

## Design and Comparison of Perturb & Observe and Fuzzy Logic Controller in Maximum Power Point Tracking System for PV System by Using MATLAB/Simulink

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**Abstract** – Energy is a substantial component for human being. One of the crucial concerns in developing power industry is that expanding energy demand compulsively. Therefore, the only way to overcome this challenge is the evolution of renewable and unlimited energy sources. Solar energy is considered a major source for producing electricity. One of the most important issues is generating the electrical power from PV panels and nowadays researchers concentrate implementation of maximum power point tracking algorithm to increase the output efficiency of PV panel. Maximum power point tracking (MPPT) system is used in PV applications to obtain maximum power which rely on different conditions like solar insolation, temperature, sunlight angle etc. In addition, a DC-DC converter is located between the PV array and load in order to acquire the desired voltage level. The converter searches a better voltage to receive higher power from the solar panels.

In this study, a Fuzzy Logic controller and a Perturb & Observe (P&O) system for the tracking of the maximum power point are analyzed. Thus, fuzzy logic controller is designed and compared with P&O technique for the operation of the MPPT controller for effective operation under non-linear parameters variations. All algorithms are simulated in Matlab/Simulink to track maximum power efficiently and so successful results are obtained.

**Keywords** – Photovoltaic applications, Maximum Power Point Tracking, Perturb and Observe, Fuzzy logic controller, Matlab/Simulink

### I. INTRODUCTION

Solar energy is one of the most important renewable energy sources. Solar energy is clean, inexhaustible and free. Photovoltaic (PV) generation systems are suffered from two main problems: efficiency of PV module is low because of weather conditions and low efficiency of the converter system which is used in PV Systems. The PV cell V-I and P-I characteristics are not linear and also depends on temperature and irradiation. If a PV cell receives solar irradiation, it can produce power. Also, the system is adjusted current and voltage outputs in order to detect the best possible power output under variable conditions such as sunlight, temperature, irradiation etc. Unpredictable weather conditions cause to change the efficiency in the solar system. Maximum power point (MPP) confirms the panels are producing the maximum power at all times. Therefore, the PV array's efficiently depends on transformation of sunlight into electrical power. This transformation is remarkably important for solar power system so as to design a system with as low budget as possible. Maximum Power Point Tracking (MPPT) techniques are explored to maximize power output. Several MPPT techniques are identified in the literature; the Incremental Conductance (IC), the Perturb and Observe (P&O), the Artificial Neural Network (ANN), the Fuzzy Logic Controller (FLC) etc. respectively. The MPPT based IC and P&O systems are used the most extensively because of convenient, simple structure and reduced number of necessary measured parameters. On the

other hand, these algorithms have the drawback that starts deviating on the maximum power point, cost, speed of convergence, sensors required, hardware implementation.

The objective of this thesis is firstly to review different MPPT algorithms. Then the most popular P&O and FLC are analyzed and compared according to the standard mentioned. After that, improvements to the P&O is suggested to succeed in the MPP tracking under conditions of changing irradiance.

MPPT algorithms and FLC technique are used in this study for controlling duty cycle of the electronic switch of DC-DC boost converter. PV system was operated depend on variable operation conditions to reach the maximum power to the resistive load.

Fuzzy Logic is focused on Artificial Intelligence. Fuzzy logic is tried to produce output similar to our brain work. the fuzzy logic control is applied in three levels: fuzzification, intelligence & rules and defuzzification. In fuzzification stage, crisp values are converted into fuzzy values depend on a membership function. In the intelligence & rules stage, the rules is identified by a set of IF-THEN statements to describe the controller attitude. In the defuzzification stage, the fuzzy values are converted to crisp values to a numerical variable based on a membership function. Fuzzy logic controllers are a very adaptable set of if-then rules. The solution is applied to available membership functions. All the simulations are used Matlab/Simulink computer software. In this study focus on the comparison of two algorithms in order to track of maximum

power point. These are Perturb & Observe and Fuzzy Logic Controller. They are simulated by using Matlab / Simulink under same condition (temperature and irradiance) and are obtained outputs of V-I and P-V curves. Their performances compared for different system parameters such as irradiation at different degree. The best performance is evaluated via simulation and two systems. In addition, the effect of DC-DC converter is investigated on the tracking quality by using Boost converter. Finally, Simulated and outputs are discussed these different MPPT algorithms.

## II. MATERIALS AND METHOD

### A. PV cell model

The equivalent circuits commonly used for modelling of a PV cell are known as single-diode and two-diode models. The two-diode equivalent circuit has a more complex structure and exhibits more nonlinear characteristics than the single-diode equivalent circuit. Therefore two-diode models are rarely used. Single cell circuit model is used the most commonly model for simulation and modeling in PV cell modeling. In this study, single-diode equivalent circuit model is preferred. The equivalent single-diode circuit model of the solar cell is given in fig.1.

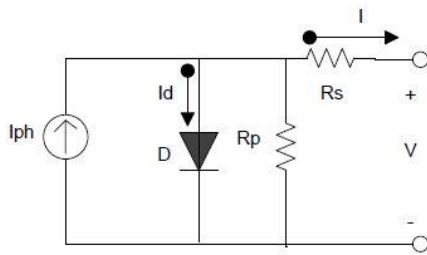


Fig. 1 One-diode Model of PV cell

In addition, the mathematical expression is obtained from above the circuit.

$$I_{pv} = I_{ph} - I_0 \left[ e^{\frac{q(V + I_{pv}R_s)}{NKT}} - 1 \right] - \frac{(V + I_{pv}R_s)}{R_p}$$

First, unknown expressions are defined on circuit.

- $I_{ph}$  is the photo current
- $I_0$  is the reverse saturation current of diode(A)
- $q$  is the electron charge (constant,  $1.602 \times 10^{-19}$  C)
- $K$  is the Boltzmann's constant ( $1.381 \times 10^{-23}$  J/K)
- $T$  is the junction temperature in Kelvin(K)
- $N$  is the ideality factor of diode
- $R_s$  is the series resistance of diode
- $R_p$  is the shunt resistance of diode
- $V$  is the voltage across the diode

### B. Characteristics of PV Module

PV panel manufacturers generally measure and obtain panel values at 25 degrees temperature and  $1000 \text{ W/m}^2$  irradiation values. On the other hand, weather conditions are unpredictable. Therefore, the output values of the PV panel should be examined under different conditions to acquire maximum power from the PV panel.

The V-I and P-V curves is shown below in Fig.2 and Fig.3 respectively under different temperatures.

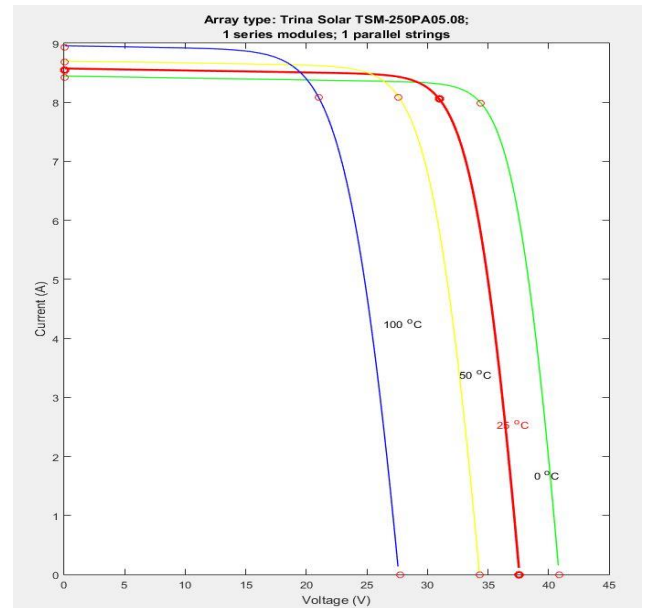


Fig. 2 V-I Characteristics

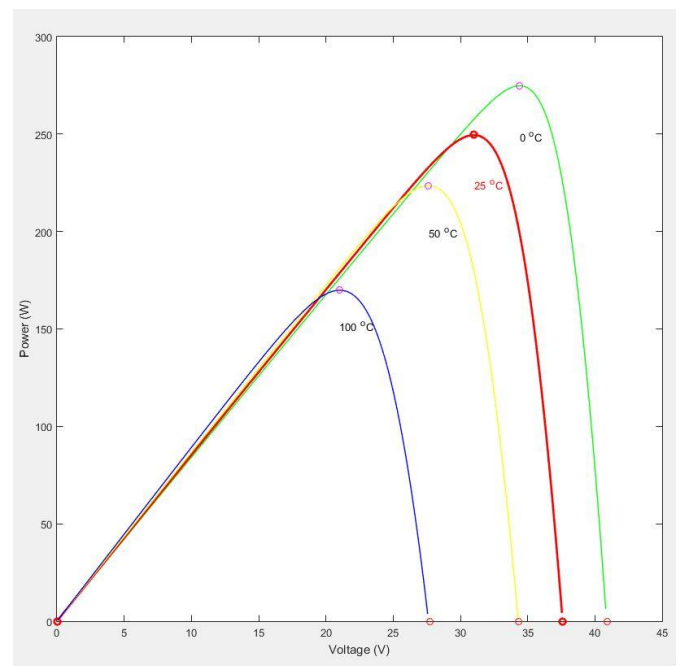


Fig. 3 P-V Characteristics

The V-I and P-V curves is shown below in Fig.4 and Fig.5 respectively under different irradiation.

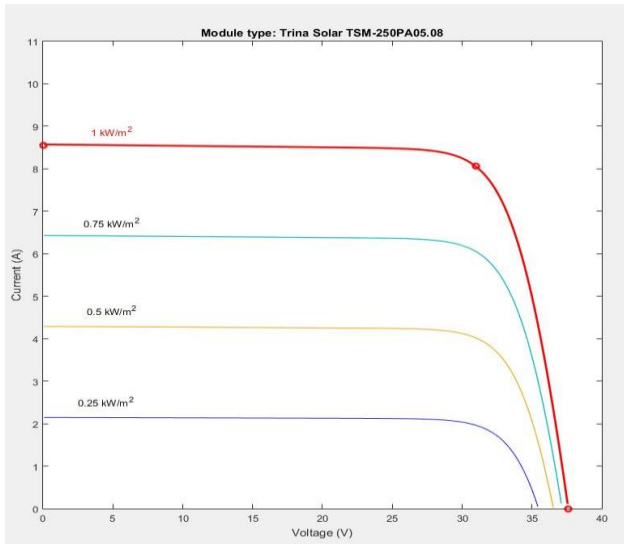


Fig. 4 V-I Characteristics

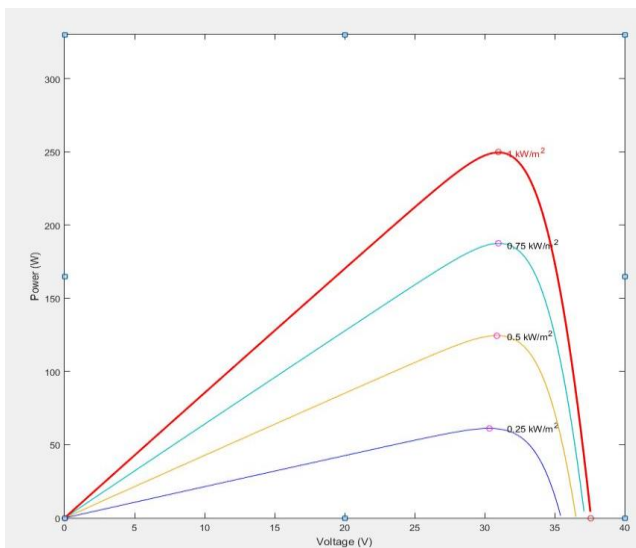


Fig. 5 P-V Characteristics

C. DC-DC Boost Converter

DC-DC Boost converter generally is preferred to maximize the power conversion of photovoltaic panels. It is used generally MPPT applications to avoid shadowing problems so it has manage to reach maximum power point. It is positioned between PV array and load to adjust specified duty ratio and switching frequency. They step up the input voltage of a solar array for a given set of conditions. It is represented below in Fig.6 in MPPT applications.

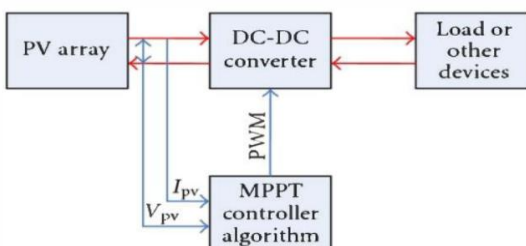


Fig. 6 Basic block diagram of PV system

In addition; DC-DC converter was designed below using Simulink/ Matlab in the Fig.7.

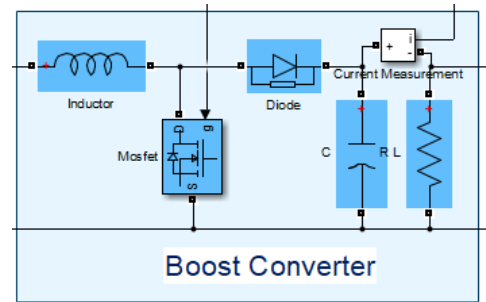


Fig. 7 DC-DC Converter in Simulink/Matlab

D. Maximum Power Point Tracking

MPPT performs a vital role in solar energy systems. The target of MPPT is that transmit the input power of the PV panel as the output power in maximum efficiency. Solar panels are affected by external factors such as partial shading, irradiance, temperature and dust. Therefore, it aims to achieve the maximum output power even under different conditions. Hence, researchers have developed MPPT algorithms.

E. MPPT Algorithms

There are several techniques are used to obtain the maximum power point. The most of popular algorithms are given below.

- Constant Voltage / Current
- Perturb & Observe Method (P&O)
- Incremental Conductance method (IC),
- Artificial Neural Network method (ANN),
- Fuzzy Logic Controller (FLC)
- Adaptive Neuro-Fuzzy Inference Scheme (ANFIS)
- Heuristic Algorithms

F. Perturb & Observe Algorithm and Simulink model

The P&O algorithm is the most extensively used algorithm in the literature due to simple, stable results and non-complexity. The output power of PV panel is continuously observed in this algorithm. A relationship is established between the change of the control variable and the change of the power value. Thus, the control variable is decided to increase or decrease according to the power value. In summary, the voltage value is increased or decreased according to the power value whether is positive or negative depend on the P-V curve of the PV panel. Flowchart of P&O techniques is shown below in Fig.8. In this study, P& O technique is simulated and designed using with Simulink /Matlab.

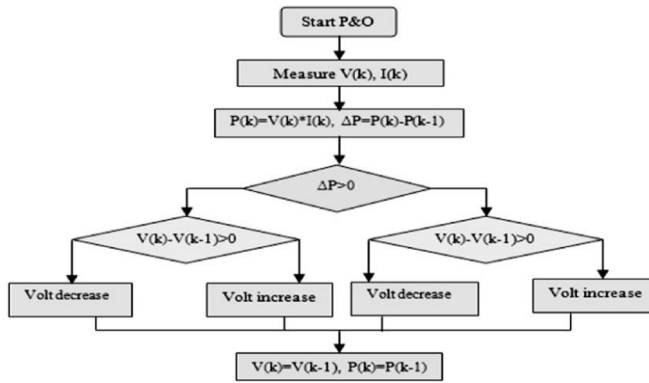


Fig. 8 Flow chart of P&O method

G. Fuzzy Logic Controller and Simulink Model

Fuzzy logic is another kind of artificial intelligence technology. Fuzzy logic is depend on the principle that human decision making isn't all about "ones and zeros" or "yes-no". The fuzzy control rules, essentially the IF-THEN rules. MPPT methods based on fuzzy logic have several advantages over conventional P&O and IC algorithms.

Fuzzy logic systems reach the maximum power point more quickly at load or under variable atmospheric conditions thanks to the soft calculation features of fuzzy logic. However, Fuzzy based on MPPT systems follow the without oscillation or negligible level after reaching the maximum power point. This system follows faster the different environmental conditions and thus reaches the maximum power point rapidly. Hence, efficiency of system is better than other systems.

In this paper, Fuzzy Logic Controller (FLC) Inference System is used with Matlab toolbox. Basic block diagram of FLC's structure is given below Fig.9.

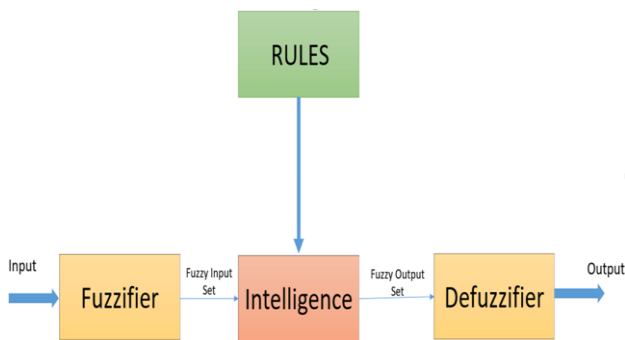


Fig. 9 Basic block diagram of FLC

- Fuzzification: Conversion of crisp values to fuzzy sets that is called membership functions
- Rule-base: It consists of a number of If-Then rules to operate the controller.
- Intelligence: Utilizing an inference to the rules and obtain conclusions with membership functions.
- Defuzzification: Transformation of output fuzzy values to crisp values

Fuzzy input "change in power" and "change in voltage" is designed with seven fuzzy variables and is given below Fig.10. Moreover, the output from the fuzzy logic controller is the change in the duty cycle.

Dp \ Dv	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NS
ZE	NS	NS	PS	PS	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

Fig. 10 Rules implemented in FLC

3-dimensional modeling of inputs and outputs is shown Fig.11.

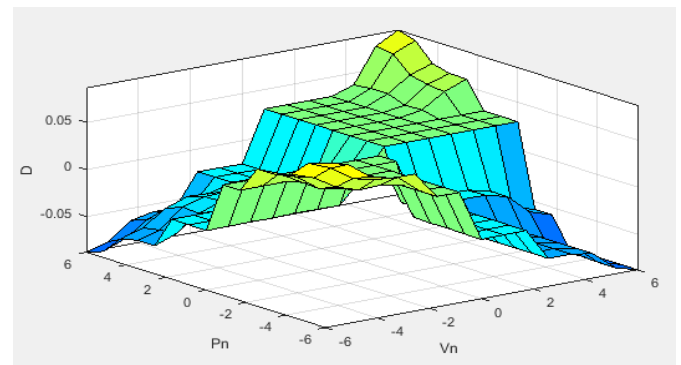


Fig. 11 Surface view of fuzzy input versus output functions

The fuzzy logic controller is also modeled in MATLAB and the output is given below Fig.12. We have to assign the .fis file which consists of rules base into the FLC block.

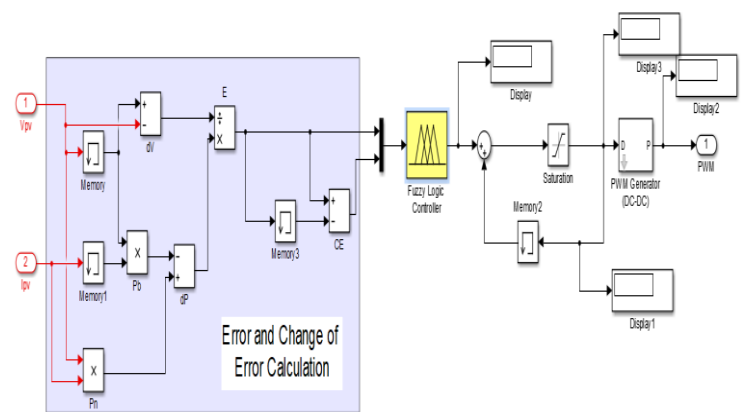


Fig. 12 MPPT based FLC in Matlab/Simulink

III. RESULTS

In Table 1 resultant data obtained from the proposed system for various irradiancies are categorized. Below, the input and output values of different panel brands are shown under the different radiation and constant temperature. In this way, the panel is preferred the best choice for the system. Results of comparison are shown Table 1.

Table 1. The output V,I,P at different irradiation for the preferred three PV panel

Irradiation at 25° C temp.	Trina Solar TSM-250PA05.08			Tynsolar TYNS62606150			Shangai JA solar Technology JAM6-60-245-SI		
	I <sub>max</sub>	V <sub>max</sub>	P <sub>max</sub>	I <sub>max</sub>	V <sub>max</sub>	P <sub>max</sub>	I <sub>max</sub>	V <sub>max</sub>	P <sub>max</sub>
W/m <sup>2</sup>	(A)	(V)	(W)	(A)	(V)	(W)	(A)	(V)	(W)
1000	8,52	37,6	249,5	8,65	22,5	149,8	8,6	37,6	243,6
800	6,8	37,2	200	6,95	22,4	120,4	6,9	37,3	195,5
500	4,3	36,5	124,5	4,4	21,9	75,4	4,3	36,5	122,2
250	2,2	35,4	61,2	2,2	21,3	37,1	2,15	35,6	60,6

From the simulation, the response time of FLC is 0.16 sec in case of P&O based MPPT is 0.6 sec. This comparison was evaluated under 800W/m<sup>2</sup> irradiation and 25-degree temperature conditions on the same brand PV panel. Also, it was designed 10 module and 4 parallel string. The results are given in the table below.

Table 2. Comparison results between P&O and FLC

MPPT	V <sub>in</sub> (V)	I <sub>in</sub> (A)	P <sub>in</sub> (W)	V <sub>out</sub>	I <sub>out</sub>	P <sub>out</sub>	Efficiency	Time
P&O	310,4	25,78	8000	744,8	9,84	7328	%91,6	0.6 sec
P&O PI	310,4	25,78	8000	744,9	9,841	7329	%91,6	0.6 sec
FUZZY	310,4	25,26	8000	750,2	10,62	7968	%99	0.16 sec

IV. DISCUSSION

The MPPT system based fuzzy logic controller is reached to steady-state to thanks to resolution logic. Therefore, it is obtained the maximum output power which is more realistic and more efficient than P&O technique. The results get from the simulation are shown below Fig 13. and Fig 14.

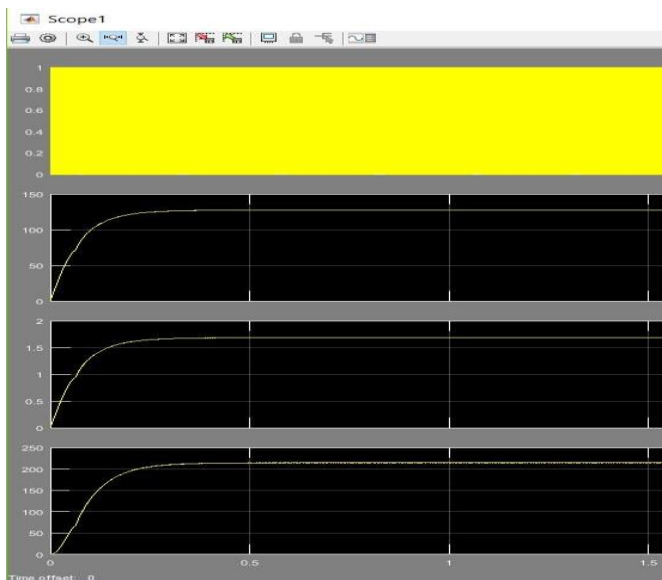


Fig. 13 MPPT based P&O respectively V,I,P output curves

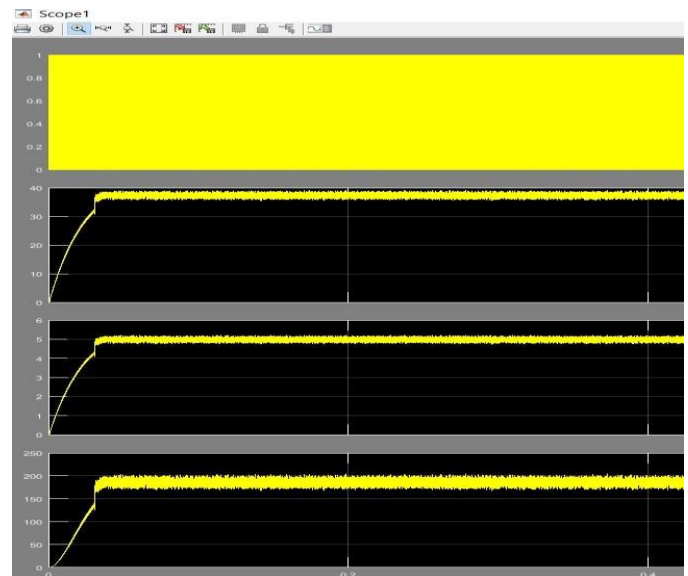


Fig. 14 MPPT based P&O respectively V,I,P Matlab/Simulink

V. CONCLUSION

In this paper, P-V and V-I curves of PV module are acquired using Simulink/Matlab. One module PV array is used at temperature of 25° C and irradiance of 1000W/m<sup>2</sup>. Fuzzy logic controller and P&O based MPPT are simulated and displayed. From the simulations results, it is observed that Fuzzy based MPPT system has less overshoot with changing conditions. In addition, it is reached to maximum power point faster than P&O based MPPT system.

REFERENCES

- [1] Habbati Bellia, Ramdani Youcef and Moulay Fatima. "A detailed modeling of photovoltaic module using MATLAB." NRIAG Journal of Astronomy and Geophysics vol. 3, no. 1, 2014, pp.53-61..
- [2] Akash Garg, R.Saida Nayak, Sushma Gupta, "Comparison of P&O and Fuzzy Logic Controller in MPPT for Photo Voltaic (PV) Applications by Using MATLAB/Simulink"IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 4 Ver. I (July – Aug. 2015), PP 53-62
- [3] NASRUDIN ABD RAHIM, HEW WOOI PING AND JEYRAJ SELVARAJ. "PHOTOVOLTAIC MODULE MODELING USING SIMULINK/MATLAB." PROCEDIA ENVIRONMENTAL SCIENCES 17 (2013): 537-546..
- [4] Biraja Prasad Nayak, Animesh Shaw, "Design of MPPT Controllers and PV cells Using MATLAB Simulink and Their Analysis," ICNTE-2017



- [5] H.Abu-Rub, A.Iqbal and Sk.M.Ahmed, "Adaptive neuro-fuzzy inference system-based maximum power point tracking of solar PV modules for fast varying solar radiations", *International Journal of Sustainable Energy*, Vol.31, No.6, December 2012, 383-398.
- [6] M.A.S. Masoum, M.Sarvi, "A new fuzzy-based maximum power point tracker for photovoltaic applications", *Iranian Journal of Electrical & Electronic Engineering*, Vol.1, January 2005.
- [7] Basil M. Hamed and Mohammed S. El-Moghany, "Fuzzy Controller Design Using FPGA for Photovoltaic Maximum Power Point Tracking", *International Journal of Advanced Research in Artificial Intelligence*, Vol.1, No3, 2012.
- [8] M.Zein Alabedin, E.F. El-Saadany, M.M.A. Salama, "Maximum Power Point Tracking for Photovoltaic System Using Fuzzy Logic and Artificial Neural Networks".
- [9] A. Talha, H. Boumaaraf, and O. Bouhali, "Evaluation of maximum power point tracking methods for photovoltaic systems," *Archives of Control Sciences*, vol. 21, no. 2, pp. 151–165, 2011.
- [10] T. Eshram and P. L.Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," *IEEE Transactions on Energy Conversion*, vol. 22, no. 2, pp. 439–449, 2007.