given in table 1.The equivalent circuit for the solar cells arranged in Np parallel and Ns series is shown in fig.3. Array current and array voltage become:

$$Ipv = NpIph - NpIsat\left\{exp\left[\frac{q}{KT}\left(\frac{Vpv}{Ns}+\frac{RsIpv}{Np}\right)\right]-1\right\} - \frac{Np}{Rp}\left(\frac{Vpv}{Ns}+\frac{RsIpv}{Np}\right) \quad (3)$$

Np : represents the number of parallel modules. It should be noteded that each module is composed of Ns cells connected in series. $NpIph$ Corresponds to the short circuit current of the solar array.

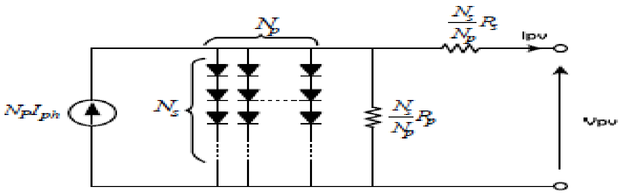


Fig.3. Electrically equivalent of solar array circuit (N_p parallel- N_s series)

The output of Simulink model is shows first; the V-P characteristics of PV module, for various irradiation levels (Fig.7), and then V-I characteristics, reference to the key specifications of the MSX60 array are illustrated in table 2 [01]. The results of Simulink PV module show the excellent correspondence to the model.

Table 1. Electrical specifications of the -60 W mono-crystalline photovoltaic module MSX60

Parameter		Value
Maximum Power	P_{PV}	200W
Tension at Pmax	V_{MPP}	26.3 V
Current at Pmax	I_{MPP}	7.61A
Open Circuit Voltage	Voc	32.9V
Short Circuit Current	Isc	8.21A
Ideality factor	A	1.3

Table 2. Electrical specifications of the - 6KW mono-crystalline photovoltaic array of 100 module of MSX60

Parameter		Value
Maximum Power	P_{PV}	60X100 = 6000W
Tension at Pmax	V_{MPP}	17.1X20 = 342 V
Current at Pmax	I_{MPP}	3.5X5 = 17.5A
Open Circuit Voltage	Voc	21.1 X20 = 422V
Short Circuit Current	Isc	3.8X5 = 19 A

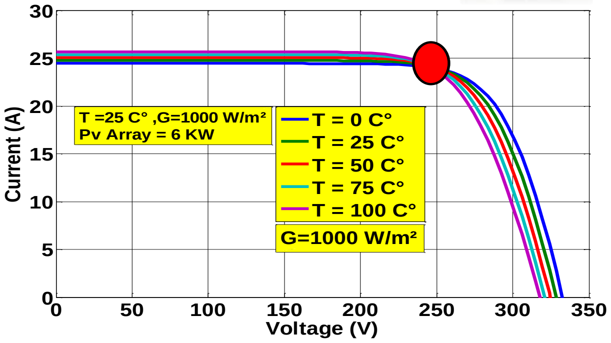


Fig .4. V-I, Characteristics of PV Array (6KW) at constant insulations and varying temperature

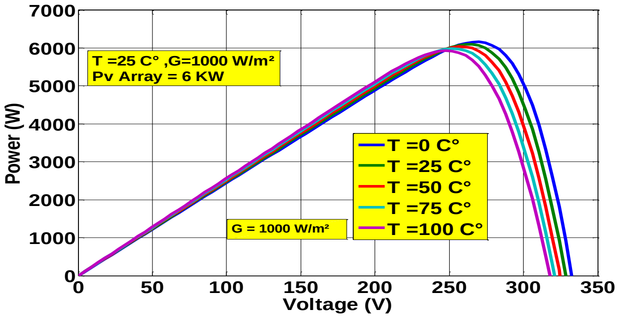


Fig.5.P-V Characteristics of PV Array (6KW) at constant insulations and varying temperature.

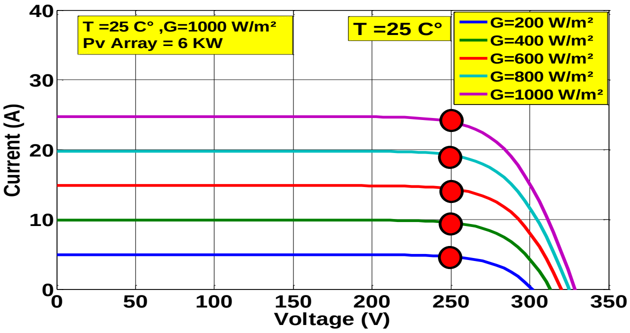


Fig .6. V-I Characteristics of PV Array (6KW) at constant temperature and varying insulations

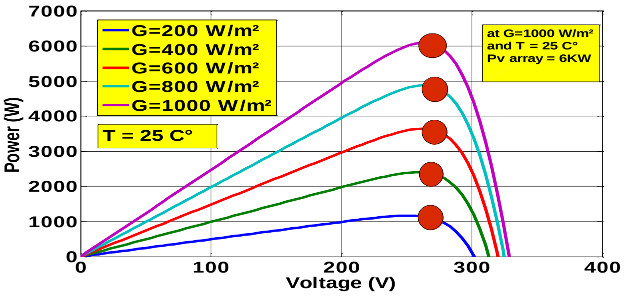


Fig .7. V-P Characteristics of PV Array (6KW) at constant temperature and varying insulations

2. DC-DC Buck-Boost Converter

The DC-DC converter is an electronics circuit, which is used to provide a loss less transfer of energy between different circuits at different DC voltage levels. There are many DC-DC converters. One of the popular types of DC-DC converters is buck-boost converter. The Buck-boost converter is used to step down and step up the DC voltage by changing the duty ratio of the MOSFET. If the duty ratio is less than 0.5, the output voltage is less than the input voltage; however, if the duty ratio is greater than 0.5, the output voltage will be greater than the input voltage. Duty ratio is the time at which the MOSFET is on to the total switching time. The buck-boost converter is shown in Figure 8.The relation between the input and the output voltages of the buck-boost converter is given as follows: [7].

$$Vout = \frac{-D}{1-D}Vin \quad (4)$$

Table 3. Buck-boost converter parameters

Buck-boost converter parameters	
L	1mH
C1	1000 µF
C2	330 µF
fs	40KHZ
Resistive Load R	5Ω

When applying Kirchhoff's laws, we find:

$$\begin{cases} \dfrac{dV_{PV}}{dt} = \dfrac{i_{PV}}{C_{PV}} - \dfrac{i}{C_{PV}} D \\ L\dfrac{di}{dt} = (1-D).V + D.V_{PV} \\ C\dfrac{dV}{dt} = -(1-D)i - \dfrac{V}{R} \end{cases} \tag{5}$$

I is the current through the inductance; V is the voltage across the capacitor; D is the duty ratio and Vpv is the voltage measured from the photovoltaic panel Fig 8.

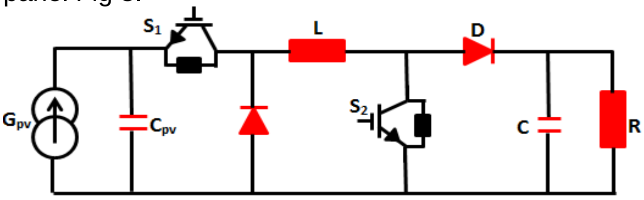


Fig. 8. The buck-Boost converter circuit

2. *Maximum Power Point Tracking*

Maximum Power Point tracking controller is basically used to operate the Photovoltaic modules in manner that allows the load connected with the PV module to extract the maximum power, which the PV module is capable to produce at given atmospheric conditions. PV cells have a single operating point, where the value of the current and voltage of the cell results in a maximum power output. With the varying atmospheric condition and because of the rotation of the earth [4], the irradiation and temperature keeps on changing throughout the day. So it is a big challenge to operate a PV module consistently on the maximum power point and for which many MPPT algorithms have been developed [1]. The most popular among the available MPPT techniques is Perturb and Observe (P&O) method. This method is having its own merits and demerits. The aim of the present work is to develop the Simulink model of P&O MPPT controller and then the fuzzy intelligent control has introduced on it to improve its overall performance

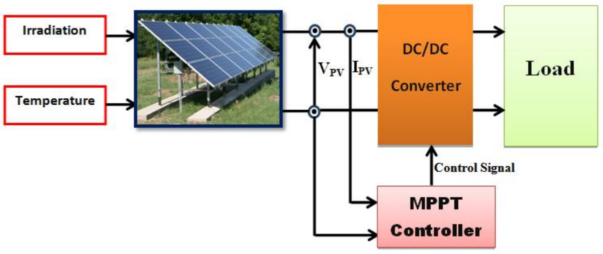


Fig. 9. Block diagram of PV Module with MPPT Controller

A. *MPPT using Perturbation & Observe*

This technique introduces a slight perturbation by decreasing or increasing the PWM duty cycle of the Buck converter. This perturbation changes the power of the solar module. If the power increases due to the perturbation, the perturbation is continues in that direction [06]. After the peak power is reached, the power at the next instant decreases and hence that the perturbation reverses. When the steady state is reached, the algorithm oscillates around the peak point. To keep the power variation small, the perturbation size is kept very small. The flow chart of algorithm has 4 cases as shown in Fig.10 [06].

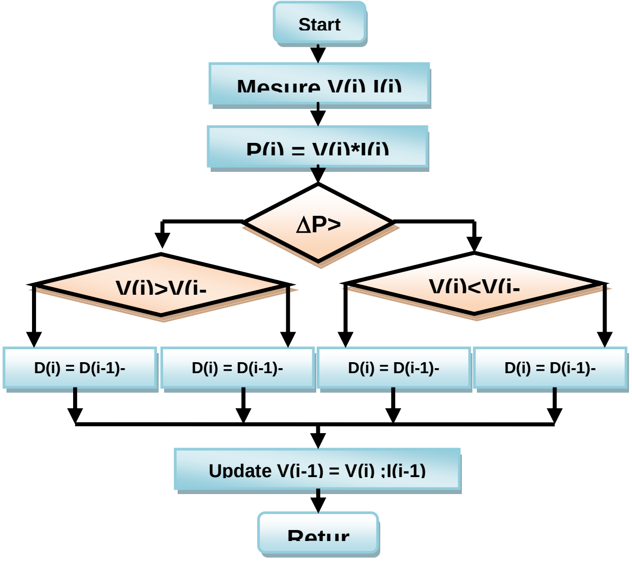


Fig .10. Configuration of Fuzzy Logic Controller in matlab/simulink

B. *MPPT using Fuzzy Logic Control*

Fuzzy logic controllers have been introduced recently in the tracking of the MPP in PV systems. They have the advantage to be robust and relatively simple to design as they do not require complete knowledge of the exact model and can handle nonlinearity. The proposed fuzzy logic MPPT Controller, shown in Figure 11, has two inputs and one output. The two input variables are the error E and change of error CE at sampled times k defined by eq. 6 and 7, where P and V are the PV panel power and voltage respectively at instant k: [8][9][10][11]

$$E(k) = \frac{P(K)pv - P(K-1)pv}{V(K)pv - V(K-1)pv} \tag{6}$$

$$CE(K) = E(K) - E(K-1) \tag{7}$$

Where:
$P(K)pv$ and $V(K)pv$ are the power and the voltage of the PV generator respectively at instant k.
The power of the PV system:

$$P(K) = i(K).V(K) \tag{8}$$

The input E(k) shows the following: the operation point at the instant k is located on the right or on the left of the MPP on the PV characteristic curve as shown in figure 12, while the input CE(k) shows moving the direction of this point.
Where the control action D is duty cycle of PWM signal that control the Buck Boost converter [5][6][7][8].

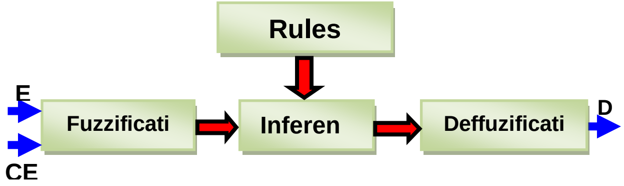


Fig.11. Block diagram of the fuzzy controller

The fuzzy controller design contains the three following steps:

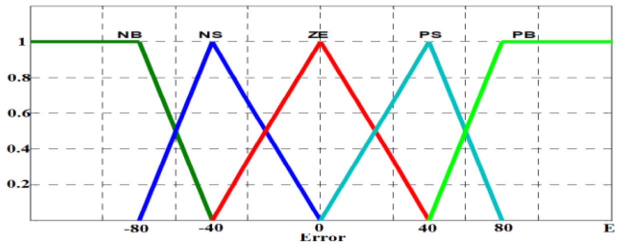
- *Fuzzification*

The fuzzification is the process of converting the system actual inputs values E and CE into linguistic fuzzy sets using fuzzy membership function. These variables are expressed in terms of five linguistic variables (such as ZE(zero), PB (positive big), PS (positive small), NB (negative big), NS (negative small)), using basic fuzzy sub sets as shown in Fig.13

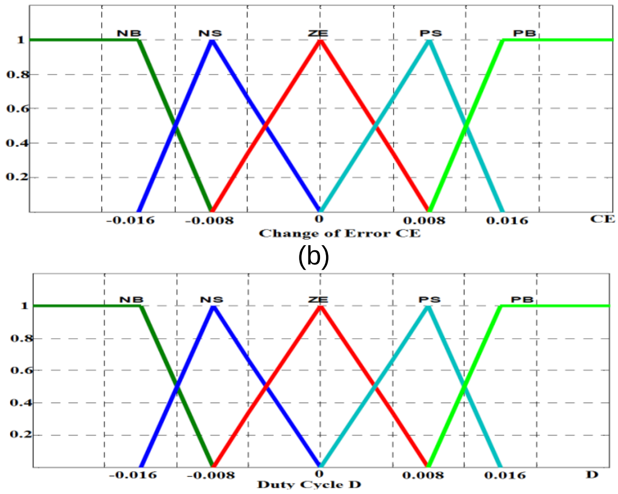
- *Rule base & inference engine*

Fuzzy rule base is a collection of if-then rules that contain all the information for the controlled parameters. It is set according to professional experience and the operation of the system control. The fuzzy rule algorithm includes 25 fuzzy control rules listed in table 3 [5] [6][7][8].

Fuzzy inference engine is an operating method that formulates a logical decision, based on the fuzzy rule setting and transforms the fuzzy rule base into fuzzy linguistic output. In this paper, Mamdani's fuzzy inference method, with Max-Min operation fuzzy combination, has been used [9][10][11].



(a)



(b)

(c)

Fig.12. Membership function of E, CE and D

- *Defuzzification*

Defuzzification of the inference engine evaluates the rules, based on a set of control actions, for a given fuzzy inputs set. This operation converts the inferred fuzzy control action into a numerical value at the output by forming the union of the outputs resulting from each rule. The center of area (COA) algorithm is used for defuzzification of output duty control parameter, i.e. If E is NB and CE is ZO, then crisp D is PB. This means that if the operating point is far away from the MPP by the right side, and the variation of the slope of the curve is almost Zero, this will increase the duty cycle.
The Output of duty cycle D is expressed by [10][11][12][13]:

$$D = \frac{\sum_{j=1}^{n}\mu(D_j).D_j}{\sum_{j=1}^{n}\mu(D_j)} \tag{9}$$

Table 4. Fuzzy Rules Table

E/CE	NG	NP	ZE	PP	PG
NG	ZE	ZE	PG	PG	PG
NP	ZE	ZE	PP	ZE	PP
ZE	PP	ZE	ZE	ZE	NP
PP	NP	NP	NP	ZE	ZE
PG	NG	NG	NG	ZE	ZE

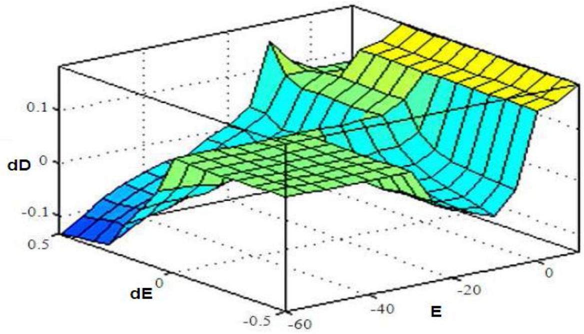


Fig. 13.The input-output surface waveform of the FLC

III. SIMULINK MODEL OF PV SYSTEM WITH P&O AND FUZZY LOGIC CONTROLLER

The performance of the tow systems, namely perturb &observe (P&O) and fuzzy logic controller, are analyzed. The performances of the controllers are analyzed in the following conditions:

Constant temperature and variable irradiation

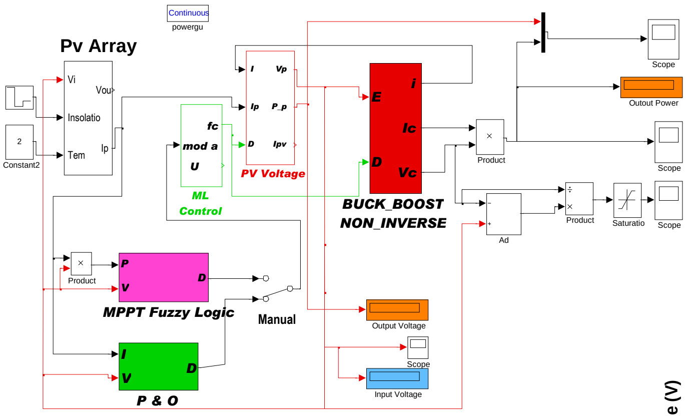


Fig 14.Simulation Block Diagram of MPPT PV systems for Maximum using P&O and Fuzzy Logic Controller

A. Operation under Constant Conditions

In this case, the temperature and irradiation are considered constant. the values are taken under standard conditions: temperature25°Cand irradiation in 1000W/m2.

B. Operation with Variable Conditions

In this case the temperature and irradiation are changing with time under different weather condition. Fig. 9 shows how the irradiance is changing for the PV solar panel. The voltage and the current vary depending on irradiance. The curve of variable irradiance is plotted using a signal builder, where the irradiance is not very realistic, because these are instantaneous changing irradiances. The simulation results are shown in the next figures. :

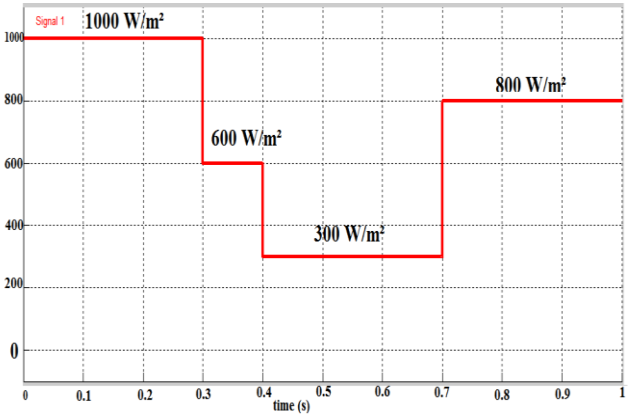


Fig.15. Variation of irradiance used in simulation.

C. P&O Mppt Controller

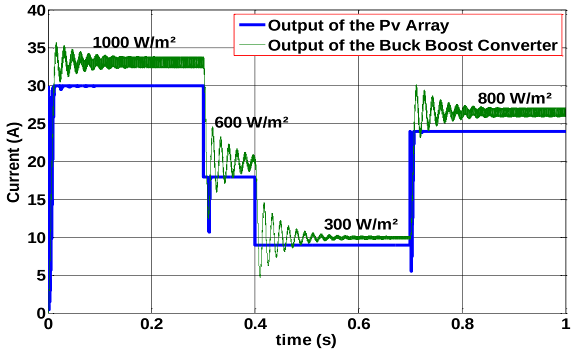


Fig.16. Input and Output Current of the Buck Boost converter with P&O Mppt Controller at constant temperature (T=25 C°) and varying insulation

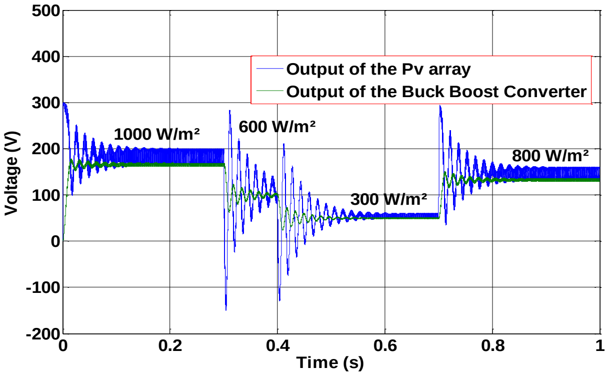


Fig.17. Input and Output Voltage of the Buck Boost converter with P&O Mppt Controller at constant temperature (T=25 C°) and varying insulation

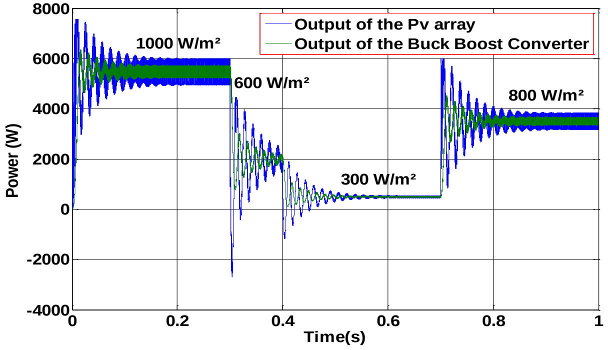


Fig.18. Input and Output Power of the Buck Boost with P&O Mppt Controller at constant temperature (T=25 C°) and varying insulation

D. Fuzzy Logic Mppt Controller

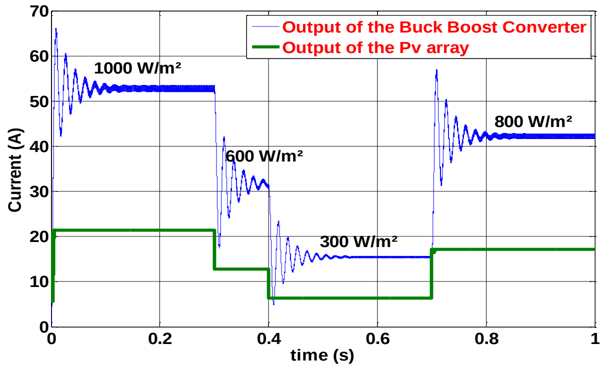


Fig.19. Input and Output Current of the Buck Boost converter with fuzzy logic Mppt Controller at constant temperature (T=25 C°) and varying insulation

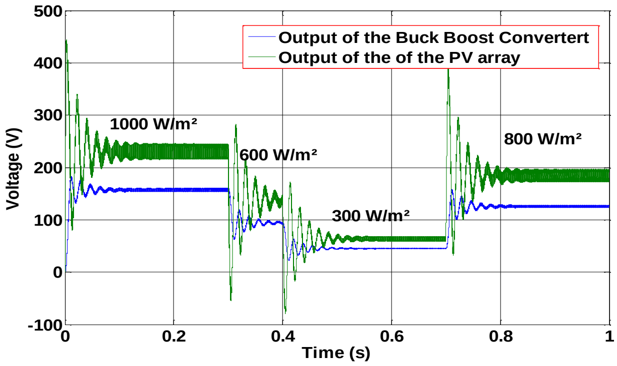


Fig.20. Input and Output Voltage of the Buck Boost with fuzzy logic Mppt Controller at constant temperature (T=25 C°) and varying insulation

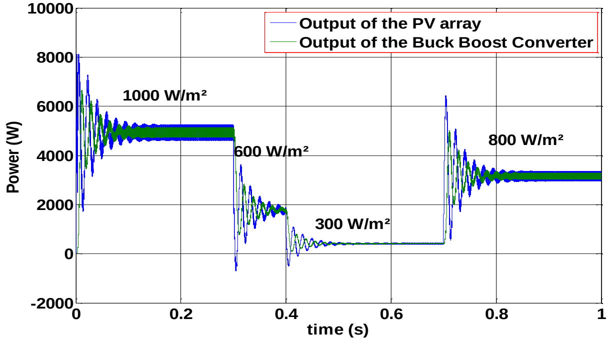


Fig.21. Input and Output Power of the Buck Boost converter with fuzzy logic Mppt Controller at constant temperature (T=25 C°) and varying insulation

As shown, fuzzy controller gives smother power signal line, less oscillation and better stable operating point than P&O. From the simulation results, it can be deduced that the fuzzy controller gives better performance than P&O, and it has more accuracy for operating at Maximum Power Point.

IV. CONCLUSION

This paper presents the performance of tow MPPT algorithms for tracking the maximum power available in PV array system, with Fuzzy Logic controller and P&O. The algorithms works as a direct method of MPPT through a buck-boost converter placed in parallel with the PV array. Based on the simulation results with MATLAB/SIMULINK, it can be observed that all of the tow MPPT controllers can be used to track the MPP under variable changes of solar irradiance and cell temperature. The tow controllers regulate the PV array voltage to operate at MPP operating voltage in order to produce the maximum power. However, it can be concluded that fuzzy logic has a better steady state, less oscillation around the MPP and dynamical performance than traditional P&O.

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