

COMPARATIVE STUDY OF DIFFERENT MPPT METHODS OF A BOOST CHOPPER OF PV GENERATOR

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ABSTRACT

In this article, we focus on improving the performance and efficiency of photovoltaic systems. The main objective is to study and compare the performance of different MPPT methods, and to find the most efficient method (in terms of convergence speed, the MPP point where the oscillation is reduced), so that the generator of maximum power supplied by the photovoltaic can be extracted.. The main points involved in this research are: Modeling of the photovoltaic system Simulation of four MPPT algorithms. The simulation results are obtained using simulink in matlab.

Keywords: P&O, boost chopper, Photovoltaic generator, INC, FL, PSO.

1. INTRODUCTION

In recent years, the growing demand for energy and the pollution caused by the use of fossil fuels have prompted the public to use renewable energies. In this case, photovoltaic energy is one of the important sources of renewable energy, bringing results to our problems of energy production. In addition, this energy seems to be the most promising, non-polluting and inexhaustible. However, the generation of this energy is non-linear and varies with light intensity and temperature. Therefore, the operating point of photovoltaic (PV) panels does not always coincide with the peak power point. Then, we use a mechanism called "Maximum Power Point Tracking" (MPPT) which allows to find and track the maximum power point, in order to continuously generate the maximum power [11].

Therefore, some work focuses on photovoltaic systems. They tried to develop an algorithm to extract the maximum energy converted by the panel, so that the photovoltaic system could reach the best operating state [12]. We have found algorithms based on the following methods in the literature, such as: mountaineering, perturbation and observer (P&O) and conductance increment (INC) [1] [2]. Other commands have also been developed, such as the measurement of the short-circuit current fraction (FCC) or the measurement of the short-circuit current fraction (Open circuit (FCO) [3] [4]. There are also so-called intelligent commands based on fuzzy logic (FL) [5] [6] (FCC).

Our article is dedicated to the research and comparison of different MPPT control technologies from photovoltaic generators (GPV) in order to operate normally in all weather conditions (temperature and lighting). The research will be carried out on a system composed of photovoltaic panels, resistive loads and DC-DC converters. We will consider some maximum power point tracking technologies, namely:

2. SUBJECT

In order to ensure the optimum operating point of the photovoltaic panels at all times, by current or voltage

control, an MPPT is necessary for this operation. This MPPT must meet the following conditions:

- PV operation should be very close to MPP under different atmospheric changes.
- Have minimum cost and maximum conversion efficiency.

The methods of MPPT can be divided into two categories:

Direct method: uses a link between the measured variable (I_{sc} or V_{co}) and the approximate position of the MPP which can be easily determined. It also counts orders based on GPV operating point estimates derived from a template of predefined parameters. There are also commands to establish an optimal voltage monitoring by considering only the change in battery temperature given by the sensor. The advantage of these commands is that they are easy to execute. They are designed for inexpensive and imprecise systems that must operate in low climate change geographic areas. Among these methods, we have found generator open circuit voltage methods, short circuit methods, etc. [5]

Indirect method: This type of MPPT control determines the best operating point (MPP) based on the current, voltage, or power measured in the system. Therefore, it can react to unpredictable changes in the functioning of GPV. Usually, these processes are based on search algorithms, with which the maximum power curve can be determined without interrupting operation. For this reason, the voltage of the operating point will increase periodically. If the output power is high, move to the next search direction, otherwise it will be reversed. Then the actual operating point oscillates around the MPP. Other algorithms can keep this basic principle to avoid misunderstandings. These errors occur, for example, due to the difference in the search direction, which is caused by an increase in power, which is caused by a rapid increase in the level of radiation. The determination of the power value of the MP generator is essential for the search for MPP, it is necessary to measure the voltage and the current of the generator and the product of these two variables. Among

these methods, we found the differential method, the Perturb & Observe (P&O) method, the conductance increment, etc... [5]

In the last two decades, numbers of different MPPT have been developed. In our study, four MPPT techniques have been selected for the purpose of comparison:

- ✓ Perturbation and Observation (P&O)
- ✓ Incremental Conductance (INC)
- ✓ Fuzzy Logic (FL)
- ✓ Particle Swarm Optimization (PSO)

To implement the MPPT algorithm, which is used to find the maximum operating point, it is necessary to introduce an interface which aims to link the programming with the boost chopper circuit. In our simulation, we used an Arduino Uno.

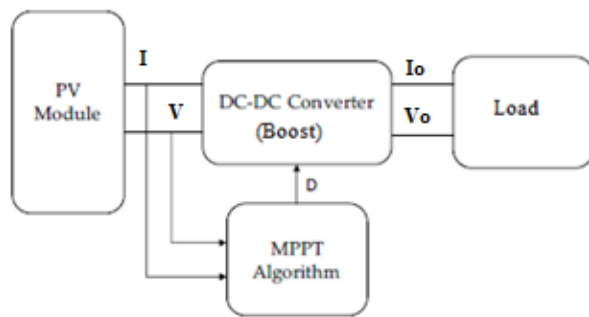


Fig. 1 Block diagram of the photovoltaic system

3. METHODS

3.1. Photovoltaic cell

The PV cell is a PN semiconductor junction diode that converts solar energy to electrical energy. Fig 2 shows the electrical circuit of PV cell.

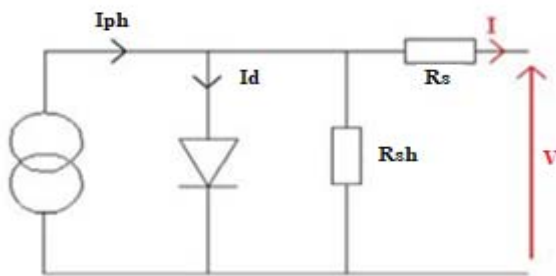


Fig. 2 Equivalent circuit of PV cell

The final equations of the photovoltaic panel model are [11]:

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

Where I_{ph} is the photo current or irradiance current, which is generated when the cell is exposed to sunlight. I_{ph} varies linearly with solar irradiance for a certain cell temperature. I_d is the current flowing through the anti-parallel diode, which induces the non-linear characteristics of the solar cell. I_{sh} is shunt current due to the shunt resistor

R_{sh} branch. Substituting relevant expressions for I_d and I_{sh} , we get

$$I_{pv} = I_{ph} - I_s \left(e^{\frac{q(V+I R_s)}{n k T}} - 1 \right) - \frac{V + I R_s}{R_{sh}} \quad (2)$$

where q is the electronic charge ($q = 1.602 \times 10^{-19}$ C), k is the Boltzmann constant ($k = 1.3806503 \times 10^{-23}$ J/K), n is the ideality factor or the ideal constant of the diode, T is the temperature of the cell, I_s is the diode saturation current or cell reverse saturation current and R_s and R_{sh} represent the series and shunt resistance, respectively.

Fig.2 shows the PV cell parameters and fig.3 shows the I-V and P-V characteristics.

The maximum power is approximatively 250W, I_{mp} is 8.07 A and V_{mp} is 30.96 V.

The electrical characteristics of this photovoltaic module. The characteristics are given in the following table:

Table 1 PV cell characteristics

Characteristics	Value
Number of series-connected cells : N_{cell}	60
Open circuit voltage : V_{oc}	36.3 V
Short circuit current : I_{sc}	8.62 A
Current maximum power : I_{mp}	8.07 A
Voltage at maximum power : V_{mp}	30.96 V

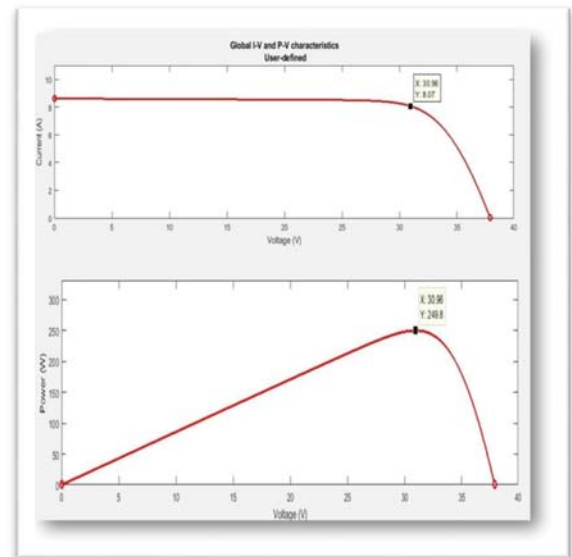


Fig. 3 I-V and P-V characteristics

3.2. Boost converter (DC/DC)

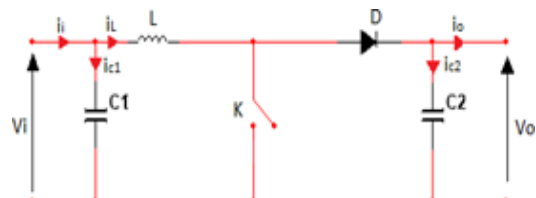


Fig. 4 Boost converter DC/DC

The boost converter is also called a step-up converter it generates a higher output voltage than the input. The suggested converter in Fig. 4 is a classical boost converter, it consists of a switch, an inductor, a diode for protecting the PV module against negative current that could damage it and capacitors [11].

Inductance and capacitors (L , C_1 , C_2) are calculated to essentially filter the current and minimize the voltage ripple at the input and output of converters [23]. These values are calculated by the following expressions [19]:

$$L \geq \frac{V_0}{4 \Delta i_{max} f} \quad (3)$$

$$C_1 \geq \frac{I_i}{4 \Delta V_{imax} f} \quad (4)$$

$$C_2 \geq \frac{V_0}{4 \Delta V_{cmax} f} \quad (5)$$

With:

L : Inductance

C_1 and C_2 : Capacities

I_i : Converter input current

V_0 : Converter output voltage

Δi_{max} : the maximum current ripple,

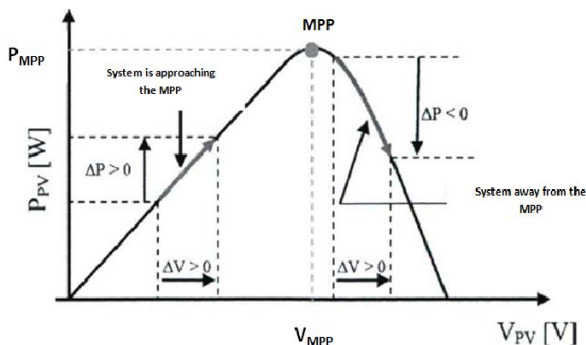
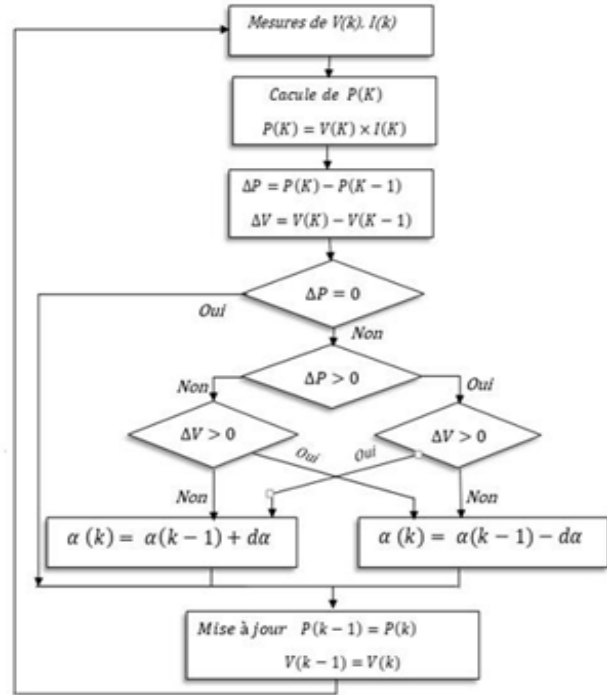
ΔV_{cmax} : the voltage ripple maximum,

f : switching frequency

3.3. Maximum power point tracking (MPPT)

3.3.1. Perturbation and Observation (P&O)

Due to the simplicity and ease of implementation of the P&O method, it is generally the most commonly used method. This algorithm is used as the value of the input voltage V_{pv} and the current I_{pv} , and as the output of the duty cycle α [26]. The principle of this algorithm (as its name suggests, as shown in Fig. 5) is to disturb the voltage V_{pv} by acting on the duty cycle α , then to follow the disturbance, and the panel P calculates the power (k) provided and compare it with the previous one $P(k-1)$ [5]: If the power increases, we are close to (MPP), and the duty cycle changes remain in the same direction. On the contrary, if the power is reduced, we will stay away from the MPP. Therefore, we need to reverse the direction of the duty cycle change. As shown in Fig. 6 [21].

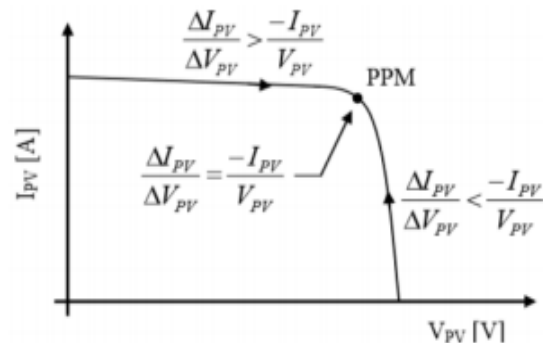
**Fig. 5** PPM research using the P&O method**Fig. 6** Flowchart of the P&O algorithm

3.3.2. Incremental Conductance (INC)

The incremental conductance algorithm is an algorithm which adapts well to rapid variations in site weather conditions, it is relatively more stable than the P&O method, and however its practical implementation is more difficult [29]. The principle of this algorithm is based on the knowledge of the value of the conductance $G = I/V$ and the increment of the conductance ($\Delta I/\Delta V$) to deduce the position of the operating point relative to MPP.

If the conductance increment ($\Delta I/\Delta V$) is greater than the opposite of the conductance ($-G$), the duty cycle is reduced.

If the conductance increment is less than the opposite of conductance, we increase the duty cycle. This process is repeated until the MPP is reached, where the derivative of the power is zero (Fig. 7) [9].

**Fig. 7** Positioning of the operating point

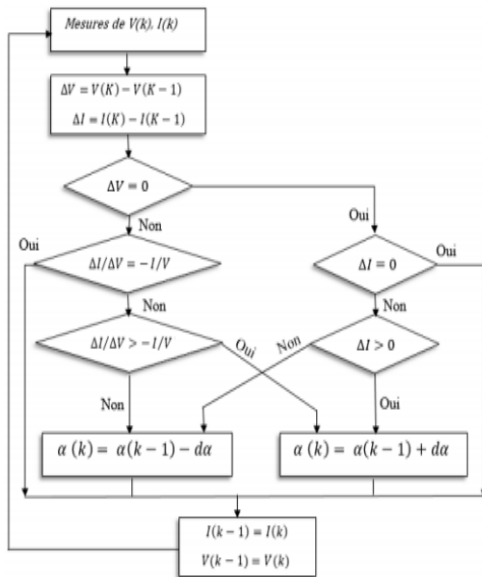


Fig. 8 Flowchart chart of the INC algorithm

3.3.3. Fuzzy Logic (FL)

Control based on fuzzy logic is used in the overpower point tracking system. The control has the following advantages: it is a robust control and does not require an exact understanding of the mathematical model of the system. In addition, they can handle non-linearity [16] [21].

The operation of this algorithm is divided into three stages (Fig. 9):

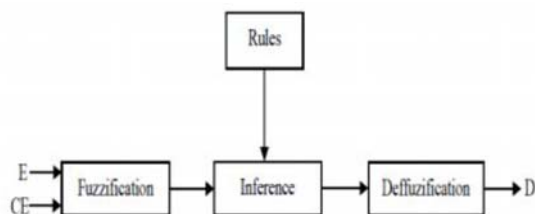


Fig. 9 General scheme of a fuzzy controller

• **Fuzzification:** used to convert physical input variables into fuzzy sets. In this step, the digital input variable will be converted into a language variable that can take the following five values: NB (large negative), NS (small negative), ZE (zero), PS (small positive), PB (large positive). Using the basic structure of fuzzy logic control as shown in the Fig. 10.

The input parameters E and ΔE are linked to the following equations [16]:

$$E = \frac{P(k) - P(k-1)}{V(k) - V(k-1)} \quad (6)$$

$$\Delta E = E(k) - E(k-1) \quad (7)$$

• **Inference:** In the inference step, use the inference rules table shown in Fig 10 [16] to make a decision on the output variable $\Delta\alpha$ based on the input variables E and ΔE . Indeed, we have established a relationship logic between input and output while defining membership rules. Next, we draw the table of inference rules [21].

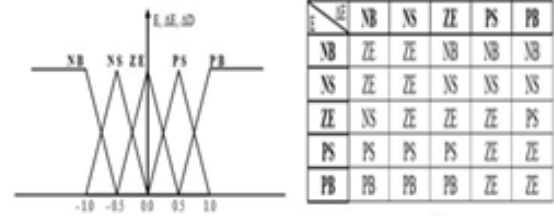


Fig. 10 Basic structure and a truth table for a Fuzzy Logic command

• **Defuzzification:** This step applies only to the output variable $\Delta\alpha$. In this step, $\Delta\alpha$ will be converted from a verbal variable into a digital variable in order to be able to control the power converter in PPM. [21]

In terms of PPM accuracy and recovery speed, this command offers the best performance. However, the drawback of this command is that its precision is linked to the complexity of the truth table used. Therefore, it is necessary to force the selection of a microcontroller with a large computing power, which will inevitably lead to the power consumption related to the microprocessor not less than the additional cost [21].

3.3.4. Particle Swarm Optimization

For the PSO-based designed MPPT system, the position of the particles, specified as the duty cycle of the power converter and the fitness evaluation function, is selected as the output power of the PPV photovoltaic system.

In the overview of the proposed method, even though the number of particles is the smallest and the number of particles is large under complex environmental conditions which lead to long computation time, more accurate MPP tracking is still obtained. Therefore, in order to ensure good tracking speed and accuracy [28].

For the initialization step of optimizing the particle swarm, the particle it can be set in a random range or placed in a fixed position. Usually, if there is data, it makes more sense to initialize the surrounding particles. Available on the position of the point of maximum overall power Search scope.

Therefore, the number of particles N is selected in the photovoltaic system as random numbers. The search spaces of the particles which cover $[0, 1]$ are initialized on a defined point. 0 and 1 are the minimum and maximum cycle value of the DC-DC converter used, respectively.

The objective of this MPPT method based on PSO is to extract power from the maximum P_{PV} of the photovoltaic. In order to evaluate the fitness value as generated power. After the output of the regulator, the pulse width modulation acts on the line position the particles

representing the state of the duty cycle, and the photovoltaic voltage V_{PV} and PV current can be measured.

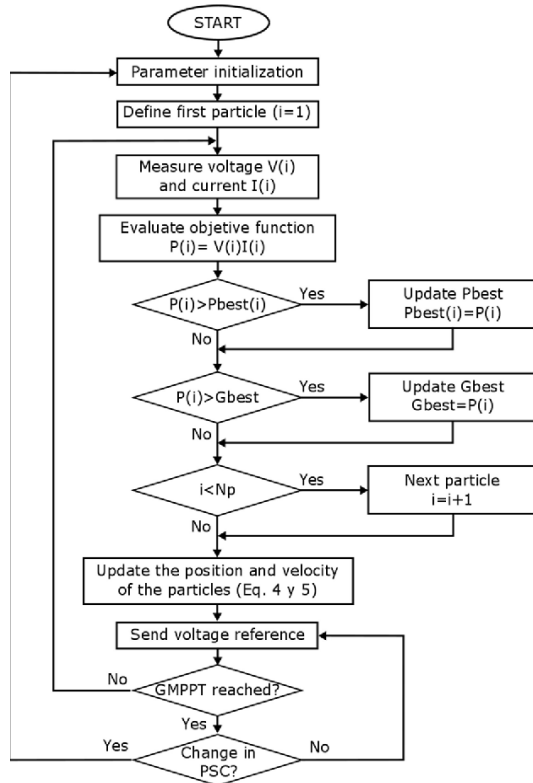


Fig. 11 Flowchart chart of the PSO algorithm

4. RESULTS

Our work consists of making a comparative study between four MPPT commands Perturbation & Observation (P&O), Incremental conductance (INC), Fuzzy Logic (FL) and Particle Swarm Optimization (PSO) to control a booster chopper. In our simulation, we used Matlab / Simulink.

We simulated the operation of a set of equipment (GPV-BOOST-MPPT and load) under fixed atmospheric conditions (lighting $1000W/m^2$ and temperature $25^\circ C$) to evaluate the performance of the MPPT photovoltaic system.

The results of the simulation obtained are shown in the graphs bellow.

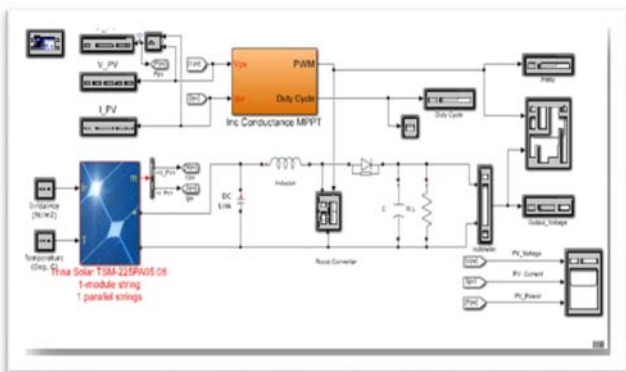


Fig. 12 Structure of the simulation diagram of the PV installation

Fig. 12 shows the structure of the simulation diagram of the PV installation associated with the MPPT command in Matlab / Simulink.

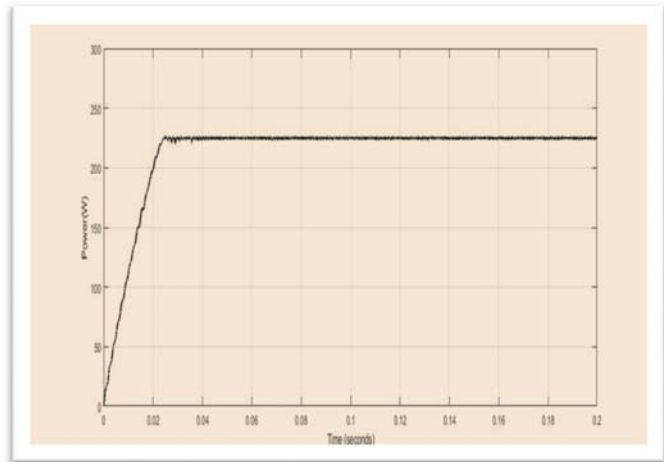


Fig. 13 PV power for P&O method

Fig. 13 shows the photovoltaic power for P&O method.

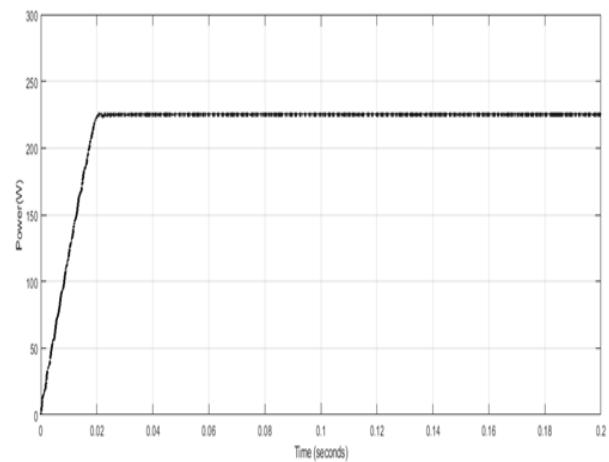


Fig. 14 PV power for INC method

Fig. 14 shows the photovoltaic power for INC method.

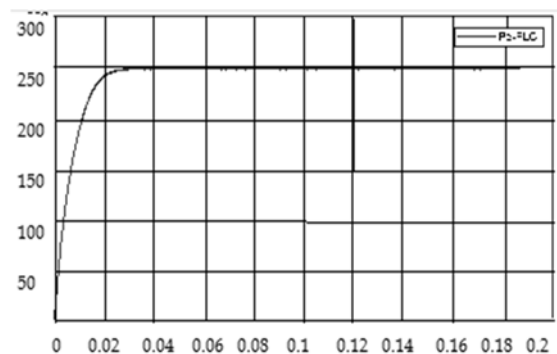


Fig. 15 PV power for FL method

Fig. 15 shows the photovoltaic power for FL method. It can be seen from the curve obtained that the control based on fuzzy logic (FL) responds correctly to the characteristics of the panel.

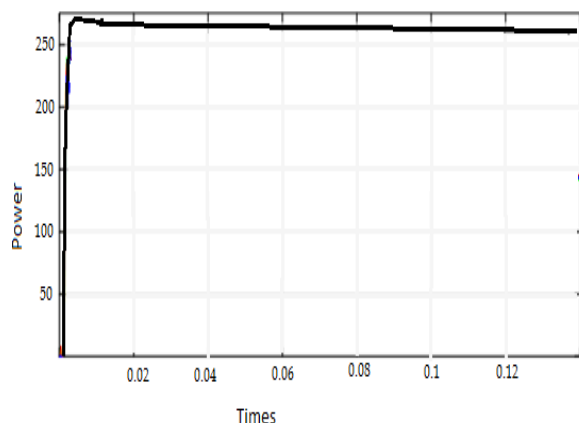


Fig. 16 PV power for PSO method

Fig. 16 shows the photovoltaic power for PSO method. It can be seen from the curve obtained that the control based on PSO responds correctly to the characteristics of the panel.

We notice that the change of the incremental step $\Delta\alpha$ affects the oscillation around the point of maximum power (PPM) for P&O and INC.

The both P&O and INC methods gave the same power 225 W.

FL method gave the maximum power that the panel can offer to know 250 W.

PSO method gave the maximum power that the panel can offer to know 270 W.

From the results obtained, we note that the INC technique presents oscillations around the PPM with a greater amplitude than that of the P&O method, because it is difficult to fulfill the condition $dP / dV = 0$.

The fuzzy logic control presents very competitive results compared to the other two methods.

The PSO control allows less power ripple in steady state, therefore good stability of the PV system in static state.

5. CONCLUSIONS

The work done is a comparative study between four different MPPT methods of a boost chopper by a panel photovoltaic: Perturbation and Observation method (P&O), Incremental conductance (INC), Fuzzy Logic (FL) and Particle Swarm Optimization (PSO).

The system with the INC command gives the same power like the P&O method, almost the same parameters as the P&O command are used.

As the duty cycle step decreases, the oscillation near the point of maximum power decreases, making the system more stable.

The control is effective in monitoring the maximum power point. Regarding the stability of the system, it should be noted that if the duty cycle stage is important, the MPPT algorithm will respond quickly to changes in the operating conditions of the system, but the stability will increase the loss.

The oscillation amplitude of INC technology around PPM is greater than that of P&O method because it is difficult to satisfy the condition $dP / dV = 0$.

The results then obtained by the use of fuzzy logic are much more promising and give a better yield with convergence at the PPM than the P&O and INC methods.

Although the PSO method gave a power of 270 W, it cannot be considered the best. So the best method is FL.

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