Study and Comparison of photovoltaic Conversion with fuzzy Control

L. Rachedi[1], C.Fetha[2]and H. Bouzeria [4]
[124] *Dept.of Electrotechnic, Engineering Science Faculty*
University of Hadj Lakhdar
Batna, Algeria
[1]nouflot@yahoo.fr -[2] cfetha@yahoo.fr-.
[4]bhamza23000@gmail.com

T Bahi [3]
[3]*Dept. of Electrotechnic Engineering*
University of Badji Mokhtar
Annaba, Algeria
[3] tbahi@hotmail.com

***Abstract* -This paper presents the study of photovoltaic Conversion and Simulated techniques for optimal of a DC–to-DC converter with fuzzy control. The Fuzzy logic controller (FLC) is one of most sufficient control strategies used for maximum power point tracking (MPPT). The Converter models for simulation are designed for the boost and buck modes of operation. The design and analysis of the converter are performed using software tools with the Matlab/Simulink environment. The results are analyzed and compared to those of the expected ideal operation to confirm the validity of the models.**

Index Terms - photovoltaic Conversion ; boost and buck converter; flc; Mppt; Matlab.

I. INTRODUCTION

Renewable energy sources play an important role in electric power generation. The solar energy is directly converted into electrical energy by solar photovoltaic module. Photovoltaic (PV) systems are ideally suited for stand alone and distributed resource applications. PV module depends on the solar insolation, the cell temperature and output voltage of PV module. Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system applications [1]. PV systems produce DC electricity when sunlight shines on the PV array, without any emissions. A DC-to-DC converter serves the purpose of transferring maximum power from the solar PV module to the load. A DC-to-DC converter acts as an interface between the load and the PV module as shown in Figure 1. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power [2]. The purpose of this paper is to study and compare advantages, execution efficiency for two type of DC-to-DC converter; boost converter and buck converter are most traditional converter used with MPPT methods, including fuzzy control methods. The FLC Method of MPPT is described here.
Matlab/Simulink is used in this paper to implement the modelling and simulations tasks, and to compare execution efficiency for the selected MPPT methods.

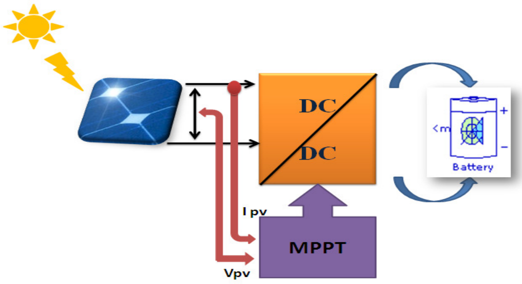

Fig. 1 Chain of photovoltaic with DC / DC converter controlled by an MPPT control of DC load.

II. PHOTOVOLTAIC CELLS AND SOLAR ARRAYS

A photovoltaic cell is a doped semiconductor so that an n-p-junction is obtained. This gives rise to an electric field inside the semiconductor. If a photon (a radiant energy quantum), hits an electron with high enough energy, it is torn off the atom and transported by the electric field to the other side of the junction, thus giving rise to a voltage across the junction. If an external load is connected between the n- and p-side, a DC-current will flow. The power from the photovoltaic cell depends on the light irradiation but also on the load and the temperature of the photovoltaic cell. The equivalent electrical circuit of an ideal solar cell can be treated as a current source parallel with a diode shown in figure 2.

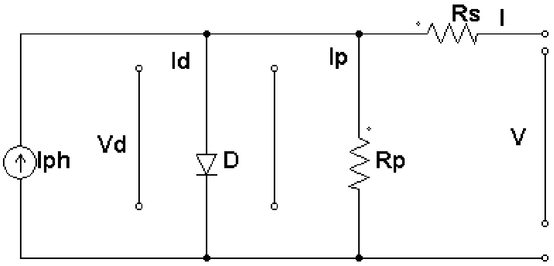

Fig. 2 Equivalent circuit of a PV cell.

The I-V characteristics of the equivalent solar cell circuit can be determined by following equations [3]. The solar cell output current:

$$I=I_{ph}-I_d-I_p \qquad (1)$$

While, the current through diode is given by:

$$I_d = I_s(e^{\frac{v+R_sI}{mV_T}} - 1) \qquad (2)$$

$$I_p = \frac{V_d}{R_p} = \frac{V+R_sI}{R_p} \qquad (3)$$

So,

$$I = I_{ph} - I_s(e^{\frac{v+R_s.I}{mV_T}} - 1) - \frac{V+R_sI}{R_p} \qquad (4)$$

Where:

I : solar cell current

I_{ph}: light generated current

I_d: diode saturation current

q : electron charge (1.6×10-19 C)

K: boltzman constant (1.38×10-23 J/K)

T : cell temperature in Kelvin (K)

V : solar cell output voltage

Rs: solar cell series resistance

Rsh:solar cell shunt resistance

A. *Building of PV Module (Array)*

For a PV module with I-V and P-V output characteristics of generalized PV model for a cell. The nonlinear nature of PV cell is apparent as shown in the Figure 3and figure 4; the output current and power of PV module depend on the cell's terminal operating voltage and temperature, and solar isolation as well.

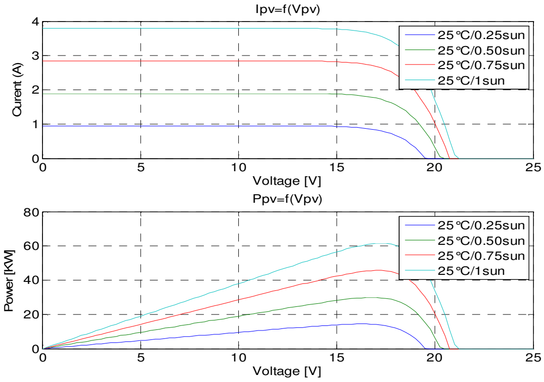

Fig.3. Simulink model I-V and P-V curves which is influenced by insolation when the cell temperature is constant at 25ºC

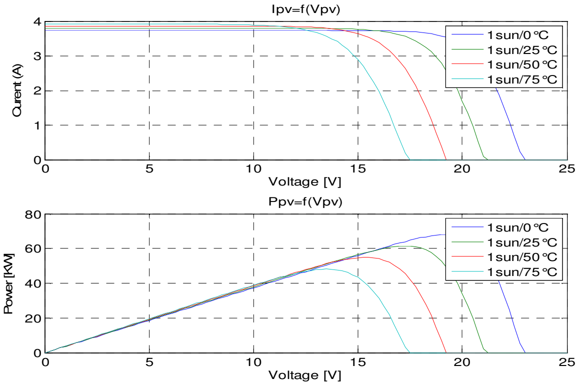

Fig.4.Simulink model I-V and P-V curves which isinfluenced by cell temperature when the insolation is constant at 1000 W/m^2.

III. DC-TO-DC CONVERTER

In most common applications, the MPPT is a DC-to-DC converter controlled through a strategy that allows imposing the photovoltaic module operation point on the Maximum Power Point (MPP) or close to it. On the literature, many studies describing techniques to improve MPP algorithms were published [4], permitting more velocity and precision of tracking. On the other hand, there is no a theory to guide the designer to choose, among the DC-to-DC converters family, the best one to operate as MPPT, thus, in most cases, the designers are tempted to use the simplest DC-to-DC converters , namely buck converter or boost converter[5].

A. *The Buck Converter*

The buck converter (Figure 5) can be often found in the literature as the step-down converter. This gives a hint of its typical application of converting its input voltage into a lower output voltage, where the conversion ratio M = Vo/Vi varies with the duty ratio D of the switch [6].

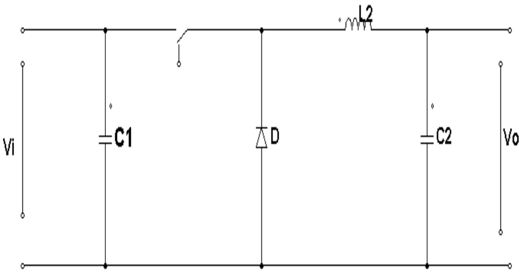

Fig.5.Ideal buck converter circuit

B. The Boost Converter

The boost converter, as shown in Figure 6, is also known as the step-up converter. The name implies its typical application of converting a low input-voltage to a high output-voltage, essentially functioning like a reversed buck converter [7].

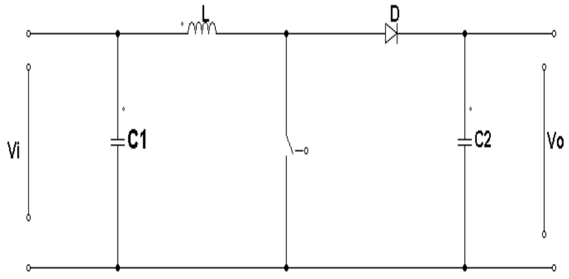

Fig.6.Ideal boost converter circuit

IV. MAXIMUM POWER POINT TRACKING

The Maximum Power Point tracking controller is basically used to operates the Photovoltaic modules in a manner that allows the load connected with the PV module to extract the maximum power which the PV module capable to produce at a given atmospheric conditions .PV cells have a single operating point where the values of the current and voltage of the cell result in a maximum power output. With the varying atmospheric condition and because of the rotation of the earth [4], the irradiation and temperature keeps on changing throughout the day. So it is a big challenge to operate a PV module consistently on the maximum power point and for which many MPPT algorithms have been developed [1]. The most popular among the available MPPT techniques is fuzzy method. The aim of the present work is to develop the simulink model of fuzzy MPPT controller has introduced on it to improve its overall performance [8].

A. MPPT Fuzzy Logic Controller

The fuzzy algorithm can make human knowledge into the rule base to control a plant with linguistic descriptions. It relies on expert experience instead of mathematical models. The advantages of fuzzy control include good popularization, high faults tolerance, and suitable for nonlinear control systems. The basic structure of a F.L.C as illustrated in Figure 7 below consists of the following components [9]:

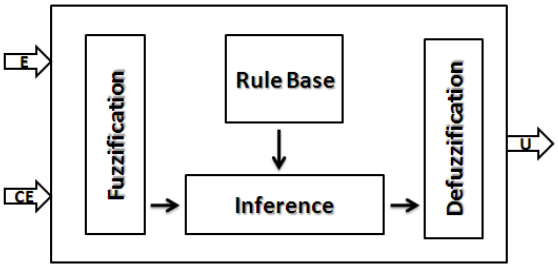

Fig.7.Block diagram of the fuzzy control

- Fuzzification, which converts controller inputs into information that the inference mechanism can easily uses to activate and apply rules.
- Rule-Base, (a set of If-Then rules), which contains a fuzzy logic quantification of the expert’s linguistic description of how to achieve good control.
- Inference Mechanism, (also called an “inference engine” or “fuzzy inference” module), which emulates the expert’s decision making in interpreting and applying knowledge about how best to control the system
- Defuzzification Interface, which converts the conclusions of the inference mechanism into actual inputs for the process

FLC has two inputs which are: error and the change in error, and one output feeding to the pulse width modulation to control the DC-to-DC converter. The two FLC input variables error E and change of error CE at sampled times k defined by:

$$Error(k)=\frac{P(k)-P(k-1)}{V(k)-V(k-1)} \qquad (5)$$

Change_Error(K)=Error(k)-Error(k-1) (6)

Where P (k) is the instant power of the photovoltaic generator. The input error (k) shows if the load operation point at the instant k is located on the left or on the right of the maximum power point on the PV characteristic, while the input CE (k) expresses the moving direction of this point. The fuzzy inference is carried out by using Mamdani method, FLC for the Maximum power point tracker. FLC contains three basic parts: Fuzzification, Base rule, and Defuzzification.

A. 1. Fuzzification

Figure 8 illustrates the fuzzy set of the Error input, the Change Error input and the Control output which contains 5 Triangular memberships

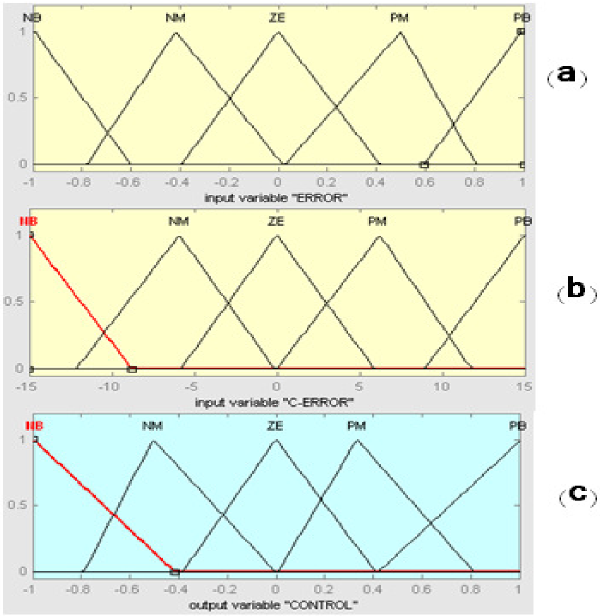

Fig.8.the fuzzy set of memberships function: (a) - the Error input, (b) - the Change Error input and (c) - the Control output.

A. 2. Control rule base

The knowledge base defining the rules for the desired relationship is between the input and output variables in terms of the membership functions .The control rules are evaluated by an inference mechanism, and represented as a set of:
IF Error is ... and Change of Error is ... THEN the output will ….
For example: Rule1: IF Error is NB and Change of Error is NB THEN the output is ZE.

The linguistic variables used are:

NB: Negative Big.
NM: Negative Medium.
ZE: Zero.
PM: Positive Medium.
PB: Positive Big.

A. 3. Defuzzification

The defuzzification uses the centre of gravity to compute the output of this FLC which is the controller output [10-11]:

$$D = \frac{\sum_{j=1}^{n} \mu(d_j) - d_j}{\sum_{j=1}^{n} \mu(d_j)} \tag{7}$$

B. MPPT Fuzzy Logic Controller Simulation

The designed fuzzy controller can connected between PV module and DC-to-DC converter module to tracking the MPP. The output, voltage, current and power is the main comparison to take into consideration. The complexity and simplicity of the circuit have been determined based on the literature. Convergence speed, hardware required and range of effectiveness [6]. Figure 9 and Figure11 take an insolation of 1000 and temperature 25 as initial value. So, for Buck converter with Mppt Fuzzy Control as shown in Figure 9.

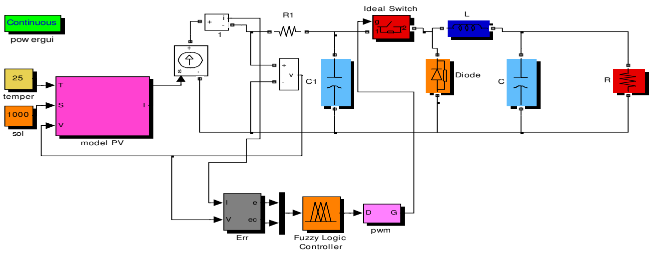

Fig.9. Block simulation of Buck converter with Mppt Fuzzy Control

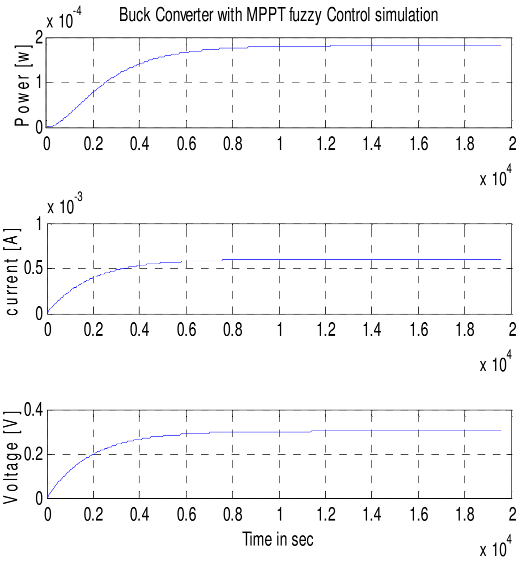

Fig.10. Output Power, current and voltage for Buck converter with fuzzy Controller.

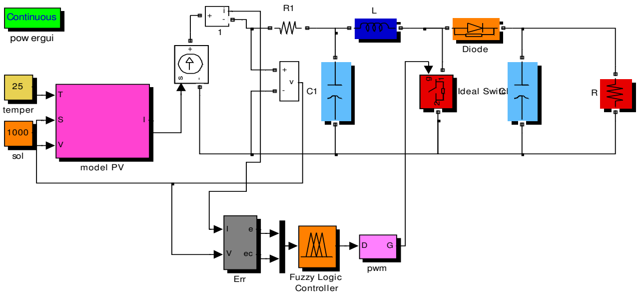

Fig.11 .Block simulation of Boost converter with Mppt Fuzzy Control.

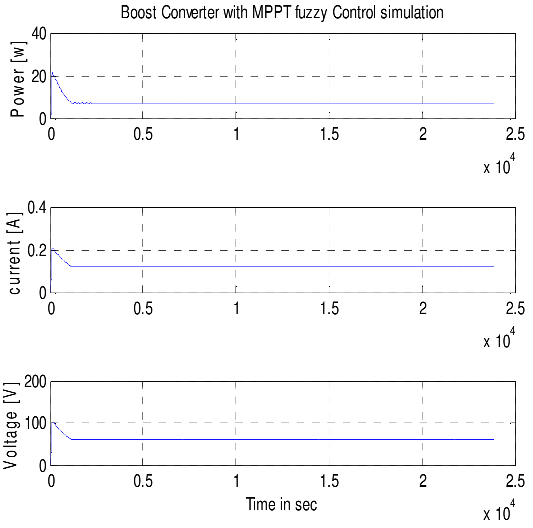

Fig.12. Output Power, current and voltage for Boost converter with fuzzy Controller.

In this comparison show that buck converter will give the best simulation result, follow by boost converter.

V. CONCLUSION

This paper focus on comparison of two different Converters which will connect with the fuzzy controller. Because maximizing energy generation from solar energy has become highly interested. One popular way to maximize the PV generation is use of MPPT and DC–to-DC converter [12]. Design of a fuzzy logic controller on control buck converter and boost converter by using Matlab has been successfully achieved. A simple algorithm based on the prediction of fuzzy logic controller, possibly using the fuzzy rules parameter, is showing to be more convenient than the circuit without fuzzy. It is confirmed that the DC-to-DC converter gives a value of output voltage exactly as circuit requirement. Hence, the closed loop circuit of DC-to-DC converter controlled that by fuzzy logic controller confirmed the methodology and requirement of the proposed approach. These studies could solve many types of problems regardless on stability because as we know that fuzzy logic controller is an intelligent controller to their appliances.

REFERENCES

[1] K.Kachhiya,M Lokhande *MATLAB/Simulink Model of Solar PV Module and MPPT Algorithm* ,National Conference on Recent Trends in Engineering & Technology 13-14 May 2011.

[2] U,Dhanapala,C.H.Wickramasinghe, *Extraction of parameters for simulating photovoltaic panels,* 6th IEEE International Conference on Industrial and Information Systems (ICIIS), pp.539-544, 16-19 Aug.2011.

[3] M. Azab, *A New Maximum Power Point Tracking forPhotovoltaic Systems*,in WASET.ORG, vol. 34, 2008.

[4] S. Yuvarajan, Dachun Yu, Shanguang Xu, *A novel power converter for photovoltaic applications*, Journal of Power Sources, Elsevier Science, Vol. 135, pp. 327-331, 2004.

[5] Roberto F. Coelho, Filipe, *A Study of Basic DC-to-DC Converters Applied in Maximum Power Point Tracking*, Proceedings of IEEE Conference, 2009, ISBN : 978-1-4244-3370-4, pp. 673-677.

[6] T.S.USTUN and S. Mekhilef, *Effects of a Static SynchronousSeries Compensator (SSSC) Based on Soft Switching 48 PulsePWM Inverter on the Power Demand from the Grid*,Journal ofPower Electronics, vol. 10, pp. 85-90, 2010.

[7] Hairul , Zainudin,S, Mekhilef, *Comparison Study of Maximum Power Point TrackerTechniques for PV Systems;*14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21, 2010.

[8] A,Panda ,M.K.Pathak, *Fuzzy Intelligent Controller for the Maximum Power Point Tracking of a Photovoltaic Module at Varying Atmospheric Conditions*; Journal of Energy Technologies and Policy_ Vol.1, No.2, 2011.

[9] Ahmed R, *Fuzzy Logic in Electric Drives*, Lubbock Engineering, Howard University, Washington, D.C., USA.2007

[10] C. Larbes, S.M. Aït Cheikh, T. Obeidi, A. Zerguerras, *Genetic algorithms optimized fuzzy logic control for the maximum power point tracking in photovoltaic system*, elsevier, Renewable Energy, Vol. 34, pp. 2094-2096, 2009.

[11] Mayssa Farhat and Lassâad Sbita *Advanced Fuzzy MPPT Control Algorithm for Photovoltaic Systems*, Science Academy Transactions on Renewable Energy Systems Engineering and Technology Vol. 1, No. 1, March 2011.

[12] M.H. Taghvaee .Radzi ,*A current and future study on non-isolated DC–DC converters for photovoltaic applications,* Renewable and Sustainable Energy Reviews 17- 2013 /216–227