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Comparative Performance Analysis of MPPT Techniques for Solar Power Extraction using Zeta Converter

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Abstract:- This research compares and contrasts the traditional and artificial intelligence MPPT techniques in terms of changing temperature and climatic conditions. The efficiency of the system is increased since the zeta converter uses a soft switching technique to eliminate the switching losses that are prevalent in conventional buck converters. The output-voltage ripple is reduced, and compensating is made simpler thanks to the zeta converter. The converter synthesises and modulates the DC power that is extracted from the PV array to meet the needs of the loads. A solar panel, a zeta dc-dc converter, and MPPT techniques that are modelled in the MATLAB/Simulink environment make up the suggested scheme.

Keywords:- *Photovoltaic (PV) modules, Fuzzy Logic Controller, Perturb and Observe, Maximum Power Point Tracker, Zeta Converter.*

I. INTRODUCTION

More than 30 to 40 percent of the energy falling on the solar panel is converted into electrical energy. Calculating the maximum power point is crucial for increasing a solar panel's output. For MPPT, there are many different approaches, such as perturb and observe (a strategy for gaining altitude), incremental conductance, fractional short circuit current, fractional open circuit voltage, fuzzy control, neural network control, etc. This study compares the tracking methods used by MPPs that are based on perturb and observe and fuzzy logic methodologies. The complexity, efficiency, cost, necessary sensors, and response time of these techniques varies. This study compares the tracking methods used by MPPs that are based on perturb and observe and fuzzy logic methodologies. In terms of complexity, efficiency, reaction time, cost, and other factors, these techniques

II. PHOTOVOLTAIC CELL

Materials such as silicon, a semiconductor, are used to make PV cells. A tiny semiconductor wafer is specially processed for solar cells to create an electric field that is positive on one side and negative on the other. Electrons are liberated from the semiconductor material's semiconductor material molecules when light energy impacts the solar cell. The electrons can be caught in the form of electric current and electrical power can be generated if the charge carriers are connected to the positive and negative sides, establishing an electrical circuit. The pile can then be managed using this electrical power. The ability to control a heap would then be possible thanks to this electric power Either a square or a circular PV cell can be developed. It is shown in the fig 1.

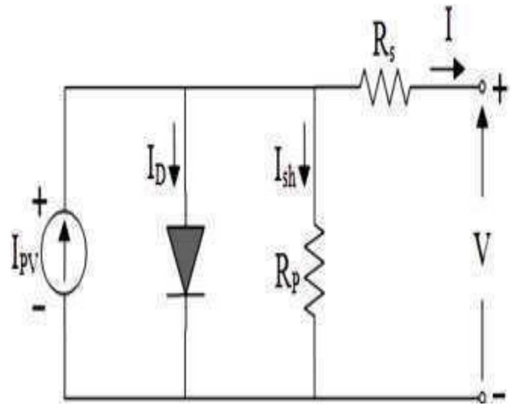


Fig. 1: Alectrical equivalent circuit of a PV cell.

III. ZETA CONVERTER

A switched-mode By temporarily storing the input energy and then discharging it at an alternating voltage level at the output, a DC-DC converter converts one DC voltage level to another. Fourth order converter Zeta has many real and complex poles and zeros. The zeta converter, which differs greatly from the sepic converter in that it lacks a right-half-plane zero, can be more easily repaid and achieves broader loop bandwidth and better load-transient results with lower output capacitance values. A zeta converter can be considered as a buck-boost buck converter with regard to the input and a buck-boost converter with regard to the output. The ZETA converter, which many creators see as a "exceptional" topology, has some advantages over the conventional SEPIC. This topology provides the same buck-boost functionality as a SEPIC while maintaining a steady output current that results in accurate, low-ripple output voltage. Certain loads, such as LEDs, which are susceptible to voltage surges, can be controlled with this low-noise output converter. In a high-dependency architecture, the ZETA converter can be employed since it offers the same DC isolation between input and output as the SEPIC converter.

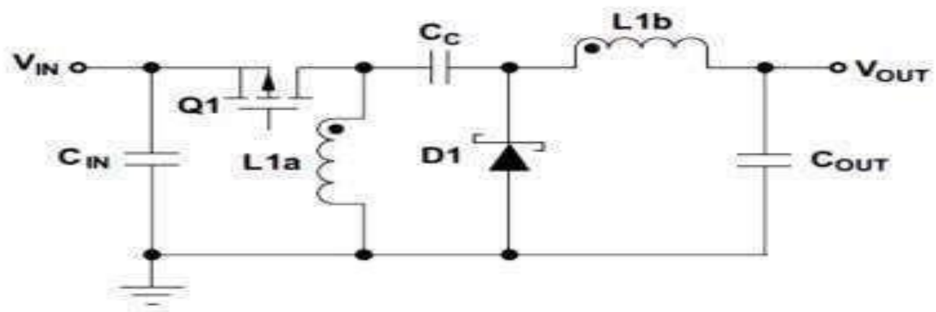
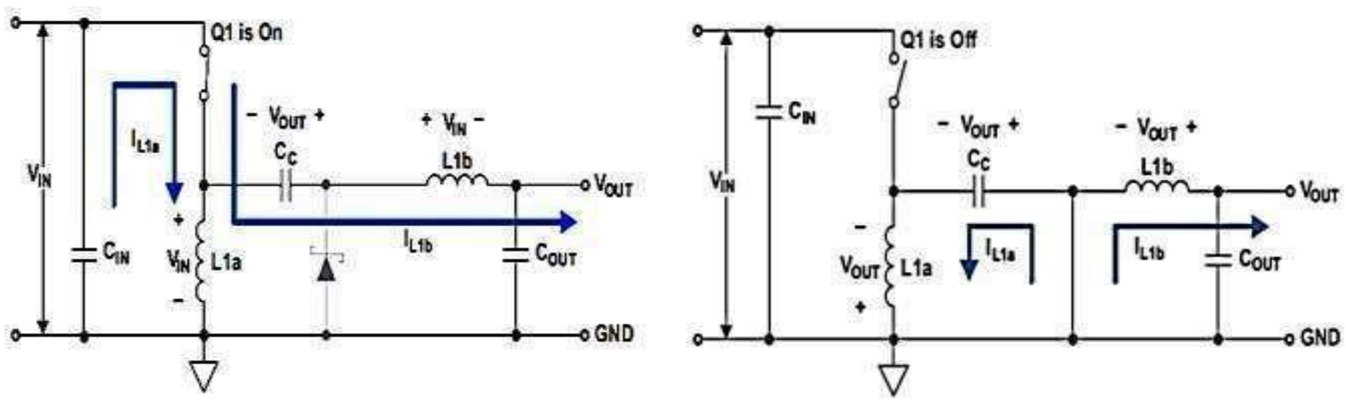


Fig. 2: Simple circuit diagram of ZETA converter

A ZETA converter's basic circuit is seen in Figure 2 and includes a power P MOSFET (Q1), an input capacitor (CIN), an output capacitor (COUT), coupled inductors (L1a and L1b), an AC coupling capacitor (CC), and a diode (D1). When Q1 is turned on and off, the ZETA converter can be seen working in CCM in Fig. 3. Analyzing the circuit at DC with both switches off and not switching is crucial to comprehending the voltages at the various circuit nodes. CC is charged to the output voltage, VOUT, during steady-state CCM since it is in parallel with COUT. The voltages across L1a and L1b during CCM operation are shown in Fig. 3.

Capacitor CC is charged to VOUT while Q1 is on..



(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

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

IV. MAXIMUM POWER POINT TRACKING

For manufactured photovoltaic modules, the conversion efficiency is just about 15%. Additionally, this proficiency may be significantly diminished due to variations in temperature, radiation, and load. A specific circuit known as the Maximum Power Point Tracker (MPPT) is used to ensure that the solar modules consistently act supplying the most power as would be reasonable and managed by surrounding working conditions. MPPT is the voltage at which a PV module can produce the maximum amount of power. The algorithm's choice is based on the length of time it takes to track the MPP, the cost of execution, and how easily it can be used.

A. Perturb and Observe Method

It is the simplest way because all that is needed to distinguish the voltage of the PV cluster is a voltage sensor. Using a P&O strategy is quite affordable. The P&O MPPT computation is frequently used since it may be efficiently actualized. It depends on the rule: when the PV array's operational voltage varies slantedly and power is extracted from the PV array, this suggests that the working point has shifted toward the MPP, and the working voltage must be

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changed in a similar manner until that point when the power is extracted from the PV array declines and the working point has drifted far from the MPP, at which point the working voltage should be perturbed in the opposite direction.By the way, the method estimates the incorrect MPP since it ignores the instantaneous change in light level and interprets it as a variation in the MPP caused by disturbances.

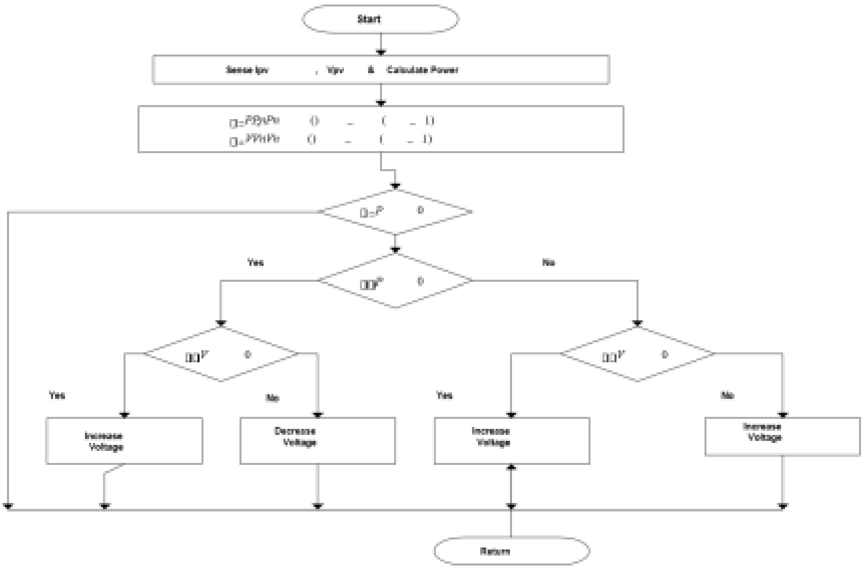


Fig. 4: Working principle of Perturb and Observe Algorithm

B. *Fuzzy Logic Control Method*

Compared to traditional validating frameworks, fuzzy logic is significantly more similar to human reasoning and natural language in spirit. The arrangement of a derivational control strategy into a programmed control method while taking into consideration the master information forms the basis of a fuzzy logic controller.

It is one of the newest systems in use and stands out for its ability to tolerate erroneous information sources, the fact that it is not dependent on an accurate numerical system, and its capacity to contain non-uniformities. Fuzzification, inference, and defuzzification are the three stages of fuzzy logic. The instructions sent to the FLC for the test time are error (E) and change in error (CE), and the FLC's response is the duty cycle, d.

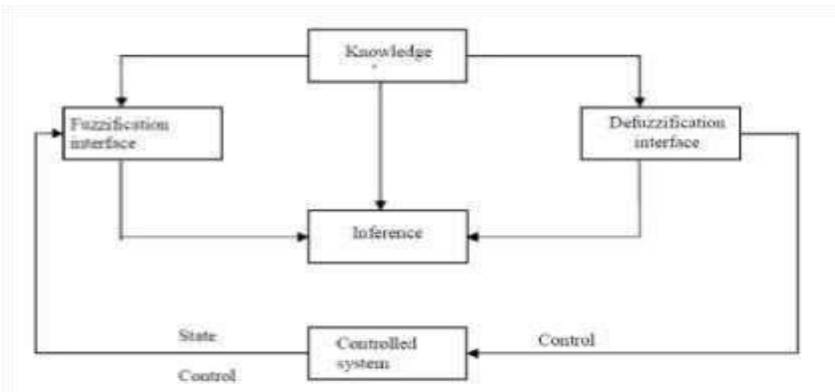


Fig. 5: Working principle of the Fuzzy Logic Controller method

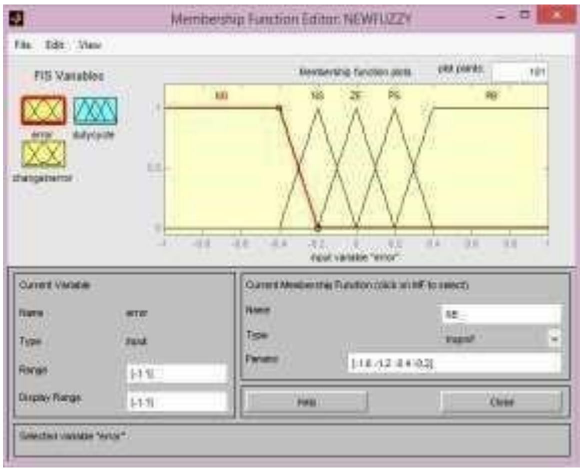
The fuzzy controller block including the fuzzifier, decision-making, and de-fuzzifier units is depicted in Figure 5. The fuzzy subset is the output of the fuzzy controller. The error in the input signal is E, and the error change is E. The fuzzy logic controller output, typically the change in duty cycle D, is discovered after E and E have been calculated and translated to linguistic variables. Panel outputs are used to measure fuzzy controller inputs. For the output variable's membership functions, five fuzzy subsets are taken into account. The linguistic variables ZE (zero), NS (negative small), NB (negative large), PS (positive small), and PB (positive big) are used to express these input variables..

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

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

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.



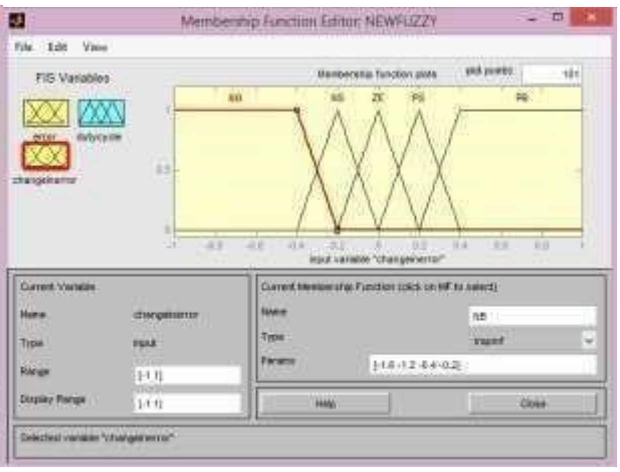


Fig. 6: Membership functions of input variable **-** error (e)Fig. 7:Membership functions of input variable –change in error (CE)

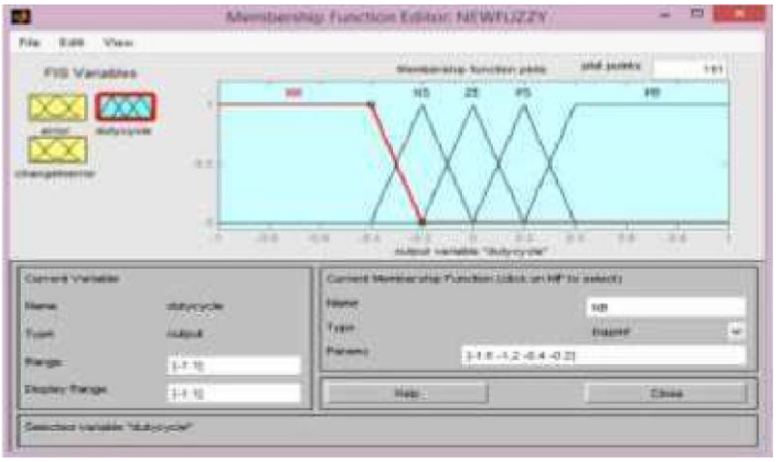


Fig. 8**:** Membership functions of output variable – duty cycle (D)

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

Table 1: Fuzzy logic based MPPT controller rule base

V. SIMULATION RESULTS

The FLC MPPT method is compared to the P&O MPPT under various ambient conditions to demonstrate that the FLC MPPT method can measure maximum power efficiently and precisely. This comparison is done in order to verify the MPP tracker for a photovoltaic simulation system. MATLAB/SIMULINK is used to run the simulation. Fig. 9 depicts the simulation model that was employed. The gating signal needed to operate the MOSFET comes out of the MPPT control block. Maximum power should be tracked by the MPP tracker under varied climatic circumstances.

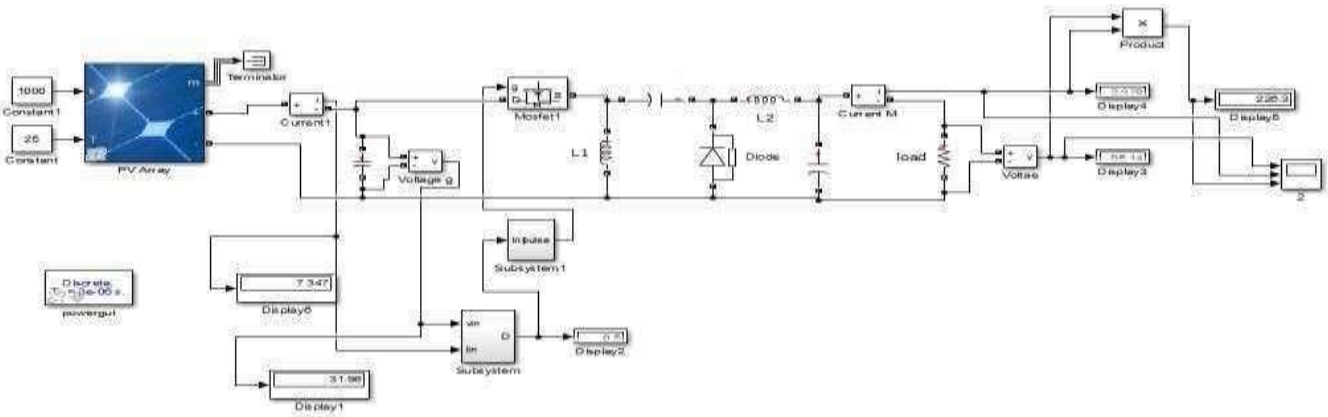


Fig. 9: the circuitry of the photovoltaic system developed in Matlab/Simulink using mppt technique

Different irradiance and temperature levels were simulated for the PV system. By adjusting the duty ratio of the zeta converter, the MPPT block's purpose is to make sure that the system delivers the maximum power to the load.

The Zeta converter output results of the P&O method are:

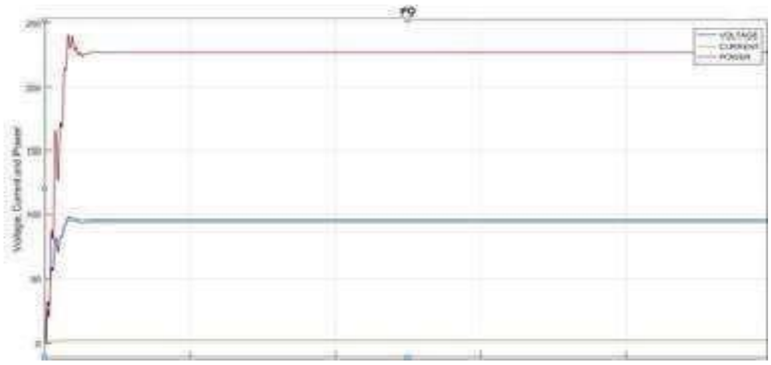


Fig. 10: Zeta converter outputs P&O Method at G=1000Wm^{-2} and$T$=25^oC with R load The Zeta converter outputresults of the FLC method are:

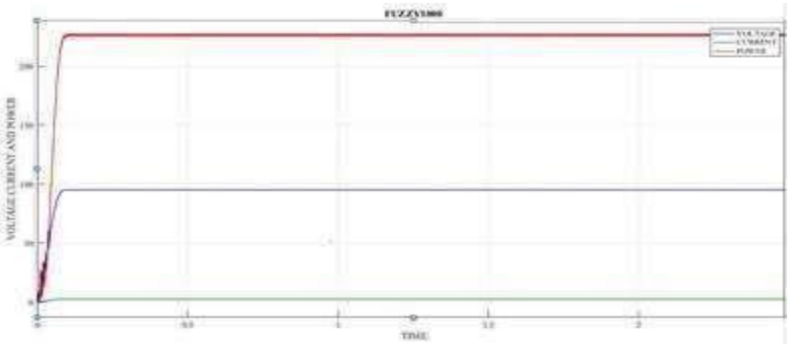


Fig. 11: Zeta converter output using FLC at G=1000Wm^{-2} and$T$=25^oC with R load

There are four different conditions which involve different values of radiation and temperature under constant environmental conditions. In these different cases the performance of PV system with P&O MPPT technique and PV system with fuzzy logic based MPPT technique is compared.

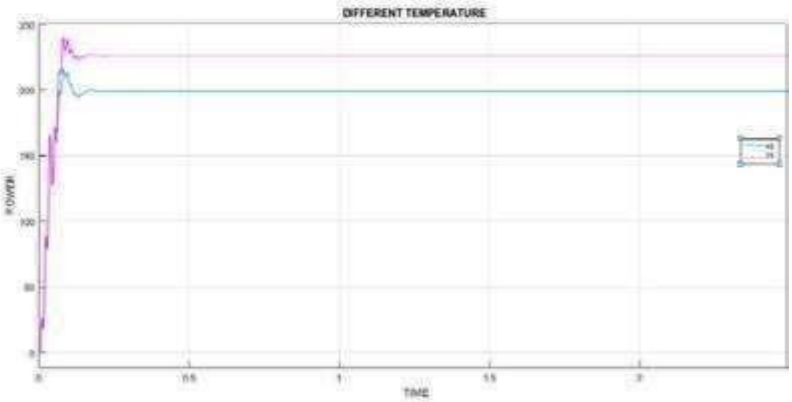


Fig. 12: Zeta converter outputs of PV System using P&O Method at a different temperature, G=1000Wm^{-2} and T = [25 45]°C

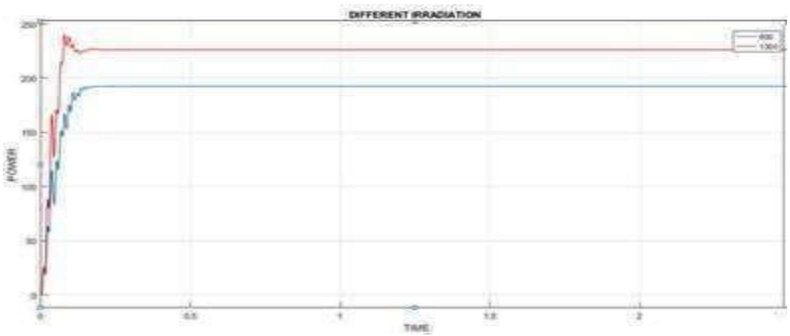


Fig. 13: Zeta converter outputs of PV System using P&O Method at different irradiation, G=[1000 800] Wm^{-2} and T = 25°C

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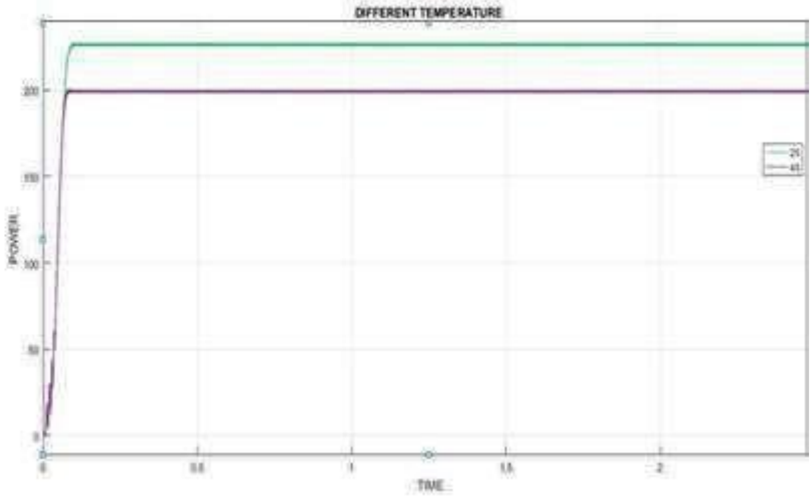

Fig. 14:Zeta converter outputs of PV System using FLC Method at a different temperature,G=1000Wm^{-2} and T = [25 45]°C

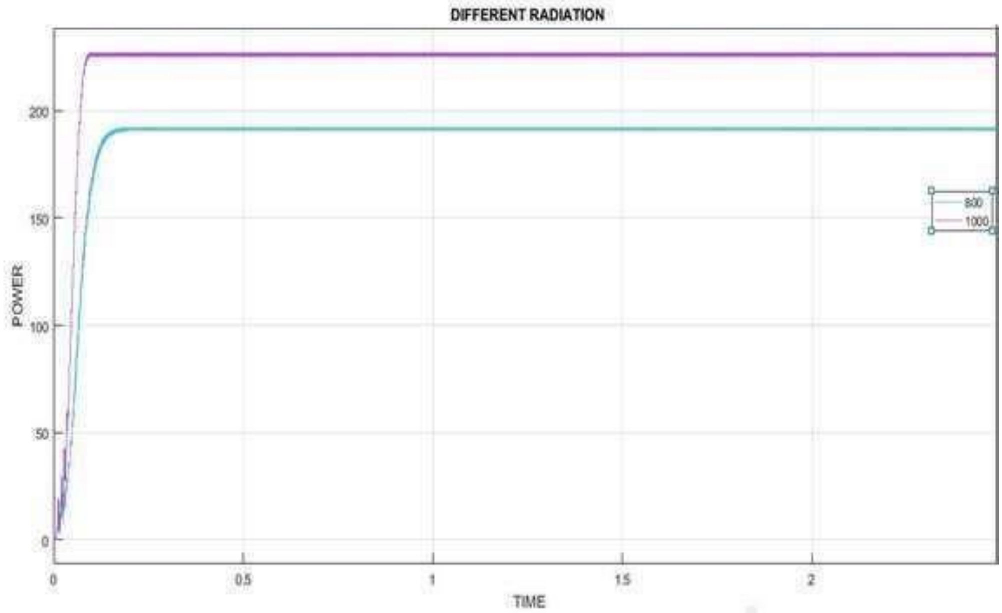

Fig. 15: Zeta converter outputs of PV System using FLC Method at different irradiation, G=[1000 800] Wm^{-2} and T = 25°C

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

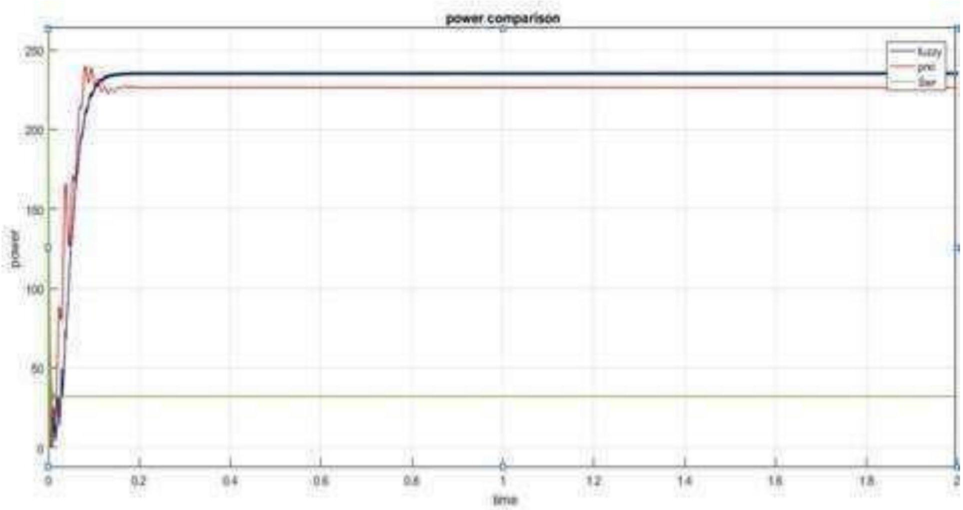

Fig. 16: Output power comparison of FLC and P&O techniques with R load

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=1000Wm^{-2} and$T$=25°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. AtG=1000Wm^{-2} and T= 45°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. 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°C

AtG = 800 W$m^{-2}$and T=25°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°C,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.

Case	G(Wm^2)	T(°C)	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**

Table 2: Results obtained under different simulation conditions

VI. CONCLUSION

This study presents a Matlab/SIMULINK photovoltaic model and a Zeta converter design with maximum power point tracking capabilities. The traditional P&O MPPT approach and the fuzzy logic controller method based on MPPT are contrasted. The models are put to the test when solar radiation and photovoltaic temperature are perturbed. According to the simulation results, the FLC method greatly outperforms P&O methods in terms of tracking accuracy and MPPT control speed. Following FLC MPPT implementation, more stable waveforms were produced. This demonstrates that transients and switching losses are kept to a minimum. As a result, the maximum amount of power can be extracted for a given level of irradiation and temperature.

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