Performances of a classical and a modified fuzzy logic charge controller applied to a PV system

A.Boukerche[1],T.bahi[2], S.Lekhchine[3]

[1*3]LGMM Laboratory, University of 20 August 1955 Skikda, 21000,
[2]Automatic and Signals Laboratory LASA, University of Badji Mokhtar Annaba, 23000, Algeria

[1]a.boukerche@univ-skikda.dz

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ABSTRACT

Solar photovoltaic energy is one of the most used renewable energies and represents a very promising field of research, the installations can include storage batteries or not, these batteries are very expensive and charge and discharge according to the need of the load and the energy of the photovoltaic generator available.

The state of these batteries will be controlled by classical or intelligent control techniques, in our work we will make a simulation of an autonomous photovoltaic system with storage using Matlab simulink software where we will see a comparison between a classical control method of the state of charge of the storage batteries and another fuzzy logic technique where we will see the impact of these two techniques on the storage bus.

I. Introduction

Solar energy is one of the most desired renewable energies and this for several reasons, essentially its availibility, this type of renewable energy is divided between solar photovoltaic and solar thermic, in our work we will focus on solar photovoltaic which in its turn is divided into two parts, autonomous installations and not autonomous installations which are dependent on public electricity network ,the autonomous photovoltaic installations are very interesting in terms of application because they are independent of the grid where the absence of the electrical grid does not affect the good functioning of the system or we can even ignore it completely. However, this type of installation has a big problem on the other hand, which is the problem of cost, because the storage batteries bring the system to an increase of 35 to 40% of the cost compared to the installation connected to the network without batteries, without forgetting that batteries have a limited life that depends on the type of battery and its physical characteristics and the mode of usage [1]..

The photovoltaic autonomous systems on which we are going to work on this paper are the photovoltaic autonomous systems where we find photovoltaic generators, DC-DC boost converters controlled by techniques of research of the point of maximum power we can find several techniques, In our work we are going to use the MPPT incremental technique of the conductance. The autonomous photovoltaic energy production systems also need storage batteries that will store the energy produced by the photovoltaic energy, this energy will be used to feed the load in case of lack of energy production caused by unfavorable weather conditions.

So these batteries will have two states a state of charge and a state of discharge these two states will be ensured by a static DC / DC converter type Buck-Boost with a specific control technique [2].

In the literature there are several control techniques for charge controllers classified by type, either classical or intelligent, In our work we are going to work on these techniques and we are going to elaborate an autonomous photovoltaic system with storage under the Matlab Simulink interface where we will use different techniques for the charge controller of the system : a classical technique with PI controller and another one based on fuzzy logic with modified rules compared to the classical fuzzy ones. We will then make a comparison between the two charge controller commades on their performances and their impact on the battery and its life cycle [3,4].

II. Studied system

The system we will study is composed of a photovoltaic generator, a boost converter controlled by the MPPT incremental technique [3], storage batteries the state of charge of the battery and control one time by a classical technique with PI controller and another time by a modified fuzzy logic technique as it is shown in the figure 1

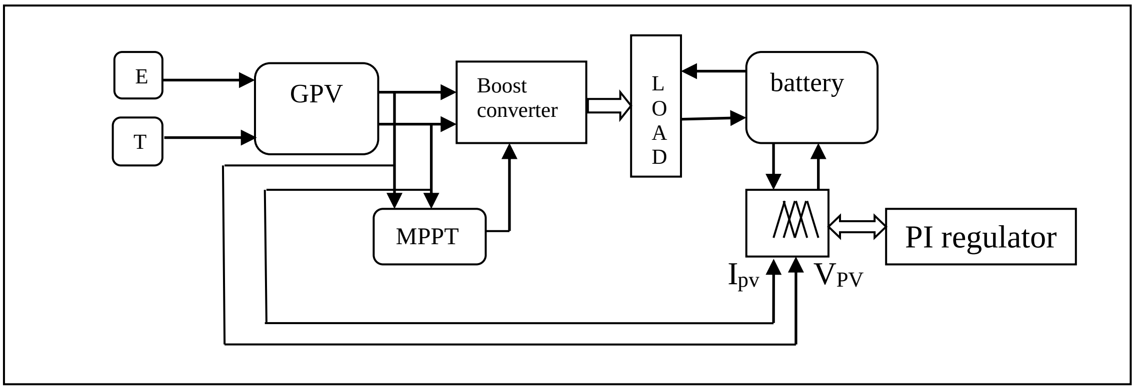


Figure 1. diagram of the system studied

II.1. Photovoltaic cell model

A solar panel is made up of several cells. The classic model of the cell a current generator a single diode (D) with two resistors one in series (Rs) and one in parallel (Rp) [4]. The figure below represents the equivalent electrical circuit to a diode of the photovoltaic cell.

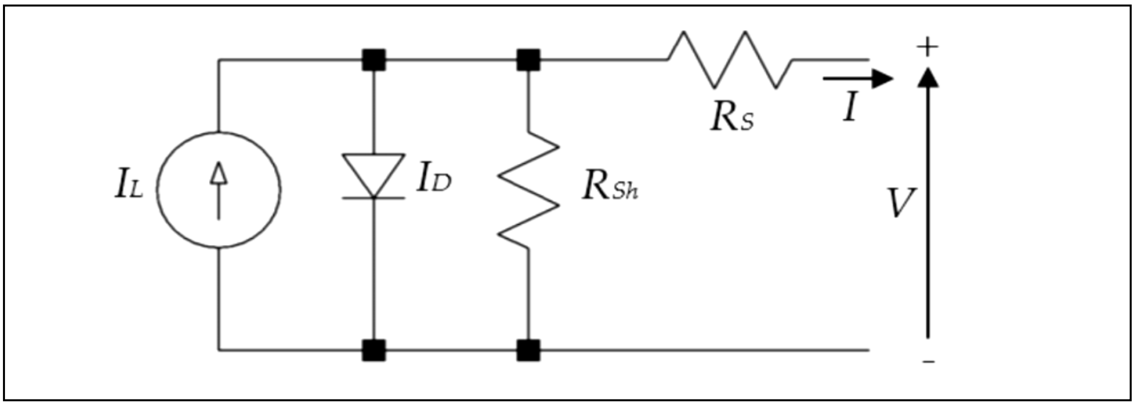


Figure 2. PV cell model

Frome the figure 2 we can deduce the expression of the current:

:

$$I = I_L - I_D - I_{RSh} \quad (1)$$

$$I = I_L - I_0\left[e^{q\left(\frac{V+I*Rs}{nKT}\right)} - 1\right] - \frac{V+I*R_S}{R_{Sh}} \quad (2)$$

where,

I_0 (A) : current of saturation of diodes ;

K : constant of Boltzmann ;

T_c (K), electron charge;

n : jonction factor ;

I_L (A) : SC current ;

I_d (A) : current of diode ;

I_{Rsh} (A) : current of R_{sh}.;

II.2. *Boost converter*

A boost converter is used to boost the voltage. The main transformation ratios of the isolation transformer (K) and the duty cycle (α) for the different converter structures with and without galvanic isolation, there are also other types of converters that have their own operating regime, as shown in Table Tab.1 [5,6].

Table.1 DC/DC converters types

Converter	Data Cycle	Galvanic Isolation
Buck	α	NO
Boost	$\frac{1}{1-\alpha}$	NO
Buck-boost	$\frac{-\alpha}{1-\alpha}$	NO
Cuk	$\frac{-\alpha}{1-\alpha}$	NO
Sepic	$\frac{\alpha}{1-\alpha}$	NO
Flyback	$K\frac{\alpha}{1-\alpha}$	YES
Push –pull	$K\alpha$	YES
Forward	$K\alpha$	YES

II.3. Incremental-Conductance MPPT Algorithm

This method requires two (2) sensors which allow measuring the output voltage and current ,it is use dI/dV to calculate the indication of dP/dV. When dI/dV is equal to (-I/V) the algorithm realize that maximum power point (MPP) has achieved and there it finish and returns the conformable value of operating voltage for MPP. Figure 3 Show flow chart of used algorithm[7].

$$\begin{cases} P = V * I \\ \dfrac{dP}{dV} = 0 \leftrightarrow P = P_{Max} \\ \dfrac{dP}{dV} \langle 0 \leftrightarrow P \langle P_{Max} \\ \dfrac{dP}{dV} \rangle 0 \leftrightarrow P \rangle P_{Max} \end{cases} \qquad (3)$$

The partial derivative $\dfrac{dP}{dV}$ is given by:

$$\frac{dP}{dV} = I + V\frac{dI}{dV} \approx I + V\frac{\Delta I}{\Delta V} \qquad (4)$$

Frome equation (3) we can deduce that:

$$\begin{cases} \dfrac{dI}{dV} = -\dfrac{I}{V} \leftrightarrow P = P_{Max} \\ \dfrac{dI}{dV} \langle -\dfrac{I}{V} \leftrightarrow P \langle P_{Max} \\ \dfrac{dI}{dV} \rangle -\dfrac{I}{V} \leftrightarrow P \rangle P_{Max} \end{cases} \qquad (5)$$

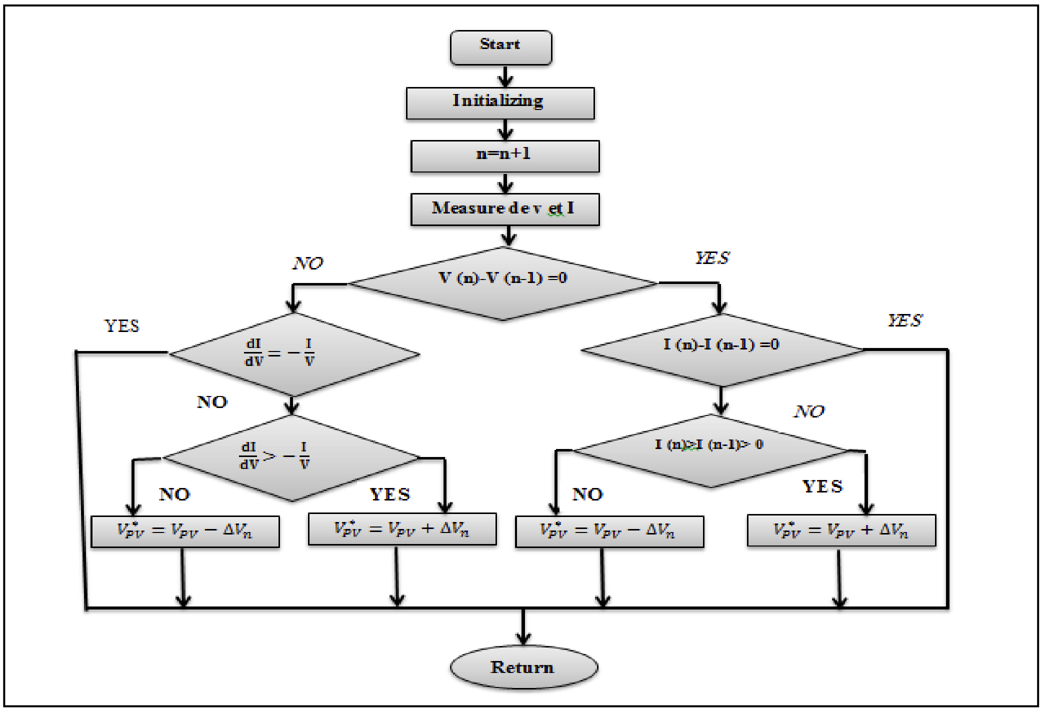


Figure 3. MPPT incremental diagram

II.4.1 Charge controller with PI regulator

The charge controller with fixed voltage consists in imposing a voltage set point for which the system will track the current according to the load point as shown in the figure Fig.4.

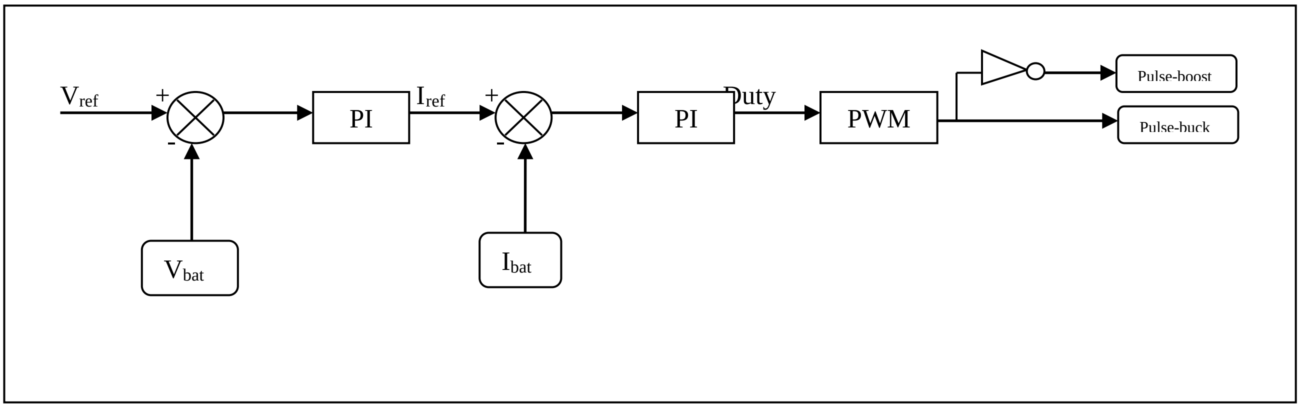


Figure 4.classic battery charger controller

II.4.2 Fuzzy logic battery controller

Many techniques are used for the control of the state of charge of the battery in the energy systems [8,9], the technique used in our work is a very known technique (the fuzzy logic) that will be based on two reference values for deciding whether to charge or discharge the battery with choice of the appropriate intensity of the action[10].

The input parameters are the available energy in comparison with the need (Ea) and the state of charge of the battery (SOC).The control circuit will be as in Figure 5.

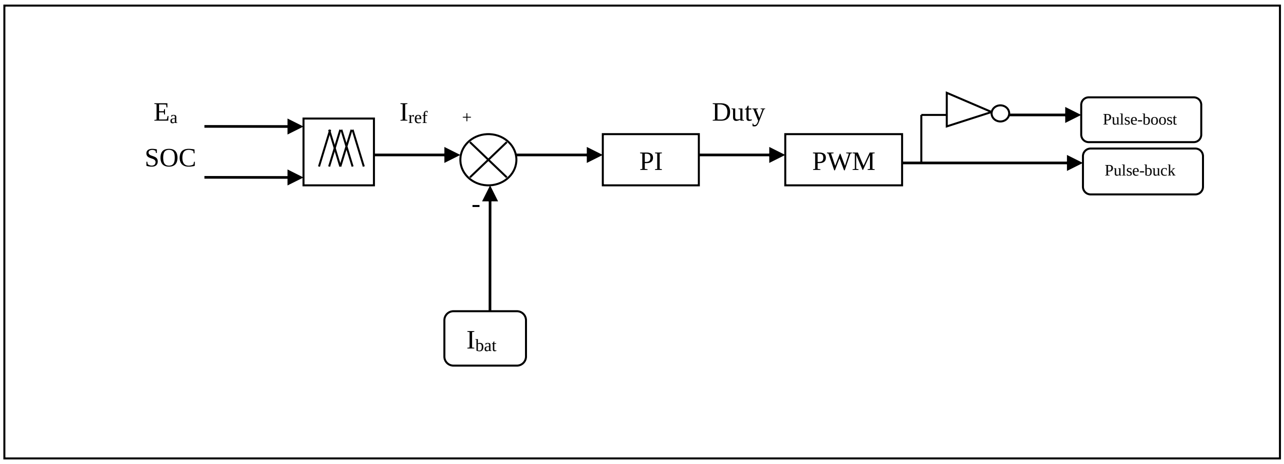
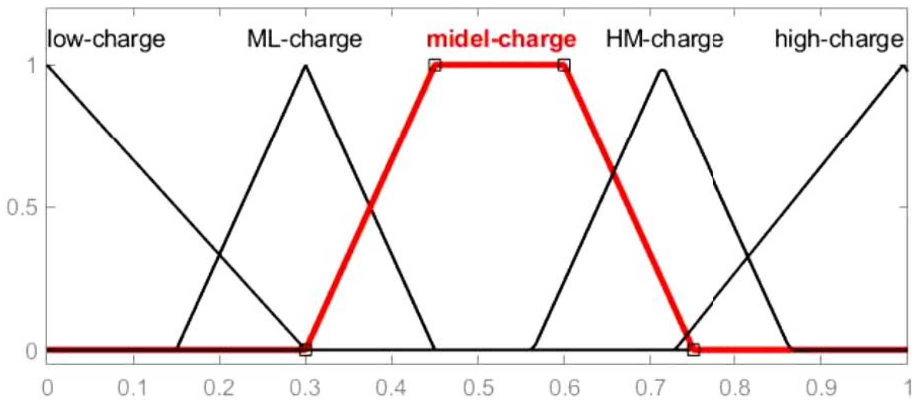
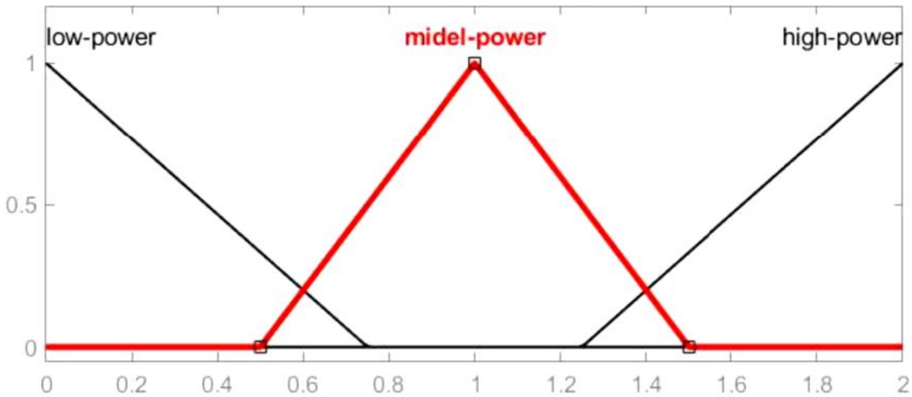


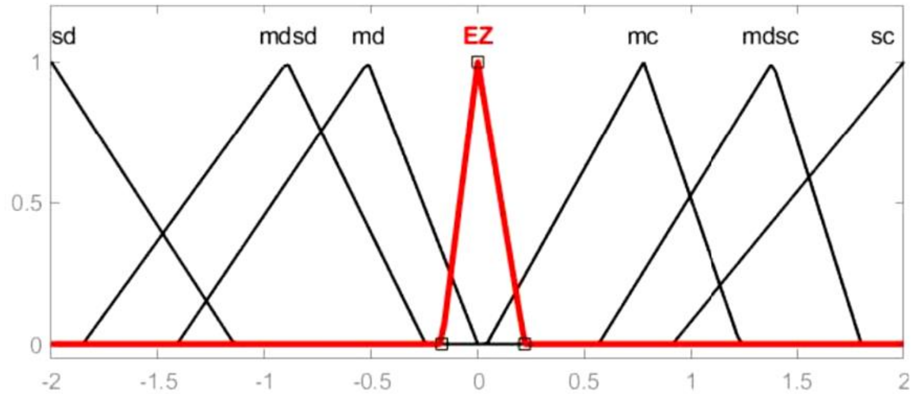
Figure 5. Fuzzy Logic battery charge controller



a) Variable of input SOC



b) Variable of input Ea



c) Variable of output

Figure 6. Inputs and output of fuzzy logic

Before controlling the buck boost converter the signal will be improved with a PI regulator, the conversion of the input values into linguistic variables will be done according to the following (a) and (b) in figures 6 for the soc and Ea respectively [11]For the output it will be limited between the charge threshold and the discharge threshold of the battery as it is shown in (c) in the figure 6, Our technique of charge control was realized by the fuzzy logic the idea is to see the state of charge of the battery as well as the availability of energy to take the decision to charge or to discharge the battery in high speed charge, medium high speed charge, medium charge, speed discharge, medium high speed discharge, medium discharge or don’t do any action in specific cases the variable of between are easier to calculate and to estimate compared to the charge controller by fuzzy logic frequent, We have consigned our system to a limit of 20 Ampere in charge and in discharge according to the characteristics of the battery[12].

The rules used for the fuzzy configuration are shown in the table Table.2

Table.2 fuzzy rules

SOC / Ea	Low charge	ML charge	MC	HM charge	High charge
Low Power	EZ	MD	MDSD	MDSD	SD
Midel Power	MC	MC	MC	MD	MDSD
High Power	SC	MDSD	MDSC	SD	EZ

III.3 Simalation and discussion

Under the interface matlab simulink we simulate a system, the system is composed of a photovoltaic generator composed of 5 panels coupled in parallel of type 1Sotech 1sth-215P, a chopper boost controlled by an incremental MPPT control of the conductance, a lead-acid battery of 24V and 50Ah with a threshold current of 20A controlled by a classical technique with PI regulator of 48V voltage and then a modified fuzzy logic technique in order to see the difference between the two, the methological conditions imposed to the system are a constant temperature at 25°c and a variable irradiation as it is shown in the figure 7.

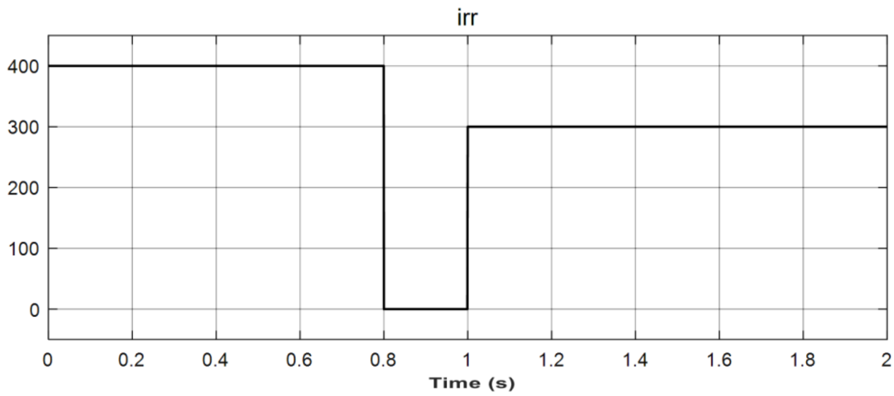
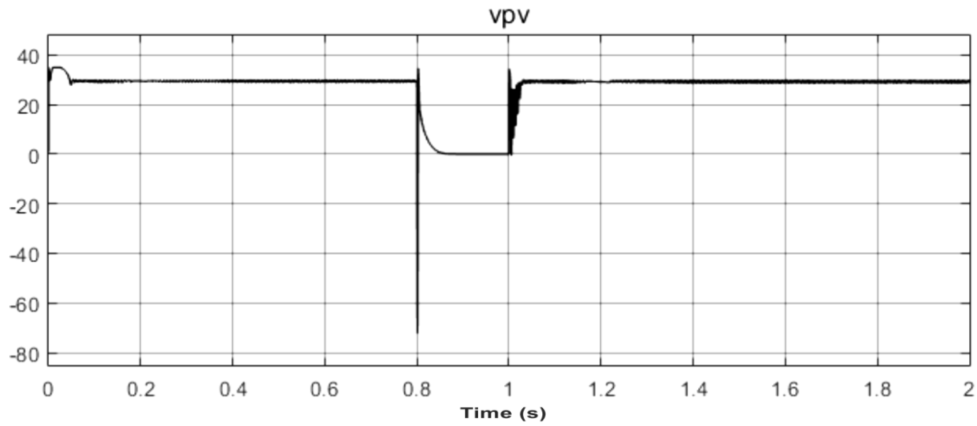


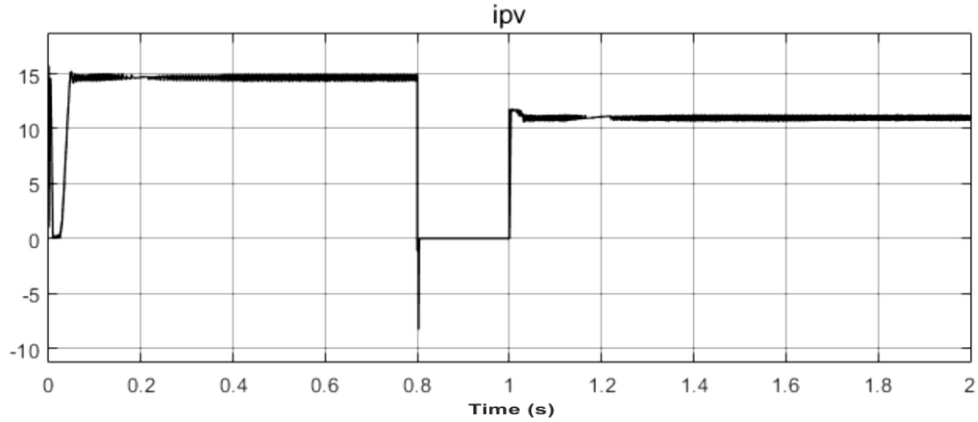
Figure 7. Irradiation imposed for the system

For the first technique (classical technique) we have removed the voltage and current of the PVs and the voltage at the load terminals in figure 8 on (a),(b) and (c) in order.

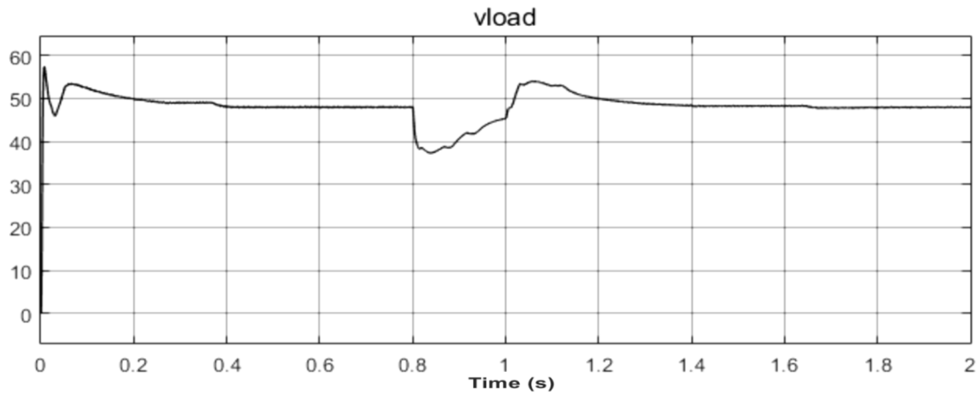
The results obtained show that the MPPT control works and that the set voltage is respected, which also confirms the functioning of the charge controller [13,14].



a) Voltage of the Pv



b) Current of the Pv



c) Voltage of the load

Figure 8. Parameters of the photovoltaic system

From the previous figures we can see that the MPPT control is working, but the voltage at the load terminal matches the voltage of the imposed set point of 48V in the figure 9.

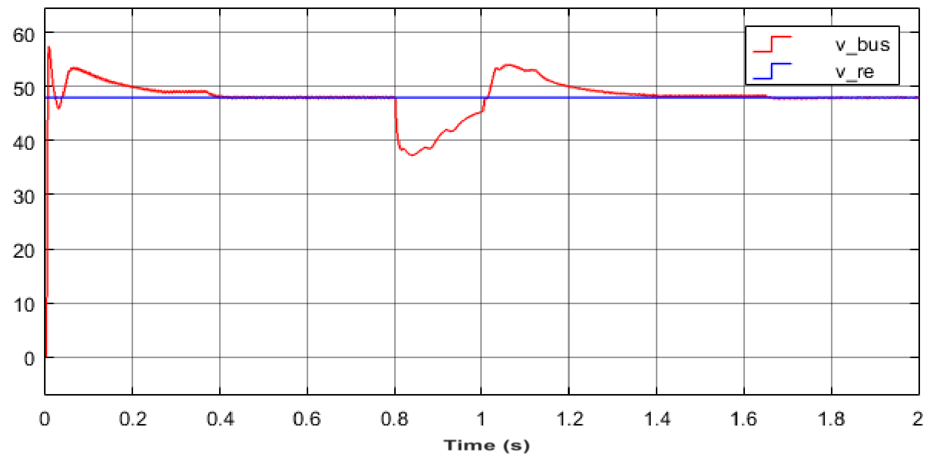


Figure 9. Vbus control

We notice that the system is disturbed at the time t=0.8s and t=1s at the moments of variation of the irradiation because the duty cycel of the converter changes but will always join the reference[15].

The charge and discharge current is shown in Fig. 10 with referene .

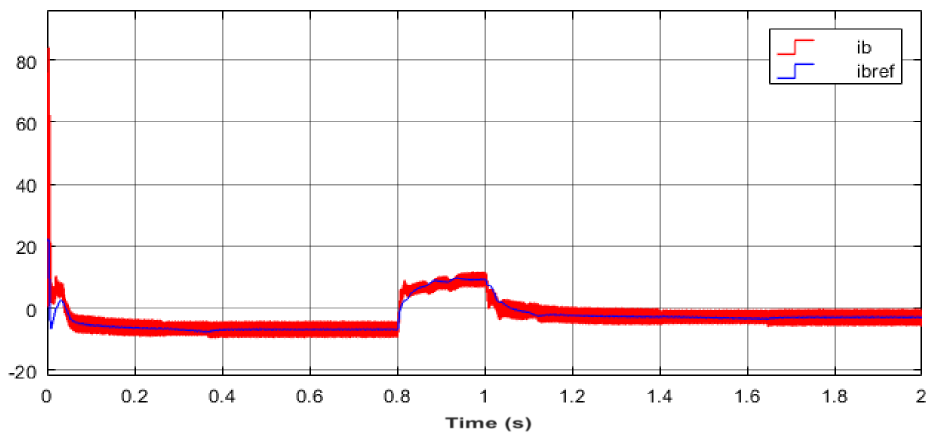


Figure 10. current control

The battery current follows perfectly the reference current, for the test survey we keep the same system we only change the storage management method we use the fuzzy logic method modified previously explained the PV current and voltage are the same but the voltage at the load terminal becomes variable because it is not recorded as shown in Figure 11.

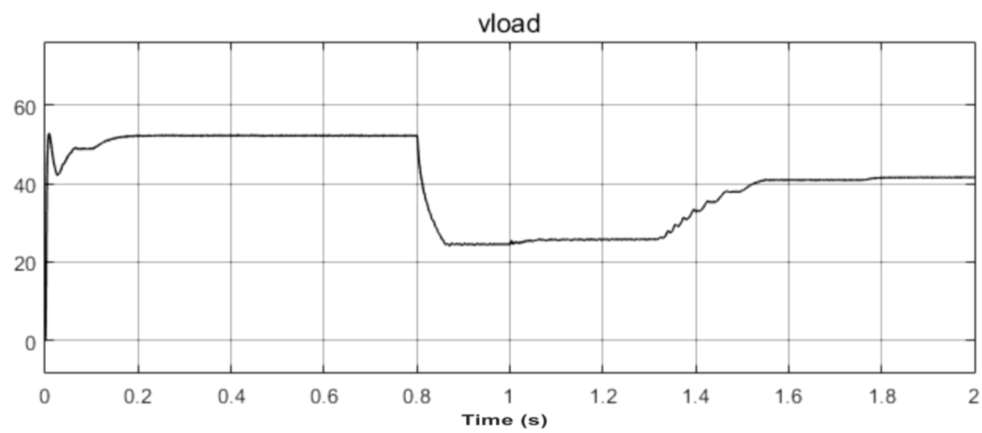


Figure 11. Voltage load in Fuzzy case

We also notice a difference in the speed of charge and discharge of the battery because the controller by fuzzy logic takes other parameters into consideration before giving the instruction of charge or discharge of the battery we can see that in figures 12 and 13.

We notice that the charge/discharge phases are the same but with different tangents because the fuzzy logic takes into account the state of charge of the battery.

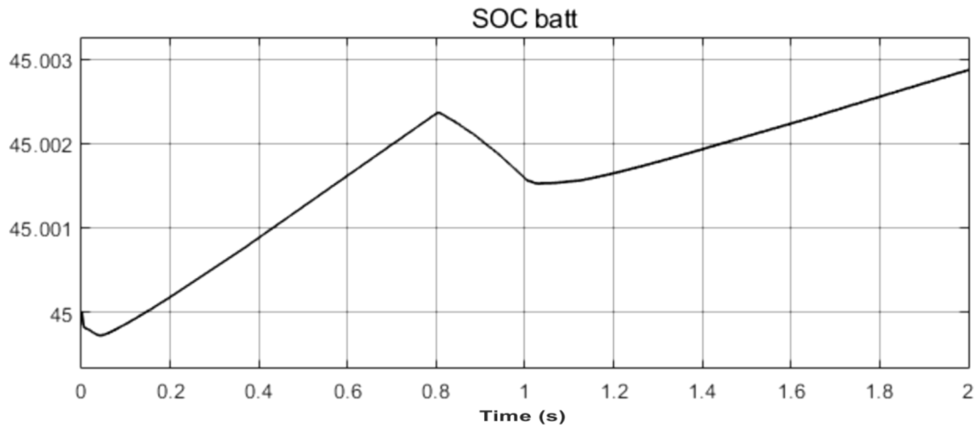


Figure 12. SOC classic battrey control

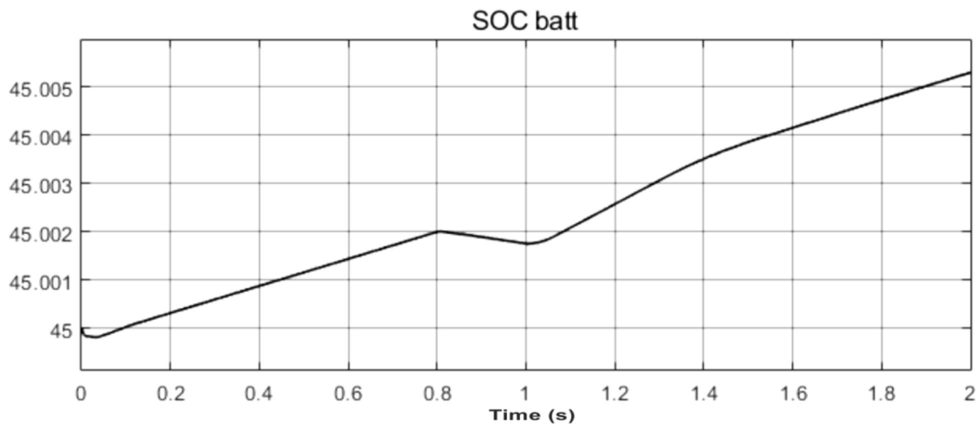


Figure 13. SOC Fuzzy control of battrey

III. Conclusion

In this work we have seen an autonomous photovoltaic system powering a DC load with incremental MPPT with energy storage management techniques, the batteries which represent a very large part of the investment in a photovoltaic installation and which have a limited life span and wcih are proportional to the mode of use, Many factors can negatively affect the life of the battery such as deep discharge, high current draw and high charging current for fast charging, Several researchers are working on techniques to protect these batteries, whether in terms of control, optimization or material[16], such as the hybridization between traditional batteries with long autonomy and supercap resistant to high current demands or the integration of artificial intelligence in the management of stored energy or even the management of hybridization of storage buses.

The proposed system based on fuzzy logic considers two very important parameters which are the available energy of the photovoltaic generator and the state of charge of the battery to act always giving a priority to the load it allows to charge and discharge the battery in an optimal way depending on the energy need and the state of charge of the battery in order to prolong the life of the battery.

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