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Optimization of the Perturbe & Observe technique for photovoltaic panel

Ourahou Meriem[#1], Wiam Ayrir [#2], Ali Haddi [#3]
Laboratory of Innovative Technologies. National School of Applied Sciences
Abdelmalek Essâdi University
Tangier, Morocco
[1]meriem.ourahou@gmail.com
[2]ayrir-ouiam@hotmail.com
[3]haddi.ensat@gmail.com

***Abstract*— Photovoltaic energy has become more and more coveted today. In the future, it will become a necessity. To ensure its optimization, maximum operating point tracking method is considered as a technological key in photovoltaic systems. One of the most used MPPT methods is the Perturbe & Observe method. In this paper, we will focus on optimizing this method based on two techniques. The first technique aims at optimizing the P&O algorithm in the case of insolation variation, and the second is an optimization based on fuzzy logic. These two techniques were developed via Matlab software, and the results obtained were interpreted to clarify the performance of each optimization.**

***Keywords*—**MPPT photovoltaic panel, P&O, variation of insolation, Fuzzy Logic...

I. INTRODUCTION

Despite the great advantages of photovoltaic energy, it remains nonlinear and very sensitive to meteorological fluctuations [1][2], the load conditions and the age of the panel itself. Indeed, the illumination and temperature levels clearly influence the operation at maximum power of the photovoltaic panel. This was the starting point for various techniques of maximum power point MPPT tracking [3][4]. The challenge is therefore to constantly determine the maximum operating point of the photovoltaic panel that makes it possible to assign permanently a maximum power to the load. In this paper, we focus on the « Perturb & Observe » (P&O) method where two optimization methods will be highlighted, one is based on the illumination variation principle and the other one is based on fuzzy logic.

This article will focus, in section 2, on the characteristics of photovoltaic modules and a description of P&O classic method. In section 3, there will be a presentation of an improved P&O algorithm in the case of insolation variation. Next, in section 4, another optimization of the P&O method based on fuzzy logic will be studied. Later, simulations, results and discussions will be detailed in section 5, and will be followed by a final conclusion.

II. PHOTOVOLTAIC SYSTEM AND CLASSIC P & O METHOD

A. Characteristics of the PV module

A photovoltaic generator (GPV) consists on several photovoltaic cells mounted in series and / or in parallel as well as a conversion system (DC-DC converter); (MPPT control) and storage (DC load). This set is called a photovoltaic system. When the received solar energy exceeds the energy gap of the module, photons are absorbed by the material thus generating electricity. Indeed, photovoltaic cells, actuators of this conversion, are not able to store energy and therefore an instantaneous conversion will take place when the light energy is available. The photovoltaic module has a characteristic curve (I-V). It varies according to the temperature (T) and the insulation (S). Also, it has an operating point which is none other than the intersection of the characteristic curve (I-V) and the load line.

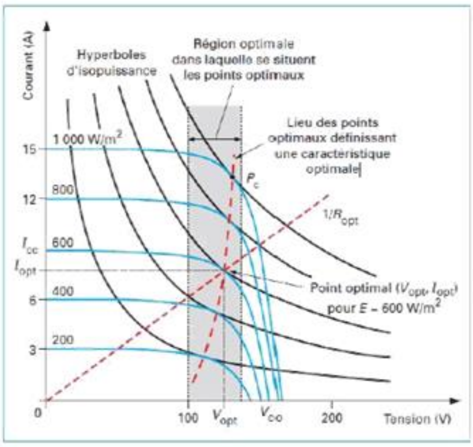

Fig.1 Variation of the operating point for different illuminations

Each optimal point is characterized by the voltage V and current I_{opt}. At this point corresponds a resistance R_{opt} for constnt temperature values and illumination. This resistance characterizes the value of the electrical load positioning the panel at the operating point where it can generate a maximum power.

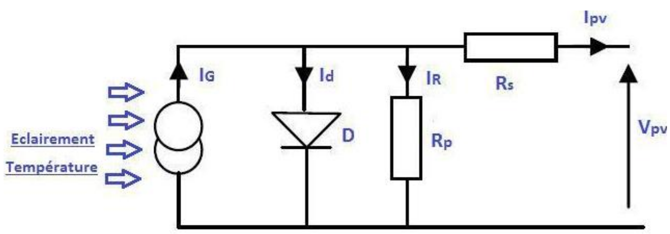

Fig. 2 Electrical model for a photovoltaic cell

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R_S: Line Contact Resistance
R_p, I_R: Leakage resistance and current due to diode and the junction effects
I_G: Current created by an absorbed solar radiation, this current is practically equal to the short-circuit current Icc.
(I_{PV}, V_{PV}): Characteristics of the photovoltaic panel

The final equation of the photovoltaic panel model is :
$I = Isc - I_0 (\exp(e [V + Rs\, I] / KT) - 1) - ([V + Rs\, I] / Rp)$

B. The MPPT Perturb & Observe command

Among the MPPT commands, Perturb & Observe is one of the most used commands because of its simple structure and the reduced number of parameters to control.
The principle is to generate disturbances by reducing or increasing the duty ratio D and to observe the effect of the generated power by the PV panel. Once the periodic V the voltage disturbance of the panel is done, it can decide on the next cycle. It is also important to note that the disturbance ΔV is low so that the power variation is not too excessive.
Thus, if:

- DP / dV> 0, we approach the MPP and the perturbation moves the operating point closer to the MPP. The cyclic ratio variation in the same direction is thus maintained until the MPP has been reached.
- DP / dV <0, we move away from the MPP and the perturbation moves the operating point farther from the MPP. The cyclic ratio variation must be done in the opposite direction until reaching the MPP.
- DP / dV = 0, we are at the MPP.

For this method there is a compromise between accuracy and speed since the disturbance must be very low so that the power change is not too big and thus minimize power losses [6] [7].

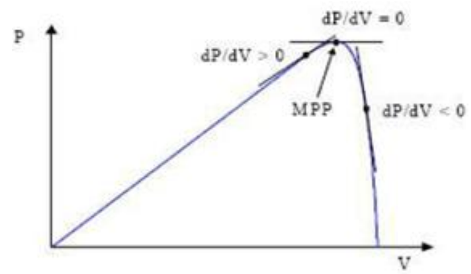

Fig.3 The power curve behavior in the P & O method

The controller based on the P&O algorithm has two input values that are measured constantly. Which are the current and the voltage. From these measurements, it calculates the power P, the voltage variation ΔV and the power variation ΔP between K and K-1 iterations.

The P&O algorithm is explained below:

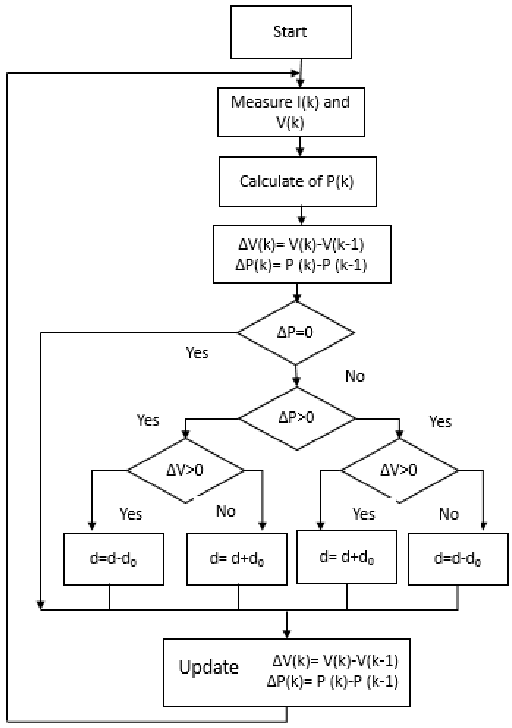

Fig. 4 P&O classic algorithm

III. First optimization of the P&O algorithm with current correction

As shown previously in Figure 1, the output power of a PV generator depends on the received irradiation. Indeed, the voltage does not vary considerably contrary to current that increases strongly.
In this case, the solution would be, not only to make a control loop over voltage and power but also over the current. It allows to control permanently current variation and thus to identify as much as possible any variation of illumination. . This will reflect any eventual insolation variation at the cycle input. Indeed, in a classic P&O algorithm, the value of current I measured at panel output is never stable and varies within a range of absolute value lower than a limit L as [8]:

$$I = i(k) - i(k-1) \text{ and } |\Delta I| < L$$

In order to make the algorithm insensible to these current changes due to the oscillation, we will set a threshold S higher than the limit L. It will allow to test insolation variation. Therefore, we take a value S > L. So if:

- $|i(k) - i(k-1)| < S$, the algorithm is a classic P&O algorithm that hasn't gone through any insolation variation.
- $|i(k) - i(k-1)| > S$, the photovoltaic panel has gone through an insolation variation. That gives a new characteristic curve I-V. And the algorithm acts directly on the cyclic ratio.

The operating direction depends on the sign of the current variationI. In fact, if

- I> 0, so the insolation variation has increased and the voltage must then be incremented by V.
- I <0, so the insolation variation has decreased and the voltage must be decremented by V.

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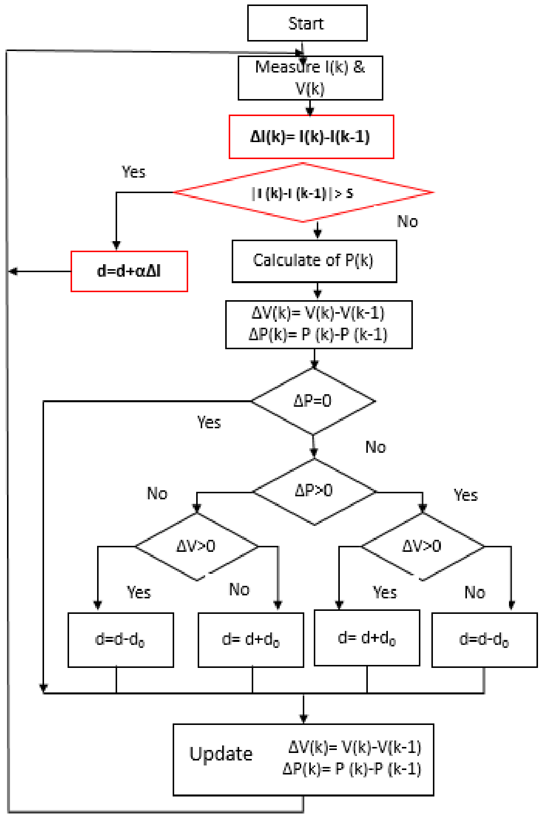

Fig.5 Optimized P&O algorithm

IV. Second optimization of the P&O algorithm based on fuzzy logic

A. Presentation of fuzzy logic method and principles

In our application case, fuzzy logic is a method that will allow the reduction of error without the need for an exact knowledge of system mathematical model. The fuzzy controller is divided into three essential steps: Fuzzification, inference and defuzzification [9].

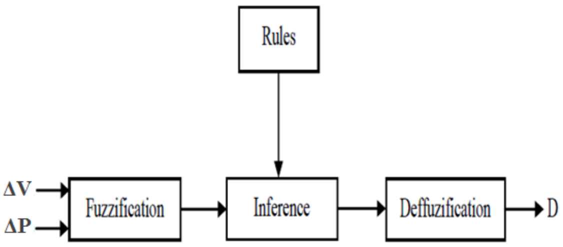

Fig.6 Fuzzy Logic Controller steps

<u>Fuzzification</u>

Fuzzification consists on converting physical variables inputs into fuzzy sets. That is based on a membership degree for each input.

<u>Inference</u>

This is where decisions are made. The inference uses rules for determining the output signal of the controller as a function of the input signals [10].

<u>Defuzzification</u>

This step allows to convert the fuzzy output variables at the end of inference step into adapted physical variables.

B. Optimization of the P&O method using fuzzy logic

The input variables for the fuzzy controller will be the power and the voltage variations. We can write:

V(k) = V(k) - V(K-1)

P(k) = P(k) - P(K-1)

We consider three intervals for the inputs V, P and the output dD which are:

P: Positive Z: Zero N: Negative.

Here are below the membership functions of the output and the two inputs.

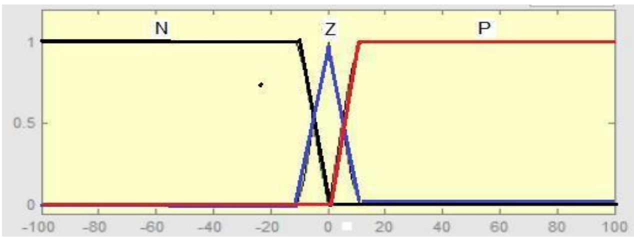

Fig. 7 Voltage variation membership function

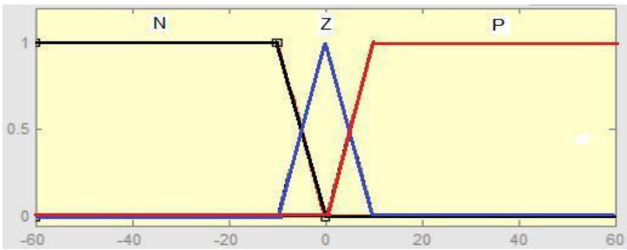

Fig. 8 Power variation membership function

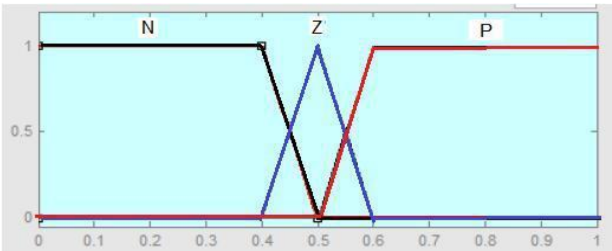

Fig. 9 dD Output membership function

The fuzzy rules can be integrated in the following inference table:

TABLE I

TABLE OF INFERENCES

Rule N°	ΔP	ΔV	dD
1	P	P	N
2	P	Z	Z
3	P	N	P
4	N	P	P
5	N	Z	Z
6	N	N	N
7	Z	P	Z
8	Z	Z	Z
9	Z	N	Z

V. Simulations, results and discussions

A. First optimization of the P&O algorithm based on insolation variation

The simulations for both classic and improved P&O algorithms are performed in the same conditions: a temperature of 25°C and a variable illumination. The power behavior for these two cases is shown in figure 10.

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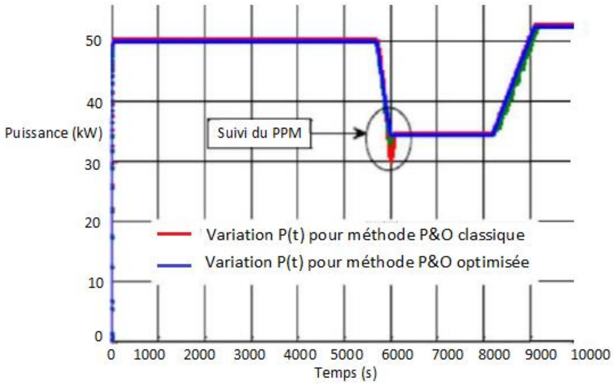

Fig. 10 Power variation for each algorithm

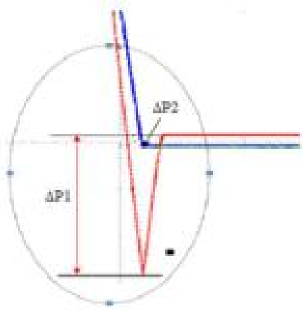

Fig. 11 Power losses for each algorithm

The Figure. 10 shows the power variation of the photovoltaic module depending on illumination variation.

It is clearly seen through the power curve that the improved algorithm has better response in the event of sudden insolation variation.

In Figure 11, we can deduct that using optimization by current correction, we are able to gain in term of photovoltaic panel power in case of illumination variation.

B. *Second optimization of the P&O algorithm based on fuzzy logic*

The simulations for both classic and fuzzy logic improved P&O algorithms is performed in a temperature of 25°C and an illumination of 1000 W/m² as shown in figure 12. Next, in figure 13, we vary the illumination while keeping the temperature fixed at 25°C. Finally, we vary the temperature while keeping fixed the illumination at 1000 W/m² as represented in figure 14.

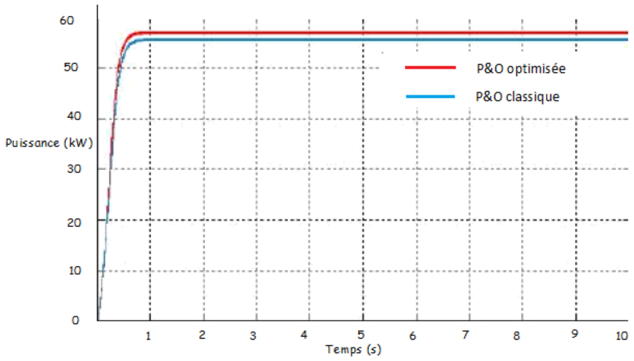

Fig. 12 Power curve for fixed climatic parameters

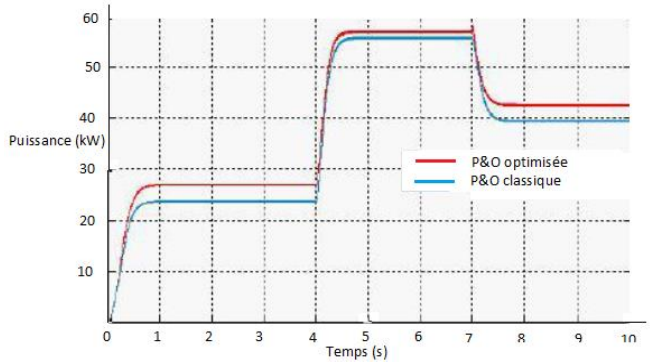

Fig. 13 Power curve for fixed temperature and variable illumination

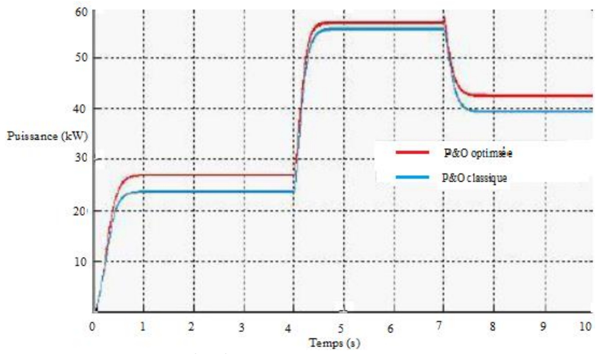

Fig. 14 Power curve for fixed illumination and variable temperature

We note that the curves have the same shape especially in terms of speed and stability. On the other hand, it can be seen that the power curve of the optimized method is more precise and that the classic P&O algorithm curve was affected by the sudden change of illumination or temperature more than the curve of P&O improved algorithm.

VI. Conclusion

In this paper we have presented the structure characterizing photovoltaic system and we have described the method of tracking the maximum operating point. The goal is to give proposals for "Perturb & Observe" (P&O) algorithm improved methods. Through applications, we could conclude that the two optimized proposed methods offer a remarkable improvement concerning power losses.

On one hand, in case of variation of illumination, the first P&O improved algorithm with correction of current, allows considerable improvement of power loss and more precision. On the other hand, the second corrected P&O algorithm based on fuzzy logic seems more accurate than the classic P&O algorithm in term of power loss, and it is less affected by sudden variation of climatic parameters.

To sum up, faced to eventual variations in the illumination of photovoltaic system, the two proposed improved methods are able to significantly improve the efficiency of the system.

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