A Contribution to Study of a GPV System MPPT with (P&O) and (FLC) algorithms

Dib Djalel, Mordjaoui Mourad, and Abdulhabeb Abdulhabeb

***Abstract*----**The current trend towards the exploitation of various renewable energy resources has become indispensable, so it is important to improve the efficiency and reliability of the GPV photovoltaic systems. Maximum Power Point Tracking (MPPT) plays an important role in photovoltaic power systems because it maximize the power output from a PV system for a given set of conditions.

In this paper presents a new fuzzy logic control based MPPT algorithm for solar panel. The solar panel is modeled and analyzed in Matlab/Simulink. The Solar panel can produce maximum power at a particular operating point called Maximum Power Point(MPP). To produce maximum power and to get maximum efficiency, the entire photovoltaic panel must operate at this particular point. Maximum power point of PV panel keeps on changing with changing environmental conditions such as solar irradiance and cell temperature. Thus to extract maximum available power from a PV module, MPPT algorithms are implemented and Perturb and Observe (P&O) MPPT and fuzzy logic control FLC, MPPT are developed and compared. Simulation results show the effectiveness of the fuzzy control technique to produce a more stable power

***Keywords*----**Photovoltaic panel, fuzzy logic control, modeling, MPPT, solar power

I. INTRODUCTION

In the last years global warming and energy policies have become a hot topic on the international agenda. Developed countries are trying to reduce their greenhouse gas emissions. Renewable energy sources are considered as a technological option for generating clean energy. Among them, photovoltaic (PV) system has received a great attention as it appears to be one of the most promising renewable energy sources. Photovoltaic power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components [1]. However, the development for improving the efficiency of the PV system is still a challenging field of research.

A photovoltaic system converts sunlight into electricity. The basic device of a photovoltaic system is the photovoltaic cell. Cells may be grouped to form panels or modules. Panels can be grouped to form large photovoltaic arrays. The term array is usually employed to describe a photovoltaic panel (with several cells connected in series and/or parallel) or a group of panels. The term array used henceforth means any photovoltaic device composed of several basic cells. The use of new efficient photovoltaic solar cells (PVSCs) has emerged as an alternative measure of renewable green power, energy conservation and demand-side management [2,3].

The performance of a PV array system depends on the operating conditions as well as the solar cell and array design quality. The output voltage, current and power of PV array vary as functions of solar irradiation level, temperature and load current. Therefore the effects of these three quantities must be considered in the design of PV arrays so that any change in temperature and solar irradiation levels should not adversely affect the PV array output to the load/utility, which is either a power company utility grid or any stand alone electrical type load. MPPT algorithms are necessary in PV applications because the MPP of a solar module varies with the irradiation and temperature as shown in Fig.1 and Fig.2, so the use of MPPT algorithms is required in order to obtain the maximum output power from a solar GPV [4].

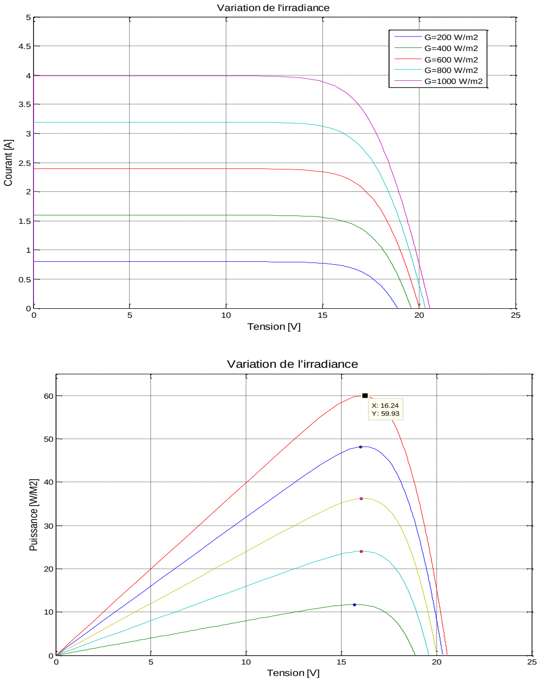

Fig. 1 PV module (a) voltage–current and (b) voltage–Power at different irradiance levels

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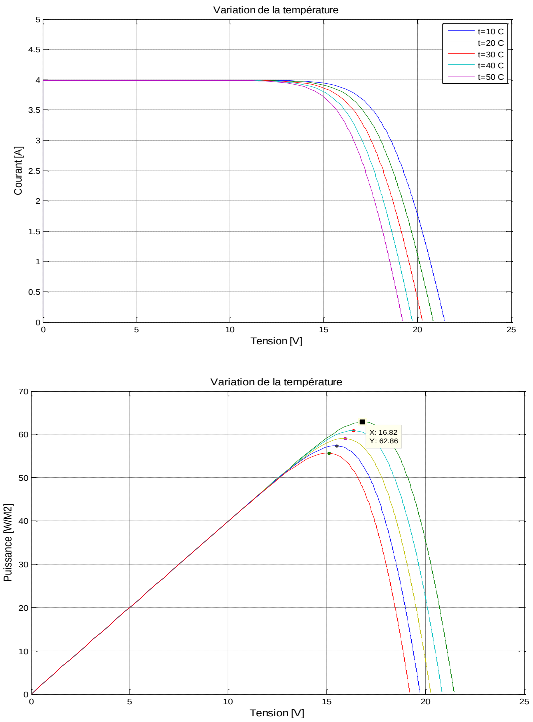


Fig. 2 PV module (a) voltage–current and (b) voltage–Power at different temperature levels

To mitigate this problem of the influencing load on the power produced by GPV a maximum power point tracker (MPPT) can be used to maintain the PV module’s operating point at the MPP. MPPT can extract more than 97% of the PV power when properly optimized[5,6]. A photovoltaic system for isolated grid-connected applications as shown in Fig.5 is a typically composed of these main components (Fig 3):

1) PV module that converts solar energy to electric one,
2) DC-DC converter that converts produced DC voltage by the PV module to a load voltage demand
3) Digital controller that drives the converter operation with MPPT capability.

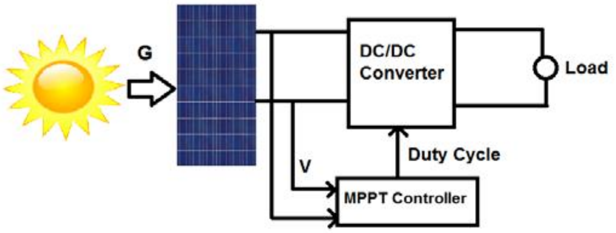


Fig. 3 Block diagram of the stand-alone PV system In the literature

II. MODELING OF PV CELL AND MODULE

A PV cell can be simulated by a real diode in parallel with an ideal current source ISC which depends on impinging radiation. The generalized equivalent circuit of the PV cell including both series and parallel resistances is shown in Fig 4. [7-8].

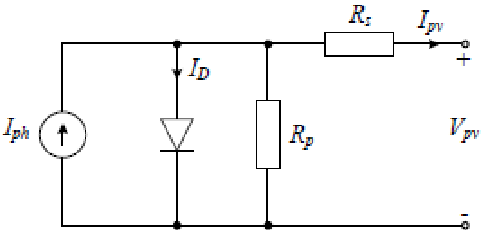


Fig. 4. Equivalent circuit of a PV cell

The mathematical equation expressing the output current of single cell is given as the following equation:

$$I = Icc - Io\left[e^{\frac{V-Rs.I}{Vch}} - 1\right] - \frac{V+Rs.I}{Rsh} \tag{1}$$

for modules or Rsh is assumed infinite, the equation reduces to:

$$I = Icc - Io\left[e^{\frac{V-Rs.I}{Vth}} - 1\right] \tag{2}$$

$$Vth = \frac{(Vop-Rs.Iop-Voc)}{log\left(1-\frac{Iop}{Icc}\right)} \tag{3}$$

$$Io = (Icc - Iop)e^{\left[1-\frac{(Vop+Rs.Iop)}{Vth}\right]} \tag{4}$$

The adaptation of the Eq.1 to other levels of radiation and temperatures gives:

$$In = Iref + \Delta I$$

$$Vn = Vref + \Delta V$$

$$\Delta I = \alpha\left(\frac{E}{Eref}\right)\Delta T + \left(\frac{E}{Eref} - 1\right)Icc \tag{5}$$

$$\Delta V = \beta\Delta T - Rs.\Delta I \tag{6}$$

With:

α is the coefficient of variation of the current with the temperature

β is the coefficient of variation of the voltage with the temperature

$$\Delta T = T - Tref \tag{7}$$

where: T is the temperature of the module

T ref is the reference temperature

III. CONTROLLER MAXIMUM POWER POINT

The follower of maximum power point tracking (MPPT) allows the photovoltaic module to operate at its maximum power point. It is usually designed with a converter that regulates the power drawn from the solar panel. By changing the order of switches, the energy transferred by the converter can be precisely controlled. The maximum power point (MPP) is usually controlled by two control variables. The voltage or power is measured each time is used again in a loop to determine if the solar module is at maximum power point.

The intercalation of a static converter DC/DC, as shown in figure 5, changes the operating point of the panel through an external control law in order to maximize the energy transferred permanently.

A. *DC-DC converter*

A boost converter is a step-up DC-DC power converter. Fig.5 shows the boost converter circuit using MOSFET switch. The converter operation can be divided into two modes. Mode 1 begins when the transistor is switched ON, the current in the boost inductor increases linearly, and the diode is OFF state, mode 2 begins when the transistor is switched OFF, the energy stored in the inductor is released through the diode to the load. The power flow is controlled by varying the on/off time of the MOSFET.

The electrical circuit of buck-boost converter is represented in figure 6.

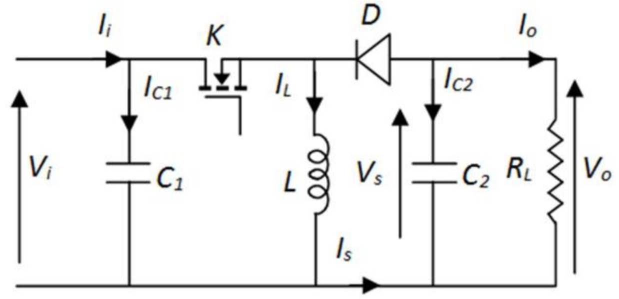


Fig. 5 DC-DC Buck-Boost converter

The dynamic model of the Buck-Boost converter is given by:

$$i_L = \frac{1}{D}\left(i_i - C_1\frac{dv_i}{dt}\right) \tag{8}$$

$$i_o = -(1-D)i_L - C_2\frac{dv_o}{dt} \tag{9}$$

$$v_i = \frac{1}{D}\left(-(1-D)v_o + R_L i_L + L\frac{di_L}{dt}\right) \tag{10}$$

The conversion report V_0/V_i is given by the following expression

$$M(d) = \frac{V_o}{V_i} = \eta\frac{-d}{1-d} \tag{11}$$

$$\eta = \frac{1}{1+\frac{R_L I_O}{(1-\delta)^2 V_O}} \tag{12}$$

Most methods of tracking maximum power point based on the power-voltage characteristic of photovoltaic energy [8]. Different control algorithms exist, we present in this paper a comparative study between different numerical method of MPPT, namely fuzzy logic (FLC), genetic algorithm and artificial neural networks (ANN).

D is duty cycle, that can be expressed by the equation:

$$D = \frac{Ton}{T} \tag{13}$$

B. *Perturb and Observe Algorithm (P&O)*

Over the past decades many methods to find the MPP have been developed and published. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others. A complete review of 19 different MPPT algorithms can be found in [9]. The Perturb and Observe (P&O) algorithm is the most commonly used in practice because of its ease of implementation. This controller is introduced briefly in Ref. [10].

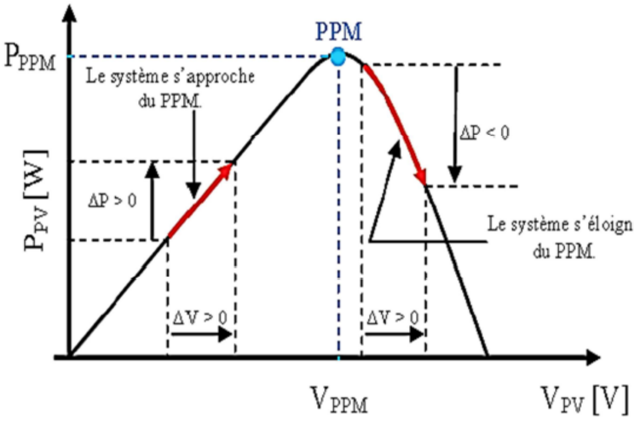


Fig. 6 P&O algorithm operating

In the P&O algorithm, the operating voltage of the PV array is perturbed by a small increment, and the resulting change in power, ΔP, is measured. If ΔP is positive, then the perturbation of the operating voltage moved the PV array's operating point closer to the MPP. Thus, further voltage perturbations in the same direction (that is, with the same algebraic sign) should move the operating point toward the MPP. If ΔP is negative, the system operating point has moved away from the MPP, and the algebraic sign of the perturbation should be reversed to move back toward the MPP. Fig.6 and Fig 7 shows the flowchart of this algorithm. P&O algorithm has some drawbacks which are in [3]; it cannot always operates at the maximum power point due to the slow trial and error process, and thus the solar energy from the PV arrays are not fully, the PV system may always operates in an oscillating mode and finally; the operation of PV system may fail to track the maximum power point.

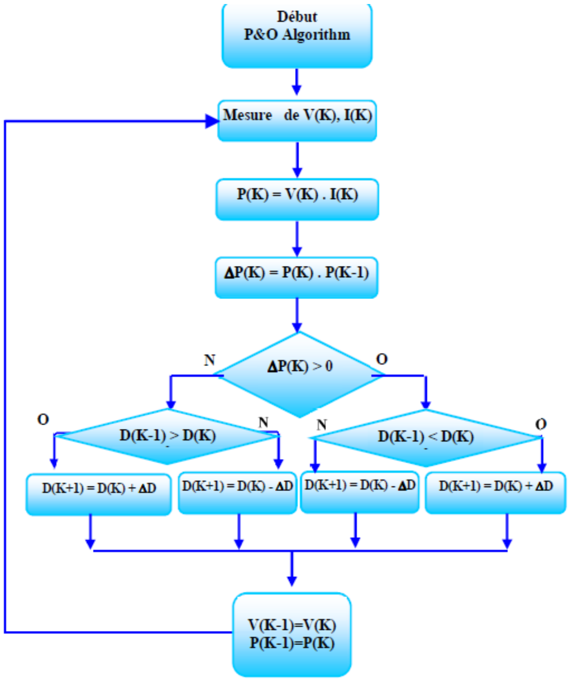


Fig. 7 Flow chart of P&O algorithm

C. MPPT Fuzzy Logic algorithm

Ease of use of fuzzy logic on any application, allowed to adapt to the field of renewable energy which includes photovoltaic. Several researchers have studied this type of algorithm, especially for its application in research and the pursuit of maximum power point tracking (MPPT). This method uses a controller based on fuzzy logic applied to a DC-DC converter [11,12].

Fuzzy logic controllers have the advantage of being robust and relatively simple to design because they do not require knowledge of the exact model. On the other hand they require perfect knowledge and complete photovoltaic system by the operator for the establishment of rules of inference.

The fuzzy controller proposed MPPT has two inputs and one output. The two input variables of the controller are the error E and the error variation CE sampled at each sampling step k. These two variables are defined by:

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

$$CE(k) = E(k) - E(k-1)$$

Where P (k) and V (k) are respectively: the power and voltage of GPV.

The value of E (k) shows the positioning of the operating point for the load at time k relative to the maximum power point. The value CE (k), it expresses the direction of movement of this point. The method chosen for inference, in our work is that of Mamdani. As for the defuzzification is the center of gravity method for calculating the output, the duty cycle of DC-DC converter, which was preferred:

$$D = \frac{\sum_{j=1}^{n} \mu(Dj) - Dj}{\sum_{j=1}^{n} \mu(Dj)}$$

Generally, a fuzzy logic control consists of three blocks

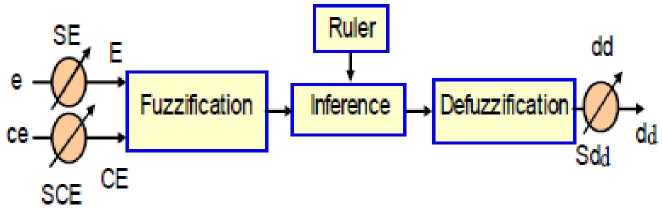


Fig.8 General structure of a fuzzy logic controller

1. Fuzzification, inference and eventually block the defuzzification.

The fuzzification itself is to define membership functions for the different variables, making the passage of a physical quantity to a quantity language. The inference rules selected were obtained from general rules applied to any system that can be ordered.

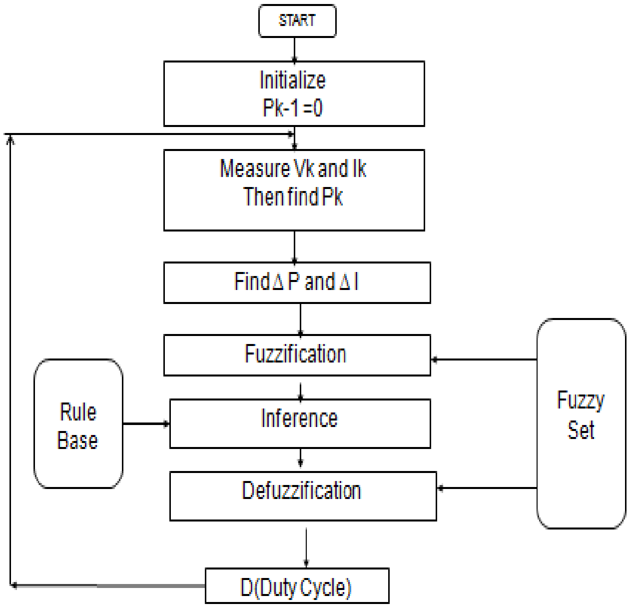


Fig. 9 Flow chart of Fuzzy MPPT

The "Table 1." shows matrix of inference of the regulator. The five linguistic variables used are: NB (Negative Big), NS (Negative Small), ZE (Zero Approximately), PS (Positive Small), PB (Positive Big) [13]. To define the control law, the fuzzy controller must be accompanied by a defuzzification procedure acts as a converter fuzzy control value in physical condition necessary for such a process. It is to calculate, based on the degrees of belonging to all the fuzzy sets of the output variable, the abscissa corresponding to the value of this output.

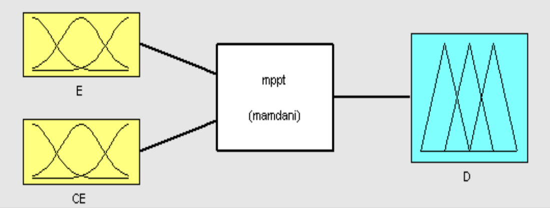
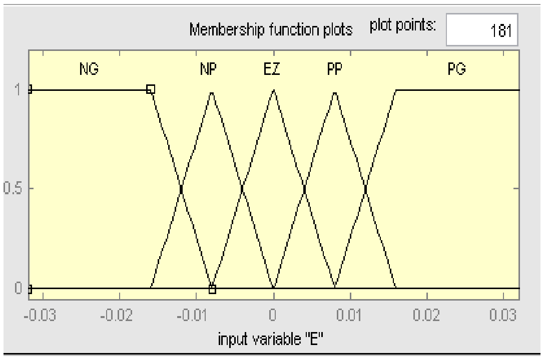
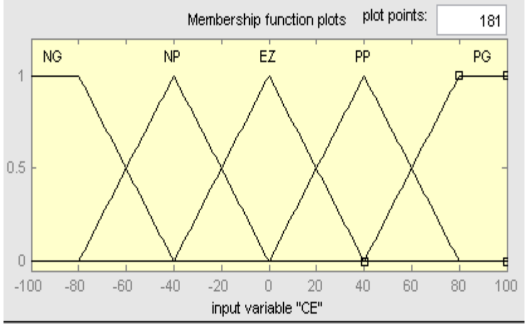


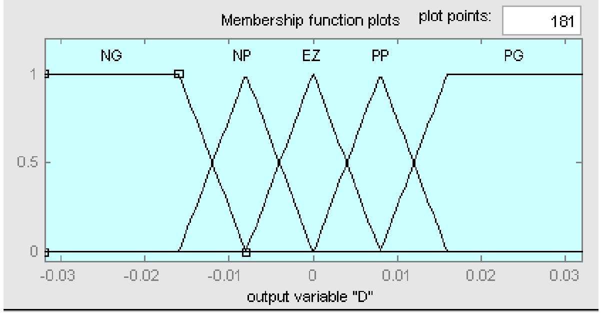
Fig.10 Fuzzylogic system in toolbox Matlab



a-Error E



(b) Duty cycle



c-Sortie D

Fig.11 Function of appurtenance (a) various input errors and output (b), Duty cycle, (c)-Sortie D

TABLEI.
MATRIX OF INFERENCE OF THE REGULATOR

E\CE	**NG**	**NP**	**EZ**	**PP**	**PG**
NG	EZ	EZ	NG	NG	NG
NP	EZ	EZ	NP	NP	NP
EZ	NP	EZ	EZ	EZ	PP
PP	PP	PP	PP	EZ	EZ
PG	PG	PG	PG	EZ	EZ

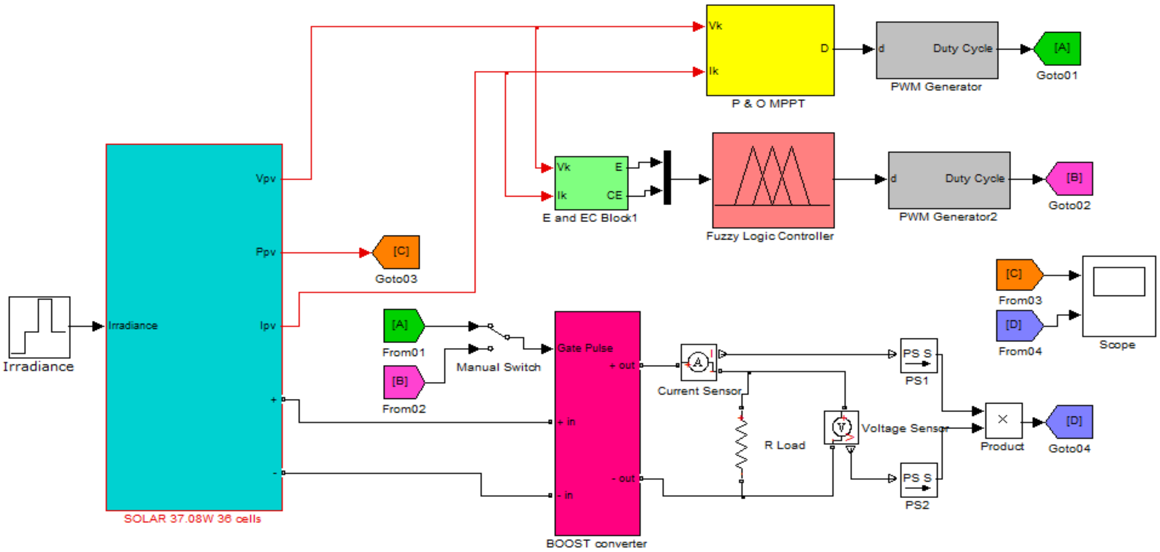


Fig. 12 Complete system implementation in SIMULINK for data analysis

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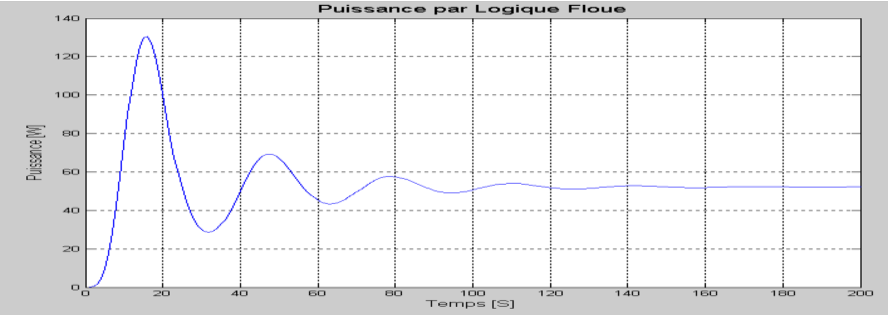

Fig. 13 Output voltage of Boost converter G=1000(w/m2) and T=25°C

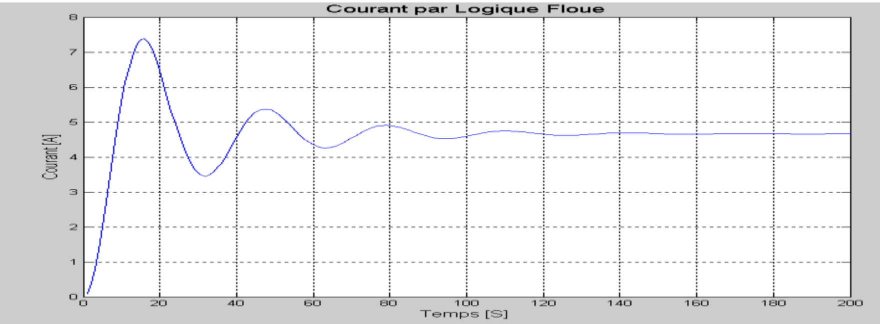

Fig. 14 Output current of Boost converter G=1000(w/m2) and T=25°C

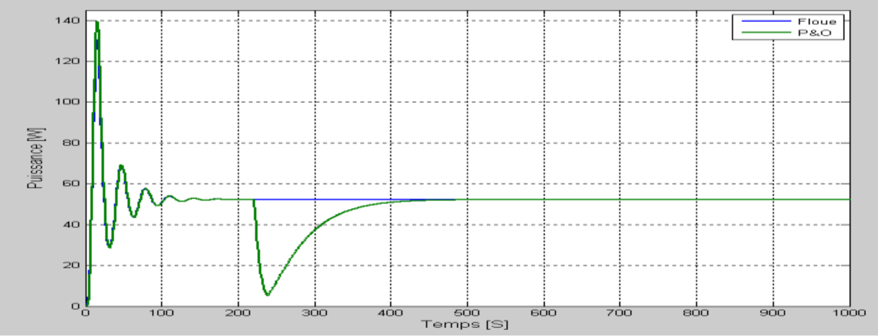

Fig.15 Output Power of Boost converter by FLC and P&O algorithms

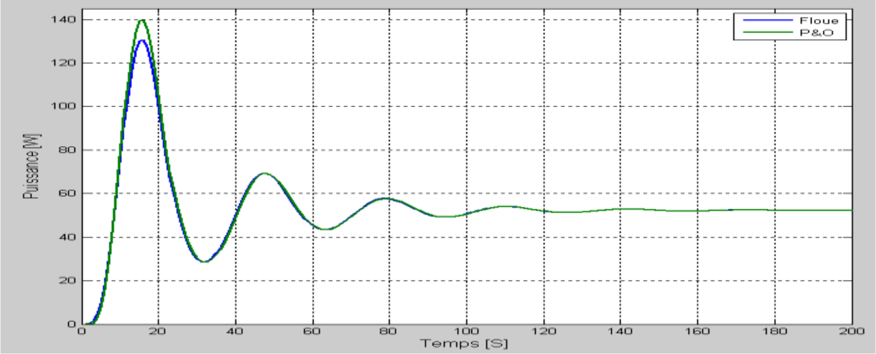

Fig. 16 Zoom of output Power of Boost converter by FLC and P&O algorithms

IV. SIMULATION RESULTS

An extensive simulation for both techniques has been done using MATLAB. Some selected results are presented with a comparison between fuzzy and P&O MPPT controllers. The following simulation were presented for insulation 1000 W/m2 at temperature of 25°C as shown in Fig.13 to Fig 16.

Fig.15 and 16 shows the output power of PV at fixed insolation level and temperature for both controllers. As shown fuzzy controller shows smother power signal line, less oscillating and better stable operating point than P&O.

From the simulation results, it can be deduced that the fuzzy controller has better performance than P&O, and it has more accuracy for operating at MPP.

V. CONCLUSION

This paper presented a mathematical model for PV. It also included MPPT at varying irradiation and temperature conditions Since the Maximum power point Tracking (MPPT) plays an important role in photovoltaic (PV) power systems because they maximize the power output from a PV system for a given set of conditions, and therefore maximize their array efficiency. We present a maximum power point tracker (MPPT) using fuzzy logic with Gaussian membership functions for a PV system.

The work focused on the well known Perturb and Observe (P&O) algorithm and compared to a designed fuzzy logic controller (FLC). A simulation work dealing with MPPT controller, a DC/DC boost converter feeding a load is achieved. The results showed the validity of the proposed fuzzy logic MPPT in the PV system.

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