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Fuzzy Logic Control for Maximum Power Point Tracking of a Photovoltaic Field

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Abstract*— Maximizing the power point tracking of photovoltaic systems is currently the purpose of several researches in the context of renewable energies improvement. In this work we optimize and enhance the maximum power point tracking algorithm based on fuzzy logic controller. Our approach focuses on determining the maximum power point in a minimal time in order to get the lowest possible energy loss. The fuzzy logic controller presented in this work provide fast response and good performance against the climatic and load change and uses directly the DC/DC converter duty cycle as a control parameter. After establishing our algorithm, we have performed a comparative study with the classical algorithm used most perturb and observe in various operating conditions. The simulation results using MATLAB/Simulink show that fuzzy logic controller provides better tracking compared to Perturb and observe despite the climatic change (solar insolation and temperature).

Index Terms*— DC-DC converter, fuzzy logic, MPPT, perturb and observe, Photovoltaic.

I. INTRODUCTION

Renewable energies manifest as a potential solution to reducing emissions of greenhouse gas emissions [1]. Among the means of producing sustainable energy, photovoltaic (PV) has emerged as the most appropriate solution for the production of electricity from non-polluting source, as it is simple to design and requires little maintenance compared to wind turbines. Furthermore, the liberalization of the electricity market has increased investment in photovoltaic's [2]. Despite its various advantages, PV systems have also some drawbacks such as the adaptation difficulty to the climate change, which occurs at non-linear variation of current-voltage and power-voltage characteristics. This problem requires a mechanism to pursue the maximum power point tracking so that the maximum power is permanently generated. Many conventional methods have been widely developed and implemented for tracking the maximum power point [3]. However, they still have a low yield. For instance, perturb and observe (P&O) which has a low MPPT stability during an abrupt climate change. Our work consists on developing an algorithm based on fuzzy logic in order to ameliorate the MPPT which ensures the good functioning of our PV system during the sunshine variation.

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II. POWER SYSTEM DESCRIPTION

The block diagram of our PV system powering a DC load is shown in Figure 1.

- The PV module (SP305) is constructed in single crystal silicon is composed of 96 cells; our photovoltaic field is composed of 66 modules connected in parallel and 5 connected in series.
- The adaptation quadruple is a DC-DC power converter booster-type. The various components of the boost are inductance L with its series resistance RL, CE and CS capacities, freewheeling diode D1 and transistor IGBT.
- The MPPT algorithm is used to find the optimal operating point of the PV generator according to the climatic conditions (temperature, solar insolation).

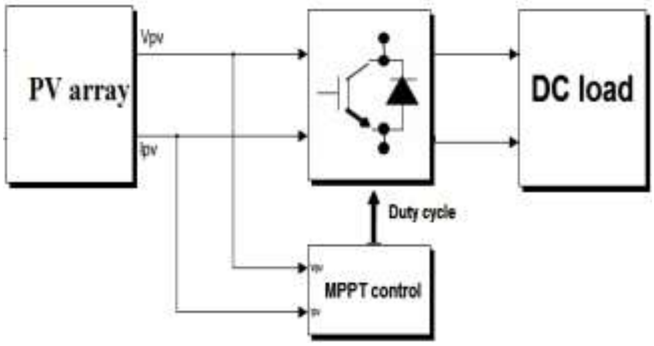

Figure 1: Block diagram of the PV system with a MPPT control

III. MODELING OF PV CELL

There are two models of the solar cell that are commonly used: the exponential model and the model with two exponential [4] and [5]. In our study we use the model with a single exponential Figure 2.

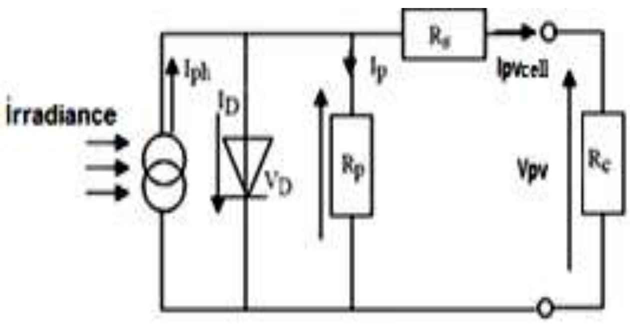

Figure 2: Model equivalent of the PV cell

$$Ipvcell = I_{ph} - I_O\left(e^{q\left(\frac{Vpv+RsIpv}{nKT}\right)} - 1\right) - \frac{V + IR_S}{R_P} \qquad (1)$$

The series resistance can be ignored, the characteristic of the PV output current Ipv can be written as:

$$Ipvcell = I_{ph} - I_O\left(e^{\left(\frac{qVpv}{nKT}\right)} - 1\right) \qquad (2)$$

In this equation, the current is a function of temperature, the voltage across the cell and the illumination. The temperature dependence is further amplified by the properties of the photocurrent Iph and of the current of the reverse diode saturation I0. This explains the effect of temperature of solar insolation and on the current-voltage characteristics of our photovoltaic panel figure 3.

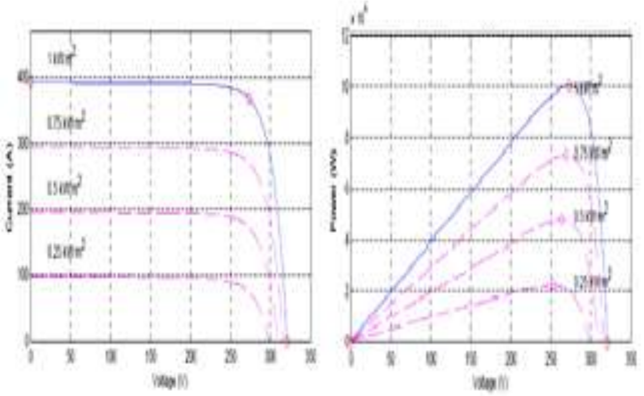

Figure 3: I-V and P-V characteristics of the PV field under different irradiation and T = 25 ° C

IV. DC-DC CONVERTER

To ensure the proper functioning of our photovoltaic field connected to a DC load, it is necessary to insert a type converter Boost [6] shown in figure 4. For this converter we will develop a command to maintain maximum power and regulate voltage at its output despite the load change and climate change.

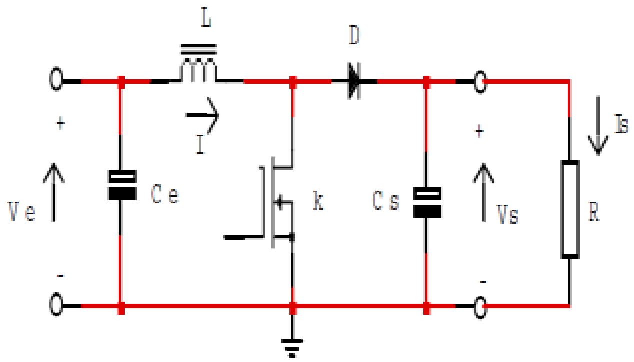

Figure 4: Diagram of boost converter

The equations governing the operation of the boost chopper is made explicit as follows:

For 0 <t <αT, the switch K is closed, the diode D is blocked then:

$$V_e = L\frac{di}{dt} \qquad (3)$$

Where:

$$i(t) = I_m + \frac{V_e}{L}t \qquad (4)$$

At t=αT:

$$I_M = I_m + \frac{V_e}{L}\alpha t \qquad (5)$$

To αT <t <T, we open the switch K, the diode becomes conductive were:

$$V_s = \frac{V_e}{(1-\alpha)} \qquad (6)$$

V. MPPT CONTROL

The maximum power that corresponds to the optimal operating point is determined by climate change. The converter DC / DC type is used for controlling the photovoltaic system by acting on the duty cycle to suit the output voltage of the chopper on the voltage required by the load. From this rule and the type of controller, there are several and different methods to extract the maximum power [7] [8]. In this paper we propose a concept based on the fuzzy logic which will be compared to the P & O algorithm.

A. Pertub and observe

This algorithm is the most commonly used, it is based on the disruption of the system by the increase or decrease of Vref which by acting directly on the duty cycle of the DC-DC converter, and then observing the effect on the output power of the panel. If the current value of the power P (k) is greater than the previous value P (k-1) then the previous same direction of perturbation is kept, if not the disturbance of the previous cycle is reversed. Figure 4 shows the flowchart of the algorithm.

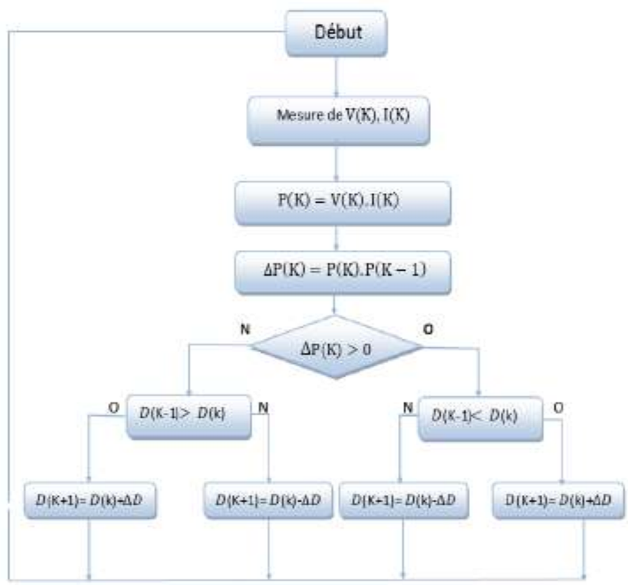

Figure 5: Perturb and observe algorithm

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B. Fuzzy logic control

Fuzzy logic is an extension of Boolean logic which offers a very valuable contribution to the reasoning that uses flexibility, making it possible to take account of inaccuracies and uncertainties. Its main advantages are its linguistic description and independence of mathematical model. A fuzzy logic controller consists of four steps: fuzzification, knowledge base, inference mechanism and defuzzification [9].

- The fuzzification corresponds to the linguistic variables.
- The knowledge base is composed of a database and a base of rules designed to achieve good dynamic response function of external perturbations of the PV system.
- The inference mechanism uses a collection of linguistic rules to convert the input into an output conditions fuzzified.
- The defuzzification is used to convert the fuzzy output control signals.

In designing a system of fuzzy logic control, the formulation of a set of rules is a key role in the improvement of system performance. The block diagram of the fuzzy controller that we have developed to control the boost chopper is shown in figure 6. These input variables are the error e and the variation of the error Δe. The output of the controller is the change of the duty ratio dD.

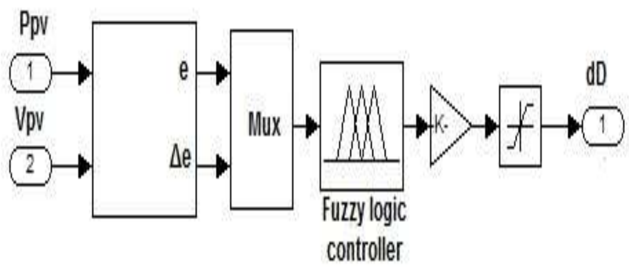

Figure 6: Model of fuzzy logic control

The fuzzy rules are summarized in Table I.

The inputs variables are e and Δe. The output variable is dD; the linguistic variables are made explicit as follows:

- NB: Negative Big
- NS: Negative Small
- ZE: Zero
- PS: Positive Small
- PB: Positive Big

Table I Table of fuzzy logic controller rules

e	Δe NB	NS	ZE	PS	PB
NB	ZE	ZE	PB	PB	PB
NS	ZE	ZE	PS	PS	PS
ZE	PS	ZE	ZE	ZE	PS
PS	NS	NB	ZE	ZE	ZE
PG	NG	NG	ZE	ZE	ZE

From these linguistic rules, the fuzzy logic controller regulates the output variable dD by the following relations:

$$P_{pv}(K) = V_{pv}(K) * I_{pv}(K) \tag{7}$$

$$\mathrm{e}(K) = \frac{P_{pv}(K) - P_{pv}(K-1)}{V_{pv}(K) - V_{pv}(K-1)} \tag{8}$$

$$\Delta e(K) = e(K) - e(K-1) \tag{9}$$

Next, the linguistic output signal is converted to numerical values by a process known as defuzzification. This can be achieved using several methods; one example is the ‘‘centre of gravity’’, which utilize the following formula:

$$dD = \frac{\sum_{j=1}^{n} \mu(D_j) - D_j}{\sum_{j=1}^{n} \mu(D_j)} \tag{10}$$

If e is PB and Δe is Z then dD is Z.

This means that if the operating point is far from the maximum power point to the left side, and the change in the slope of the curve (Ppv = f (Vpv)) is approximately zero; then keep the same duty cycle (dD) as figure 7 shows.

We have chosen the Mamdani method as the inference method with operation (MAX-MIN).

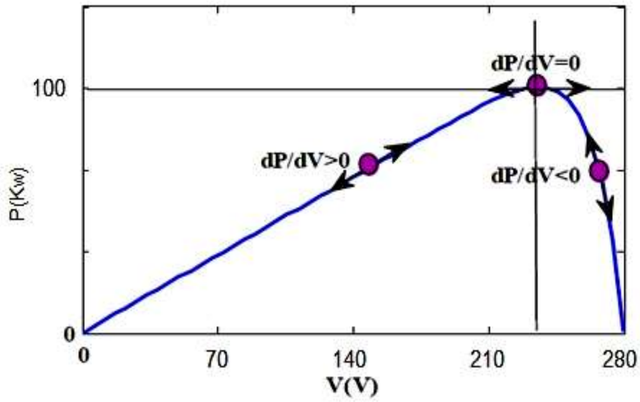

Figure 7: Slope characteristics of the PV curve at different points

VI. SIMULATION RESULTS AND DISCUSSION

In this section, two MPPT methods are studied by simulation; our own tracking method using the fuzzy controller and P&O method. The two systems are simulated in combination with the DC / DC converter under stable environmental conditions and then with a rapid variation of solar insolation under two constants temperatures.

A. Operation under standard conditions

In this test the temperature and insolation are kept constant. It takes the values of standard conditions (T= 25 ° C and solar insolation G = 1000W/m2). The purpose of these simulations is to visualize the shift of the operating point from point MPP. It also serves to evaluate losses oscillations around this point. Figure 8 presents the way that the voltage, which is generated by the source, changes related to the converters duty cycle until it reaches the value which corresponds to the maximum power point. Figures 9-10 shows the maximum current and power generated by the PV field. Figures 11-12 shows the regulated voltage Vdc of boost converter and the Photovoltaic field characteristics Ppv-Vpv.

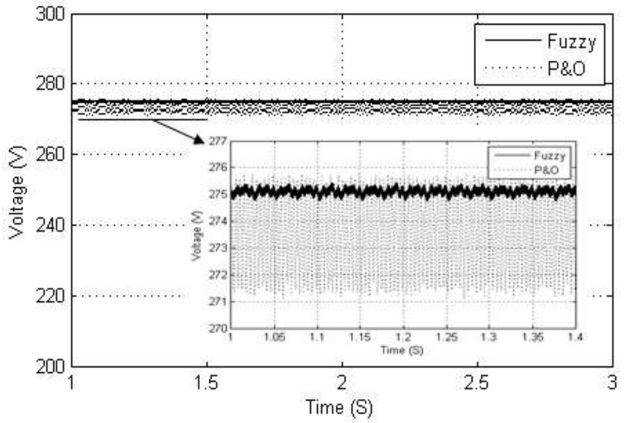

Figure 8: Voltage Vpv of photovoltaic field

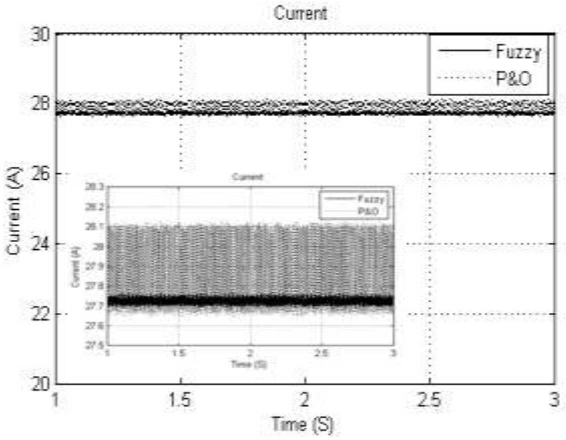

Figure 9: Current Ipv of photovoltaic field

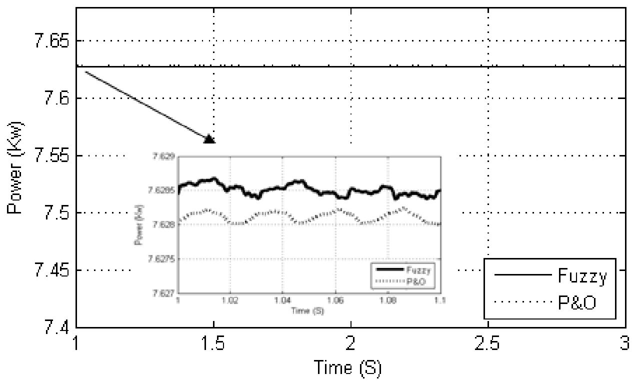

Figure 10: Power Ppv of photovoltaic field

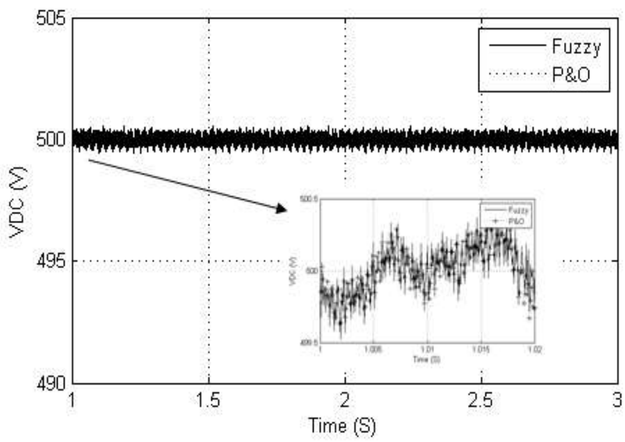

Figure 11: Regulated voltage Vdc of boost converter

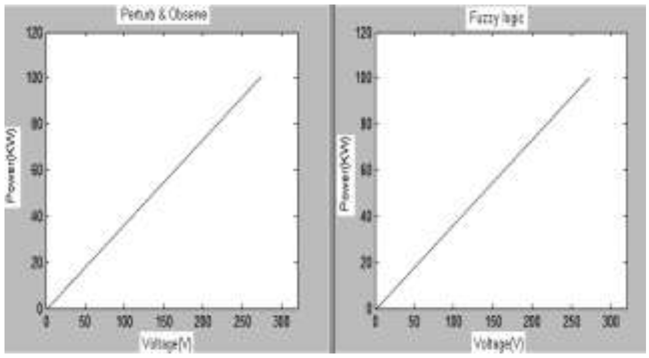

Figure 12: Photovoltaic field characteristics Ppv-Vpv

B. Behavior of the system to a change of illumination and temperature

To test the performance of the two algorithms we have performed a rapid variation of solar insolation (250W/m2 to 1000W/m2) with two constants temperatures 25 ° C and 40°C. Figure 13 shows a variation of the illumination. In these conditions, for the MPPT (P&O) controller we see the effect of the rapid increase in power caused by increased solar isolation. In which case, the P&O continues to disrupt the system in the same direction as he is in the wrong direction, which causes a deviation the operating point of the true MPP. This deviation once stabilized insolation takes some time to be recovered, and causes a delay time, implying a fall of system efficiency, Unlike the P&O, we note that fuzzy logic controller is faster and the losses generated by the oscillations are very weak. Figures 14.a-16.a and figures 14.b-16.b shows respectively the effect of change of insolation on the voltage, current, power delivered by the photovoltaic field with two controllers (P&O and fuzzy logic controller) under the temperature of 40 °C and 25°C. Figure 17.a show the regulated voltage Vdc of the boost converter under 40°C and figure 17.b under 25°C. Figure 18 show the photovoltaic field characteristics Ppv-Vpv under 25°C.

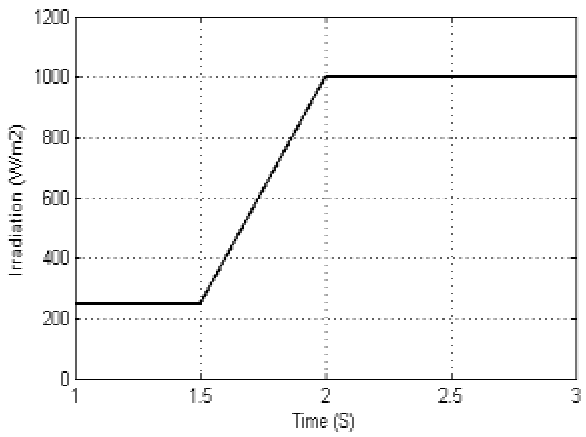

Figure 13: insolation variation

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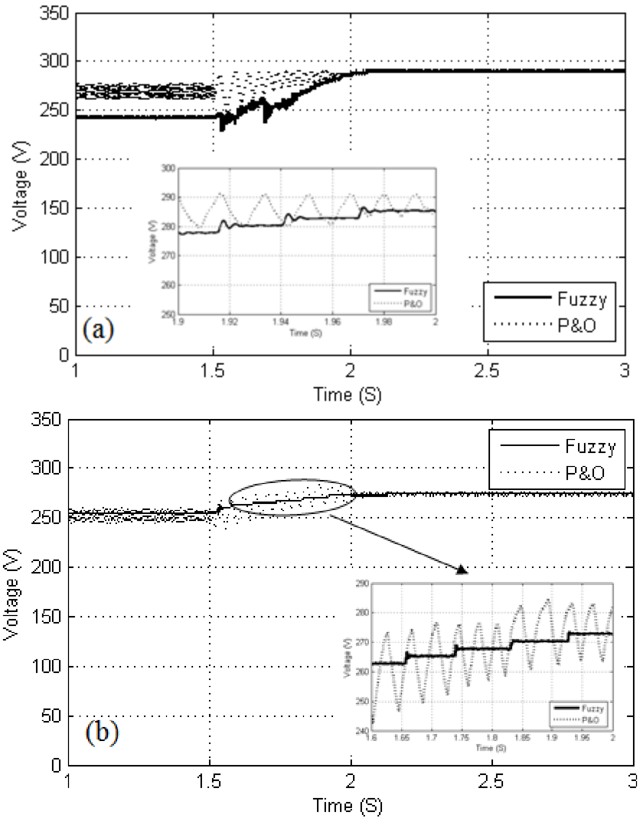

Figure 14: Voltage Vpv of photovoltaic field under 40° (a) and 25° (b)

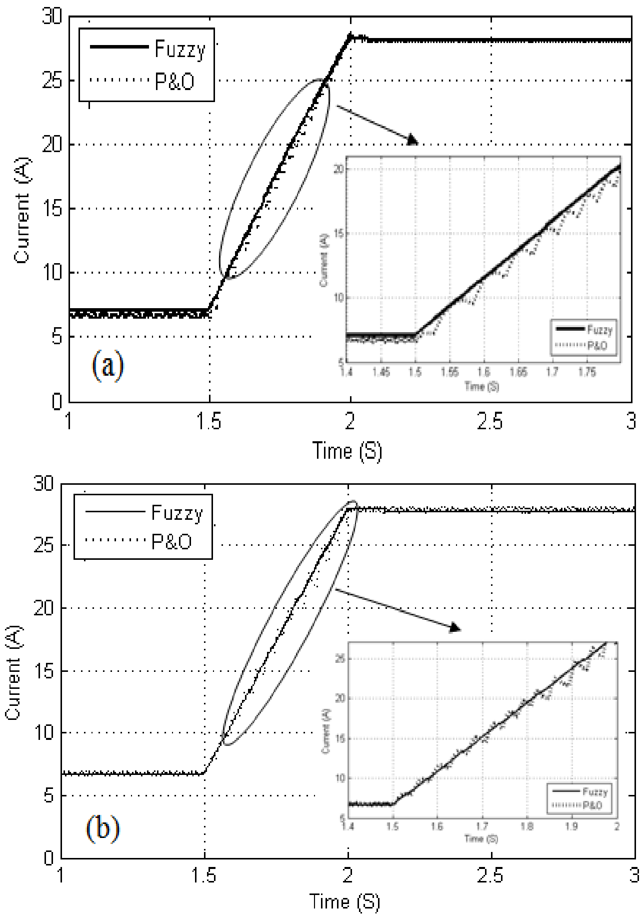

Figure 15: Current Ipv of photovoltaic field under 40° (a) and 25° (b)

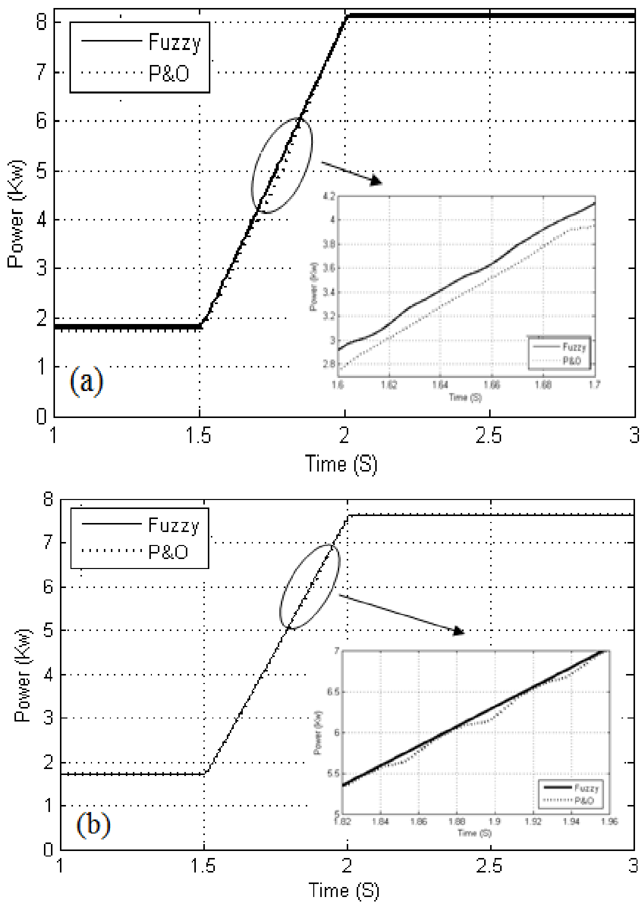

Figure 16: Power Ppv of photovoltaic field under 40° (a) and 25° (b)

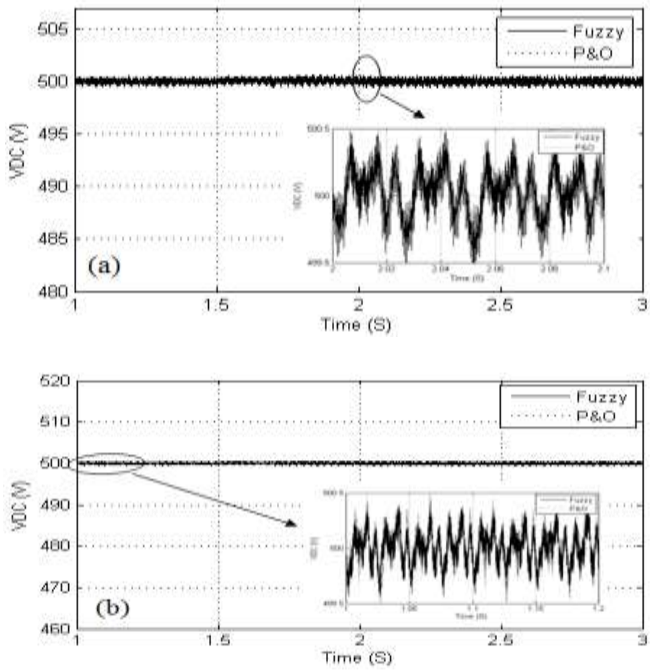

Figure 17: Regulated voltage of boost converter under 40° (a) and 25° (b)

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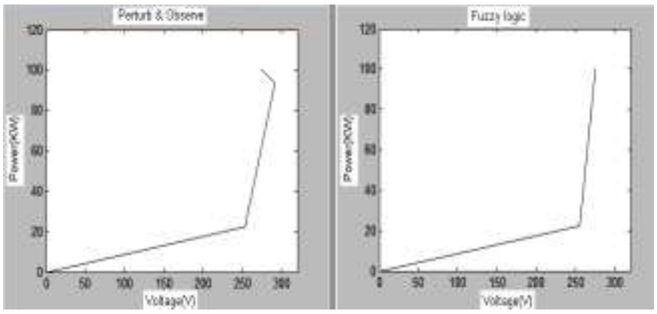

Figure 18 : Photovoltaic field caracteristics Ppv-Vpv under 25°

VII. CONCLUSION

The In this paper, a new fuzzy logic controller has been synthesized for tracking maximum power point; the simulation results obtained under strong climatic variations confirm the proposed control MPPT of photovoltaic field. The fuzzy logic controller pursues with satisfaction the strong climatic variations with a very short response time and less than that of the algorithm P & O. This eliminates the fluctuations of the power, the current and the voltage at a steady state. A fast and stable fuzzy logic controller MPPT has been obtained, the latter has proved that it guaranties better performance, faster response time; moreover, it has proved its robustness to different climatic variations.

REFERENCES

1. R. R. Hernandez, S. B. Easter, M. L. Murphy-Mariscal, F. T. Maestre, M. Tavassoli, E. B. Allen, C. W. Barrows, J. Belnap, R. Ochoa-Hueso, S. Ravi, et M. F. Allen, « Environmental impacts of utility-scale solar energy », Renew. Sustain. Energy Rev., vol. 29, p. 766-779, janv. 2014.
2. D. Streimikiene et I. Siksnelyte, « Electricity market opening impact on investments in electricity sector », Renew. Sustain. Energy Rev., vol. 29, p. 891-904, janv. 2014.
3. D. P. Hohm et M. E. Ropp, « Comparative study of maximum power point tracking algorithms », Prog. Photovolt. Res. Appl., vol. 11, no 1, p. 47–62, 2003.
4. A. Ortiz-Conde, F. J. García Sánchez, et J. Muci, « New method to extract the model parameters of solar cells from the explicit analytic solutions of their illuminated I–V characteristics », Sol. Energy Mater. Sol. Cells, vol. 90, no 3, p. 352-361, févr. 2006.
5. M. Wolf et H. Rauschenbach, « Series resistance effects on solar cell measurements », Adv. Energy Convers., vol. 3, no 2, p. 455-479, avr. 1963.
6. H. De Battista et R. J. Mantz, « Variable structure control of a photovoltaic energy converter », Control Theory Appl. IEE Proc. -, vol. 149, no 4, p. 303-310, 2002.
7. A. Zegaoui, M. Aillerie, P. Petit, J. P. Sawicki, A. Jaafar, C. Salame, et J. P. Charles, « Comparison of Two Common Maximum Power Point Trackers by Simulating of PV Generators », Energy Procedia, vol. 6, p. 678-687, 2011.
8. N. Kasa, T. Iida, et L. Chen, « Flyback Inverter Controlled by Sensorless Current MPPT for Photovoltaic Power System », IEEE Trans. Ind. Electron., vol. 52, no 4, p. 1145-1152, 2005.
9. E. Koutroulis, K. Kalaitzakis, et N. C. Voulgaris, « Development of a microcontroller-based, photovoltaic maximum power point tracking control system », IEEE Trans. Power Electron., vol. 16, no 1, p. 46‐54, 2001.

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