Comparative Performance Analysis of Conventional and Fuzzy Logic MPPT Techniques for a PV System

Dinesh Kumar[1], Dr. Ankit Kumar Srivastava[2], Dilip Kumar[3] and Dr.A.S.Pandey[4]

[1,2,3]Assistant professor, Electrical Engineering Department, Dr.RMLAU, IET, Ayodhya (U.P.)
[4]Professor, Electrical Engineering Department, KNIT, Sultanpur (U.P.)

Abstract - *This paper aims to analyze the comparative performance analysis between the conventional and artificial intelligence MPPT techniques in terms of variable atmospheric conditions with zeta converter. The reason for choosing the Zeta converter is that it provides the soft switching technique to reduce the switching losses due to which the efficiency of the system is improved and this converter includes lower output-voltage ripple and easier compensation. The proposed scheme consists of a solar panel, a zeta dc-dc converter, and MPPT techniques that are fabricated in the MATLAB/Simulink environment.*

Key Words: **Photovoltaic (PV) modules, Zeta converter, Fuzzy Logic Controller (FLC); Perturb and Observe (P&O); Maximum Power Point Tracker (MPPT),**

1. INTRODUCTION

Nowadays electrical energy crises increase day by day and Fossil fuels are also decreasing day by day but electrical energy is very necessary for daily life so to overcome all electrical energy problems solar energy is the best option. A solar panel changes over 30-40% of energy incident on it to electrical energy. A Maximum PowerPoint Tracking calculation is important to build the productivity of the solar panel. There are diverse strategies for MPPT, for example, Perturb and Observe (slope climbing technique), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control and so on[1-3]. This paper presents a comparative study of MPPT tracking strategies based on Perturb & Observe and Fuzzy logic. These techniques vary in complexity, effectiveness, time response, cost and sensors required.

2. PHOTOVOLTAIC CELL

PV cells are build of very good quality semiconductor materials, such as silicon. The solar cells are covered with a thin semiconductor material that is uniquely treated to shape an electric field, one side positive and other side negative. At the point when light strength strikes the solar cell, electrons are move free from the molecules in the semiconductor material. In this incident electrical conveyors are joined to the negative and positive sides that shaped an electrical circuit, the electrons are caught as an electric current and produce electric power[4-5]. Then this generated electric power would be able to be utilized to control a whole circuit. A Photovoltaic cell can either be square or roundabout in construction. PV cell is a non-linear device and it can be represented as a current source in parallel with a diode as shown in the Fig. 1.

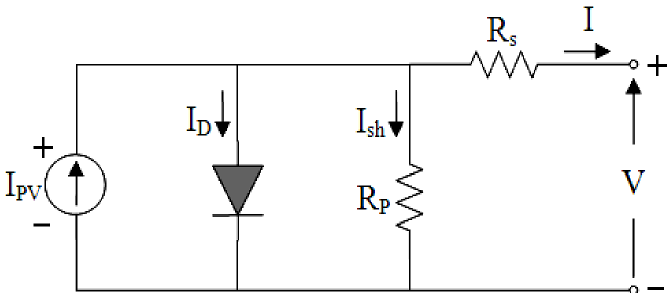


Fig -1: Electrical circuit of a PV cell

3. CONVERTER TOPOLOGY

Zeta converter is a fourth-order converter with various genuine and complex poles and zeroes. Just Like the SEPIC converter, the Zeta converter does not have a right-half-plane zero and can be all the more effortlessly repaid to accomplish a wider loop bandwidth and better load-transient outcomes with littler output capacitance value. A zeta converter as to input can be viewed as a buck-boost buck converter and concerning the output, it can be viewed as a boost buck-boost converter[7].

Considered by numerous originators as an "extraordinary" topology, the ZETA converter offers certain points of interest over established SEPIC. This topology has similar buck-boost usefulness to SEPIC, yet the output current is persistent, giving a perfect, low-ripple output voltage make[10]. This low-noise output converter can be utilized to control certain sorts of loads, for example, LEDs, which are delicate to the voltage swell. ZETA converter offers a similar DC isolation between the input and output as the SEPIC converter and can be utilized as a part of high-dependability frameworks

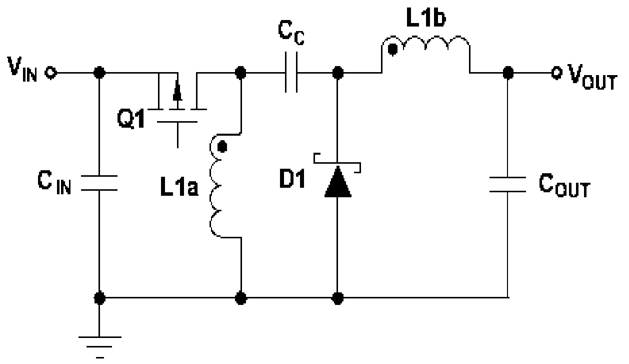
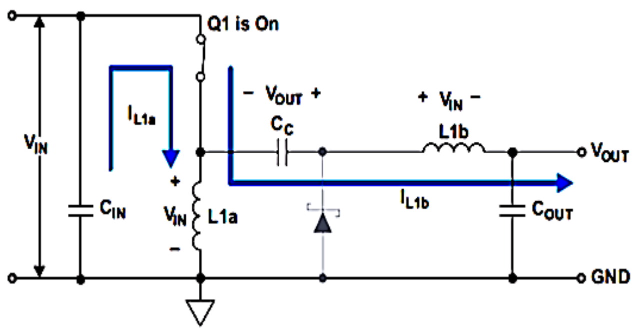


Fig. 2: Simple circuit diagram of ZETA converter

Figure 2 shows a simple circuit diagram of a ZETA converter, consisting of an input capacitor, CIN; an output capacitor, COUT; coupled inductors L1a and L1b; an AC coupling capacitor, CC; a power P MOSFET, Q1; and a diode, D1. Fig.3-shows the ZETA converter operating in Continuous Conduction Mode when P MOSFET Q1 is on and off. To figure out the voltages at the various circuits Point, it is important to analyze the circuit at DC when both switches are off and not switching. Capacitor CC will be in parallel with COUT, so CC is charged to the output voltage, VOUT, during steady-state CCM. Fig. 3 shows the voltages across L1a and L1b during Continuous Conduction Mode operation.



When P MOSFET Q1 is on, capacitor CC, charged to VOUT, is connected in series with L1b; so the voltage across L1b is +VIN, and diode D1 sees VIN + VOUT. The currents flowing through various circuit components are shown in Fig. 3(a),(b).

Fig. 3(a): When Q1 is on

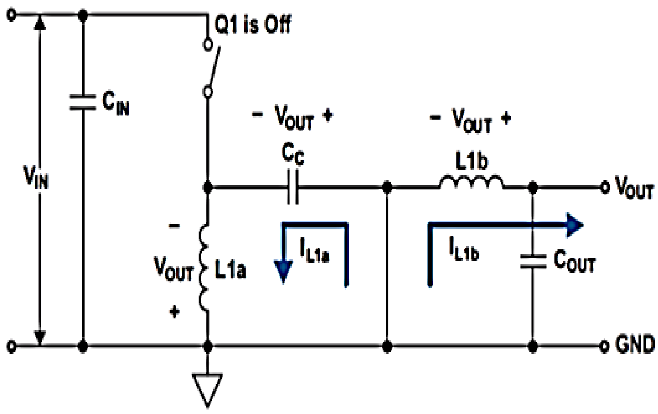


Fig. 3(b): When Q1 is off

When the P MOSFET Q1 is on, input supply energy is being stored in L1a, L1b, and CC. L1b also provides IOUT. When P MOSFET Q1 turns off, L1a's current continues to move ahead from the current provided by CC, and L1b again provides IOUT. When P MOSFET Q1 is off, the voltage across L1b should be VOUT since it is in parallel with COUT. Since COUT is charged to VOUT, the voltage across Q1 when P MOSFET Q1 is off is VIN + VOUT; therefore the voltage across L1a is –VOUT relative to the drain of Q1.

Considering 100% efficiency, the duty cycle, D, for a ZETA converter operating in Continuous conduction mode is given by

$$D = \frac{V_{OUT}}{V_{IN} + V_{OUT}} \quad \text{...(1)}$$

4. MAXIMUM POWER POINT TRACKING TECHNIQUES

Photovoltaic modules have a low conversion proficiency of around 15% for the made ones. Also, because of the temperature, radiation, and load varieties, this proficiency can be exceptionally lessened. To guarantee that the photovoltaic modules dependably act providing the greatest power as would be prudent and managed by encompassing working conditions, a particular circuit known as Maximum Power Point Tracker (MPPT) is utilized. The voltage at which the PV module can deliver the most extreme power is known as MPPT. The decision of the algorithm relies upon the time unpredictability the algorithm takes to track the MPP, execution cost, and the simplicity of usage[8-9].

4.1. Perturb and Observe Method

Perturb and Observe is the less demanding methodology where just a voltage sensor is used for obtaining the PV cluster voltage. P&O strategy usage is very cheap. P&O MPPT calculation is for the most part utilized, as it can be actualized effectively. It depends on the guideline: when the operational voltage of the PV array differs in a slanted way and the power extracted from the PV array rises, this proposes the working point has moved toward the MPP and, thus the working voltage must be altered in a similar course until the point when the power drawn from the PV array declines thus the working point has digressed far from the MPP and, henceforth, the direction of perturbation of working voltage perturbation should be inverted[4].By the by, the technique does not think about the moment change of illumination level and it sees it as variety in MPP on account of perturbation and wraps up by assessing the wrong MPP[6].

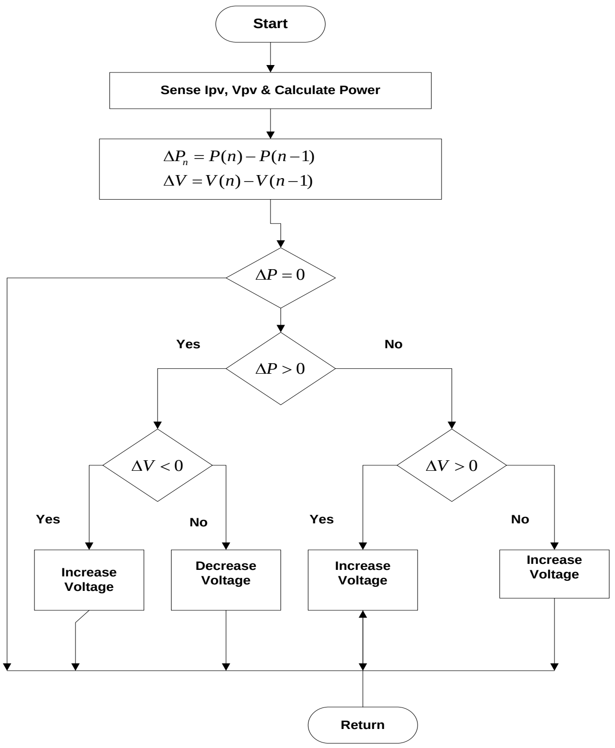


Fig. 4: Working principle of Perturb and Observe Algorithm

4.2. Fuzzy Logic Control Technique

Fuzzy Logic is substantially nearer in the soul to human reasoning and natural language than the customary legitimate framework[7]. The basic piece of the fuzzy logic controller is an arrangement of an etymological control strategy because of the master information into a programmed control methodology.

It is a standout amongst the latest to be utilized as it can control inappropriate information sources, does not require a correct numerical system, and can hold non-uniformity.

The fuzzy logic contains three stages: fuzzification, inference system, and defuzzification . Error (E) and change in error (CE) are the directions given to FLC at test time k while the reaction of FLC is the duty cycle, D.

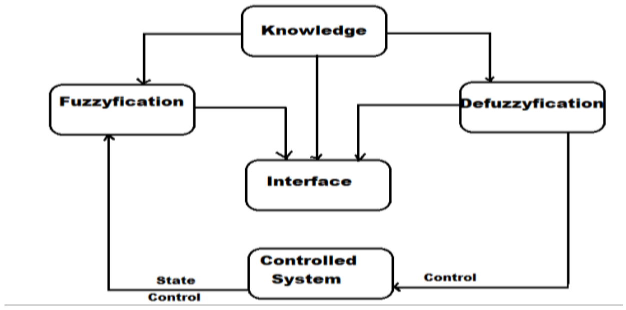


Fig. 5: Fuzzy Logic Controller method

Fig.5: shows the fuzzy controller block which consists of fuzzifier, decision making, and de-fuzzifier units. The output of the fuzzy controller is a fuzzy subset. The input signals are Error E and Change in Error ΔE. Once E and ΔE are calculated and converted into linguistic variables, the fuzzy logic controller output, typically the change in Duty Cycle ΔD is found.

Fuzzy controller inputs are measured from the panel output. Five fuzzy subsets are considered for membership functions of the output variable[13]. These input variables are expressed in terms of linguistic variables such as ZE (zero), NS (Negative small), NB(Negative big), PS(positive small), and PB(positive big) being basic fuzzy subsets.

$E(n) = [P(n) - P(n-1)] / [V(n) - V(n-1)]$ ....(1)
$\Delta E(n) = E(n) - E(n-1)$ ....(2)
where E is error and ΔE is change in error

Figure 6, 7 and 8 shows the membership functions of error (E), change in error (ΔE) and change in duty cycle (ΔD). Two inputs are combined using "AND" operator to form 25 rules as both inputs have 5 membership functions.

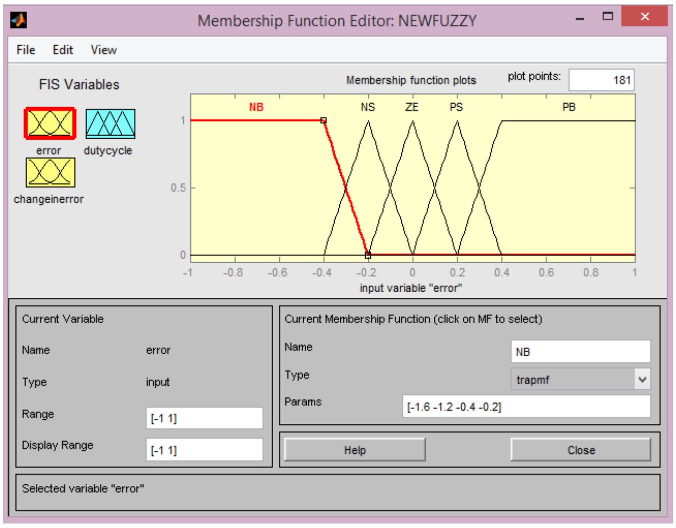


Fig. 6: Membership functions of input variable - error (e)

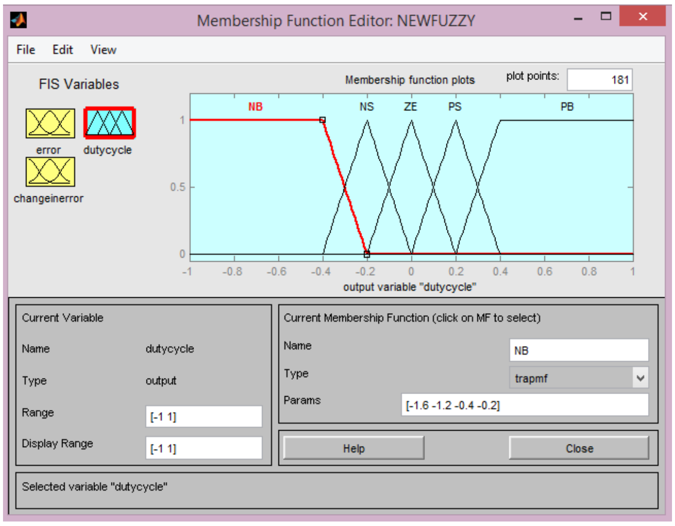


Fig. 7: Membership functions of input variable –change in error (CE)

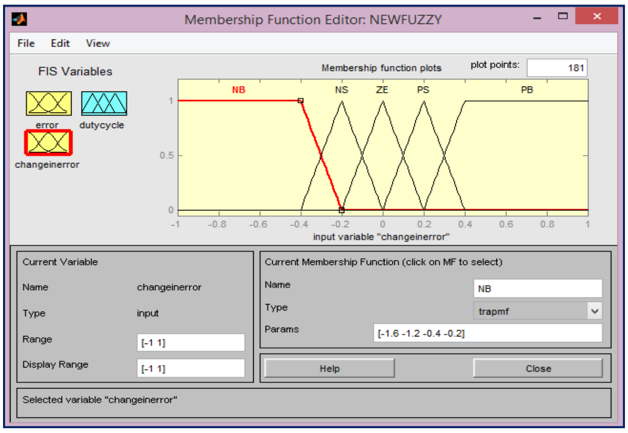


Fig. 8: Membership functions of output variable – duty cycle (D)

Table-1: Fuzzy logic based MPPT controller rule base

E \ CE	NB	NS	ZE	PS	PB
NB	NB	NB	NB	NS	ZE
NS	NB	NB	NS	ZE	PS
ZE	NB	NS	ZE	PS	PB

PS	NS	ZE	PS	PB	PB
PB	ZE	PS	PB	PB	PB

5. SIMULATION PARAMETER, MODEL & RESULTS

The PV system model is simulated under various irradiance and temperature conditions. The function of the MPPT block is to ensure that the system delivers the maximum power to the load by varying the duty ratio of the Zeta converter. The zeta converter is set to operate at the inductor of 24.2 mH, the capacitor of 3.48e-4 F and the load is a purely resistive load of 150Ω.

Table -2 Parameters of the Power Solar Systems at

$T = 25^{o}C$, $G = 1000\, Wm^{-2}$

I_{mp}	8.3 A
V_{mp}	30V
$P_{max,e}$	249W
I_{sc}	8.83A
V_{oc}	36.8
K_V	-0.33V/K
K_I	0.063805A/K
N_s	60

The simulations are made to illustrate the response of the PV system for different temperature and solar irradiance levels. For this purpose, the irradiance (G) was initially set to 1000 Wm^{-2} and temperature was set to be constant as 25°C at the simulation time.For obtain the Maximum power point tracking for the photovoltaic simulation system, the Fuzzy logic control (FLC) MPPT method is compared with P&O MPPT at different ambient conditions to show how the FLC MPPT method can effectively and accurately track the maximum power[10]. The simulation is done using MATLAB/SIMULINK. The model used for the simulation is shown in Fig. 9. The output of the MPPT control block is the gating signal which is used to drive the MOSFET. The MPP tracker tracks the maximum power under different atmospheric conditions.

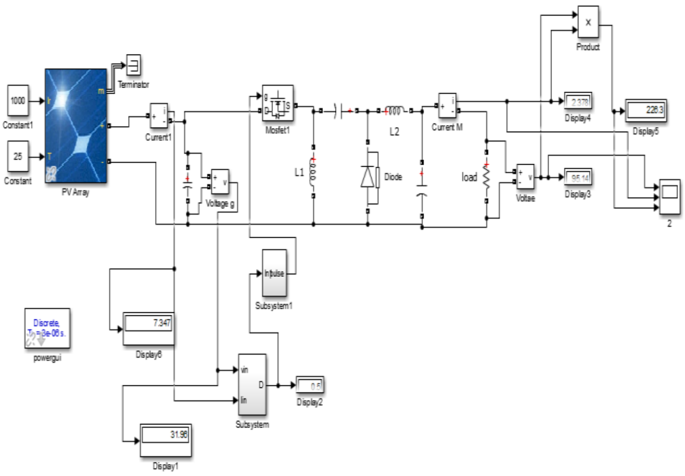


Fig. 9: Simulink Circuit of the photovoltaic system using MPPT technique and Zeta converter.

The PV system was simulated under a variation of irradiance and temperature levels. The function of the MPPT block is to ensure that the system delivers the maximum power to the load by varying the duty ratio of the Zeta converter.

CASE.1: Voltage, current and power output results of the P&O method are:

At G =1000Wm^{-2} and T= 25^{o}C When PV panel is directly connected to load, it provides the 42.2-watt power to load and PV system with P&O MPPT technique gives 2.1A, 95.1V, & 226.3W current, voltage & power respectively as shown in Fig.10 . On the other hand, a PV system with Fuzzy logic controller based technique gives 2.4A, 95.8V, 236.9W current, voltage, and power respectively as shown in Fig.14.

Case 2 At G =1000Wm $^{-2}$ and T= 45^{o}C

When the PV panel is directly connected to load, it gives 36.3-watt power to load. PV system with P&O MPPT technique gives 2.3A, 89.2V, &198.1W current, voltage & power respectively as shown in Fig.11. On the other hand, the PV system with Fuzzy logic controller based technique gives 2.42A, 89.7 V, 209.8 W current, voltage, and power respectively as shown in Fig.15.

Case 3 At G = 800 Wm^{-2} and different temperature T= [25 45]^{0}C: When PV panel is directly connected to load, it gives 41.2 watt power to load. PV system with P&O MPPT technique gives 2.19A, 87.7V, &192.5W current, voltage & power respectively as shown in Fig.12. On the other hand, the PV system with Fuzzy logic controller based technique gives 2.43A, 88.1 V, 199.8 W current, voltage and power respectively as shown in Fig.16.

Case 4: At different irradiation *G= [800* 1000] Wm^{-2} and, T= 25 ^{0} *C* with R load:

When PV panel is directly connected to load, it gives 35.3 watt power to load. PV system with P&O MPPT technique gives 2.28A, 84V, &176.7W current, voltage & power respectively as shown in Fig.13. On the other hand, the PV system with Fuzzy logic controller based technique gives 2.41A, 84.6 V, 180.5 W current, voltage and power respectively as shown in Fig.17.

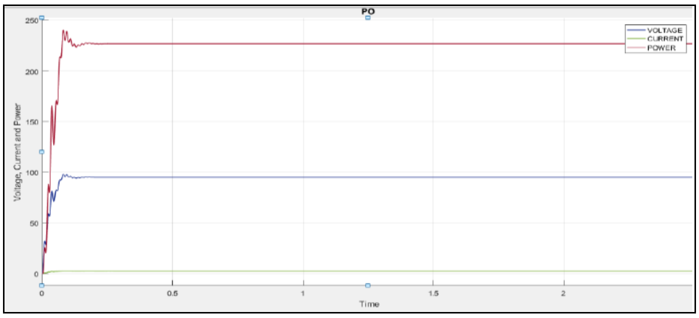


Fig.10. PV System outputs using P&O Method at *G=* 1000Wm^{-2} and, *T* 25^0 *C* with R load

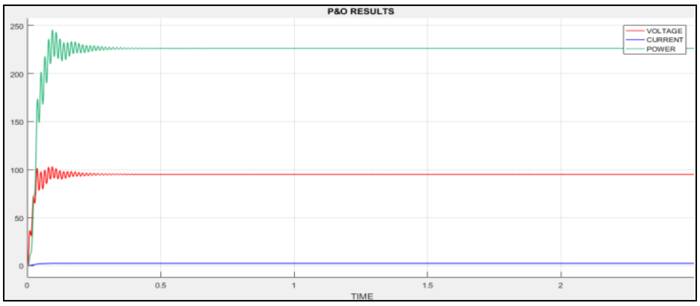


Fig.11. PV System outputs using P&O Method at *G=* 1000Wm^{-2} and, *T* 5^0 *C* with RL load

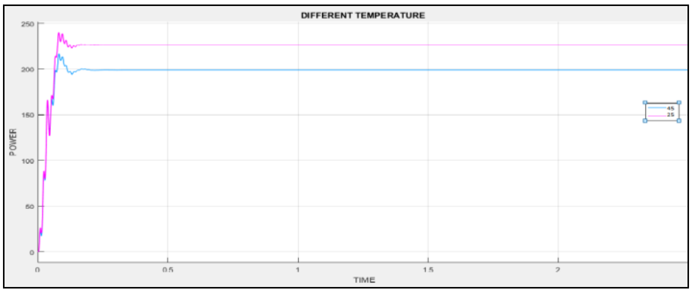


Fig.12. PV System outputs using P&O Method at *G=* 800Wm^{-2} and,T=25 45]^0 *C* with R load

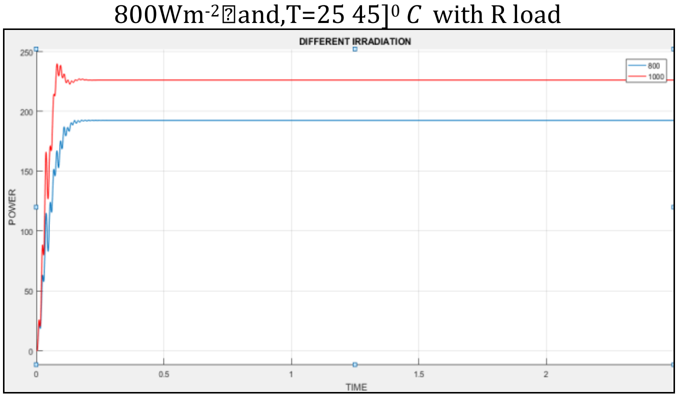


Fig.13. PV System outputs using P&O Method at *G= [800* 1000] Wm^{-2} and,T= 25 ^{0} *C* with R load

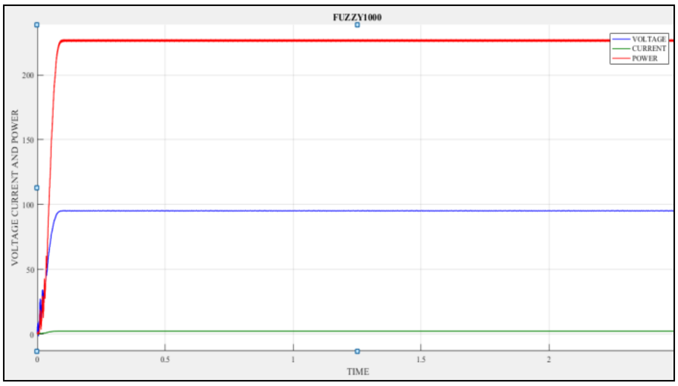
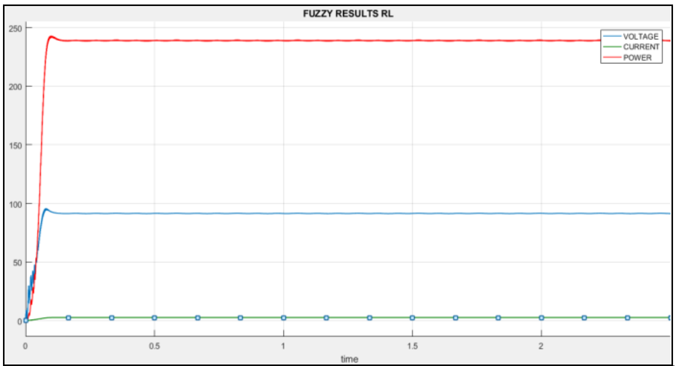


Fig.14. PV System outputs using FLC Method at *G*= 1000Wm^{-2} and, T 25^{0} C with R load



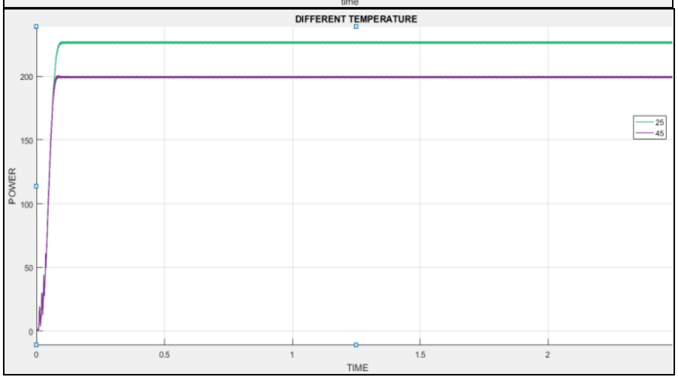


Fig.16. PV System outputs using FLC Method at *G*= 1000Wm^{-2} and,T= [25 45]^{0} C with R load

Fig.15. PV System outputs using FLC Method at *G*= 1000Wm^{-2} and, T 25^{0} C with RL load

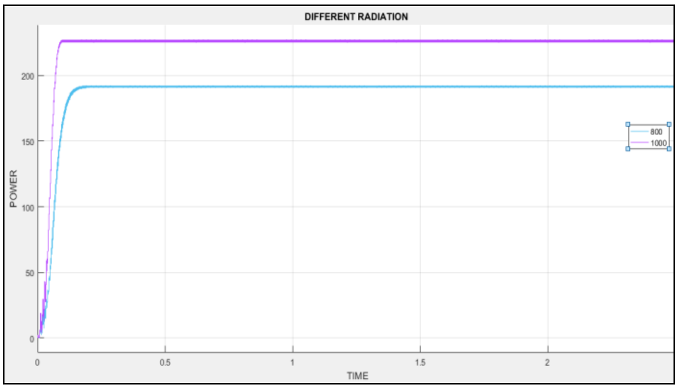


Fig.17. PV System outputs using P&O Method at *G= [800* 1000] Wm^{-2} and,T=25]^{0} C with R load

6. CONCLUSIONS

The models are tested under disturbance in both solar radiation and photovoltaic temperature shown in performance table -3. Simulation results show that the FLC method significantly improves the tracking accuracy and speed of the MPPT control compared to P&O methods. The waveforms obtained after implementing the FLC MPPT are more stable. This shows that switching losses and transients are minimized. This improves the conversion efficiency resulting in maximum power extraction for a given irradiation and temperature.

Table :3 Performance simulation output at various atmospheric condition

Case	G(Wm^2)	T(°C)	Power Without	Method	PV Array i(A)	PV Array v(V)	PV Array p(W)	Zeta Converter i(A)	Zeta Converter v(V)	Zeta Converter p(W)	Efficiency (%)
1	1000	25	42.2	P&O	6.6	31.9	205.14	2.1	95.1	226.3	**10.02**
				Fuzzy	6.8	32	**220.48**	2.4	95.8	**236.9**	
2		45	36.3	P&O	6.4	29.9	187	2.3	89.2	198.1	**7.5**
				Fuzzy	6.94	30	**197.2**	2.42	89.7	**209.8**	
3	800	25	41.2	P&O	6.50	29.5	185.42	2.19	87.7	192.5	**5.6**
				Fuzzy	6.54	29.8	**194.02**	2.43	88.1	**199.8**	
4		45	35.3	P&O	5.85	28.2	164.7	2.28	84	176.7	**3.4**
				Fuzzy	5.9	29.2	**173.09**	2.41	84.6	**180.5**	

REFERENCES

[1] B. Amarnath Naidu1 , S. Anil Kumar2 and Dr. M. Siva Sathya Narayana "Fuzzy Intelligent Controller for the MPPT of a Photovoltaic Module in comparison with Perturb and Observe algorithm" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, pp. 10058-10062, Number 11 (2018).

[2] Anwesha Panigrahi and Kanhu Charan Bhuyan "FuzzyLogic Based Maximum Power Point Tracking Algorithm for Photovoltaic Power Generation System" Journal of Green Engineering, Vol: 6 Issue: 4, Article No: 4 Page: 403-426 October 2016

[3] Yoganandini A.P., Anitha G.S., "Insights of the Advancement in Maximum Power Point Tracking Techniques in PV Module", Communications on Applied Electronics (CAE) – ISSN: 2394-4714, Volume 4– No.3, January 2016.

[4] V R Bharambe, Prof. K M Mahajan, "Implementation of P & O MPPT for PV System with using Buck and Buck-Boost Converters", International Journal of Research in Electrical Engineering, Volume: 02, Issue: 03, 2015

[5] Aditi Bajpai, Arvind Mittal, " Solar Powered Dc To Dc Buck-Boost Converter With MPPT Control", International Journal of Electronics, Electrical and Computational System, IJEECS, ISSN 2348-117X, Volume 3, Issue 5, July 2014.

[6] Ahmed M. Atallah, Almoataz Y. Abdelaziz, and Raihan S. Jumaah, "Implementation of Perturb and observe MPPT of PV System with Direct control Method Using Buck and Buck-Boost converters", Emerging Trends in Electrical, Electronics & Instrumentation Engineering: An International Journal (EEIEJ), Vol. 1, No. 1, February 2014.

[7] Venkatanarayanan, S. and Saravanan, M. "Fuzzy logic based PV energy system with SEPIC converter". J. Theor. Appl. Inf. Technol, 59, pp. 89–95. 2014.

[8] Jaw-Kuen Shiau, Min-Yi Lee, Yu-Chen Wei and Bo-Chih Chen, "Circuit Simulation for Solar Power Maximum Power Point Tracking with Different Buck-Boost Converter Topologies", Energies,7, pp. 5027-5046,2014.

[9] Liu, C.L., Chen, J.H., Liu, Y.H., and Yang, Z.Z. "An asymmetrical fuzzy-logic-control based MPPT algorithm for photovoltaic systems" Energies, 7, pp. 2177–2193, 2014.

[10] N. Sowmya Smitha Raj, B. Urmila, "PV fed Zeta converter", International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 4, pp.2692-2696, Jul-Aug 2013.