Efficiency of Different Control Algorithms for a PV Panel

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Abstract- **This work, presents a comparative study of three intelligent control methods in order to optimize the efficiency of the solar PV system. We have proposed a control law for extract the maximum power point (MPP) based on artificial intelligence algorithms such as artificial neural networks (NNA) or fuzzy logic (FL),the main contribution is to compared them with the classical P&O technique, through simulations, in order to choose the most efficient technique.**

*Key words: **Maximum power point, Perturb and Observe, Fuzzy Logic Control, Artificial Neural Networks Control, Photovoltaic system, Boost Converter**.*

I. INTRODUCTION

Solar energy is becoming increasingly essential in the area of renewable energy as the cost of photovoltaic panels continues to drop due to large scale manufacture.To improve the performance of this GPV and due to the non-linear electrical characteristics of the photopiles, it is advisable to use the techniques of maximum power point tracking (MPPT) that we will focus on in this paper particularly to the development and optimization of a procedure that allows the tracking of the maximum power point of a photovoltaic generator (GPV), for a good operation, under any weather conditions (temperature and irradiance) [3].The aim of our work is to develop a three intelligent control methods in order to optimize the extraction of the maximum power,in the following three sections are presented:

• In the first section, we will present the characteristics, modelling and simulation of a GPV.

• In the second section, we will present the principle of finding the maximum power point, by integrating between the GPV and the load an adaptor stage consisting of a statistical DC-DC converter controlled by MPPT techniques that we will detail.

• The third section is devoted to the simulation results, analysis Moreover, a study comparison of the responses of the PV system controlled by these MPPT techniques in order to choose the best performing control. Finally some comments and conclusions are given.

II. CARACTERISTIC OF THE PV GENERATOR:

It is assumed that the PV cells, the basic element of the PV panel, have the same physical properties, and that they are exposed to the same metrological conditions [1]

To describe the PV panel we have used a mathematical model with five parameters. [2]

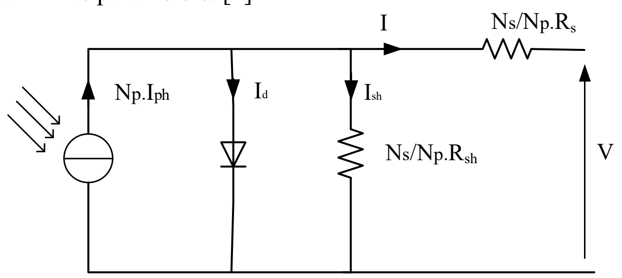

Fig . 1 . Equivalent electrical diagram of a PV module

Rs : is the series resistance which takes into account the ohmic losses of the material, high contact resistances between metal and semiconductor which considerably reduce the voltage and current and limit the conversion efficiency.

R_{sh} : Characterises a shunt resistance (or leakage resistance) Vagabond currents due to charge recombination, impurity defects, irregularities in the thickness of the N, P and the space charge zone so the existence of cracks becomes comparable to a parallel resistance.

I_{ph} : The photo-current generated by a single PV cell.

I : The current delivered by the GPV.

N_p : Number of associated PV cells in parallel.

N_s : Number of associated PV cells in series.

V : The terminal voltage of a PV cell.

The current-voltage characteristic equation of the PV panel can be derived from Fig.1 by applying Kirchhoff's law:

$$I = N_P . I_{PH} - I_d - I_{sh} \qquad (1)$$

$$I = N_P . I_{Ph} - I_S .(\text{Exp} (\frac{V + I.\frac{N_S}{N_P}.R_S}{A.V_t}) - 1) - \frac{V + I.\frac{N_S}{N_P}.R_S}{\frac{N_S}{N_P}.R_{sh}} \qquad (2)$$

The saturation current depends on the temperature, the diode surface (therefore of the PV cell) and the junction caracteristics, it varies exponentially with temperature and can be giving by:

$$I_s = I_{sc}.(\frac{T_{op}}{T_{ref}})^3 .Exp(\frac{q.E_g}{A.k}.(\frac{1}{T_{ref}} - \frac{1}{T_{op}})) \qquad (3)$$

I_{sc} : The short circuit current of the cell PV.
T_{op}: The operating temperature of the cell PV.
T_{ref} : The reference temperature of the Cell PV.
E_g : The optical gap of the material.
A : The quality factor of the diode is usually between 1 and 2
q : Elementary electric charge (1,6 .10-19 C).
V : The voltage imposed on the diode.

$$V_t = \frac{k.T}{q} = 26\ mv\ at\ 300K .$$

K : The Boltzman constant $k = 1.38\ 10^{-23}$ J/ K .
T : The absolute temperature in °K.
Is : The saturation current of the diode.

$$I_{ph} = [I_{sc} + k_i (T_{op} - T_{ref})] * \frac{G}{G_0} \qquad (4)$$

I_{sc} : The short-circuit current of the module.
K_i : Short circuit temperature coefficient.
G_0 : Irradiation for the STC.

Tab . 1 . Electrical characteristics of the PV panel

Short circuit temperature coefficient (k_i)	0.0032 A/K
The quality factor of the diode (A)	1.3
The optical gap of the material (E_{go})	1.1ev
The series resistance (R_s)	0.221Ω
The shunt resistance (R_{sh})	415.405Ω
The open circuit voltage (V_{oc})	32.9V
The short circuit current (I_{sc})	8.21A
Number of cells associated in series (N_s)	54cell

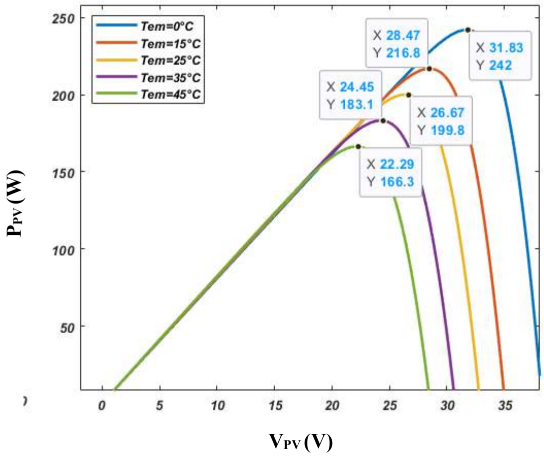

Fig. 2 . P-V characteristic curve as a function of temperature variation and illuminance 1000w/m²

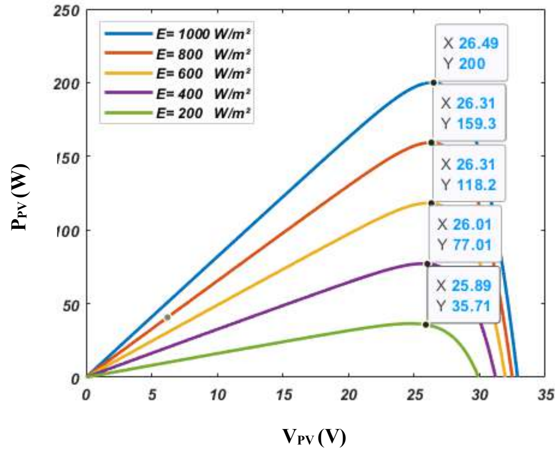

Fig. 3 . P-V characteristic curve as a function of the variation in illuminance at a temperature 25°C

From the figures 2 and 3, we can deduce that, On the one hand, we observe that an increase in temperature degrades the power delivered by the GPV and this is reflected in the voltage drop across it. *Fig(2)*

On the other hand, the increase in illumination creates an increase in the power produced by the GPV and results in an increase in the current produced by the latter.

III. Configuration of the PV system.

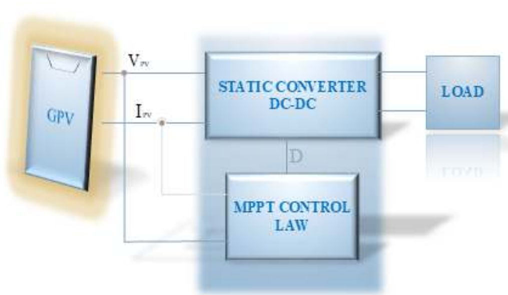

Fig. 4 . Schematic diagram of the indirect connection of the GPV to a load

Figure.4. presents an adaptator stage that is based on the acquisition of the voltage Vpv and the current Ipv of the PV module output. It consists of a DC-DC boost converter [3] that incorporates MPPT to control and optimise the input voltage of this device, which should ideally be equal to that corresponding to the maximum power point (MPP).

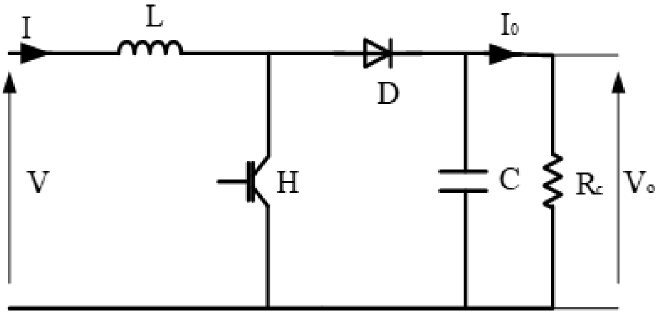

Fig. 5. Schematic diagram of Boost converter

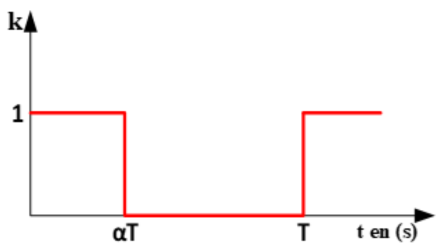

Fig. 6 . control of the switch H

Note that figures 5 and 6, shows the diagram of a boost converter, whose electronic switch H is MOSFET, the last one controlled by a PWM signal of period T and duty cycle α. The switch H is closed for a time αT and open for a time (1-α)T for each period.

The first phase, when switch H is closed, diode D is blocked and behaves as an open switch, the voltage source supplies energy to the inductor, it is a phase of energy accumulation.

And when switch H is open, diode D is on and behaves like a closed switch. The inductance that was charged during phase 1 is now in series with the generator so its f.e.m adds up to that of the generator (Booster effect)

A generalized dynamic equation of a boost converter can then be determined, as a function of the state of the switch H (noted k).

$$I = \frac{1}{L}\int (\mathrm{V} - (1-k)\,\mathrm{V}_0)\,dt \tag{5}$$

$$V_0 = \frac{1}{c}\int ((1-\mathrm{k})I - I_0)\,dt \tag{6}$$

- The average value of the Voltage

$$< V_0 > = < V > . \frac{1}{(1-\alpha)} \tag{7}$$

- The average value of the current

Given that the converter efficiency is 1, we can write

$$V_0 . I_0 = V . I$$

So $< I > = < I_0 > . \frac{1}{(1-\alpha)}$ (8)

A. Using the command MPPT to extract the maximum power

Driving this non-linear system to operate at MPP without knowing in advance the parameters that have influenced and perturbed it, commands whose target is to track this MPP, allow the GPV to be operated in such a way that it always generates its maximum power, whatever the metrological conditions (temperature and/or illumination). While maintaining a perfect match between the generator and the load in order to extract the maximum power. [4].

The converter control sets the system to the maximum operating point (Vmpp , Impp). It varies the duty cycle of the static converter, by an adequate electrical signal (pulse width modulation), to extract the maximum power from the GPV.

In general; The MPPT algorithms are based on the variation of the duty cycle of the static converter and also depends on the input parameters of the converter (I and V).

B. control laws MPPT :

1) Command Perturb and Observe

The principle of this algorithm is to perturb the voltage at the output of the GPV by varying the duty cycle α, then we calculate the variation of the power in relation to the variation of the voltage.

If the positive result, we will keep the same direction of perturbation.

If it is negative, we will inversing the direction of the perturbation.

If no one does anything.

The P&O algorithm can be represented by the following mathematical equation:[4]

$$V_k = V_{k-1} + \Delta V . \mathrm{sign}(\frac{dP}{dV} \|_{V_{k-1}}) \tag{9}$$

2) *Fuzzy command MPPT*

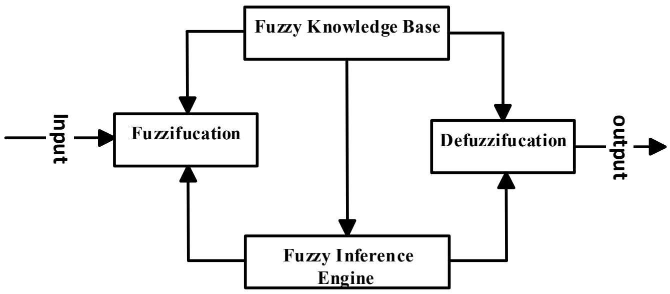

Fig. 7. Principle of fuzzy control

a) Fuzzifucation :

The development of a fuzzy regulator of a control MPPT is based on two input variables which are:

The error $$E(k) = \frac{P(k) - P(k-1)}{V(k) - V(k-1)} \quad (10)$$

The variation of the error $$\Delta E = E(k) - E(k-1) \quad (11)$$

And the variation of the duty cycle $\Delta\alpha$ as an output variable of the controller, it is responsible for controlling the static converter.

P(k) and V(k) respectively the power and voltage of the PV panel

E(k) is zero at the maximum power point of the PV array, these input variables are expressed in terms of linguistic variables such as :

Table.2. Linguistic variables

NG: Big négative	NM: Medium négative	NP: Small négative
PG: Big Positive	PM: MediumPositive	PP: Small positive
	EZ: Equal to Zero	

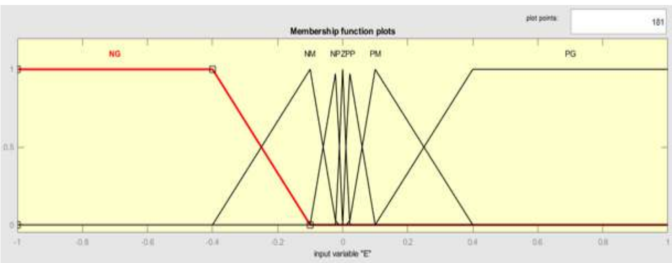

Fig. 8 . Membership functions E, ΔE et α

b) Fuzzy Inference Method

This phase consists of defining a logical relationship between the input and output variables, the control rule must be designed so that the input variable (E) is always zero.

Mamdani's Min-Max inference method is used . It can be seen that, if the operating point is to the left of the MPP, the error (E) is positive and if it is to the right the error is negative. Similarly, the variation of the error (ΔE) defines the direction of movement of the operating point.

The value of the output variable is selected depending on the variables attributed to the controller inputs [5] [6].

Table.3. Fuzzy inference rule

E /ΔE	NG	NM	NP	Z	PP	PM	PG
NG	NG	NG	NG	NG	NM	NP	Z
NM	NG	NG	NG	NM	NP	Z	PP
NP	NG	NG	NM	NP	Z	PP	PM
Z	NG	NM	NP	Z	PP	PM	PG
PP	NM	NP	Z	PP	PM	PG	PG
PM	NP	Z	PP	PM	PG	PG	PG
PG	Z	PP	PM	PG	PG	PG	PG

c) Déffuzification

This is the reverse phase of Fuzzifucation, for which the centre of gravity method is used to obtain a comprehensible value for the control of the static converter.[9]

3) *MPPT control based on ANN*

a) Principle of the command:

We adopt a multi-layer perceptron type ANN with an input layer that receives two inputs, current and voltage, a hidden layer of 10 neurons that admits the tangential sigmoid activation function and an output layer with a single neuron that had the linear activation function and gives the voltage value at the MPP [8].

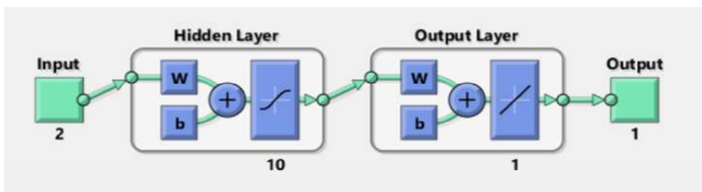

Fig. 9 . ANN structure

IV. Simulation Results and Discussion

A. System response to rapid changes in climatic conditions

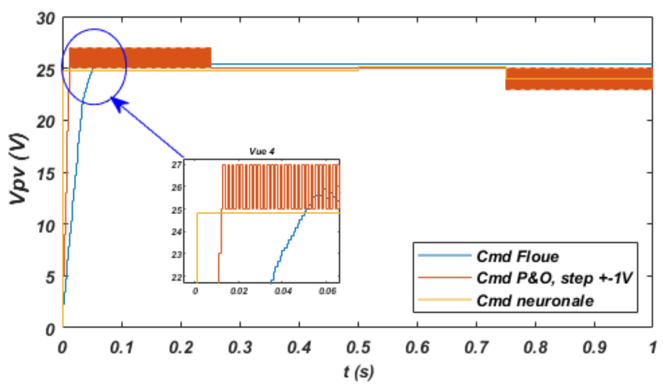

Fig. 10 . PV panel voltage (Vpv)

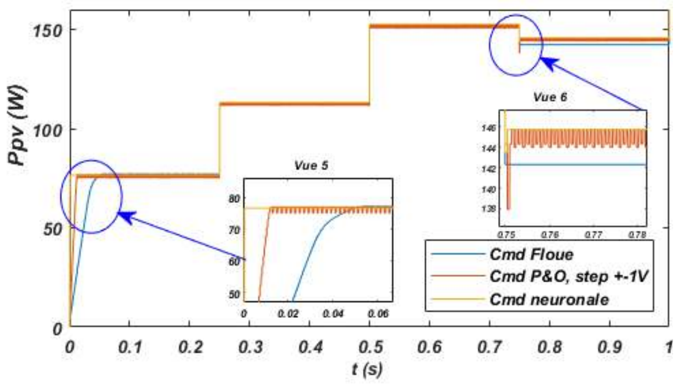

Fig. 11 . PV panel power (P_{pv})

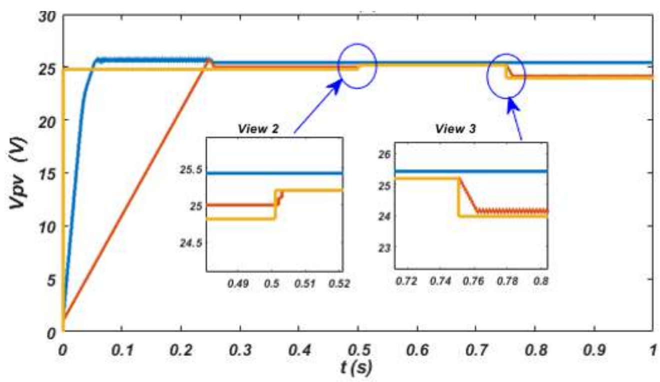

Fig .12. Panel voltage PV (Vpv) Responses to controls P&O with a pitch of +-0.05V and intelligent

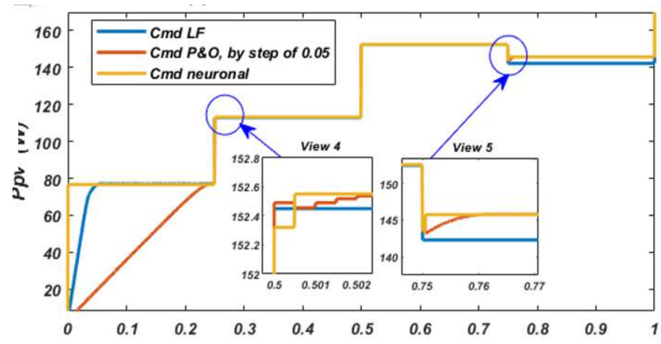

Fig .13. PV panel power (Ppv)

Figure 10 shows that the P&O algorithm with a step size of 1V, has good dynamic performance, it converges more quickly to the stationary state and takes 0.02s to go to the PPM, however the oscillation in permanent mode is very high. However, with a step of 0.05V, it becomes slow and takes 0.25s to attain the MPP,figure 12 *vue(2)* and the oscillation in permanent mode has been completely attenuated.

Neural control shows a very considerable speed .Fuzzy control shows better stability.

B. Response of the PV system to progressive variations in climatic conditions:

The following figures show the superposition of three curves following simulation of the PV system in the face of progressive variations in irradiation and temperature :

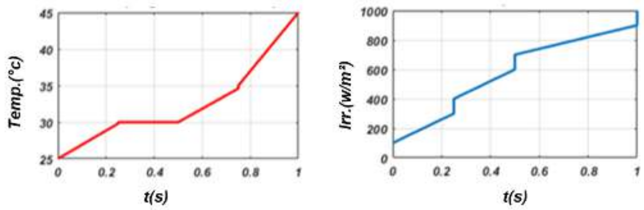

Fig.14-a. Progressive variations irradiance and temperature

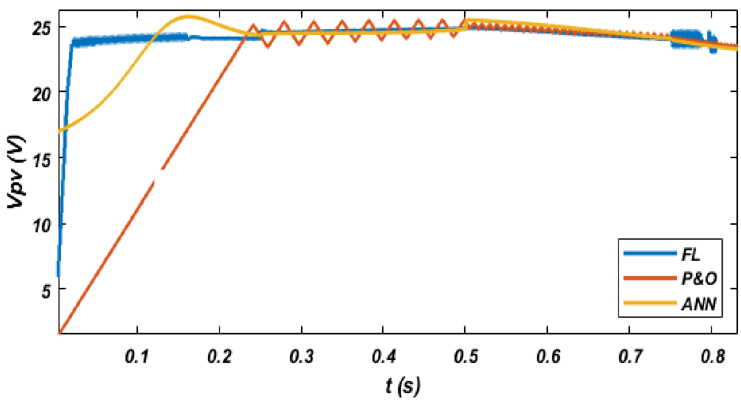

Fig .14-b . the panel voltage PV (Vpv) as a result of progressive variations in irradiance and temperature; P&O command responses with +-0.05V step and intelligent.

Figure 14 shows an oscillating response of the P&O control following progressive variation of temperature and illumination, and this is because the algorithm reacts as if this increase is produced by the previous perturbation effect, then it continues in the same direction which is the wrong direction, that it takes it out of the true point of maximum power. This process continues until the irradiance is stable and it returns to the true maximum power point.

V. CONCLUSION :

A GPV is a system with non-linear behaviour; the maximum power that generates it depends mainly on the meteorological conditions (temperature and irradiance).It increases with irradiance and decreases with temperature.

the studied fuzzy and neural intelligent MPPT techniques show quite desirable performance, in terms of speed, stability and do not need to know the system to be controlled on the other hand, the conventional P&O shows oscillations around the PPM and so a divergence during a progressive change in climatic conditions.

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