Comparative Study of Fuzzy Logic MPPT Controllers, using Different Membership Functions - for PV Modules

Vipul Kumar Jha[1], Sulata Bhandari[2]

[1]Student, ME (Electrical), PEC University of Technology, Chandigarh
[2]PEC University of, Technology, Chandigarh

Abstract: As the global electrical energy demand is steadily increasing, there is a need to increase the power generation capacity. Shortage of conventional energy sources, demands to change focus on renewable energy sources. The amount of power generated from a photovoltaic (PV) system mainly depends on factors, such as temperatures and solar irradiances. The low energy conversion efficiency of a PV module can be increased using MPPT controllers, and the maximum power point changes with solar irradiances and load variations. In this paper, Fuzzy Logic (FL) Maximum Power Point Tracking (MPPT) controller is used in photovoltaic system, using different rule bases of FL. It is well known that choice of membership function is a key problem in a fuzzy logic controller. The proposed controllers with different membership functions are simulated, analyzed, compared and its impact on the output of the PV module discussed.

Keywords: Photovoltaic Power System; Maximum Power Point Tracking; Fuzzy Control, Different Membership Functions.

1. INTRODUCTION

Solar energy technology development is one of the most important issues in the search for a renewable energy source. Solar energy is clean with zero emissions during the energy conversion process [1-9]. Solar energy systems have been used in many industrial fields, such as residential, vehicular, space and naval applications. P−V module characteristic varies with many atmospheric conditions such as irradiance and temperature [1].Photovoltaic solar cell is a semiconductor device; its voltage and current are affected by temperature and light intensity. When solar cells are irradiated by light and connected with load, photo-current flows through the load, and set up the terminal voltage across the load [2].

Accurate modelling of the PV module is the first step of the simulation process. Though a number of publications have already described different types of PV modelling techniques. But these works were very complicated and time consuming. In addition, MATLAB coding based simulator were used by most of the authors for illustrating I-V and P-V curves. The problem with these simulators is that they cannot be used for different modules simultaneously. Herewith there exists some possibility of data manipulation. The proposed technique can be used to illustrate the characteristic curves of any specific model instantly. [10]

2. PV MODELLING

A. Circuit Configuration

From the solid-state physics point of view, the cell is basically a large area p-n diode with the junction positioned close to the top surface. So an ideal solar cell may be modelled by a current source in parallel with a diode that mathematically describes the I-V characteristic by [11].

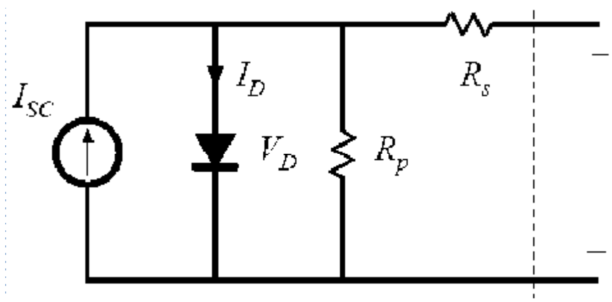


Fig.1: Typical circuit of PV solar cell

The basic equations describing the I-V characteristic of the PV model are given in the following equations [12]:

$$0 = I_{SC} - I_D - \frac{V_D}{R_P} - I_{PV} \quad (1)$$

$$I_D = I_0(e^{V_D/V_T} - 1) \quad (2)$$

$$V_{PV} = V_D - R_S I_V \quad (3)$$

Where:

I_{PV} = cell current (A).

I_{SC} = light generated current (A).

I_D = diode saturation current (A).

R_S = cell series resistance (ohms).

R_P = cell shunt resistance (ohms).

V_D = diode voltage (V).

V_T = temperature voltage (V).

V_{PV} = cell voltage (V).

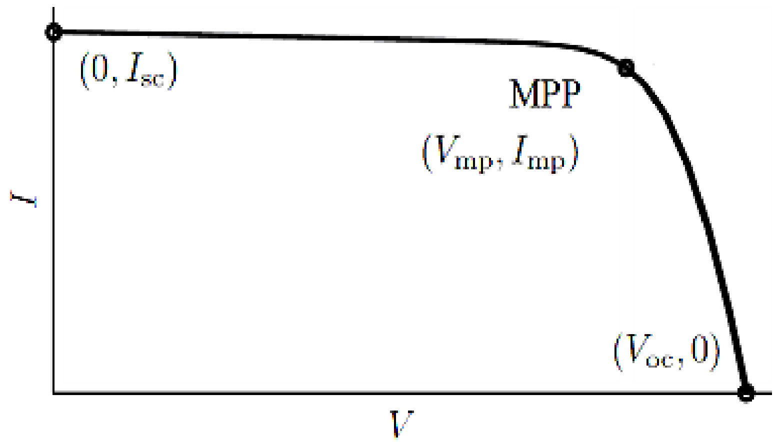


Fig.2:Characteristic I-V curve of a practical PV device

Output Characteristic of Photovoltaic Array:

A typical characteristic curve of PV model's current and voltage curve is shown in Fig.2, and the power and voltage curve is shown in Fig.3 [11].

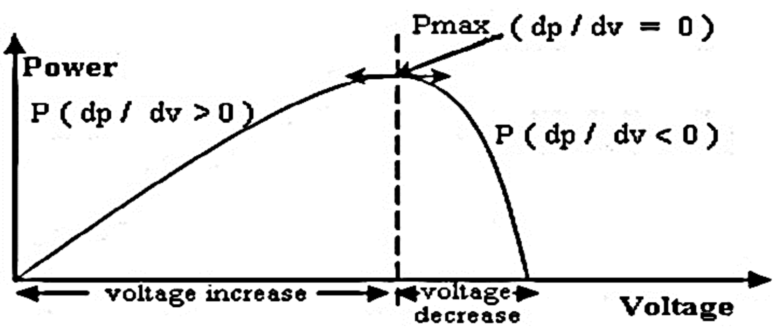


Fig.3: Power-voltage characteristic of a PV module

MPPT Using Fuzzy Logic Control

MPPT using Fuzzy Logic Control gains several advantages of better performance, robust and simple design. In addition, this technique does not require the knowledge of the exact model of system. The main parts of FLC, fuzzification, rule-base, inference and defuzzification, are shown in Fig. 4. In the proposed system, the input variables of the FLC are the change in PV array power (ΔP_{pv}) and the change in PV voltage (ΔV_{pv}), whereas the output of FLC is the magnitude of the change of boost converter Duty cycle. The Duty cycle of PWM is the command for controlling the current drawn from the PV. Flow chart of the proposed FLC is shown in Fig. 4[12] . The equations for ΔP_{pv} and ΔV_{pv} are given as follows:

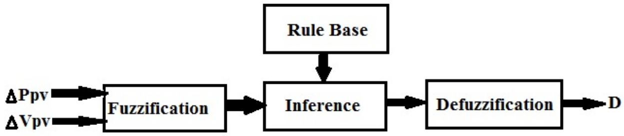
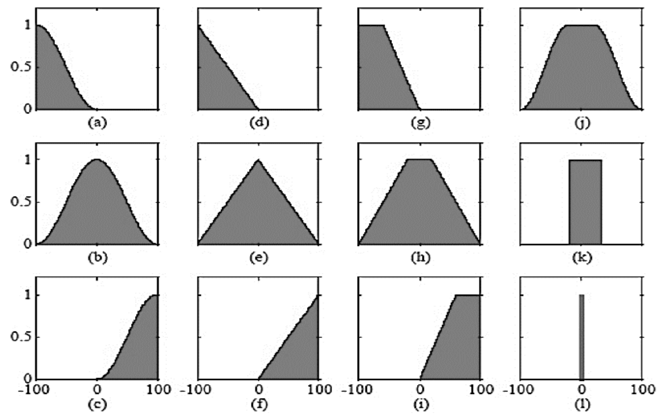


Fig.4: The Fuzzy Logic Controller



$$P_{pv}^{k} = V_{pv}^{k} \, . I_{pv}^{k} \quad (4)$$

$$\Delta P_{pv}^{k} = P_{pv}^{k} - P_{pv}^{k-1} \quad (5)$$

$$\Delta I_{pv}^{k} = I_{pv}^{k} - I_{pv}^{k-1} \quad (6)$$

$$\Delta V_{pv}^{k} = V_{pv}^{k} - V_{pv}^{k-1} \quad (7)$$

Fig. 5: Different shapes of membership functions (a) *s_function, (b) π_function, (c) z_function, (d-f) triangular versions, (g-i) trapezoidal versions, (j) flat π_function, (k) rectangle, (l) singleton.*

Basic Operations on Fuzzy Sets

Every fuzzy set can be represented by its membership function. The shape of membership function depends on the application and can be monotonic, triangular, trapezoidal or bell shaped as shown in Fig. 5.

The membership function could be defined as a graphical representation of the quantity of participation of the inputs. It links a value with each of the inputs parameters that are treated, defines functional overlap amongst inputs, and finally defines an output parameter. The rules usually take the input membership parameters as features to establish their weight over the "fuzzy output sets" of the final output response. Once the functions are deduct, scaled, and combined, they have to be defuzzified into a crisp output which leads the application. There are some different memberships functions linked to each input and output parameter.

As an example: If warm of the linguistic variable "temperature" shown in Fig. 6. If the measured temperature in one system is x, then the level of membership of x in the fuzzy set positive small is given by μ(x) and it is 0.7. We can say that the level of truth for the proposition: " The temperature x is warm is 0.7 or 70%".

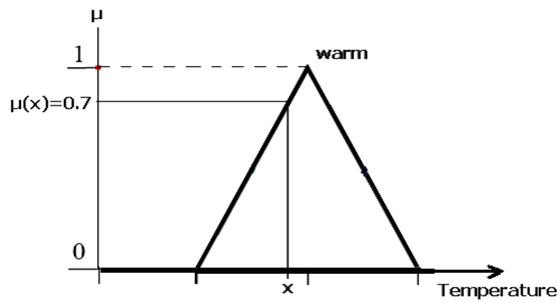


Fig.6: Membership function (warm temperature)

The Simple Principle of Fuzzy Control for MPPT

The Input and Output Variables of Fuzzy Controller:

According to the basic principles of Perturb and Observation (P & O), the output power is taken as the objective function, duty cycle D as the control variable. According to the power change and duty cycle before the moment, the adjustment step size is determined. The k^{th} moment input of the Fuzzy controller is the k^{th} power variation of photovoltaic system and the $(k-1)^{th}$ step values of duty cycle, the k^{th} moment output is duty cycle of k^{th} time. Duty cycle output connected with PWM which gives the Gate Pulse to boost converter switch, MOSFET. Connections of ΔPpv and ΔVpv with FLC controller is shown in fig. 7.

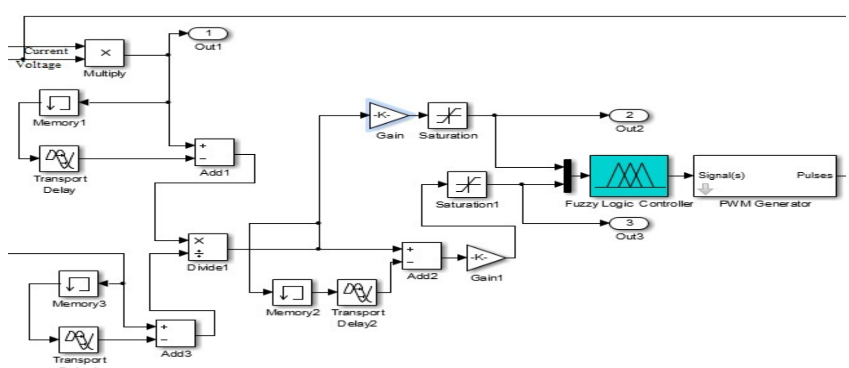


Fig.7 Connection of ΔPpv & ΔVpv with FLC Controller

Fuzzy Sets and Universe of the Input and Output Variables

Membership Function

According to the characteristics of photovoltaic power system, triangular shape is selected as the shape of the membership function. The membership function of power difference Error, Change in Error and Duty Cycle steps are respectively shown in Fig. 8, Fig. 9 and Fig. 10.

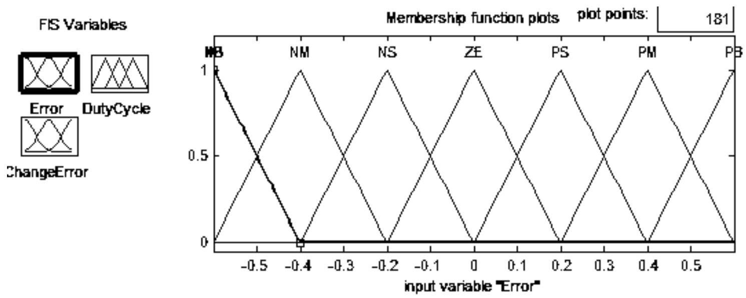


Fig. 8: Membership Function of Power Error

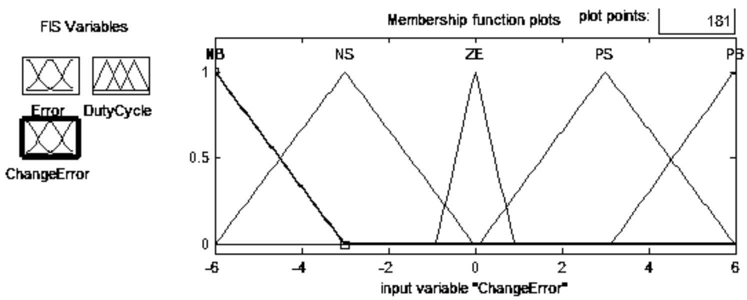


Fig.9: Membership Function of Change in Error

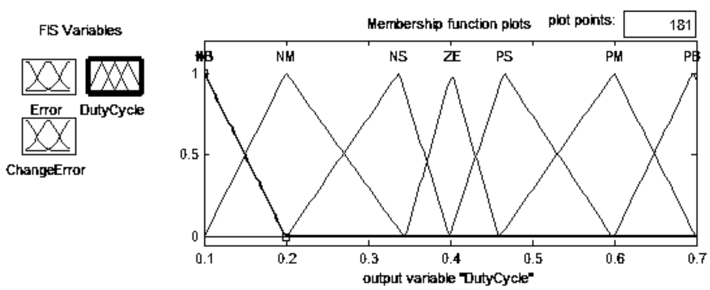


Fig.10: Membership Function of Duty Cycle

Fuzzy Decision Table

According to the analysis of the characteristic curve between the PV system output power P and the duty cycle D can be obtained the following principles.

i) If the output power increases, continue to adjust to the long direction of the original step, otherwise take the opposite direction.
ii) A maximum power point farther away, larger step to accelerate the tracking speed; near the maximum power point, using a smaller step size to reduce the search losses.

Temperature, sunlight intensity, and factors such as changes lead to larger changes in the power of the photovoltaic system, the system can quickly respond.

Change in Error	Error						
	NB	NM	NS	ZE	PS	PM	PB
NB	ZE	ZE	NS	NM	PM	PM	PB
NS	ZE	ZE	ZE	ZE	PS	PM	PB
ZE	NB	NM	NS	ZE	PS	ZE	ZE
PS	NB	NM	NS	ZE	ZE	ZE	ZE
PB	NB	NM	NS	PM	ZE	ZE	ZE

Control Rule Table of Fuzzy control

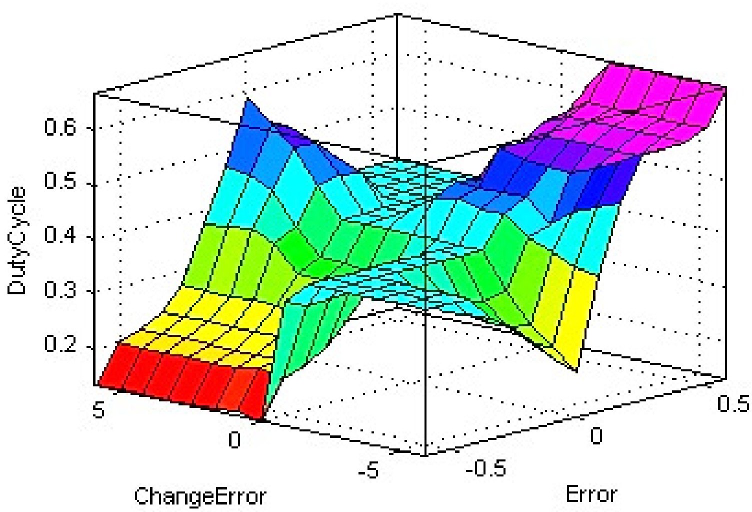


Fig.11: The Surface view of control rule

Operation and Design of Boost Converter:
Output voltage is higher than the input voltage, it is called boost converter. It is implemented in this proposed system by using a diode and a MOSFET. In the boost converter the average output

current is less than the average inductor current. and a much higher rms current would flow through the filter capacitor due to this reason a large value of the inductor and filter capacitor is required than those of buck converter[5][15]. Boost converter works in two states. When the switch S is open, current in the boost inductor increases linearly, and the diode D is off at that time. When the switch S is closed, the energy stored in the inductor is released through the diode to the output RC circuit [14]. Diagram of boost converter shown in fig.12.

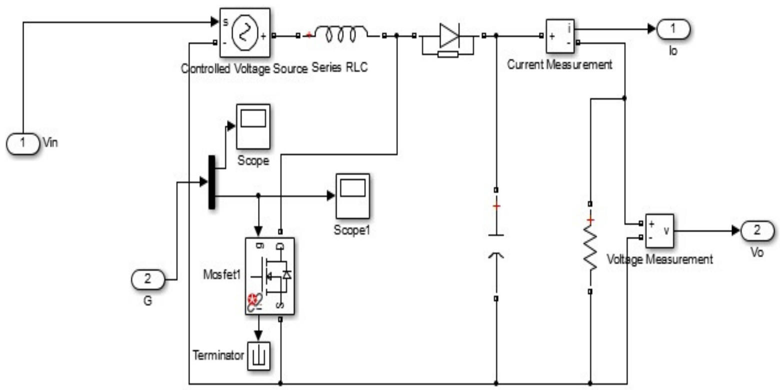


Fig. 12 Diagram of boost converter

Simulation Result and Discussion

In this complete setup system consist PV module, boost converter, Fuzzy logic controller, DC load. According to the mathematical model of the PV array, solar cell model is established by MATLAB/Simulink. Solar model parameters is set as follows:

Reference temperature: 25°C; reference solar radiation: 1000W/m^2; Open Circuit Voltage 21.1V; Short Circuit current 3.8A, Career Frequency of PWM 10000Hz.

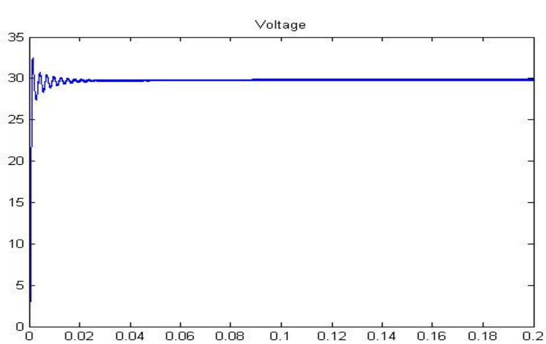


Fig.13 Output voltage using triangular membership function

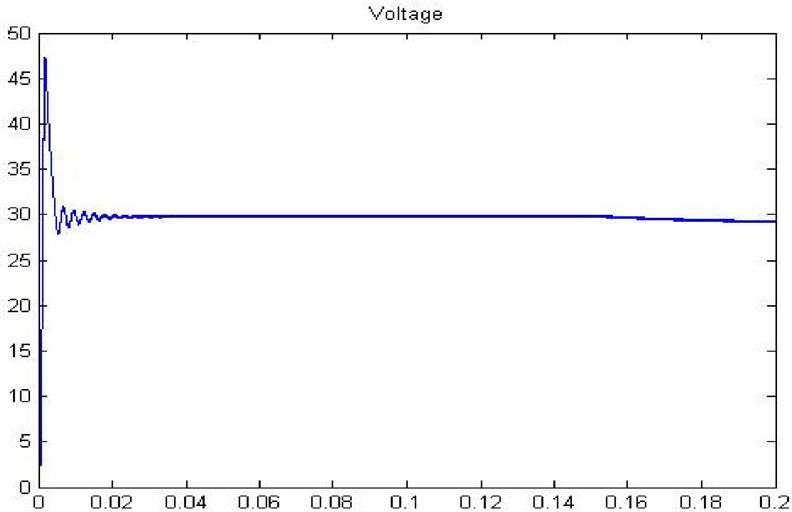


Fig.14 Output voltage using trapezoidal membership function

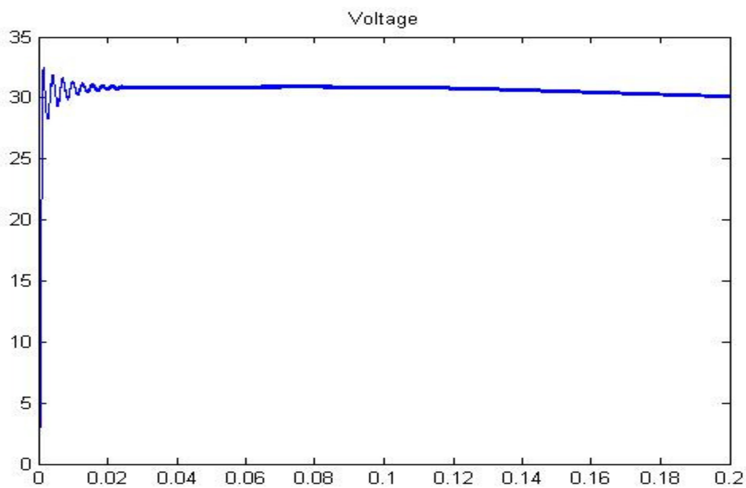


Fig.15 Output voltage using Gaussian membership function

Here results can compare the output power of PV using different membership function. When system use triangular membership function shown in fig.8, fig.9 and fig.10 it obtain maximum voltage, power and current within 0.025seconds i.e. 29.88V, 59.55W and 1.99A respectively and it remain constant till the end as shown in fig. 13. But when the system use trapezoidal and Gaussian membership function the maximum power and voltage decreases with time as shown in fig.14 and fig.15 respectively.

3. CONCLUSION

In this paper, various and efficient techniques of PV module with Fuzzy Logic Base MPPT has been implemented. The main objective of this paper were to find the MPPT with different membership function and compare them, thus we conclude that for small variation in temperature triangular wave are very effective, more steep, and easy to improve the resolution. Simulation results show that Photovoltaic power generation system, which applies fuzzy control, can fast and efficiently track the maximum power point of photovoltaic solar array.

REFERENCES

[1] Wei-Yi Yang, Zong-Ying Yang, Yuang-Shung Lee,Chien-Liang Chen and Jih-Sheng Lai, "*Fuzzy Logic Maximum Power Point Tracking Control for PV Inverter"* IEEE 7th International Power Electronics and Motion Control Conference - ECCE Asia June 2-5, 2012, Harbin, China, 2012

[2] JING Qiufeng,LIU Sujuan and YANG Hai-zhu, "*Maximum Power Point Tracking in Photovoltaic System by Using Fuzzy Algorithm"* IEEE DOI 10.1109/ICICCI.2010.28, 2010

[3] Mohamed M. Algazar, Hamdy AL-monier, Hamdy Abd EL-halim, Mohamed Ezzat El Kotb Salem, "*Maximum power point tracking using fuzzy logic control*" 0142-0615/$ - see front matter _ 2011 Elsevier Ltd. All rights reserved, doi:10.1016/j.ijepes.2011.12.006

[4] Sung-Jun Kang 1, Jae-Sub Ko2, Jung-Sik Choi3, Mi-Geum Jang4, Ju-Hui Mun 5, Jin-Gook Lee6 and Dong-Hwa Chung7, "*A Novel MPPT Control of photovoltaic system using FLC algorithm*" 11th International Conference on Control, Automation and Systems Oct. 26-29, 2011 in KINTEX, Gyeonggi-do, Korea, 2011.

[5] Abubakkar Siddik. A, Shangeetha. M, "*Implementation of Fuzzy Logic controller in Photovoltaic Power generation using Boost Converter and Boost Inverter*" International Journal of Power Electronics and Drive System (IJPEDS) Vol. 2, No. 3, September 2012, pp. 249~256 ISSN: 2088-8694

[6] C. S. Chin, P. Neelakantan, H. P. Yoong, K. T. K. Teo, "*OPTIMISATION OF FUZZY BASED MAXIMUM POWERPOINT TRACKING IN PV SYSTEM FOR RAPIDLYCHANGING SOLAR IRRADIANCE"* Transaction on Solar Energy and Planning ISSN: 2229-8711 Online Publication, June 2011

[7] G. Gangadhar Gupta and K.Mahesh, "*To Elevate the Grid Stability of PV System by Using Fuzzy MPPT Control*" IJERA Vol. 3, Issue 4, Jul-Aug 2013, pp.1954-1958, 2013

[8] F.Bouchafaa, I.Hamzaoui and A.Hadjammar, "*Fuzzy Logic Control for the trackingof maximum power point of a PV system*" 1876–6102 © 2011 Published by Elsevier Ltd. doi:10.1016/j.egypro.2011.05.073

[9] Subiyanto, Z. A. Ghani, A Mohamed, M A Hannan, "*Prototype Development of An Intelligent PowerConditioning Unit For PV Generation System*" IEEE,2013

[10] Hasan Mahamudul, Mekhilef Saad, and Metselaar Ibrahim Henk, **"***Photovoltaic System Modeling with Fuzzy Logic Based Maximum Power Point Tracking Algorithm"* Hindawi Publishing Corporation International Journal of Photoenergy Volume 2013, Article ID 762946.

[11] Basil M. Hamed, Mohammed S. El-Moghany, "*Fuzzy Controller Design Using FPGA for Photovoltaic Maximum Power Point Tracking"* (IJARAI) International Journal of Advanced Research in Artificial Intelligence, Vol. 1, No. 3, 2012.

[12] Pongsakor Takun, Somyot Kaitwanidvilai and Chaiyan Jettanasen, *"Maximum Power Point Tracking using Fuzzy Logic Control for Photovoltaic Systems"* Proceedings of International MultiConference of Engineering and Computer Scientists 2011 Vol II, IMESC 2011, March 16-18,2011, Hong Kong.

[13] Xuecheng Zhao, Yuhong Zhao, "*Control Method of Photovoltaic Maximum Power Point Tracking Based on the Theory of fuzzy*" 2nd International Conference on Electronic & Mechanical Engineering and Information Technology (EMEIT-2012).

[14] Hasan Mahamudul, Mekhilef Saad, and Metselaar Ibrahim Henk *"Photovoltaic System Modeling with Fuzzy Logic Based Maximum Power Point Tracking Algorithm"* Hindawi Publishing Corporation International Journal of Photoenergy, June 2013.

[15] Christophe Batard, Frédéric Poitiers, Christophe Millet and Nicolas Ginot *"Simulation of Power Converters Using Matlab-Simulink",* 2012.

[16] Chao Zhang, Dean Zhao *"MPPT with Asymmetric Fuzzy Control for Photovoltaic System",* ICIEA 2009.

[17] A.Daoud, A. Midoun "*A Fuzzy Logic Based Photovoltaic Maximum Power Tracker Controller*"