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Fuzzy Logic Control of a Photovoltaic System

S. Lekhchine[#1], T. Bahi [*2], A. Henchiri[*1], Z. Layate[*3]

[#1,*1] *20 August 1955-Skikda University, Skikda 21000, Algeria*
slekhchine@yahoo.fr, ab.henchiri@gmail.com
[*2]*Automatic Laboratory and Signals LASA*
Badji Mokhtar University, Annaba, 2300, Algeria
tbahi@hotmail.fr
*[3] *University of Djilali Bounaama Khemis Miliana*
zakarialayate@gmail.com

Abstract- In this study, we applied a smart control strategy to obtain a DC/DC driver component which provides peak power control output. For this, a maximun power point traker control method based on fuzzy logic is applied to optimize the operation of the generator photovoltaic. The analysis of the performances of the structure of the proposed system is carried out by MatLab/ Simulink .The system is analyzed under different operating conditions taking into account the change in temperature, radiation and load. The study shows the fuzzy controller reacts according to these conditions by bringing the photovoltaic capture system back to its peak power point. Furthermore, the robustness of the controllers is verified against variation for considered climatic conditions.

Keywords- Renewable energy, PV system, DC/DC converter, MPPT, fuzzy logic controller.

1. INTRODUCTION

As an alternative to using fossil resources (uranium, oil, coal and natural gas) to protect the environment from pollution while meeting the energy needs of the population, recourse to resource use renewable energy is needed to provide the opportunity to produce electricity that satisfies ecological requirements. Unfortunately, this issue meets economic constraints; high cost and low yield [1-2]. the development of renewable energy sources continues to interest more and more researchers. Indeed solar energy can be used with photovoltaic solar conversion systems to convert solar radiation into electrical energy. Since a typical PV cell produces a small amount of power, the cells must be connected in series-parallel configuration on a module to produce enough high power. These sources of energy take a very important place in energy conversion systems but the performances are influenced by the climatic conditions. In this context, the photovoltaic systems (PV) require an effective control allowing to to ensure maximum efficiency of solar panels whatever the weather conditions: temperature (T) and solar radiation (E) as well as when changing the load. This consists in forcing the photovoltaic generator (GPV) to operate at its maximum power point (MPP) to extract the maximum power. So, to produce the maximum power from a solar array, maximum power point tracker MPPT algorithms are proposed in literature. Among the most used optimization methods to extract the maximum power are: perturbation and observation techniques (P & O) [3], conductance incrementation (IncCond) [*2] but these are, unfortunately, imperforming under a rapid change in weather conditions. As a result, many researchers have made modifications to these algorithms to improve their performance .

Many research teams are interested in the study of renewable energy source (RES). DC/DC converters which are mainly used for voltage regulation are fundamental components of PV systems [4-6]. So, for that the using of a Boost converter is necessary to connect the output of PV to the load. Moreover, given the variable nature of the power delivered by the photovoltaic generator and that of the load, a tracking command of the maximum power point developing an optimal duty cycle (D_{opt}) for boost control is often used adopting the functional structure of the PV system .

2. STRUCTURE OF PHOTOVOLTAIC SYSTEM AND MODELING

The photovoltaic system studied is constituted by a photovoltaic generator (GPV). The boost converter is used to transfers maximum power from the solar array to the DC bus, in a coordinated way and at a voltage always greater than the input magnitude. Where, we applied a smart control strategy to obtain a DC/DC driver component which provides peak power control output. , MPPT algorithm and a load. The figure 1 shows the system structure considered.

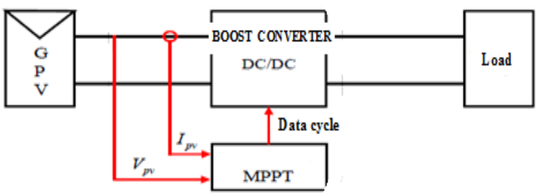

Fig.1. Photovoltaic system

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2.1 Modeling of the PV cell

Mathematical models have been developed for the PV cell. Among which we cite: model a diode, model two diodes and the polynomial model [7 -10]. In this work, we consider the single-diode model consists of a current generator that is directly dependent on the sun and the temperature for modeling the incident luminous flux, an antiparallel diode for the cell polarization phenomena, a series resistor representing the various contact and connection resistances and a parallel resistor characterizing the various leakage currents due to the diode and edge effects of the junction . The equivalent circuit of the PV cell is shown in FIG.

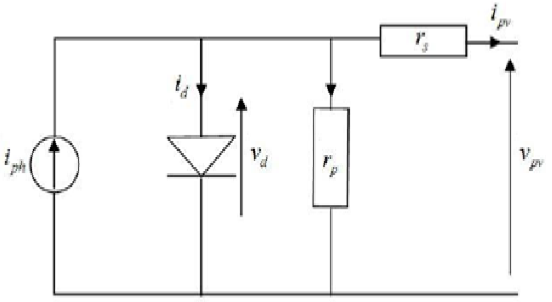


Fig.2. Equivalent scheme of the photovoltaic cell

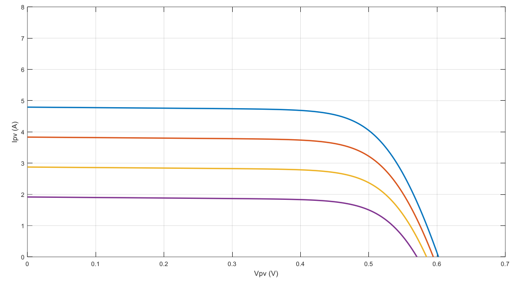
Considering that the PV cell is ideal, this is saying considering that the series resistance is very small and the parallel resistance is sufficiently large and that the cell is illuminated, we deduce the following expression [1]:

$$i_{pv} = i_{ph} - i_d = i_{ph} - I_s\left[\exp\left(\frac{qv_{pv}}{ak_bT}\right) - 1\right] \qquad (1)$$

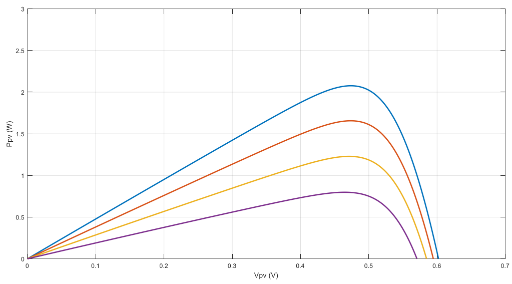
Where, I_s is the saturation current of the diode ; a is ideality factor of the junction ; K_b is the Boltzmann constant (1.38 10-23 J/K) ; T is the junction temperature of the cells and q is the elementary charge of the electron (1.6 10-19 C).

The GPV has non-linear current-voltage characteristics that depend on the illumination and temperature of the cell. Then, a DC / DC converter is used as an adaptation stage. The Boost converter is chosen in this study because of its simple structure and its highest voltage-to-voltage ratio compared to other topologies. After determining the structure of the converter adopted, we will present some existing MPPT techniques that allow the GPV to operate at its maximum power. The design of an adaptation stage equipped with an MPPT algorithm makes it possible to optimize the energy conversion and easily connect a GPV to its load.

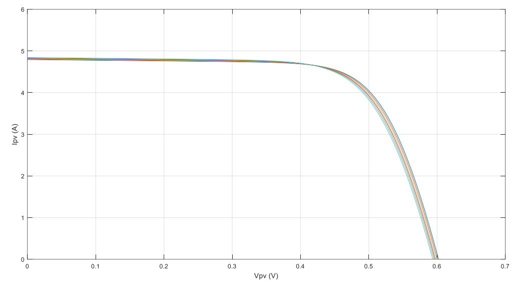
The different characteristics under different climatic conditions are represented by the figures 3a,b,c,d. The figures 3a et 3b show, respectively, the characteristics I=f(V) and P=f(V) for different radiation values but a standard temperature 25°C. In contrary; the figures 3c et 3d, they are obtained by keeping the lighting constant E=1000W/m2 and different values of the temperature.



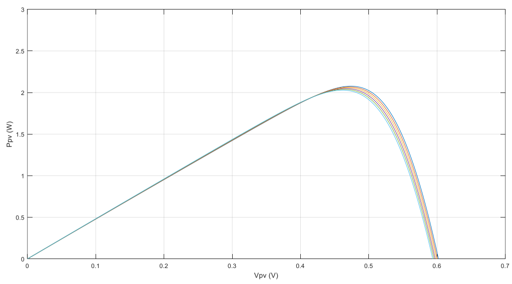
a) I=f(V) for T=25°C and E variable



b) P=f(V) for T=25°C and E variable



c)I=f(V) , for E=1000W/m2 and T variable



d)P=f(V) for E=1000W/m2 and T variable

Fig.3 I=f(V) and d) P=f(V) caracteristics

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2.2 Boost converter

It is a DC-DC converter type Boost. It is essentially composed of a switch (IGBT ou MOSFET) and a diode . The switch is controlled by a Pulse Width Modulated signal (PWM) fixed switching period and variable duty cycle [12]. Figure 4 shows the block diagram of the converter

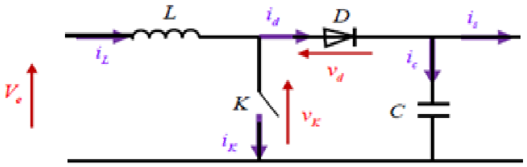

Fig.4 Boost converter circuit

During each period, the two semiconductors (K and D) operate in complement, when K is closed D is open; and when K is open, D is closed. From which, we deduce, the two following cases:

- **0< t <** $\boldsymbol{\alpha T_d}$: Si K=1 (fermé) et D=0 (Ouvert)

$$L\frac{di_L}{dt}=V_e \tag{2}$$

$$i_L=I_{\min}+\frac{V_e}{L}t \tag{3}$$

Where Imin the minimum value of the current in the inductance. At time $t=\alpha T_d$, the current in the inductor reaches its maximum value Imax.

$$I_{\max}=I_{\min}+\frac{V_e}{L}\alpha T_d \tag{4}$$

- $\boldsymbol{\alpha T_d}$ **< t < T$_d$** : Si K=0 (ouvert) et D=1 (fermé)

$$L\frac{di_L}{dt}=V_e=V_s \tag{5}$$

$$i_L=I_{\max}+\frac{V_e-V_s}{L}(1-\alpha)T_d \tag{6}$$

At time t = t_d, the current in the inductance reaches its minimum value I_{min}

$$I_{\min}=I_{\max}+\frac{V_e-V_s}{L}(1-\alpha)T_d \tag{7}$$

The ripple of the current in the inductor is:

$$\Delta i_L=I_{\max}-I_{\min} \tag{8}$$

$$L\frac{di_L}{dt}=V_e=V_s \tag{9}$$

$$i_L=I_{\max}+\frac{V_e-V_s}{L}(1-\alpha)T_d \tag{10}$$

Based on previous development, we deduce:

$$V_s=\frac{1}{1-\alpha}V_e \tag{11}$$

We note that we can control the output voltage of the converter by varying its input voltage or duty cycle. The latter always being between 0 and 1, so the assembly operates as boost converter.

2.3 . MPPT by fuzzy logic control

The power is a function of the meteorological parameters (temperature and radiance). Therefore, maximum power operation is more difficult to achieve. Then, a command for the continuation of the PPM based generally on the adjustment of the data cycle ratio of the converter is essential.

A Fuzzy
Controller is generally designed in the light of experience and expert knowledge [13]. The knowledge base of a Fuzzy Logic Controller (FLC) contains two components, namely, a fuzzy rule base and a data base [14], both being closely related to the concept of a linguistic variable [15]. A rule-base, i.e., a collection of fuzzy IF–THEN rules, is used to describe a particular control strategy.

The Fuzzy Logic Control is done in three steps: fuzzification, roles and défuzzification. The input variables are usually the error and the error change and the output variable is the change in the duty cycle. In particular, in the case of the continuation of the PPM, the error and the change of error are calculated according to the instantaneous values of the power and the voltage as follows . The fuzzy controller has two (2) inputs : the error E(t) which allows to determine the position of the optimal power point of the characteristic P=f(V), the variation of the error ΔE(t) which determines the direction of variation and an output corresponding to the variation of the duty cycle (dD) . For this, a MPPT control method based on fuzzy logic is applied to optimize the operation of the GPV.

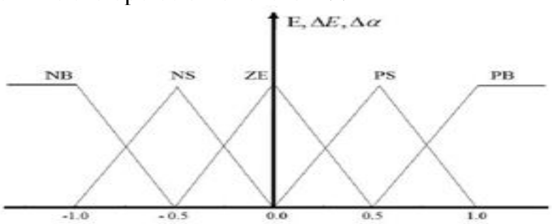

Fig.5 Fuzzy control rules

$$E(n)=\frac{P(n)-P(n-1)}{V(n)-V(n-1)} \tag{12}$$

$$\Delta E(n)=E(n)-E(n-1) \tag{13}$$

During the fuzzification, numeric input variables are converted to linguistic variables that can take the following five values (Figure 5):NB (Negative Big), NS (Negative Small), ZE (Zero), PS (Positive Small), PB (Positive Big). Based on their evolutions and a truth table as shown in Table 1, a value is assigned to the output parameter.

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Table.1

E \ ΔE	NB	NS	ZE	PS	PB
NB	ZE	ZE	NB	NB	NB
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS
PS	PS	PS	PS	ZE	ZE
PB	PB	PB	PB	ZE	ZE

The variations in the duty cycle depend on the difference in position between the PF and a PPM. Thus, as soon as the latter approaches the PPM, the increments applied to sharpen until reaching the PPM. Defuzzification consists in converting the output variable of a linguistic variable into a numerical variable.

3. SIMULATION RESULTS

Figures 6a, b and 7 show 7a, b present the characteristic quantities of the conversion chain. Figure 6a shows the solar class continuous voltage, the Ipv current and the power produced under the effect of different levels of irradiation E (see Figure 6B); In addition, the same magnitudes (see Figure 7a) are represented under the effect of the temperature change as shown in Figure 7b. It is found that good performance obtained with the control adopted.

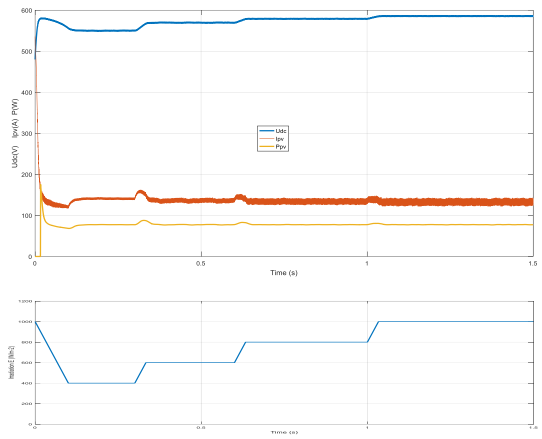

Fig.6. Udc, Ipv and Ppv for E variation

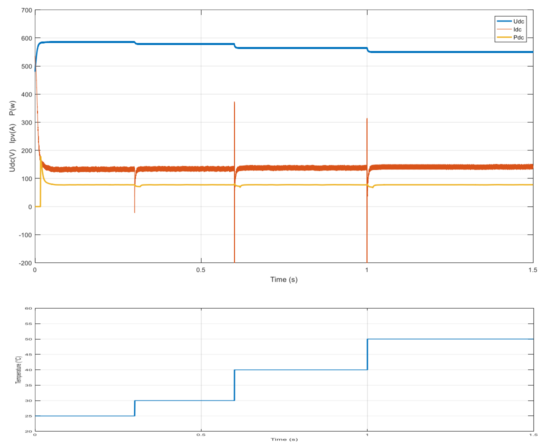

Fig.7. Udc, Ipv and Ppv for T variation

4. CONCLUSION

The current-voltage characteristic is strongly nonlinear and has a single optimum operating point. The insertion of static converters with a fuzzy logic based MPPT command, between the generator and its load, makes it possible to optimize the transfer of energy. The advantage of these fuzzy logic-based techniques is that they can operate with inaccurate input values and do not require a high precision mathematical model. In addition, they can deal with nonlinearities

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