A Comparative Study between hill climbing algorithm and fuzzy Logic controller algorithm of MPPT for GPV system

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Abstract **The major problem in PV power generation systems is that the amount of electric power generated by PV module is always changing with weather conditions, i.e., irradiation. Therefore, Maximum Power Point Tracking (MPPT) algorithms is implemented which has led to the increase in the efficiency of operation of the solar modules. This paper, presents a comparative study of two intelligent control methods in order to optimize the efficiency of the solar PV system. This paper presents in details comparative study between hill climbing algorithm and fuzzy Logic controller algorithm applied to a DC/DC Boost converter device. The Boost converter increases output voltage, it is depends on the duty cycle of switch device. The proposed controllers are adjusting the duty cycle of the DC-DC converter switch to track the maximum power of a solar PV array. Finally performance comparison between hill climbing and Fuzzy logic controller method has been carried out which has result shown the effectiveness of Fuzzy controller to draw more energy, decreases fluctuations and fast response, against change in variable weather condition. The final result show the fuzzy logic controller exhibits a better performance compared to hill climbing algorithm.**

***keywords* :** *GPV, Boost Converter ,Maximum Power Point Tracking, , P&O, Hill climbing Algorithm, Fuzzy logic Controller, Matlab /Simulinks*

I. Introduction

The photovoltaic (PV) generation system is one of the renewable energy sources that have attracted the attention of researchers in the recent decades due to its non-polluting, renewable, and inexhaustible nature. Photovoltaic energy is the conversion of sunlight into electricity [1]. A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power. A photovoltaic cell is a non-mechanical device usually made from silicon alloys. Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum .When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity. The output power of PV arrays is always changing with weather conditions, i.e., solar irradiation and atmospheric temperature. Therefore, a MPPT control to extract maximum power from the PV arrays at real time becomes indispensable in PV generation system.

Photovoltaic (PV) panels have a nonlinear voltage-current (I-V) characteristic with a unique point where the power generated is maximum. This is known as the maximum power point (MPP) at which the PV system operates at its

highest efficiency. This point, located on the knee of the I-V curve, depends on the ambient temperature, T_{amb} , of the panel as well as the irradiance of the sun, E, which changes during the day.

The MPPT is a process which tracks maximum power from array and by varying the ratio between the voltage and current, increase the output power of the system. There are many different MPPT techniques based on different topologies and varying complexity, cost and production efficiency, these techniques are used for increase the efficiency of PV system [13, 5, 8]. In this paper, presents a comparative study between two algorithm technique which are hill climbing (HC) and fuzzy Logic controller (FLC) used to maximize the efficiency of the solar generator under variation of solar irradiation, temperature and electrical loads. Indeed the MPPT algorithm are used to control a Dc-Dc Boost converter to generate the maximum power point of the GPV . The proposed techniques are well adjusting the duty cycle of the boost converter switch to track the maximum power and increase efficiency of a solar PV array.[5] In this paper, intelligent controller techniques using fuzzy logic controller is associated to an increase energy conversion efficiency and compare to Hill climbing . The proposed controller method is simulated by using Matlab/Simulink simple Matlab Tool. The Simulation and analysis of Hill climbing and fuzzy logic controller are presented.

I. PV Generator and these Performance

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted into electricity through the PV effect [2, 15]. When exposed to sunlight, photon with energy greater than the band-gap of the semiconductor creates the electron-hole pairs proportional to the incident radiation which is responsible for the generation of photocurrent.

Fig. 1 shows the normal equivalent circuit of the solar cell and Fig. 2 shows the equivalent circuit for the solar array where the cells arranged in NP-parallel. The I-V characteristic of the one-diode equivalent circuit with the series resistance Rs and the shunt resistance Rsh is given by:

$$I = I_{PV} - \underbrace{I_0\left(e^{\left(\frac{q(V+R_s I)}{A\,k\,T}\right)} - 1\right)}_{I_d} - \frac{V + R_s I}{R_p} \quad (1)$$

Where,

I_{PV} : current generated by the incident light
I_d: The Shockley diode equation
I_o: The reverse saturation current of the diode
q: electron charge (1.60217646*10^-19c)
k: Boltzmann constant (1.3806503*10^-23)
T: cell Temperature in Kelvin (k)
V: solar cell output voltage (V)
R_S: solar cell series resistance (Ω)
R_p: solar cell parallel resistance (Ω)

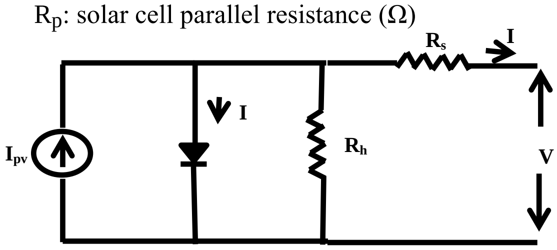


Fig. 1 Equivalent electrical circuit of a solar cell

The PV module is constituted by a grouping, series and/or parallel of a large number of elementary cells(units) (Fig.2). The association of mass cells(units) allows to increase the tension of the GPV [9]. A parallel association of cells(units) is possible to increase the current of GPV.

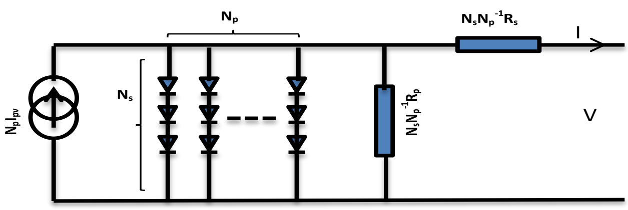


Fig. 2 Equivalent circuit of PV module.

The relation between the current and the tension in a module PV, constituted by several cells (units) connected in series and in parallel is given by the following equation:

$$I = N_p I_{PV} - N_p I_0\left(e^{\left(\frac{q(V+R_s I N_s/N_p)}{A\,k\,T\,N_s}\right)} - 1\right) - \frac{V + R_s I\, N_s/N_p}{R_p.\, N_s/N_p} \quad (2)$$

GPV is heavily influenced by the variation brightness and. Indeed, in Figure 3 is the GPV subjected to changes in temperature where it appears clearly the reduction of the power and the change the MPP. This entails reconciling these behaviours with the load

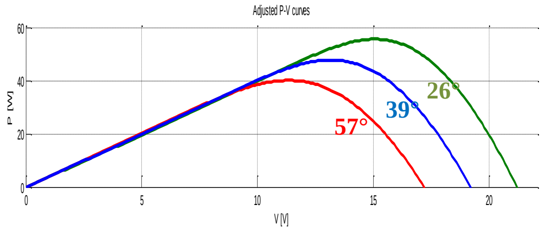


Fig. 3 Temperature influence on MMP

In Figure 4 the PV array is subject to variation in brightness temperature constant; again the MPP exchange

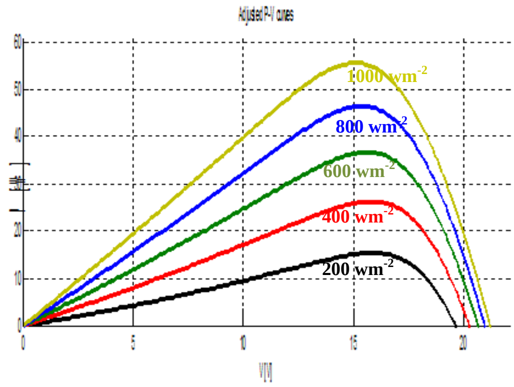
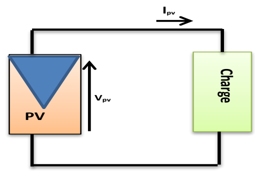


Fig. 4 Changing the MPP according to the brightness

This entails reconciling these behaviours with the load. When the source-load connection, it is therefore essential to take into account the variable nature of the power issued by the PV generator, but also characteristic of the load to a point of operation is possible. The operating point corresponds to the intersection of these two characteristics (Figure 5B).

A)



B

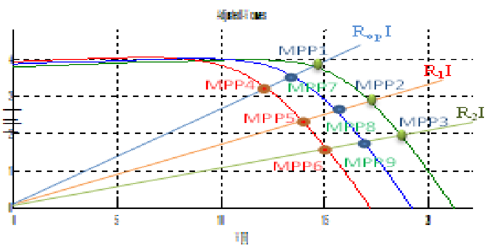


Fig.5 A) Direct electrical connection between a PV generator and a load.
B) Influence of the load on theoperating point

The operation of the generator GPV is highly dependent on characteristics of the load with which it is connected. In addition, for different values of R, adaptation optimal product for a single operating point of (R_{op}) called expired MPP. (maximum point power) MPP. Each one of these 9 MPP s corresponds to a variation of the model.in This case MPP1, MPP2, MPP3,……, MPP9

Accordingly, so that the generator operates the most often at its maximum point, the solution commonly used is to introduce a converter DC/DC that is playing the role of load source adapter (Figure 6), in this case, the generator delivers a maximum power. Furthermore, the selection of suitable DC-DC converter topology for integration with solar PV system or other renewable energy sources has not been investigated explicitly even though its integration to solar PV system will increase its optimum utilization effectively [10].

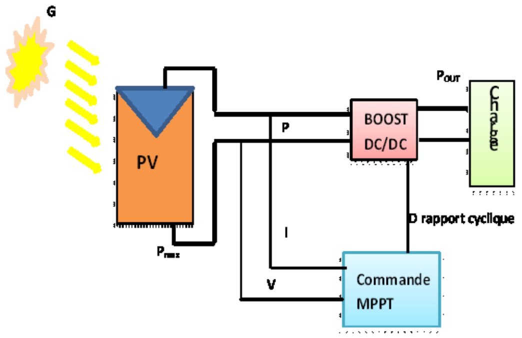


Fig.6 Photovoltaic system (PV module – Boost converter– load)

II. TOPOLOGIES OF DC-DC BOOST CONVERTER

Figure 7 shows basic circuit topology of a DC-DC boost converter circuit consists of power switch (Mos), diode (D), inductor (L), capacitor (C), switching controller and load (R). This topology can be used for interface connection between low PV array voltage to a high battery bank input voltage or any DC load [3]. The DC-DC boost converter will boost up or step up the output voltage to be greater than input voltage [4], [11].

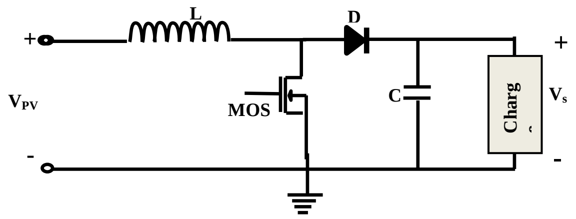


Fig.7 Structure of the converter BOOST

The functioning of the circuit divides in two according to the interval of switching of the transistor MOS (T_{ON} ,T_{OFF}).

Interval T_{ON}

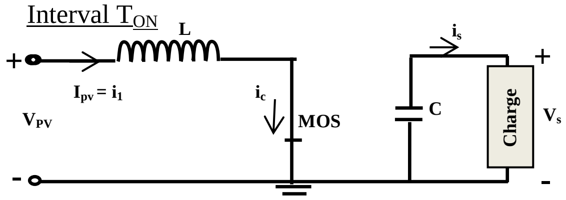


Fig.8 Equivalent circuit for T_{ON}

$$V_e = L\frac{d\,i_1}{d\,t} \Longrightarrow i_1(t) = \frac{V_e}{L}\,t + I_1 \qquad (3)$$

Or I_1 the initial current. During this interval the current crossing the inductance increases.

Interval T_{OFF}

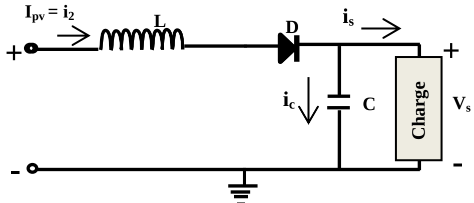


Fig.9 Equivalent circuit for T_{OFF}

$$V_e = L\frac{d\,i_2}{d\,t} + V_s \Longrightarrow i_2(t) = \frac{V_e - V_s}{L}\,t + I_2 \qquad (4)$$

Or I_2 the initial current for interval T_{OFF}.

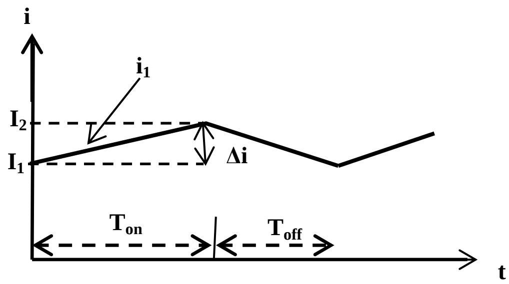


Fig.10 period of switching

In the continous conduction mode the period of switching is $T = T_{ON} + T_{OFF}$ and duty cycle is $D = \frac{T_{ON}}{T}$

$$V_s = \frac{1}{1-D}\,V_{PV} \qquad (5)$$

$$I_s = (1-D)\,I_{PV} \qquad (6)$$

The optimal adaptation is realized when I_{pv} and V_{pv} is respectively worth I_{opt} and V_{opt} this corresponds then to an optimal resistance R_{opt} of the generator spreading in the following equation:

$$R_{OPT} = \frac{V_{OPT}}{I_{OPT}} = (1-D^2)\,\frac{V_s}{I_s} = (1-D^2)\,R_s \qquad (7)$$

The connection between a source and a load can be optimized by adjusting the duty cycle α has so that on one side, the generator can work to R_{OPT} and on the other hand, so that the load can vary "as he/she pleases" as far as the intersection point source-load continues to exist.

III. Commande MPPT

The control technique ommonly used is to act on the duty cycle automatically .which results in the impedance adjustment of the load to bring the generator to its optimum operating value whatever the weather instabilities or sudden changes in loads that can occur at any time.

Several method are presented for maximum power point tracking (MPPT) from photovoltaic system such as constant voltage method, Hill climbing method, perturbation and observation (P&O) method, Incremental Conductance (IC) method, open circuit voltage method, short circuit current method, Fuzzy logic controller method, Neural network etc. [7,14].

MPPT Technique	complexity	speed	Reliability
Measure Isc	Medium	Medium	Low
Measure Voc	Low	Medium	Low
IC	Medium	Varies	Medium
Hil climbing	Low	Varies	Medium
Fuzzy logic	High	Fast	Medium
Neural Network	High	Fast	Medium

Table 1. Comparisons of Common MPPT Methods

As we know that, the maximum power point (MPP) of photovoltaic system depends on array temperature and solar irradiation, so it is necessary to constantly track MPP of solar PV array. For years, research has focused on many MPP control algorithm to draw the Maximum power of the solar array. In this paper, the effectiveness most popular two different control algorithms are thoroughly investigated via mathematical simulation [12].

A. Hill Climbing Algorithm

Hill climbing algorithm is widely used in practical PV systems because of its simplicity and because it does not require prior study or modeling of the source characteristics and can account for characteristics drift resulting from ageing, shadowing or other operating irregularities.

It starts with measuring the present values of the PV array voltage (V (k)) and current (I (k)). Therefore, the generated power (P (k)) can be calculated and compared to its value calculated in the previous iteration. According to the result of comparison; the sign of a 'slope' is either complemented or remains unchanged and the PWM output duty cycle is changed accordingly [6]. The hill climbing algorithm is shown in Fig. 3.

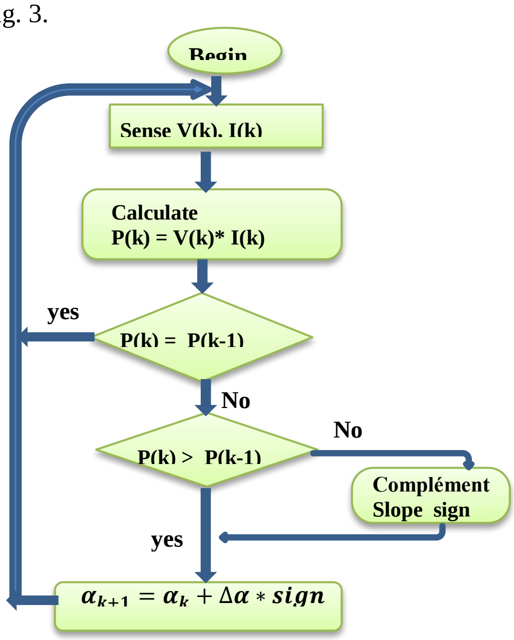


Fig.10 *Flow chart of the hill climbing based MPPT algorithm*

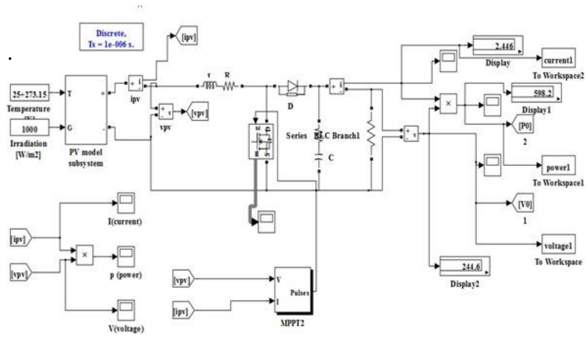


Fig.11 *Simulink model for hill climbing Algorithm*

B. Fuzzy logic Control

We take the PV system's output power as the objective function and duty cycle as control variables. According to the variation of the power value and the duty cycle adjustment step before the moment, we can determine step size that need to adjusted at this moment. The first n moments of the fuzzy controller input is the n-moment variation of the power photovoltaic system and the n-1 time of the duty cycle step, the n- time output is the first n moments of the duty cycle step. [15]

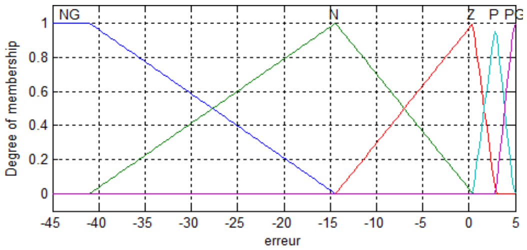


fig.13 *Fis error*

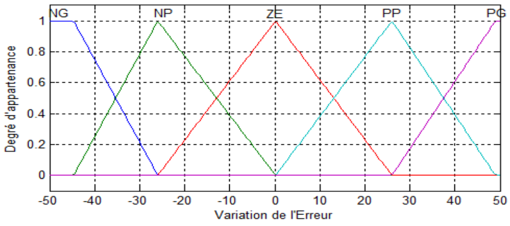


Fig.14. Fis *delta error*

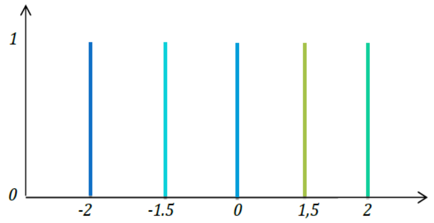


fig.15. *Duty cycle membership functions.*

The structure of the fuzzy controller is based on the changing the control linguistic to form of the if-then in an automatic control system and best knowledge and experience can be more useful instead of understanding a technical behaviour of the system . In this system we use fuzzy logical operator, AND for Intersection, OR for union and NOT for complement

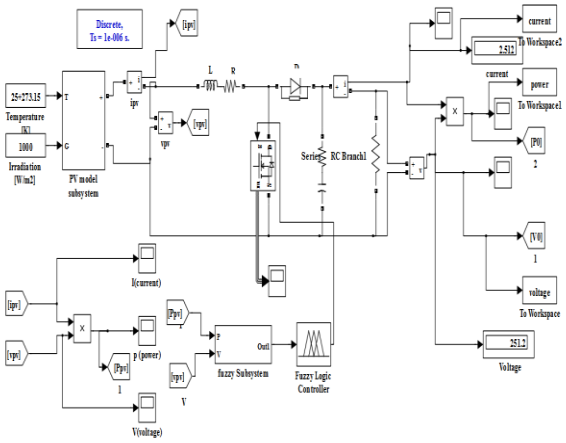


Fig 16.Simulink Model for the fuzzy logic MPPT control

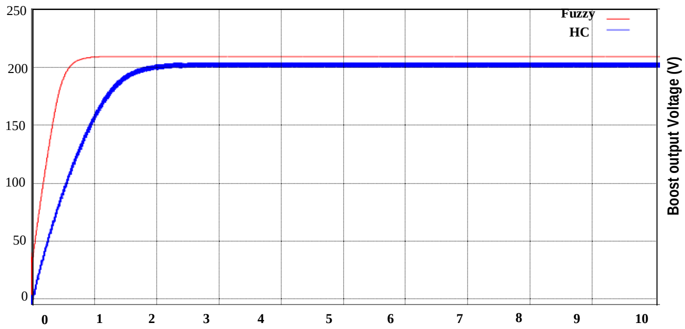


Fig.14 The Boost output voltage Results of HC controller and Fuzzy Logic

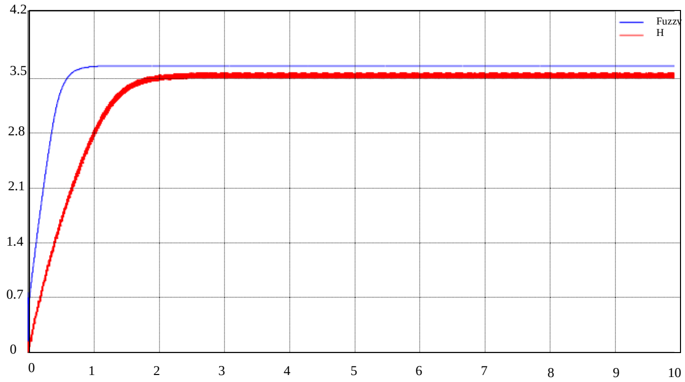


Fig.16The Boost output current Results of HC controller and Fuzzy Logic controller

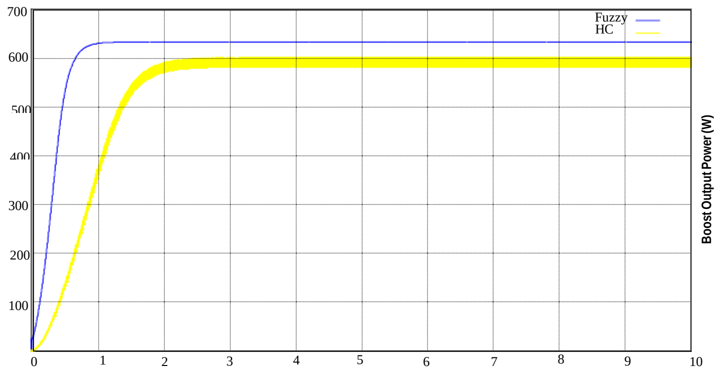


Fig.17 The Boost output power Results of HC controller and Fuzzy

V. CONCLUSION

This paper presents a comparative study between hill climbing algorithm and Fuzzy Logic MPPT controller methods in Matlab/Simulink. The solar PV system main problem, efficiency low and cost is high, and output is change in cloudy weather conductions. So we need a effective MPPT controller. Finally performance of comparative study, we found that the Fuzzy Logic controller is effectiveness compare to hill climbing algorithm. The Fuzzy Logic controller Increase output power, less fluctuation and fast Response, against change in weather conductions. The Fuzzy controller is superior compared to hill climbing algorithm

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