode Model of PV cell [6].

regarding the single diode model, we have:

$$I = I_{ph} - I_d - I_p \quad (1)$$
$$I_{ph} = I_{sc}.G/1000 \quad (2)$$
$$I_p = (V + R_s.I)/R_p \quad (3)$$
$$I_d = I_0.(\exp((V+R_s.I)/V_t -1) \quad (4)$$

with

I: rhe current supplied by the cell (A);

I_{ph}: the photo-current dependent on the illumination G (A);

I_d: the current of the diode (A);

I_p: the leakage current related to the resistor R_p (A).

Repalcing eqs. (2) to (5) in (1), we obtain:

$$I = I_{ph} - I_0.(\exp((V+R_s.I)/V_t -1) - (V + R_s.I)/R_p \quad (5)$$

B. DC-DC Boost Converter

The adaptation stage commonly used in photovoltaics constitutes by DC-DC boost converter controlled by an MPPT controller [7]. The operation of a boost converter can be divided into two distinct phases depending on the state of the switch K (Fig. 3).

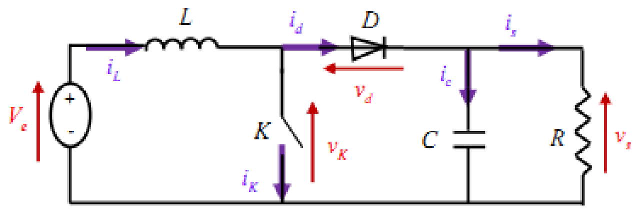


Fig. 3 Boost converter.

The two phases are described below:

- When the switch K is closed (on state), this leads to an increase in the current in the inductance, thus the storage of a quantity of energy in the form of magnetic energy (energy accumulation phase) . The diode D is then blocked and the load is then disconnected from the power supply (Fig. 4) [4].

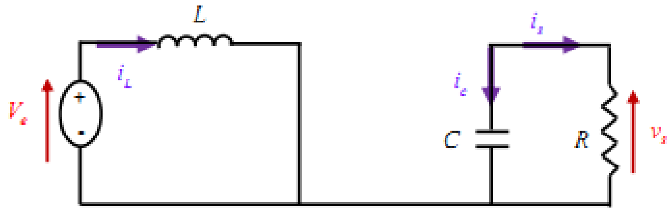


Fig. 4 Circuit equivalent when switch K is closed [4].

When the switch K is closed ($0 < t < \alpha T$), we have:

$$Ve = L \times dI_L/dt \quad (8)$$
$$I_L = I_{min} + (Ve /I).t \quad (9)$$

with

I_{min}: the minimum value of the current in the inductance;

At time t = αT, the current in the inductance reaches its maximum value I_{max}:

$$I_{max} = I_{min} + (Ve/L).\alpha T \quad (10)$$

- When the switch K is open, the inductor is then in series with the generator (boosting effect). The current flowing through the inductance then passes through the diode D, the capacitor C and the charge R. This results in a transfer of the energy accumulated in the inductance to the capacitance (accumulated energy transfer phase) (Fig. 5) [4].

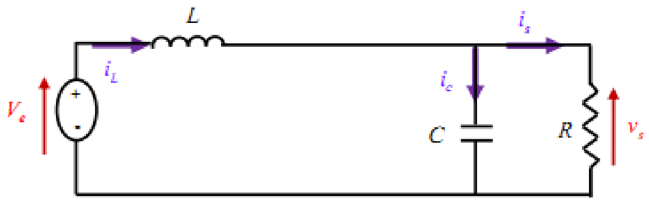


Fig. 5. Circuit equivalent when switch K is open [4].

When the switch K is opne ($\alpha T < t < T$), we have:

$$Ve - Vs = L \times dI_L/dt \quad (11)$$
$$I_L = I_{max} + ((Ve - Vs) /L).(t - \alpha T) \quad (12)$$

At t = T, we have:

$$I_{min} = I_{max} + ((Ve - Vs)/L).(1 - \alpha)T \quad (13)$$

Let $\Delta I_L = I_{max} - I_{min}$ be the ripple of the current in the inductance. By equating the values of the current ripple from equations (10) and (13), the mean value of the output voltage Vs can be deduced:

$$Vs = Ve/(1 - \alpha) \quad (14)$$

it is noted that the output voltage of the converter can be controlled by varying its input voltage or its duty cycle. The duty cycle is always between 0 and 1, so the circuit works as a voltage booster [4].

By applying the principle of power conservation between the input and the output of the converter, the average value of the current in the inductance can be established as a function of the mean current in the load and of the duty cycle:

$$I_L = Is/(1-\alpha) \quad (15)$$

The current ripple is expressed by:

$$\Delta I = (\alpha Ve/L).Td = (\alpha Vs /(L\times f) \quad (16)$$

with f the switching frequency [4].

C. *MPPT command*

The principle of this control is based on the automatic variation of the duty ratio α to the optimum value in order to maximize the power delivered by the PV panel [8]. It allows to control the power converter so that it ensures the best possible adaptation between the GPV and its load [9].

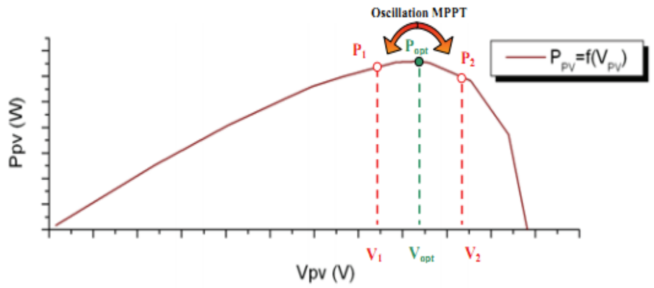


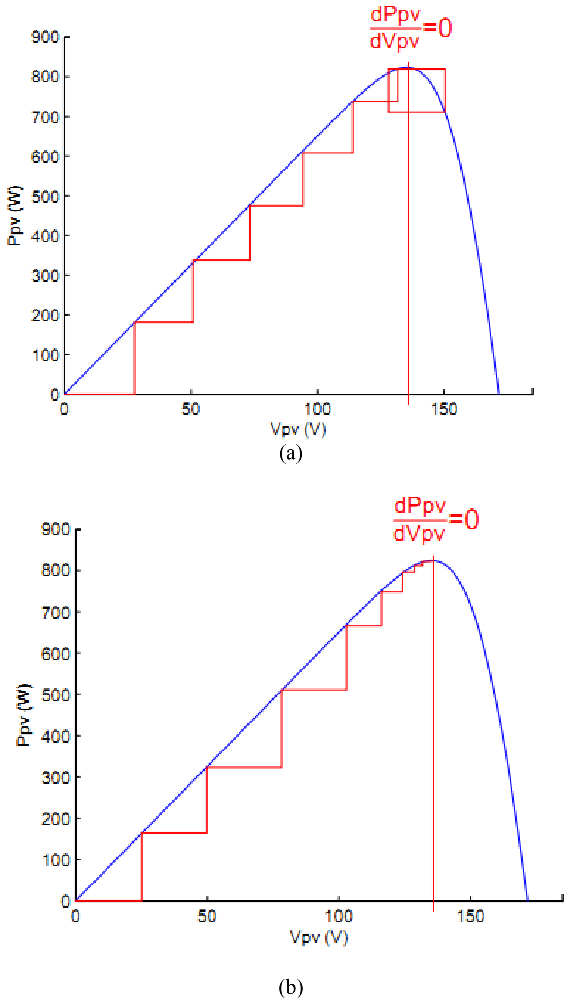
Fig. 6 Oscillation around the MPP [10].

Numerous methods of maximum power point tracking have been developed to allow the system to extract the maximum power of the most used photovoltaic generator are [10] such as Perturb and observe (P&O) or Incremental Conductance (IC). The first defect of these algorithms is their fixed step (Fig. 7.a) which causes an oscillation around the optimal point for a wide step; while it causes a long response time in the case of a small step. To solve this problem, adaptive step size algorithms have been proposed (Fig.7.b), in particular whereby the step size decreases when approaching the maximum power.

D. *Proposed system*

The photovoltaic conversion chain was fully modeled and studied using Matlab/Simulink software. It consists of the following functional blocks:

- GPV module MSX60 in monocrystalline silicon constitutes of 36 elementary photovoltaic cells; it can deliver under the standard test conditions (CST) a power of 60W an optimal current of 3.5A at an optimal voltage of 17.1V;
- DC-DC converter type boost between the GPV and the load controlled by the MPPT stage which provides the duty cycle;
- MPPT control (P&O or IC) to monitor the optimum operating point of the PV generator depending on weather conditions by directly acting on the duty cycle of the DC/DC converter;
- A resistive load.



(a)

(b)

Fig. 7. a) Fixed step, b) variable step[11].

Tables I summarizes the PV and DC-DC parameters:

TABLE I. PV MODUE PARAMETERS.

Optimal voltage (Vopt) (V)	17.1
Optimal current (Iopt) (A)	3.5
Short circuit current *Isc* (A)	3.8
Open circuit voltage V_{co} (V)	1.1
Number of cells in series	36

While Table II gives the corresponding DC-DC parameters.

TABLE II. DC-DC BOOST PARAMETERS.

C_{DC} (F)	$217.5*10^{-6}$
L (H)	$3*10^{-3}$
D	0.5
R (Ohm)	13

III. RESULTS AND DISCUSSION

We evaluated the two MPPTs studied (IC and P&O) independently by considering the two cases: fixed step and variable step. Then making a comparison of the two methods studied (IC and P&O).

We tested the system composed of the GPV, the boost converter controlled by the two MPPTs commands studied and the load. For this purpose, we used the irradiation test pattern given in Fig. 8.

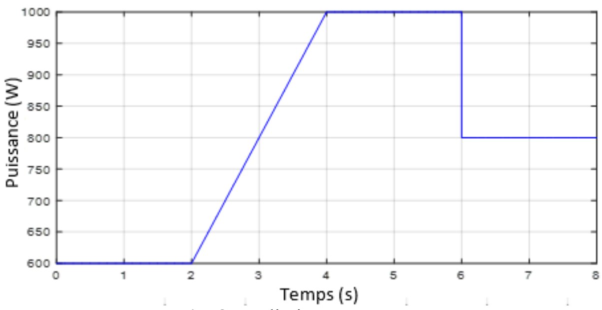


Fig. 8 Irradiation pattern test.

A. Tests of the IC and P & O command

A.1 IC method

- **Fixed step**

We used two values ΔD = 0.0001 and ΔD = 0.0003. Figs. 9 to 11 give the obtained results.

- **Variable step**

We used ΔD = 0.0002 with an adaptation factor equal to |dP /dV|. Figs. 12 to 14 give the obtained results.

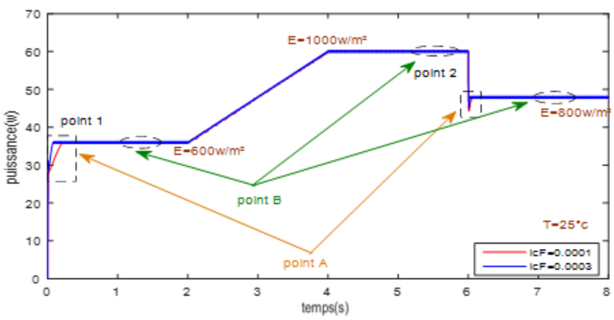


Fig 9 Fixed step test.

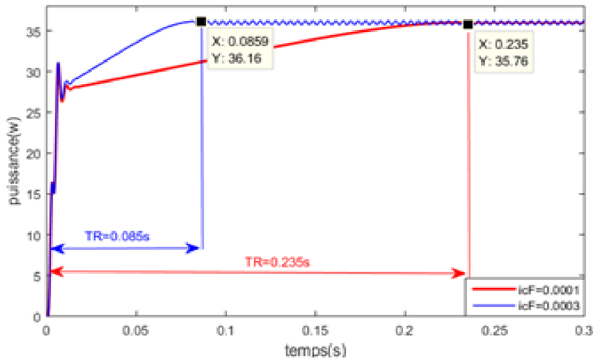


Fig 10 Fixed step: Response time.

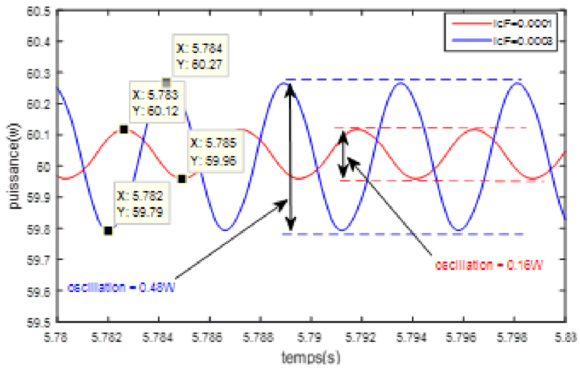


Fig 11 Fixed tep: Oscillation around MPP.

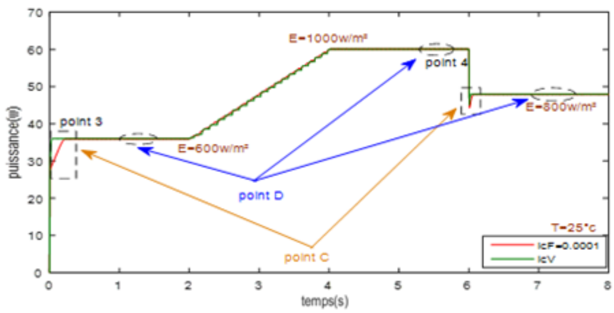


Fig. 12 Variable step test.

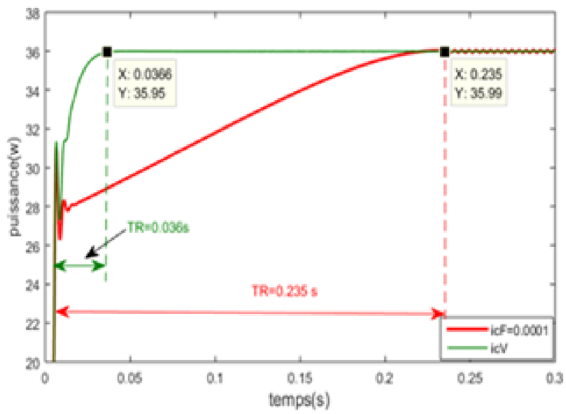


Fig 13 Variable step: Response time.

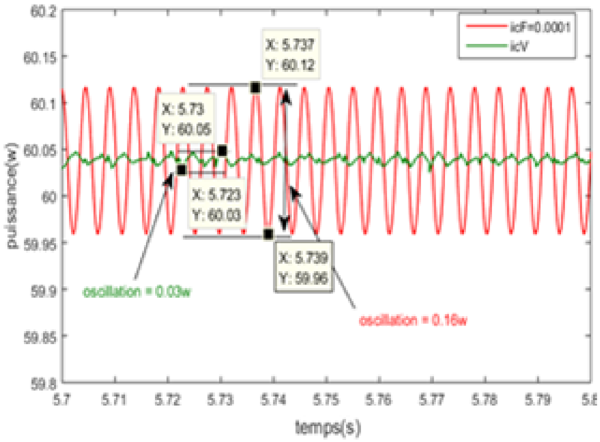


Fig 14 Variable step: Oscillation around MPP.

A.2 P&O method

- **Fixed step**

We used two values ΔD = 0.0001 and ΔD = 0.0003. Figs. 15 to 17 give the obtained results.

- **Variable step**

We used ΔD = 0.00008 with an adaptation factor equal to |dP /dV|. Figs. 18 to 20 give the obtained results.

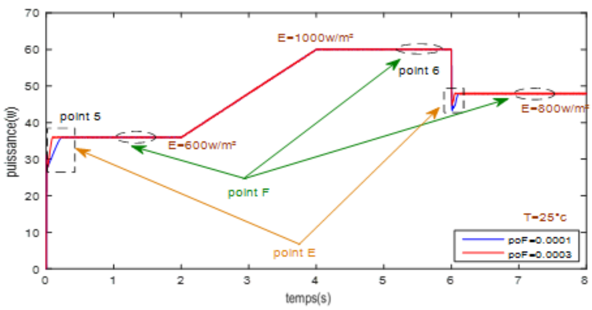


Fig 15 Fixed step test.

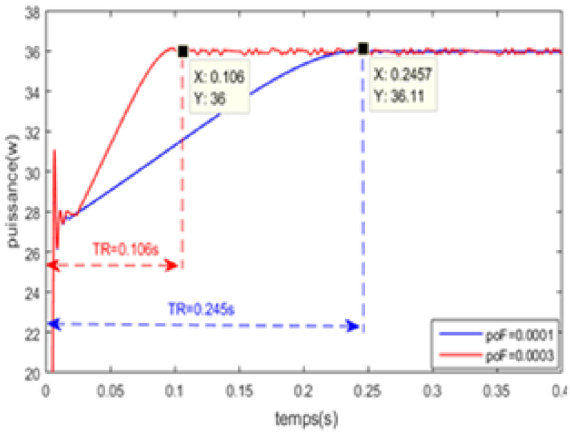


Fig 16 Fixed step: Response time.

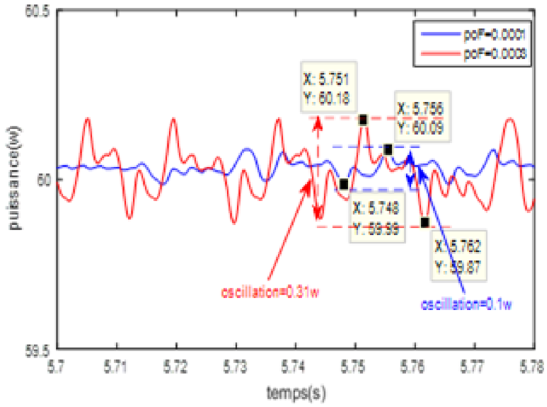


Fig 17 Fixed step: Oscillation around MPP.

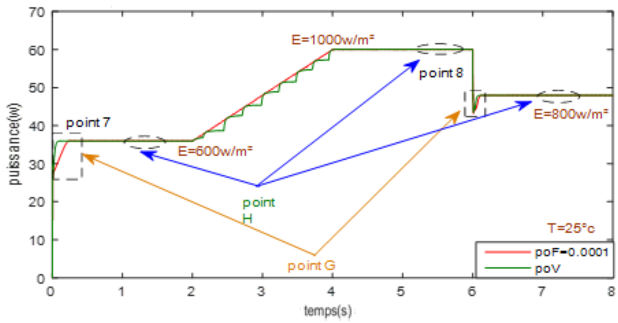


Fig 18 Variable step test.

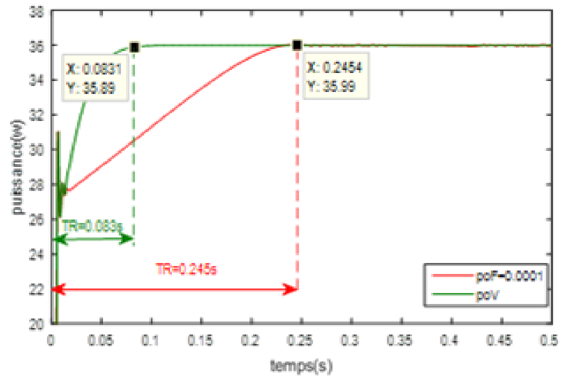


Fig 19 Variable step: Response time.

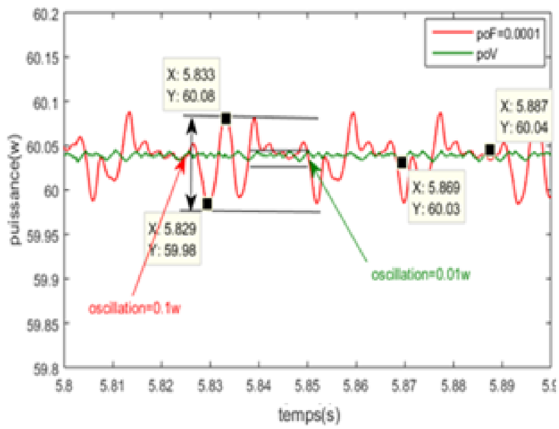


Fig 20 Variable step: Oscillation around MPP.

A.3 Comparison between P&O and IC

The comparison between the two methods is carried out using the irradiation pattern defined in Fig. 21. For both methods, we took a fixed step of 0.0003 (Fig. 22).

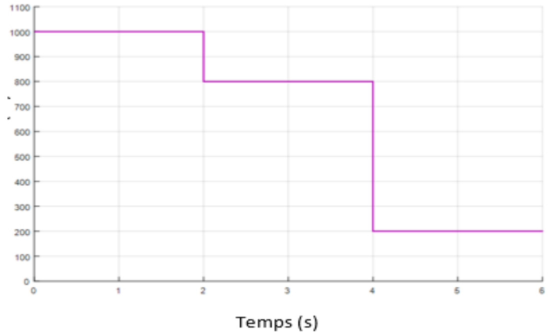


Fig. 21 Irradiation pattern test 2.

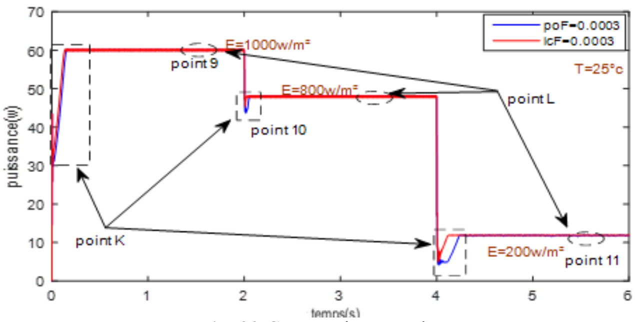


Fig. 22 Comparaison results.

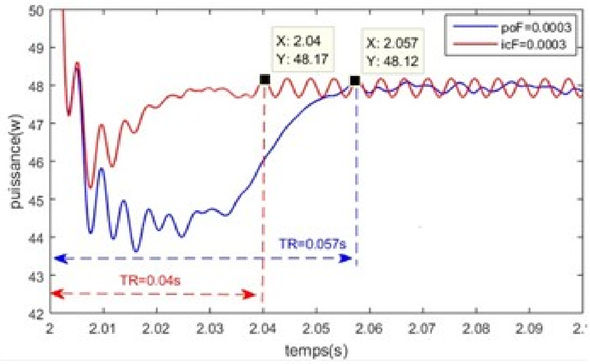


Fig. 23 Comparaison results: Response time.

I. Conclusion

In this paper we investigate two MPPTs commands (P&O and IC) for PV systems. The obtained results using Matlab/Simulink environment show that the accuracy with the P&O method in the case of high irradiation is less than with the IC method; On the other hand, the precision with the IC method for low irradiation is much less than with the P&O method. As for the response time, the IC method exhibits a better convergence time irrespective of the level of irradiation.

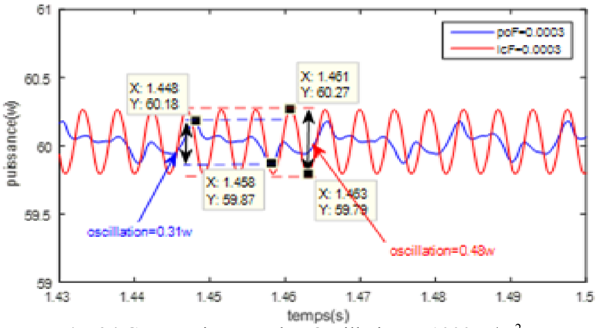


Fig. 24 Comparaison results: Oscillation at 1000W/m^2.

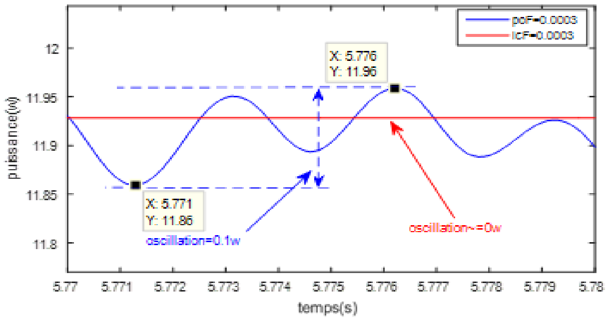


Fig. 25 Comparaison results: Oscillation at 200W/m^2.

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