MPPT P&O Algorithm Optimization by Fuzzy Logic

Chrysostome Andrianantenaina, Dona Bruno Victorien, Jean Nirinarison Razafinjaka

Abstract— **There are several techniques for maximum power point tracking (MPPT) used in system PV. The P&O algorithm is one of widely used among them. However, this technique presents some drawbacks: it is strongly related to the characteristic of the power according to the tension of the photovoltaic generator (GPV) and it presents sometimes oscillations around the maximum power point (MPP). This paper deals with a new method for its optimization by using fuzzy logic. Simulations results show that the new proposal is easy to be implemented and leads to better performances.**

Index Terms— **PV system, DC-DC converter, MPPT, P&O algorithm, Fuzzy Logic, Optimization.**

I. Introduction

Currently, renewable energies are interesting alternative solutions to face the impoverishment of fossil energies and with the environmental problems [1]. Solar energy belongs to these renewable energies having the advantages to be free and considered as inexhaustible. Photovoltaic (PV) generation represents one of the most promising sources of renewable green energy. However, photovoltaic panels offer a fluctuating energy and depend on weather conditions as light intensity and temperature. Consequently, the panel operation point does not always coincide with the maximum power point. To bring solutions of these problems, techniques of maximum power point tracking (MPPT) are used. Nowadays, various methods are proposed [2]-[7]. Among them, the technique P&O (Perturb and Observe) can be quoted. Although this technique is widely used in systems PV for the MPPT because of its low-coast and easy implementation, it presents however some drawbacks: it is strongly related to the characteristic of the power P according to the tension V of the photovoltaic generator (GPV) and it presents sometimes oscillations around the maximum power point (MPP). In [8], Otmani *and al*. propose a method using fuzzy logic to optimize the P&O technique. Two input variables, ΔP and ΔV are used in this case. In [9], a simple MPPT algorithm using high output voltage DC-DC boost converter is proposed. In this paper, fuzzy logic is yet used for the optimization but the new proposal uses only one input variable.

The paper is organized as follows: first, the classic P&O algorithm is briefly described. Then the new method using fuzzy logic for optimization is presented. Simulation results obtained by the two methods and their comparison are discussed in the next section. Last section concludes with the main scope of the proposed study.

Manuscript received November 24, 2017

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II. System PV Conversion

The system PV conversion is based on several blocs as presented in Figure 1.

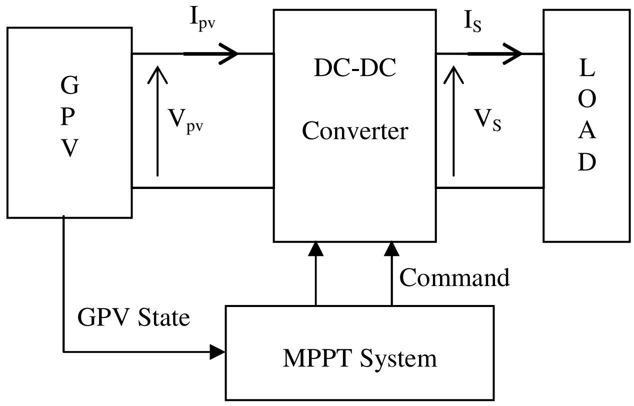
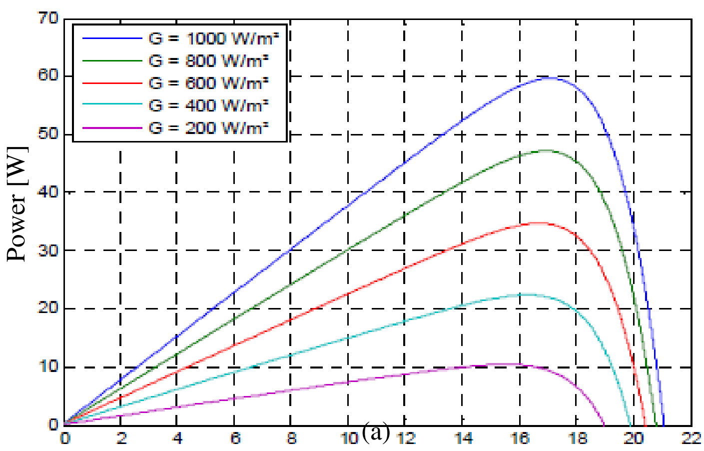
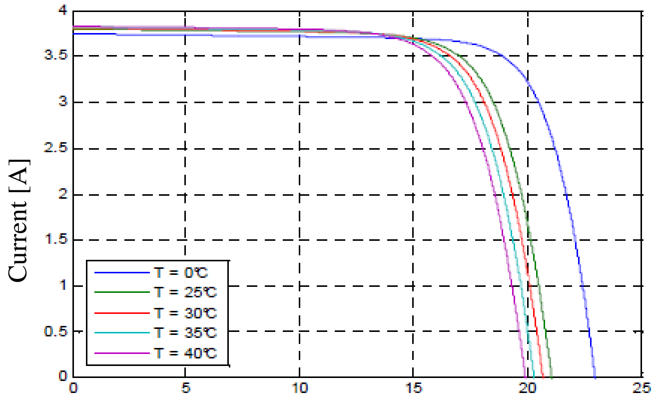


Fig.1 System PV converter

The GPV state is strongly influenced by the solar radiation (G) and temperature (*T*) variations. Figures 2 (a) and (b) show the characteristics PV and IV when *T* or *G* are varying.





(b)

Fig.2: GPV Characteristics. (a) PV when T = 25 [°C]; (b) I-V when G = 1000[W/m²]

It is here well shown that the characteristics depend on the weather conditions especially the solar radiation and the temperature. Optimization techniques are so needed to obtain the maximum power in every condition. The DC-DC boost converter is here used to adapt the load to the GPV and to maintain PV array's operating at its maximum power point (MPP). For this purpose, Maximum Power Point Tracking (MPPT) techniques are required. Among these techniques, the Perturb and Observe (P&O) appears as a most used method.

A. *The DC-DC Boost Converter*

As said above, the DC-DC boost converter adapts the load with the GPV. Figure 3 shows the basic scheme of this kind of converter.

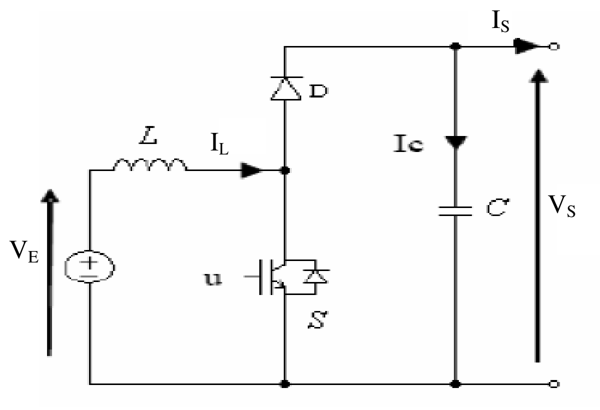


Fig. 3 Basic scheme of a DC-DC boost converter

The mean values of the tension and the current outputs are given by (1):

$$\begin{cases} V_S = V_E / (1-D) \\ I_s = (1-D).I_L \end{cases} \quad (1)$$

Here *D* denotes the duty cycle.

According (1), when *D* increases, the output voltage V_S increases in the same way but the output current I_S varies in the contrary direction.

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

In this algorithm, a slight perturbation is introduced. This perturbation causes the power of the solar module to change continuously. If the power increases due to the perturbation then the perturbation is continued in the same way [7]. The algorithm oscillates around the MPP when the steady state is reached. In order to keep the power variation small, the perturbation size is kept too very small. Figure 4 shows the usual P&O algorithm.

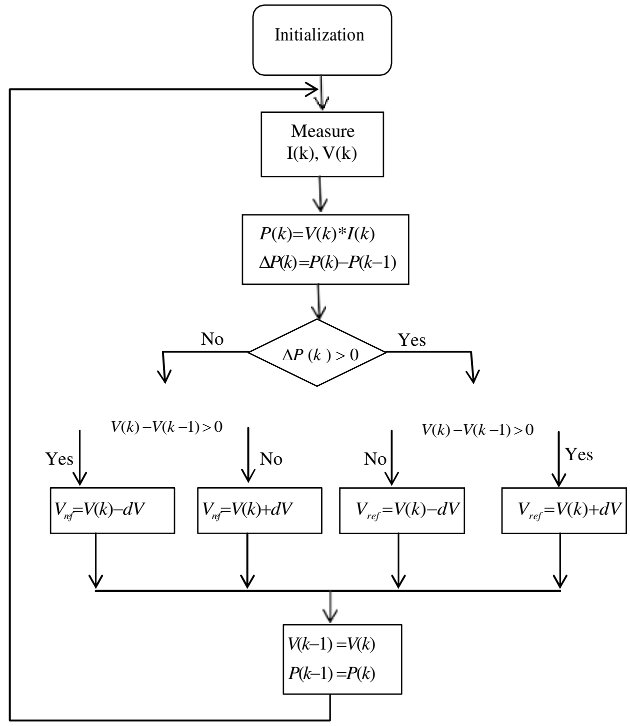


Fig.4 Classic P&O algorithm

Although, the P&O algorithm is simple to be implemented, it is less powerful to track the MPP under fast varying atmospheric conditions. The next section presents a new algorithm using P&O algorithm optimized by Fuzzy Logic controller.

III. P&O ALGORITHM OPTIMIZED BY FUZZY LOGIC

The proposed method uses always the P&O algorithm. Here, Fuzzy Logic is used for the decision for the optimization. The reasoning rests on the characteristic P-V as presented in Figure 5.

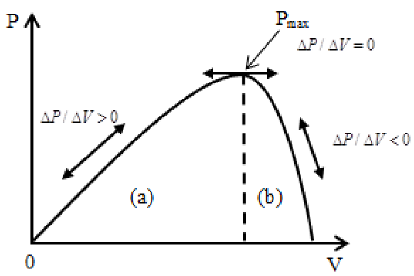


Fig.5 Characteristic P-V

The characteristic is divided by two areas : area (a) where $\Delta P / \Delta V > 0$ and area (b) with $\Delta P / \Delta V < 0$.

At any time, relation (2) is taken:

$$V(k) = V(k-1) + \Delta V \qquad (2)$$

For the duty cycle *D*,

$$D(k) = D(k-1) + dD \qquad (3)$$

1) At the MPP, $\Delta P / \Delta V = 0$, the voltage is unchanged and *the* incrementing voltage ΔV = 0. It means that the incrementing duty cycle is also kept unchanged.

$$\Delta V = 0 \Leftrightarrow dD = 0 \qquad (4)$$

2) When ($\Delta P / \Delta V > 0$), the voltage must be increased

$$\Delta V > 0 \Leftrightarrow dD > 0 \qquad (5)$$

3) When ($\Delta P / \Delta V < 0$), the voltage must be decreased

$$\Delta V < 0 \Leftrightarrow dD < 0 \qquad (6)$$

A. *Fuzzy Logic Controller*

The fuzzy logic controller design requires three stages: the fuzzification, the inference and the defuzzification. Fig. 7 shows the basic scheme for fuzzy logic controller.

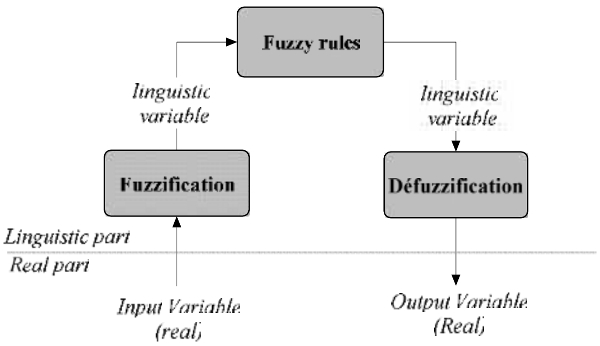


Fig. 6 Fuzzy Logic basic scheme

In the fuzzification stage, real variables are converted in linguistic variables. Each variable has a degree membership on the linguistic variables. Standard representations are adopted in this case. For instance for five linguistic variables:

NL: Negative Large
NM: Negative Medium
Z: Zero
PM: Positive Medium
PL: Positive Large

Usually, standard triangular and trapezoidal membership's functions are chosen.

At the inference or fuzzy rules, relations between inputs and outputs are established by reasoning from rules. For example,

IF (A = NM and B = Z) THEN S = PL (7)

Here A and B are the inputs and S the output.

At this stage of reasoning, the output S is obtained by max-min inference method and it still a fuzzy variable.

The defuzzification bloc consists to convert fuzzy variables to real ones. The Center Gravity Method (CGM) is here adopted. In this paper, Takagi Sugeno method is used. In this case, the output becomes directly a singleton.

IF (A = NM and B = Z) THEN S = k (8)

Here *k* is a constant.

And the conclusion gives a simple expression for he activated rules:

$$u = \left(\sum \mu(k_j).k_j\right) / \left(\sum (\mu(k_j)\right) \qquad (9)$$

B. *Application*

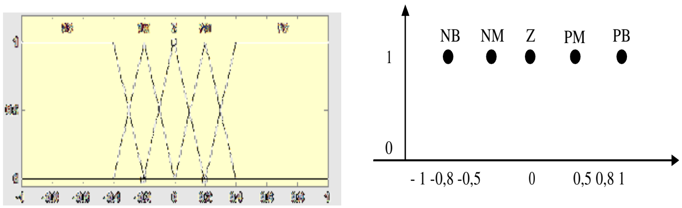
In several applications of the fuzzy logic controller, two inputs are often used: the error ***e*** and the variation of this error Δ***e***. It is also the method adopted in [8]. In this paper, only one input ***E(k)*** is used. It is defined by (10).

$$E(k) = \Delta P(k) / \Delta V(k) \qquad (10)$$

With,

$\Delta P(k) = P(k) - P(k\text{-}1)$ and $\Delta V(k) = V(k) - V(k\text{-}1)$. (11)

The output is the incrementing step of the duty cycle *dD*. Figures 7 (a) and (b) show the membership functions of these variables. As said above, singleton membership is chosen for the output *dD*.



(a) (b)

Fig. 7 Membership functions: (a) input *E(k)* – (b) output *dD*

All the rules are resumed in Table I.

TABLE I: INFERENCE RULES

N° Rule	*E(k)*	*dD*
1	NL	NL
2	NM	NM
3	Z	Z
4	PM	PM
5	PL	PL

Fig. 8 shows the modified algorithm for optimization

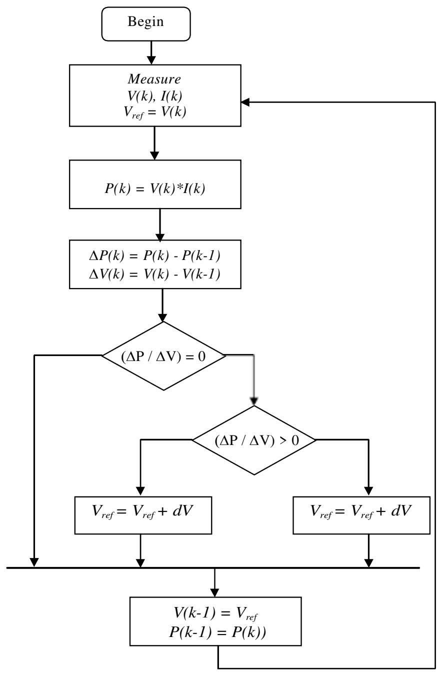


Fig. 8 Modified algorithm

The reasoning is draw from Fig. 5. At any case, as presented in (3), the duty cycle expression is:

$$V(k) = V(k-1) + \Delta V \Leftrightarrow D(k) = D(k-1) + dD \quad (12)$$

Here dD may be positive or negative, i.e. the duty cycle can increase or decrease.

The fuzzy logic rules detect the position of the point in comparison by the PPM and decision is made consequently. This method generates a variable incrementing step thus and fixes its sign. Fig. 9 shows the realization of the MPPT P&O algorithm optimized by fuzzy logic in Matlab/ Simulink.

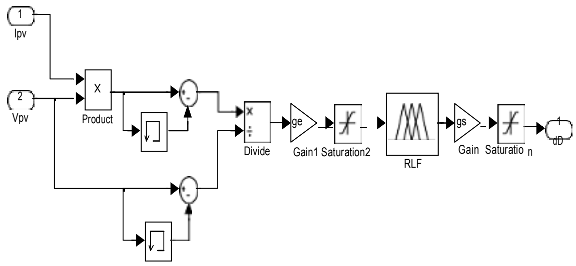


Fig. 9 MPPT P&O algorithm optimized by Fuzzy Logic

IV. Simulation Results

Fig. 10 shows the Simulink model of the complete system.

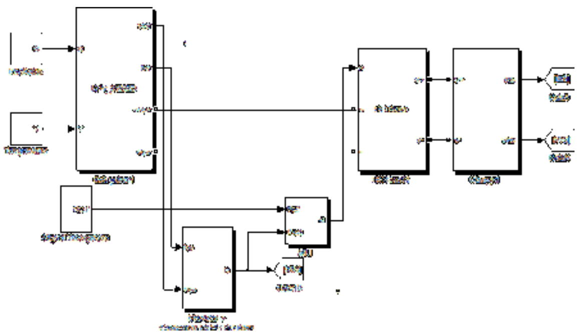


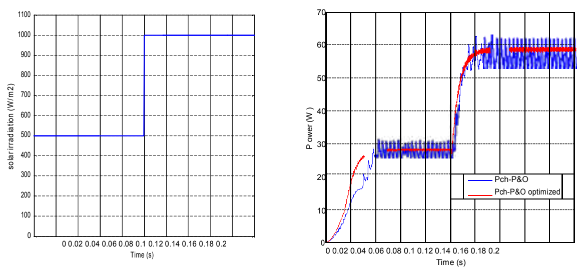
Fig. 10 Simulink Model for the complete system

Three test conditions are made to verify the performances brought by the new method:

1) Varying the temperature with constant solar radiation
2) Varying the solar radiation with constant temperature
3) Varying simultaneously temperature and solar radiation

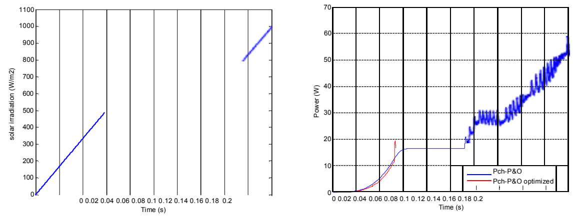
A. Simulation results

Figures 11 to 14 resume the obtained simulation results.



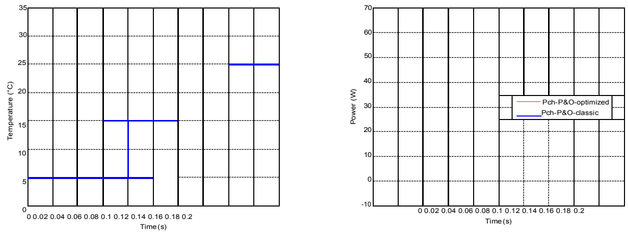
(a) (b)

Fig. 11 Powers output at T = 25°(C)



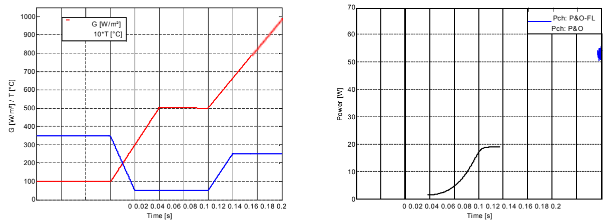
(a) (b)

Fig. 12 Powers output with T = 25(°C)



(a) (b)

Fig. 13 Powers output with G = 1000(W/m²)



(a) (b)

Fig. 14 Powers output under variation of G and T

B. Discussions

Figure 11 shows that, at temperature constant (T=25°C), the two algorithms follow well the set point (here the power delivered by the GPV, P_{PV}, according the solar radiation). However, the P&O algorithm presents oscillations around the MPP. It is also less fast than the P&O optimized Fuzzy Logic one (P&O-FL).

In Fig. 12, it can be noted that the P&O algorithm is less powerful to follow slope variation of the GPV power.

With a constant solar radiation, both the output powers decrease when the temperature increases. The oscillations around the MPP with P&O algorithm are always present (Fig. 13).

In Fig. 14 (a), the temperature is multiplied by a factor 10 for the representation. Fig. 14 (b) shows the weakness of the P&O when the solar radiation ant temperature vary simultaneously. On the contrary, the optimized algorithm (P&O-FL) well always follows the power P_{PV} delivered by the GPV.

At any conditions, P&O-FL algorithm leads to best efficiency.

V. Conclusion

In this paper, a new method is proposed to improve performances obtained by classic MPPT P&O algorithm used in solar system. A fuzzy logic controller is chosen for this purpose. If, usually, two input variables are used for this kind of controller (the error ***e*** and its variation Δ***e***), only one input is used in this new proposal. It is easy to be implemented and at any conditions, leads to better performances as best efficiency, best stability around the PPM and good behavior in front of strong variations of the solar radiation and of the temperature.

REFERENCES

[1] Mukund R. Patel, “Wind and Solar Power Systems”, CRC Press LLC, Washington, D. C. , 1999.
[2] D. P. Hohm, M. E. Ropp, “Comparative Study of Maximum Power Point Tracking Algorithms Using an Experimental, Programmable, Maximum Power Point Tracking Test Bed”, 0-7803-5772-8/00,IEEE, 2000, 1699-1702.
[3] N. Pongratananukul and T. Kasparis, “Tool for Automated Simulation of Solar Arrays Using General-Purpose Simulators”, IEEE Conference Proceedings, (0-7803-8502-0/04), 2004, 10-14.
[4] Trishan Esram, and Patrick L. Chapman, „Comparison of Photovoltaic Array Maximum PowerPoint Tracking Techniques,‟ IEEE Transactions on Energy Conversion, 22 (2), 2007, 439-449.
[5] Hairul Nissah Zainudin, Saad Mekhilef, „Comparison Study of Maximum Power Point Tracker Techniques for PV Systems,‟ Proc. 14th International Middle East Power Systems Conference (MEPCON‟10), Cairo University, Egypt, 2010, 750-755.
[6] H. Abbes, H. Abid, K. Loukil, A. Toumi, M. Abid, “Compartive studies of five MPPT algorithms for PV systems”, (in French), Revue des Energies Renouvelables, Vol. 17, N°3 ,2014, pp 435-445.
[7]I. W. Christopher, R. Ramesh, “Comparative Study of P&O and InC MPPT Algorithms”, American Journal of Engineering Research (AJER), p-ISSN:2320-0936, Vol. 02, Issue 12, pp 402-408.
[8] H. Otmani, H. Chaouali, D. Mezghani, A. Mami, “ P&O Algorithm Optimization by Fuzzy Logic”, (in French), 3rd International Conference of Renewable Energies, CIER-2015, Tunisia.
[9] P. Sanjeevikumar, G. Grandi, P. W. Wheeler, F. Blaabjerg, J. Loncarski, “A Simple MPPT Algorithm for Novel PV Power Generation System by High Output Voltage DC-DC Boost Converter”, IEEE Trans. Power Electron, pp. 234-240, 2015.

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