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Comparative Performance Analysis of MPPT Techniques For Solar Power Extraction Using Zeta Converter

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***ABSTRACT** - In this paper, the comparative study between the conventional and artificial intelligence technique of MPPT is analyzed in terms of variable atmospheric conditions and temperature. Zeta converter uses soft switching technique to reduce the switching losses which is found prominently in the conventional buck converter, thus the efficiency of the system is improved. The benefits of the zeta converter include lower output-voltage ripple and easier compensation. The DC power extracted from the PV array is synthesized and modulated by the converter to suit the load requirements. The proposed scheme consists of a solar panel, a zeta dc-dc converter, and MPPT techniques that aresimulated in the MATLAB/Simulink environment.*

***Keywords**—photovoltaic (PV) modules; fuzzy logic controller (FLC); Perturb and Observe (P&O); maximum power point tracker (MPPT), Zeta converter*

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I. INTRODUCTION

A solar panel changes over 30-40% of energy incident on it to electrical energy. A Maximum Power Point 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.

This paper presents a comparative study of the tracking strategies of the MPP based on Perturb & Observe and Fuzzy logic techniques. These techniques vary in complexity, effectiveness, time response, cost and sensors required.

II. PHOTOVOLTAIC CELL

PV cells are made of semiconductor materials, for example, silicon. For solar cells, a thin semiconductor wafer is uniquely treated to shape an electric field, positive on one side and negative on the other. At the point when light vitality strikes the solar cell, electrons are thumped free from the molecules in the semiconductor material. In the event that electrical conveyors are joined to the positive and negative sides, shaping an electrical circuit, the electrons can be caught as an electric current and produce electric power. This electric power would then be able to be utilized to control a heap. A PV cell can either be roundabout or square in development.It is a non-linear device and can be represented as a current source in parallel with a diode as shown in the Fig. 1.

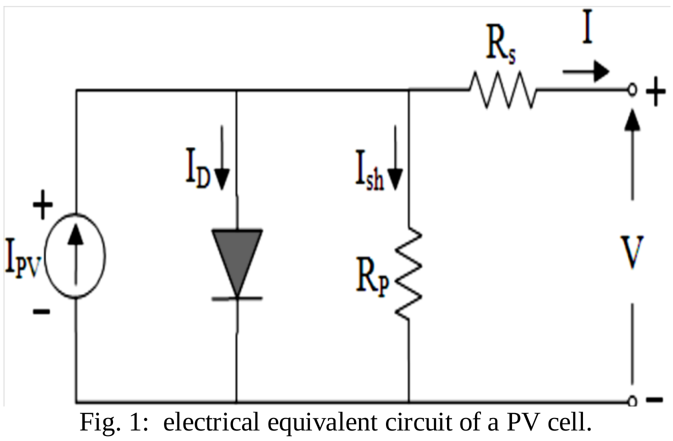


Fig. 1: electrical equivalent circuit of a PV cell.

III. ZETA CONVERTER

The switch-mode DC-DC converter, change over one DC voltage level to another level by temporarily storing the input energy and afterward discharging that energy to the output at an alternate voltage level.

Zeta converter is a fourth-order converter with various genuine and complex poles and zeroes. Not at all 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.

Considered by numerous originators as an "extraordinary" topology, 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. 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

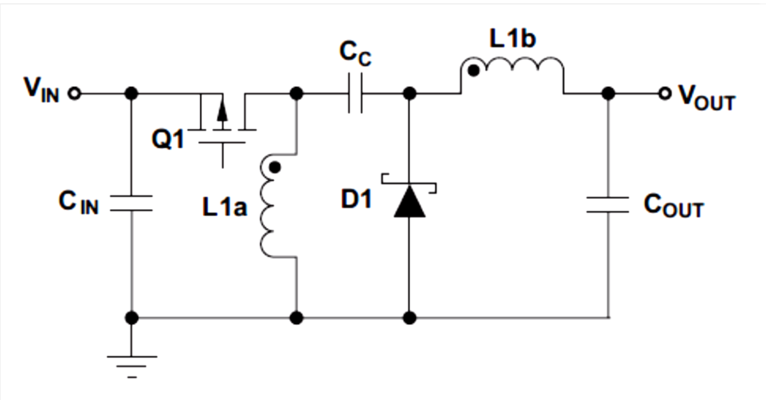
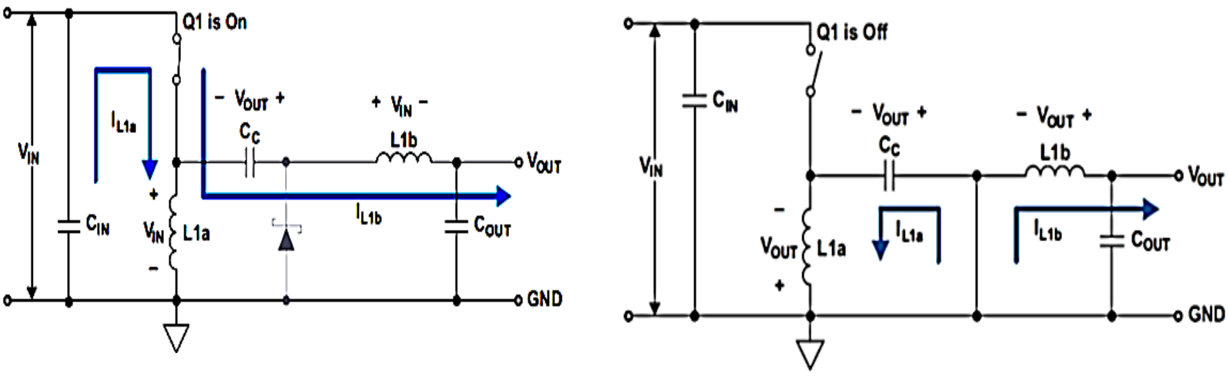


Fig. 2: Simple circuit diagram of ZETA converter

Figure 2 shows a simple circuit diagram of a ZETA converter, consisting of an input capacitor, C_{IN}; an output capacitor, C_{OUT};coupled inductors L_{1a} and L_{1b}; an AC coupling capacitor, CC; a power P MOSFET, Q_1; and a diode, D_1. Fig. 3 shows the ZETA converter operating in CCM when Q_1 is on and when Q_1 is off. To understand the voltages at the various circuit nodes, it is important to analyze the circuit at DC when both switches are off and not switching. Capacitor CC will be in parallel with C_{OUT}, so CC is charged to the output voltage, V_{OUT}, during steady-state CCM. Fig. 3 shows the voltages across L_{1a} and L_{1b} during CCM operation.

When Q_1 is on, capacitor CC, charged to V_{OUT}, is connected in series with L1b; so the voltage across L_{1b} is $+V_{IN}$, and diode D1 sees $V_{IN} + V_{OUT}$. The currents flowing through various circuit components are shown in Fig. 3.



(a) When Q1 is on (b)When Q1 is off

Fig. 3:ZETA converter operation

When Q_1 is on, energy from the input supply is being stored in L_{1a}, L_{1b}, and CC. L_{1b} also provides I_{OUT}. When Q_1 turns off, L_{1a}'s current continues to flow from current provided by CC, and L_{1b} again provides I_{OUT}.When Q_1 is off, the voltage across L_{1b} must be V_{OUT} since it is in parallel with C_{OUT}. Since C_{OUT} is charged

to V_{OUT}, the voltage across Q_1 when Q_1 is off is $V_{IN} + V_{OUT}$; therefore the voltage across L_{1a} is $-V_{OUT}$ relative to the drain of Q_1.
Assuming 100% efficiency, the duty cycle, D, for a ZETA converter operating in CCM is given by

$$D = \frac{V_{OUT}}{V_{IN} + V_{OUT}} \quad (3.1)$$

IV. MAXIMUM POWER POINT TRACKING

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.

4.1 Perturb and Observe Method

It is the least demanding methodology where just voltage sensor is utilized for distinguishing 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.

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.

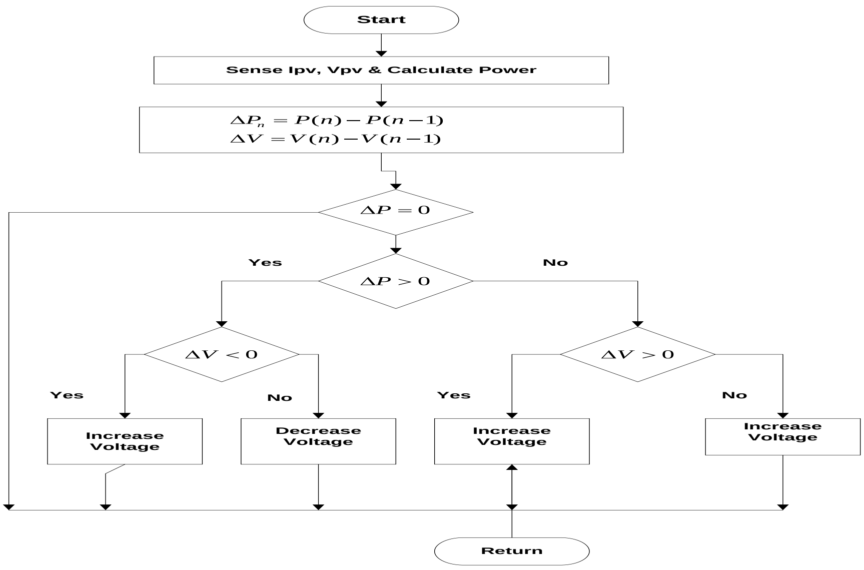


Fig. 4: Working principle of Perturb and Observe Algorithm

4.2 Fuzzy Logic Control Method

Fuzzy Logic is substantially nearer in the soul to human reasoning and natural language than the customary legitimate framework. The basic piece of the fuzzy logic controller is an arrangement of an etymological control strategy in view of 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.

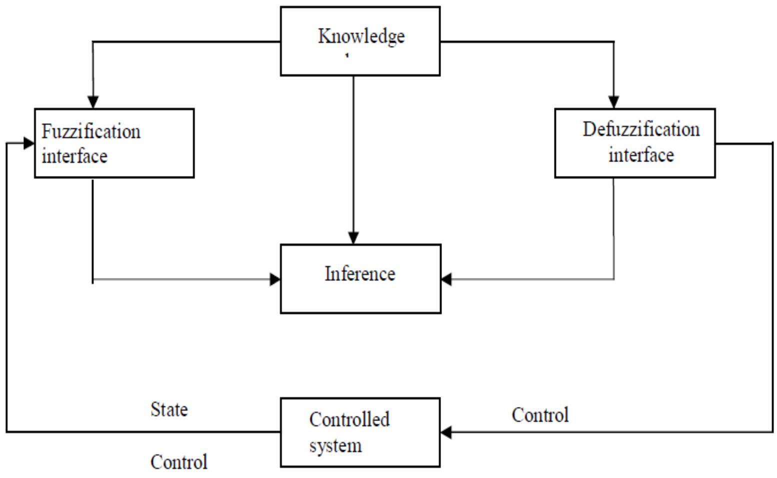


Fig. 5: Working principle of the Fuzzy Logic Controller method

Figure 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.

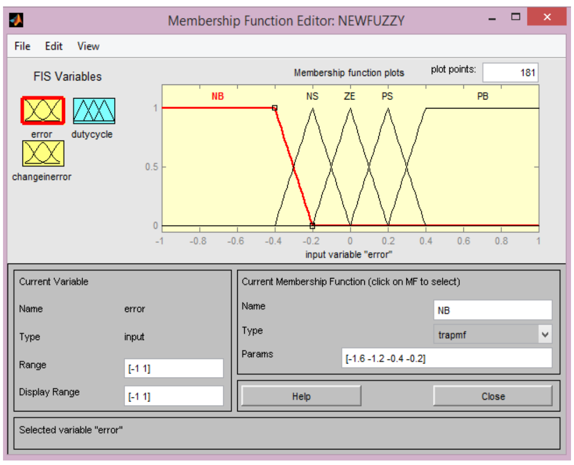
Fuzzy controller inputs are measured from the panel output. Five fuzzy subsets are considered for membership functions of the output variable. These input variables are expressed in terms of linguistic variables such as ZE (zero), NS (Negative small), NB(Negative big), PS(positive small) and PB(positive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

$$E(n) = [P(n) - P(n-1)] / [V(n) - V(n-1)] \quad (4.1)$$

$$\Delta E(n) = E(n) - E(n-1) \quad (4.2)$$

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.



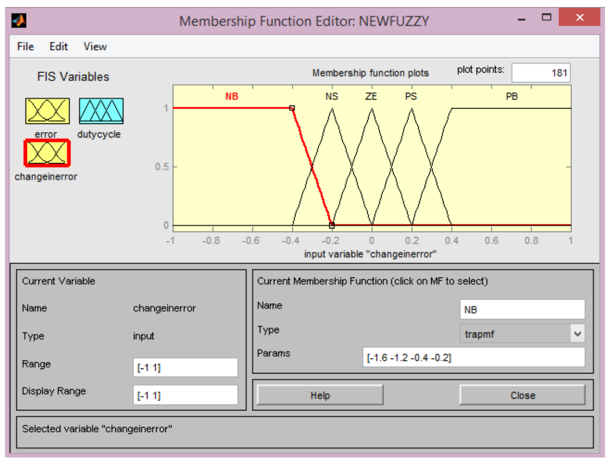


Fig. 6:Membership functions of input variable - error (e)Fig. 7:Membership functions of input variable –change in error (CE)

Table 4.1: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

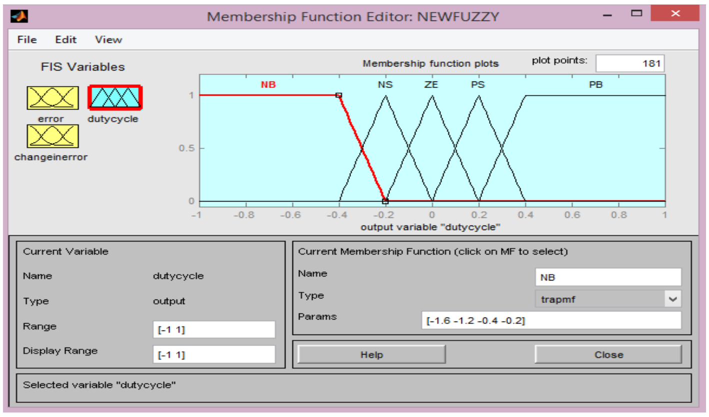


Fig. 8**:** Membership functions of output variable – duty cycle (D)

V. SIMULATION RESULTS

In order to verify the MPP tracker for the photovoltaic simulation system, the 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. The simulation is done using MA TLAB/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 must track the maximum power under different atmospheric conditions.

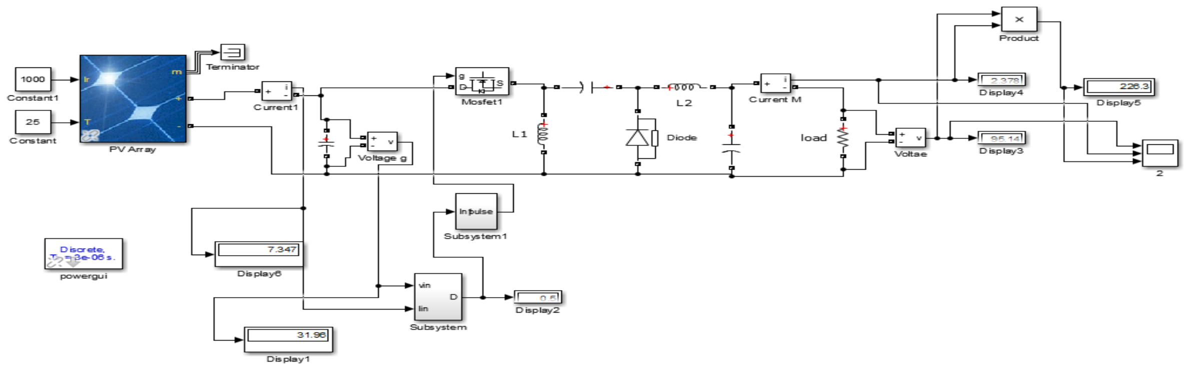


Fig. 9: the circuitry of the photovoltaic system developed in Matlab/Simulink using mppt technique

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.

TheZeta converter outputresults of the P&O method are:

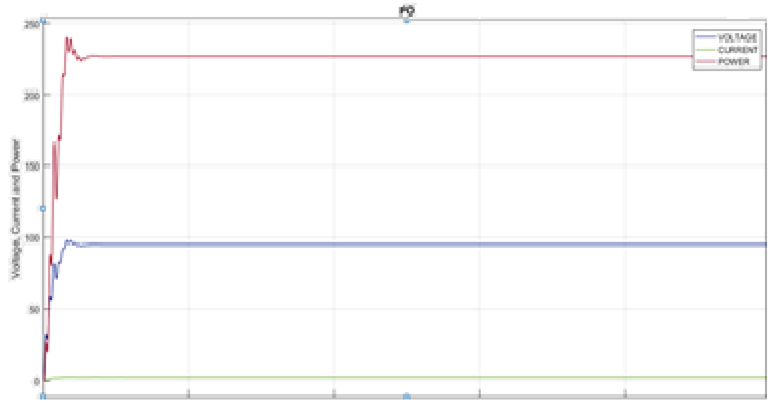


Fig. 10: Zeta converter outputs P&O Method at $G = 1000\ Wm^{-2}$ and $T = 25^{o}C$ with R load

TheZeta converter outputresults of the FLC method are:

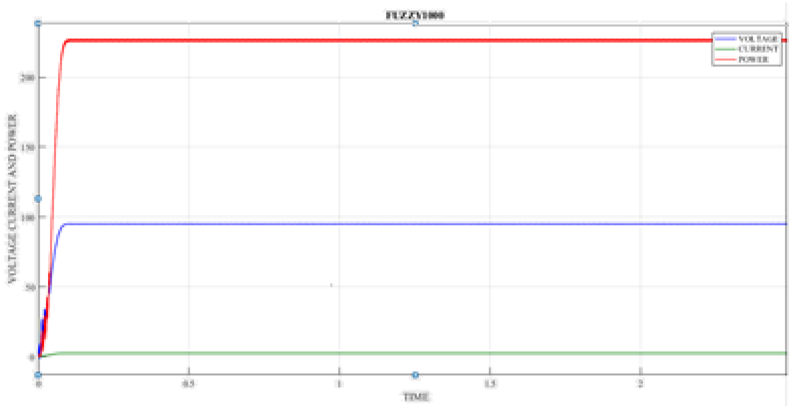


Fig. 11: Zeta converter output using FLC at $G = 1000\ Wm^{-2}$ and $T = 25^{o}C$ with R load

There are four different conditions which consist of different values of Irradiance and temperature in constant environmental conditions. Under these different cases performance of PV system with P&O MPPT technique & PV system with fuzzy logic based MPPT technique is compared.

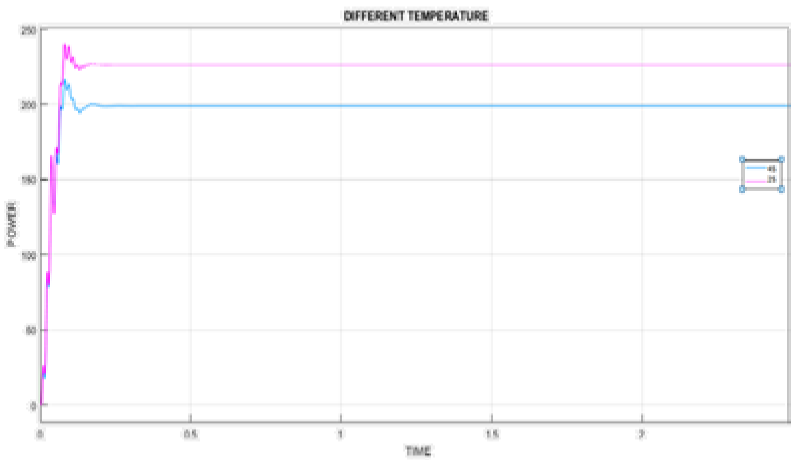


Fig. 12: Zeta converter outputs of PV System using P&O Method at a different temperature, $G = 1000\ Wm^{-2}$ and T = [25 45]°C

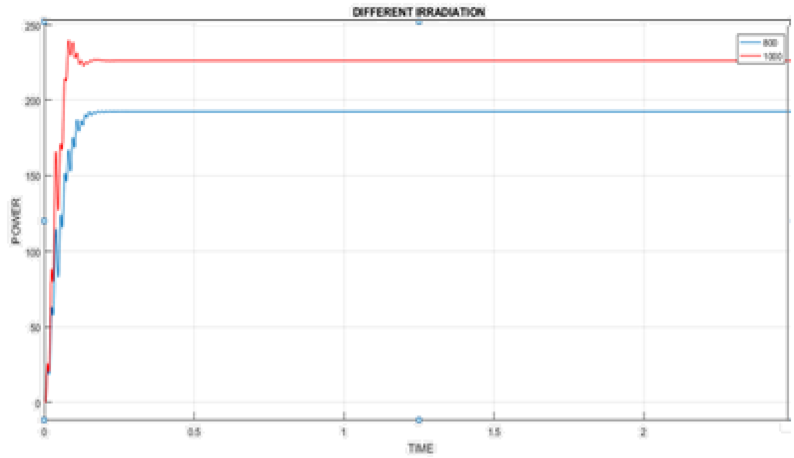


Fig. 13: Zeta converter outputs of PV System using P&O Method at different irradiation, G=[1000 800] Wm^{-2} and T = 25℃

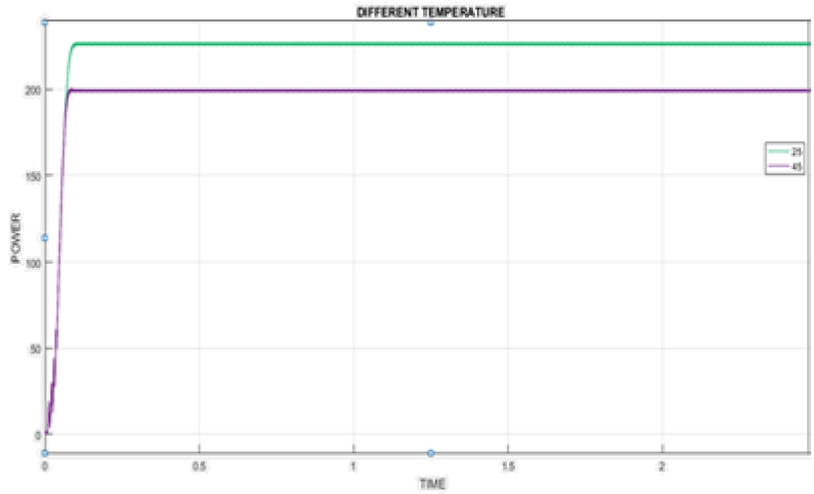


Fig. 14:Zeta converter outputs of PV System using FLC Method at a different temperature, $G = 1000\ Wm^{-2}$ and T = [25 45]℃

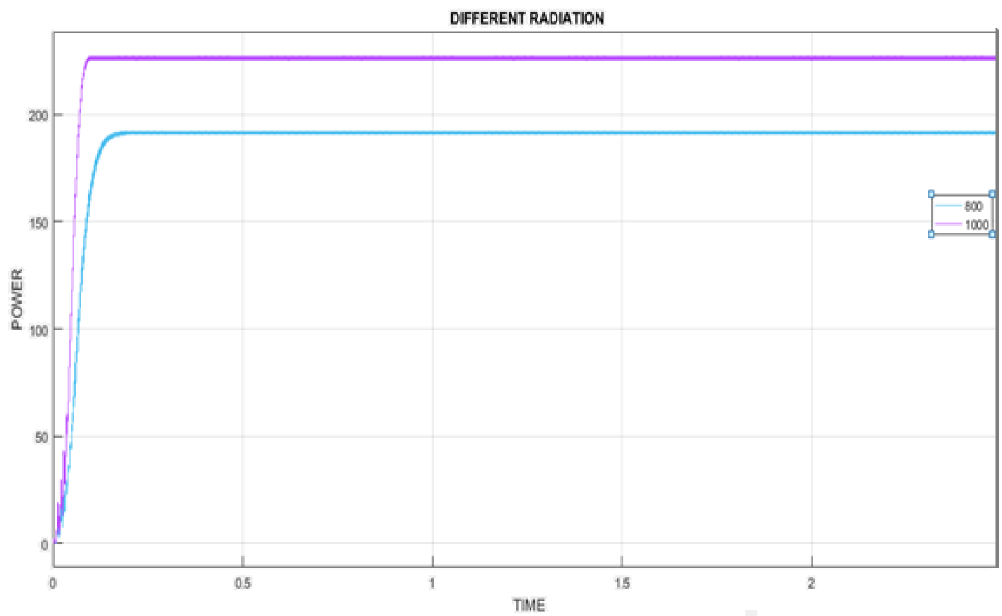


Fig. 15:Zeta converter outputs of PV System using FLC Method at different irradiation, G=[1000 800] Wm^{-2} and T = 25℃

At $G = 1000\ Wm^{-2}$ and $T = 25^{o}C$, the performance of P&O and FLC techniques are compared in Fig. 16.

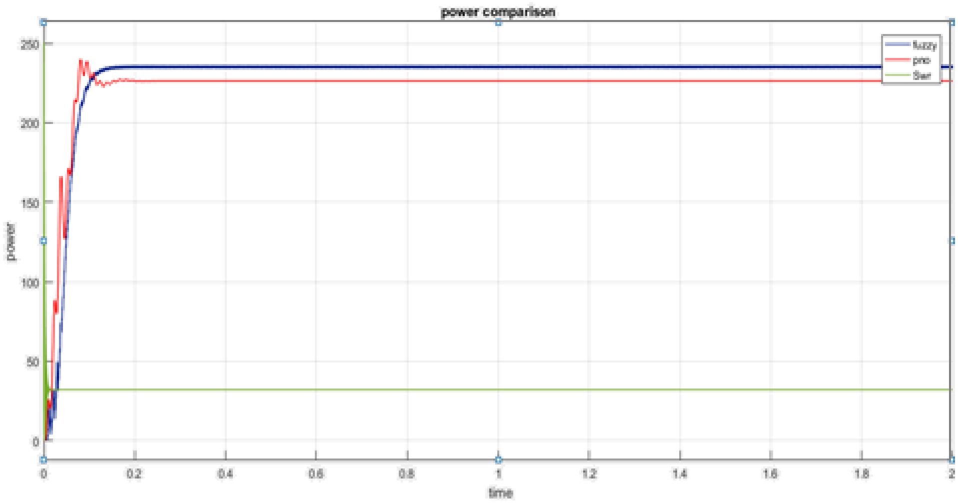


Fig. 16: Output power comparison of FLC and P&O techniques with R load

Summarized results under different cases are shown in Table 5.1. It is to be noted that in each case Photovoltaic Energy Conversion System having FLC MPPT Control, the output obtained is having fewer oscillations and higher amplitude as Compared to P&O MPPT control. So it is quite clear from the above illustrations that proposed FLC MPPT method is better than the previous method.

At $G = 1000\ Wm^{-2}$ and $T = 25^{o}C$ When PV panel is directly connected to load, it gives 42.2-watt power to load. PV system with P&O MPPT technique gives 2.1A, 95.1V, &226.3W current, voltage & power respectively. 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.

At $G = 1000\ Wm^{-2}$ and T= 45℃,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. 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.

At G = 800 Wm^{-2} and T= 25℃

AtG = 800 W$m^{-2}$and $T = 25^{o}C$ 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. 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.

At G = 800 W$m^{-2}$and T= 45℃,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. 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.

Table 5.1 Results obtained under different simulation conditions

Case	$G(Wm^2)$	$T(^oC)$	Power Without MPPT	Method	PV Array			Zeta Converter		
					i(A)	*v(V)*	*p(W)*	*i(A)*	*v(V)*	*p(W)*
1	1000	25	42.2	P&O	6.6	31.9	205.14	2.1	95.1	226.3
				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
				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
				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
				Fuzzy	5.9	29.2	**173.09**	2.41	84.6	**180.5**

VI. CONCLUSION

Photovoltaic model using Matlab/SIMULINK and design of Zeta converter with maximum power point tracking facilities are presented in this paper.MPPT based fuzzy logic controller method is compared with the conventional P&O MPPT method. The models are tested under disturbance in both solar radiation and photovoltaic temperature. Simulation results show thatthe 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.

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