



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

Benslimane Abdelkader and Merabti Abdelhak

EasyChair preprints are intended for rapid dissemination of research results and are integrated with the rest of EasyChair.

May 1, 2020

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

Abdelkader Benslimane #1, Abdelhak Merabti #2
Département : des Sciences Exactes. École normale supérieure
Béchar, Algérie
ikada.benslimane71@gmail.com
zmerabti73@yahoo.com

Abstract: Climate change, i.e. irradiation, creates a major problem in PV energy production systems because it directly and continuously influences the amount of electrical energy produced by the PV module. In order to maximize the output power of a photovoltaic system (PV) which generally depends on solar radiation and cell temperature several methods of Maximum Power point tracking (MPPT) are used. This paper, presents a 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 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, the result of this comparison of the performances between the two methods (IC- Fuzzy controller) which was carried out showed the efficiency of Fuzzy controller to attract more energy, decreases fluctuations and presents a rapid response, against changing variable weather conditions. 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 /Simulink

I. INTRODUCTION

Renewable energy sources play an important role in power generation they offer a great opportunity to generate electricity while reducing greenhouse gas emissions [1] A photovoltaic cell, is the technology used to convert solar energy directly into electrical power. They are usually made of silicon alloy. When photons strike a PV cell, they may reflect off the cell, pass through the cell, or be absorbed by the semiconductor material. Only the absorbed photons provide energy to generate electricity. The power generated by solar panels varies according to weather conditions, i.e. solar irradiation and atmospheric temperature. For this, an MPPT control to extract the maximum power from the photovoltaic panels in real time becomes necessary in the PV generation system.

The single point where the power generated is maximum (MPP) at which the PV system operates at its highest efficiency. This point, located on the knee of the non-linear curve I-V, depends on the ambient

temperature, T_{amb} , of the panel as well as on 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 currently a significant number of MPPT control techniques based on different topologies in many aspects such as complexity, cost and production efficiency, these techniques are used to increase the efficiency of the 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. In reality, the MPPT algorithm will enable to control a Dc-Dc Boost converter to generate the maximum power point of the GPV. The proposed MPPT command acts on the duty cycle automatically. to follow the maximum power and increase the efficiency of a photovoltaic solar generator. [5] . In this article, smart controller techniques using a fuzzy logic controller are associated with increased energy conversion efficiency and compare to escalation. The proposed controller method is simulated using Matlab / Simulink simple Matlab Tool. The simulation and analysis of the escalation controller and fuzzy logic are presented.

II. PV GENERATOR AND THESE CHARACTERISTICS

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The PV effect is the direct conversion of electromagnetic radiation from solar energy into direct current electricity .

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 R_s and the shunt resistance R_{sh} is given by:

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

Where,

I_{PV} : current generated by the incident light

I_d : The Shockley diode equation

I_0 : The reverse saturation current of the diode

q : electron charge ($1.60217646 \cdot 10^{-19} \text{C}$)

k : Boltzmann constant ($1.3806503 \cdot 10^{-23}$)

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)

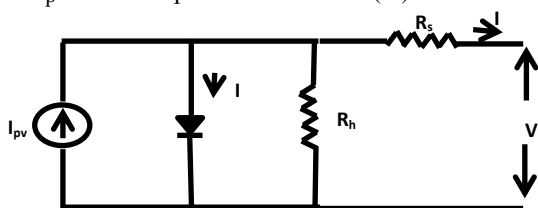


Fig. 1 Equivalent electrical circuit of a solar cell

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

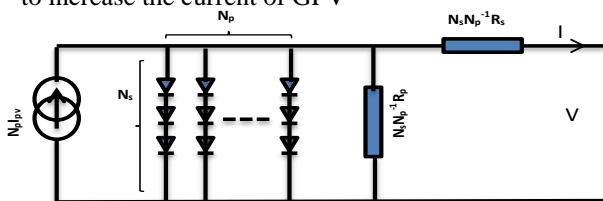


Fig. 2 Equivalent circuit of PV module

The current delivered by the GPV module is given by the expression:

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

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

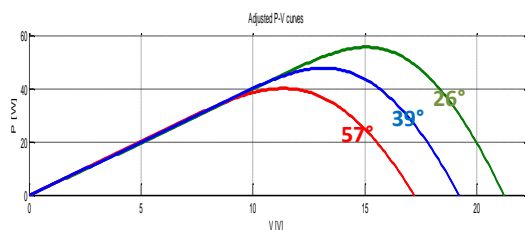


Fig. 3 Temperature influence on MMP

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

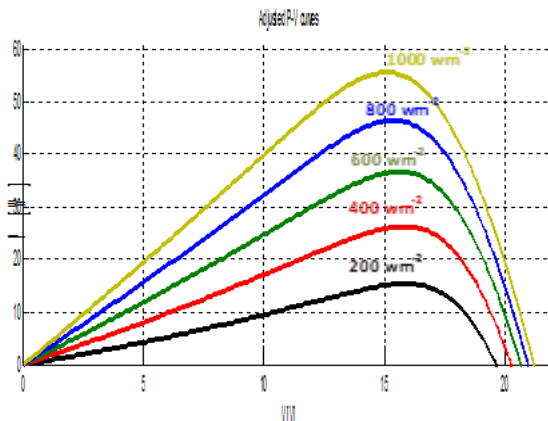


Fig. 4 Changing the MPP according to the brightness

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).

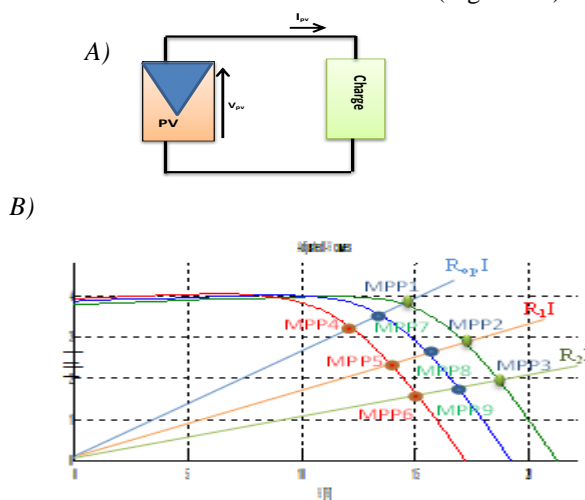


Fig.5 A) Direct electrical connection between a PV generator and a load.

B) Influence of the load on the operating 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.

for this reason, the use of an adaptation stage (DC / DC converter) is the most popular solution in order to extract at all times the maximum power available at the terminals of the GPV and to transfer it to the load. a DC-DC converter topology suitable for integration with a photovoltaic solar system or other renewable energy sources has not been explicitly studied, although its integration into the photovoltaic solar system will effectively increase its optimal use [10].

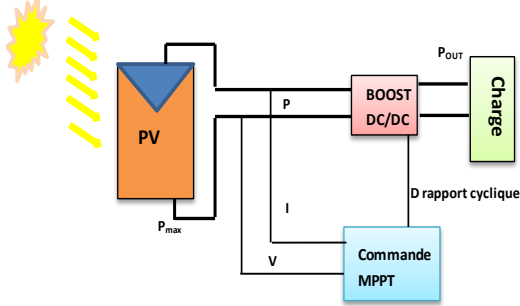


Fig.6 Photovoltaic system (PV module – Boost converter–load)

III. 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]. A

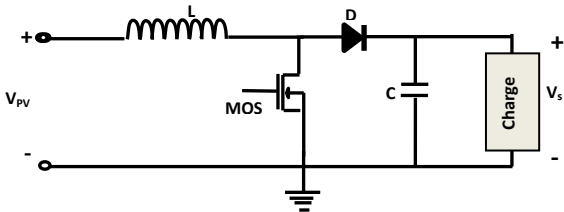


Fig.7 Structure of the converter BOOST

The operation of the circuit is divided into two parts according to the switching interval of the MOS transistor (TON, TOFF).

Interval T_{ON}

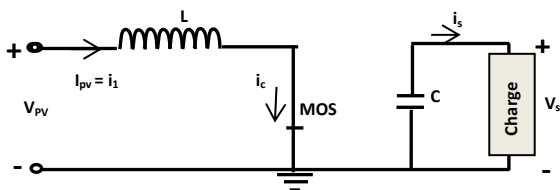


Fig.8 Equivalent circuit for T_{ON}

$$V_e = L \frac{d i_1}{d t} \Rightarrow i_1(t) = \frac{V_e}{L} t + I_1 \quad (3)$$

Or I₁ the initial current. During this interval the current crossing the inductance increases.

Interval T_{OFF}

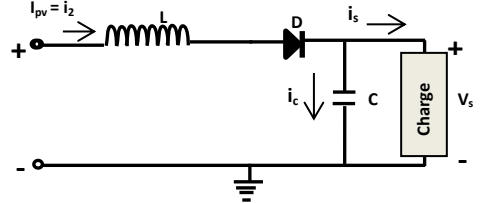
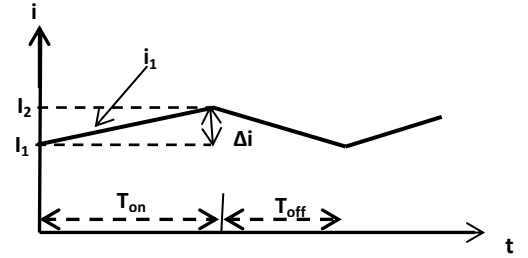


Fig.9 Equivalent circuit for T_{OFF}

$$V_e = L \frac{d i_2}{d t} + V_s \Rightarrow i_2(t) = \frac{V_e - V_s}{L} t + I_2 \quad (4)$$

Or I₂ the initial current for interval T_{OFF}.



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

$$V_s = \frac{1}{1 - \alpha} V_{PV} \quad (5)$$

$$I_s = (1 - \alpha) I_{PV} \quad (6)$$

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:

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

Also, the duty cycle, are written according to the resistance R_{opt} and R_s.

$$\alpha = 1 - \sqrt{\frac{R_{OPT}}{R_s}} \quad (8)$$

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.

IV. 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.

There are several operating principles of MPPT controls more or less performance based on the properties of the GPV, such as the constant voltage method, the hill climb method, the perturbation and observation method (P&O), the incremental conductance method (IC), the circuit voltage method open, 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, the maximum power point of a photovoltaic module varies continuously over time, mainly due to the different light intensity and temperature of the cells, so it is necessary to constantly monitor the MPP of the photovoltaic solar generator. For years, research has focused on many MPP control algorithms to draw maximum power from the solar generator. In this article, the efficiency of the two most popular control algorithms is studied in depth by mathematical simulation [12].

I. 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.

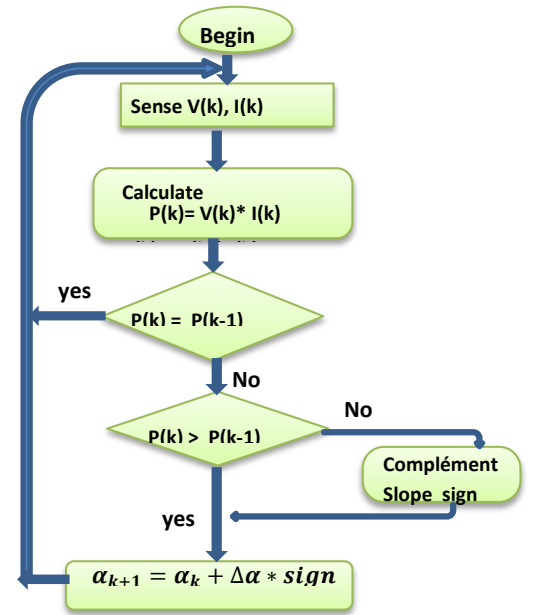


Fig.10 Flow chart of the hill climbing based MPPT algorithm

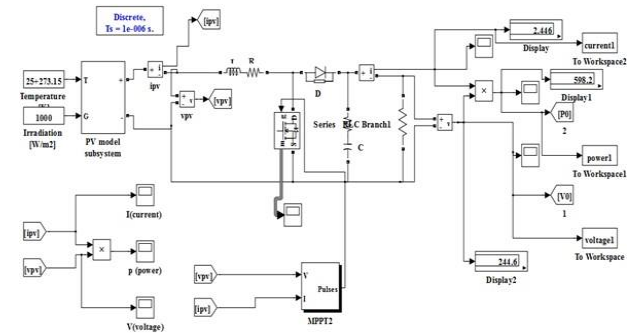


Fig.11 Simulink model for hill climbing Algorithm

II. 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-th time output is the first n moments of the duty cycle step. [15]

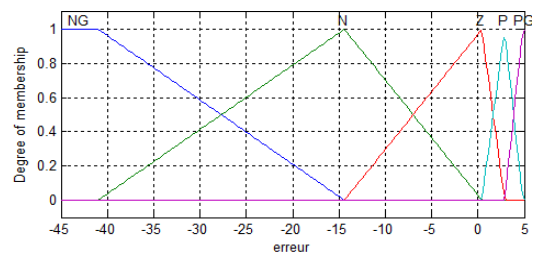


Fig.13 Fis error

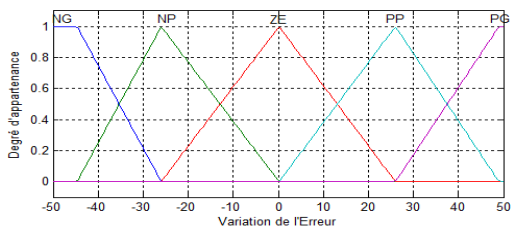


Fig.14. Fuzzy delta error

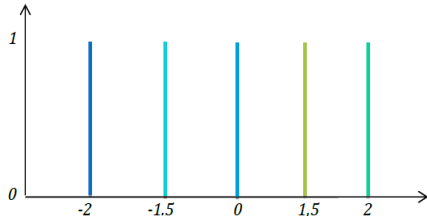


fig.15. Duty cycle membership functions.

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

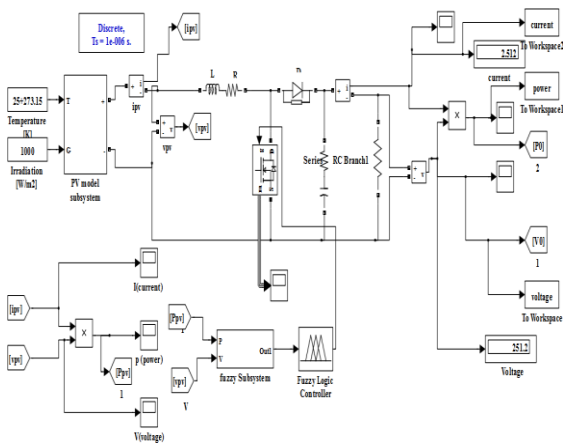


Fig 16.Simulink Model for the fuzzy logic MPPT control

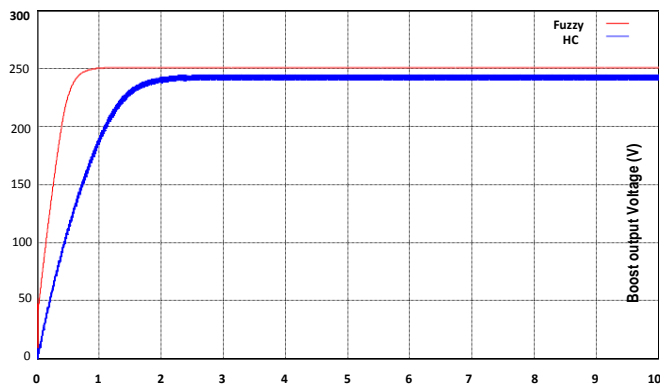


Fig.14 The Boost output voltage Results of HC controller and Fuzzy Logic

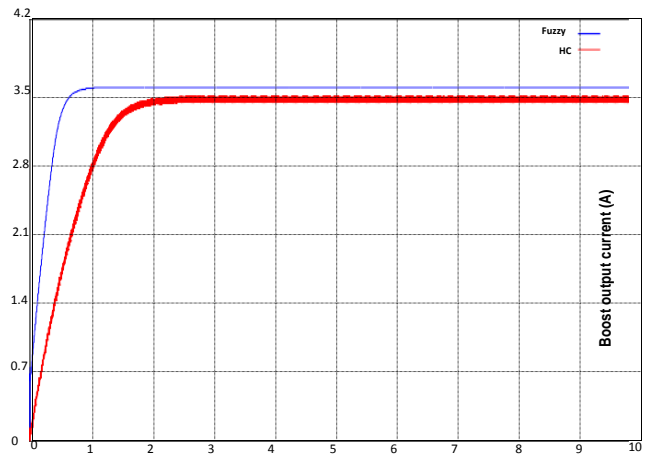


Fig.16 The Boost output current Results of HC controller and Fuzzy Logic controller

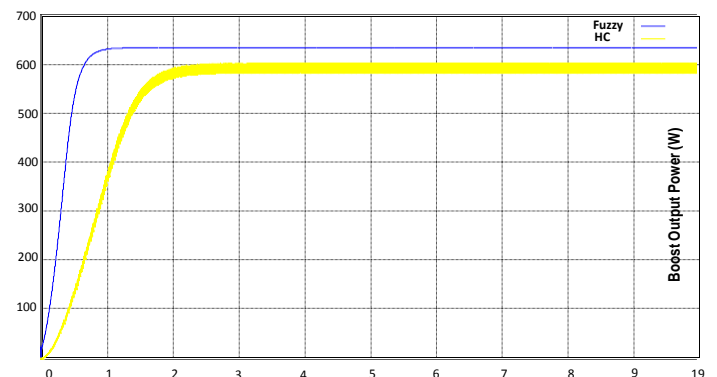


Fig.17 The Boost output power Results of HC controller and Fuzzy Logic controller

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

REFERENCES

- [1]. S. Sivasubramaniam, A. Faramus, R. D. Tilley, and M. M. Alkai, "Performance enhancement in silicon solar cell by inverted nanopyramid texturing and silicon quantum dots coating," *J. Renewable Sustainable Energy* 6, 011204 (2014).
- [2]. Qiang Mei, Mingwei Shan, Liying Liu, and Josep M. Guerrero, "A Novel Improved Variable Step-Size Incremental-Resistance MPPT Method for PV Systems" *IEEE Transactions On Industrial Electronics*, Vol.58, No.6,pp.2427-2434,June 2011.
- [3] F. Ding, P. Li, B. Huang, F. Gao, C. Ding and C. Wang, "Modeling and Simulation of Grid-connected Hybrid Photovoltaic/Battery Distributed Generation System", National

Natural Science Foundation, National 973 Project, China
International Conference on Electricity Distribution.

- [4]. Zainudin H. N., Mekhilef S., "Comparison Study of maximum Power Point Tracker Techniques for PV Systems", *Proc. of 14th International Middle East Power System Conference (MEPCON)*, Egypt, PP.750-755, Dec. 19-21, 2010
- [5]. M.S. Khireddine, M.T.Makhloufi, A. Boutarfa., "Tracking Power Photovoltaic System With a Fuzzy Logic Control Strategy", *IEEE International Conference on CSIT*, PP.42-49, 2014.
- [6]. Shahrooz Hajjghorbani, M.A.M. Radzi, M.Z.A.Ab Kadir, S.Shafie, Razieh Khanaki, and M. R. Maghami, "Evaluation of Fuzzy Logic Subsets Effects on Maximum PowerPoint Tracking for Photovoltaic System," *International Journal of Photoenergy*, Volume 2014, Article ID 719126, pp.1-13, 2014.
- [7]. Mohammad Seifi, Azura Bt. Che Soh, Noor Izzrib. Abd. Wahab, and Mohd Khair B. Hassan, "A Comparative Study of PV Models in Matlab/Simulink" *International Science Index* Vol:7, No.2, pp.102-107,2013.
- [8]. Mei Shan Ngan, Chee Wei Tan., "A Study of Maximum Power Point Tracking Algorithms for Stand-alone Photovoltaic Systems" *IEEE Applied Power Electronics Colloquium Malaysia*, p.p.22-27, 2011.
- [9]. Shilpa Sreekumar, Anish Benny, "Fuzzy Logic Controller Based Maximum Power Point Tracking of Photovoltaic System Using Boost Converter" *IEEE ICCCNT Forth International conference*, p.p. 1-6, July 4-6, 2013.
- [10]. Jenifer A., Newlin Nishia R., Rohini G., and Jamuna V., "Development of MATLAB Simulink Model for Photovoltaic Array", *Proc. of IEEE International Conference on Computing, Electronics and Electrical Technologies, Kumara Coil, Tamil Nadu*, pp. 436-442, 2012.
- [11]. Youjie M., Deshu C., Xuesong Z., and Runrui G., "MPPT Control of Photovoltaic System based on Hybrid Modeling and its Simulation", *Proc. of International Conference on Sustainable Power Generation and Supply, Nanjing, China*, pp. 1-5,2011.
- [12]. Zainudin H. N., Mekhilef S., "Comparison Study of maximum Power Point Tracker Techniques for PV Systems", *Proc. of 14th International Middle East Power System Conference (MEPCON)*, Egypt, 19-21, December 2010.
- [13]. M. T. Makhloufi, M. S. Khireddine, Y. Abdessemed and A. Boutarfa, "Maximum Power Point Tracking of a Photovoltaic System using a Fuzzy Logic Controller on DC/DC Boost Converter" *IJCSI International Journal of Computer Science Issues*, Vol. 11, Issue 3, No 2, May 2014.
- [14]. Trishan Eswam, Patrick L. Chapman, "Comparison of Photovoltaic Array Maximum PowerPoint Tracking Techniques" *IEEE Transaction on Energy Conversion*, Vol.22, No. 2, p.p. 439-449, June, 2007.
- [15]. Fangrui Liu, Shanxu Duan, Fei Liu, Bangyin Liu, and Yong Kang, "A Variable Step Size INC MPPT Method for PV Systems" *IEEE Transactions On Industrial Electronics*, Vol.55, No.7, p.p.2622-2628, July 2008.