COMPARATIVE STUDY P&O AND FUZZY LOGIC MPPT SYSTEM FOR SOLAR ENERGY CONVERSION SYSTEM

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ABSTRACT: -

Maximum power point trackers are so important to improve the efficiency of photovoltaic systems. Many methods have been proposed to achieve the maximum power that the PV modules are capable of producing under different atmospheric conditions. This paper proposed a fuzzy logic based Maximum Power Point Tracking (MPPT) algorithm for solar system. The solar panel is simulated and analyzed in MATLAB/SIMULINK. Photovoltaic system is connected to a DC-DC Buck-boost converter. The Solar panel can produce maximum power at a certain operating point called Maximum Power Point (MPP).To achieve maximum power and to get maximum efficiency, the whole system must operate at that Maximum Power point. Maximum power point of PV panel keeps same on changing with changing solar irradiance and temperature of cell. Then to obtain maximum power from a PV system, MPPT algorithms are implemented. So that, fuzzy logic based MPPT is developed and Simulation results show the effective of the fuzzy based controller to produce more stable power.

Keywords: *MPPT, Fuzzy Logic, PV Modeling, Buck-Boost Converter.*

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I. Introduction

As we know energy has the great role in our life and economy. The energy demand has greatly increased day by day due to the technical revolution. Fossil fuels have been started to be gradually depleted. On the other hand the greenhouse gases emissions are increasing due to the conventional generation of energy. It is a really critical challenge to reduce carbon dioxide emissions and ensuring safe, improve and affordable energy, and to achieve better energy systems. Renewable energy sources are considered for generation of clean and sustainable energy.[1,2]

There are many available renewable energy sources are such as solar energy, wind energy, etc. Photovoltaic (PV) system has a huge research area for upcoming energy requirement.[4] So it taken a great attention by the researchers and it appears to be one of the most sustainable renewable energy sources. Solar energy is a secure, less maintenance, pollution free and noiseless generation due to absence of moving parts.[3,5]

However, two important factors affect the implementation of photovoltaic systems. These are high initial cost and less efficient at energy conversion. So to reduce photovoltaic system cost and to increases the conversion efficiency of solar energy, the maximum power point tracking system of photovoltaic modules is one of the effective method. Maximum power point tracking, frequently referred to as MPPT, is a system used to extract the maximum power of the PV module to deliver it to the load, and system efficiency increases.[6,7]

PV systems are dependent power sources with nonlinear I-V characteristics under different environmental (insolation and temperature) conditions. In addition they have high installation cost and low energy conversion efficiency. These are the reasons for the less efficiency of PV systems. To overcome the problems, the Maximum power point tracking of the PV system is used (at a given condition) at on-line or off-line algorithms and the system operating point is forced toward this to desired condition.

In literature, various maximum power point tracking (MPPT) techniques are proposed and implemented. These techniques include look-up table methods, perturbation and observation (P&O) methods and computational methods. One of the computational methods which have demonstrated fine performance using fuzzy-based MPPT technique.[7-11]

The fuzzy theory based on fuzzy logic sets and fuzzy algorithms provides a general method of expressing linguistic rules so that they may be processed quickly by a computer. Recently

some application of fuzzy control has been successful in photovoltaic applications. The fuzzy controller introduced in uses dP/dI and its variations D(dP/dI) as the inputs and computes MPPT converter duty cycle. The shortcoming of this approach is the ignorance of duty cycle variations, which results in an acceptable accuracy level with improved dynamic characteristics. The fuzzy tracker of reference considers variation of duty cycle, but replaces dP/dI by the variation of panel power. This tracker has fine dynamic behavior with limited accuracy.[9,10]

This paper presents a photovoltaic system including a solar panel, a fuzzy MPP tracker and a resistive load is designed, simulated and constructed. Simulated and measured results are presented.

II. The Photovoltaic System

There are many equivalent circuits of a solar cell, where the single-diode and two-diode models could be the mostly used. So that the single-diode model is simple and accurate enough in many cases. Its equivalent circuit with series and parallel resistance is shown in Figure 1.[2,4]
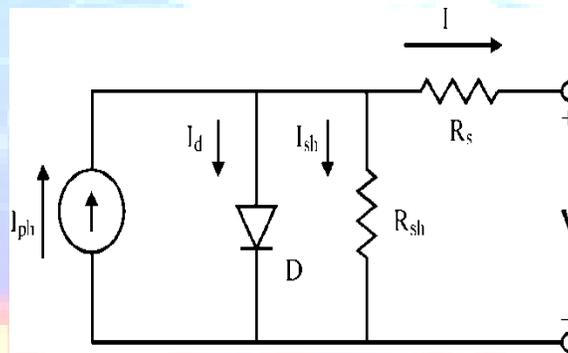

Fig. 1: Equivalent circuit of a single solar cell

The symbols in Fig. 1 are defined as follows:

I_{ph} : photocurrent;

I_d : current of parallel diode;

I_{sh} : shunt current;

I   : output current;

V   : output voltage;

D   : parallel diode;

R_{sh} : shunt resistance;

R_s : series resistance;

Using the equivalent circuit of Fig.1, the nonlinear I-V characteristics of solar cells is given by the following equation:

$$I = I_{ph} - I_0 \left\{ e^{\frac{q(v+R_sI)}{AKT}} - 1 \right\} - \frac{V + R_s I}{R_{sh}} \quad \dots(1)$$

Where I_o is the reverse saturation current of the diode, q is the electron charge ($1.602 \times 10{-19}$ C), A is the curve fitting factor, and K is Boltzmann constant ($1.38 \times 10{-23}$ J/K).

Model of a PV Module

If a solar cell type tends to have an I–V curve in which the slope at short circuit is almost zero, the value of R_{sh} can be assumed to be infinite. In this case, the last term in (1) could be ignored. And taking I_{ph} as I_{SC}, (1) will become

$$I = I_{SC} - I_0 \left(e^{\frac{q(v+R_sI)}{AKT}} - 1 \right) \quad \dots(2)$$

Where I_{SC} is the short-circuit current. Equation (2) is valid for a solar cell. For the accurate application of this equation for a PV module, the term of $q(V + R_s I)/AKT$ is changed to $q(V + Rs I)/N_sAKT$, in which N_s is the number of series-connected solar cells in a PV module.

…(3)

A simple PV module model will be derived from (2) in this section. When a PV module is in a open-circuit situation, I = 0 and the item q/N_sAKT in (2) will be solved as follows:

$$\frac{q}{N_sAKT} = \frac{In\left(\frac{I_{SC}}{I_0} + 1\right)}{V_{OC}} \quad \dots(3) \qquad \dots(4)$$

where V_{OC} is the open-circuit voltage of a PV module. Substituting (3) into (2), we get

$$I = I_{SC}\left[1 - \frac{I_o}{I_{SC}}\left(e^{In\left(\frac{I_{SC}}{I_o}+1\right)\frac{(v+R_sI)}{V_{OC}}} - 1 \right) \right] \quad \dots(4) \qquad \dots(5)$$

Fig. 2 shows the P-V curves of the PV module under changing solar radiation from 200W/m^2 to 1000W/m^2 while keeping the temperature constant at 25°C. Fig. 3 shows the P-V curves of the PV module under changing temperature from 10°C to 55°C while keeping the solar radiation constant at 1000W/m^2.
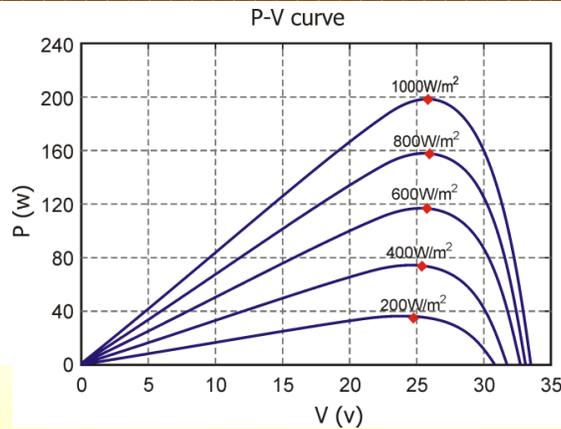
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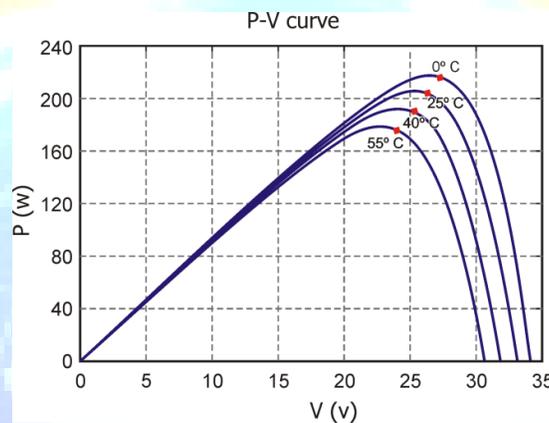Fig. 2: P-V curves under changing the solar radiation

Fig. 3: P-V Curves under changing the temperature

III. 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. Buck-boost converter is circuit that operating using switching mode power supply. Buck-boost converter used to step up and step down the DC voltage by changing the duty ratio of the switch. When the duty ration is less than 0.5, the output voltage is less than the input voltage and vice versa. The buck-boost converter circuit is shown in Fig. 4.[2,3]
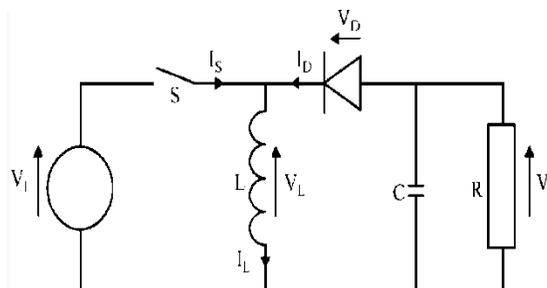
Fig. 4: Schematic of a buck–boost converter.

The operation of the Buck-boost converter is as follows:

- When the transistor is turned ON, the diode is reverse-biased and being not conducting. Turning on the transistor is accomplished during $o < t < DT$ s interval. The voltage across the inductor in this stage is given as:

$$V_I = V_L \ldots (5)$$

- When the transistor is turned off, the diode is conducting. Turning on the transistor is accomplished during $DTs < t < Ts$ interval. The voltage across the inductor in this stage is given as:

$$V_L = V_O \ldots (6)$$

It is known that for steady-state operation, the net change in the inductor current must be zero over one switching cycle. By applying volt-second balance we get:

$$V_I D + V_O (1 - D) = 0 \ldots (7)$$

Where D is the duty cycle of the converter which is given as:

$$D = \frac{T_{on}}{T} \ldots (8)$$

From (7) the relation between the input voltage to the output voltage of the buck-boost converter is given as[3]:

$$\frac{V_o}{V_i} = \left(\frac{D}{D-1)} \right) \ldots (9)$$

IV. Perturb and Observe

Perturb and observe (P&O) method is widely used to track the MPP of the PV module. The algorithm applies a small increment or decrement of perturbed voltage ΔV to the PV module operating voltage. The operation of the P&O MPPT can be shown as in Fig. 5.
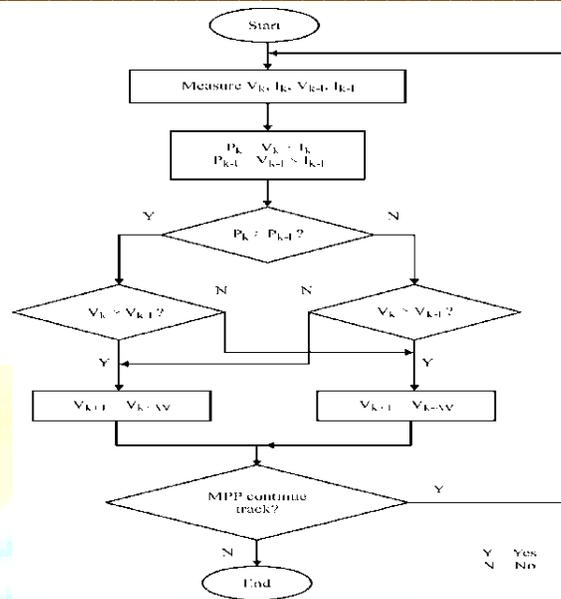
Fig. 5: Flowchart shows the operation of P&O MPPT

The measurement of actual state k and previous state k-1 of parameters V and I are taken. Comparison has been made between the actual and previous state of the parameters power, P and voltage, V. Based on the conditions as stated in Fig. 5, increment or decrement of perturbed voltage, ΔV will be applied to the PV module operating voltage. Fig. 6 shows the power-voltage characteristic of PV model which is used to discuss the principle of MPP tracking. There are four possible cases which will influence the direction of the tracking in P&O MPPT.

Case I where $P_k > P_{k-1}$ and $V_k > V_{k-1}$, the situation can be described as path α in Figure 6. When the operating voltage is increased, the PV power is increased also. Therefore, a small change of voltage ΔV need to be added to the present PV operating voltage followed by monitoring of the PV power. The process is continued until the MPP is identified.

Case II where $P_k > P_{k-1}$ and $V_k < V_{k-1}$ referred to path β in Fig. 6. It can be noticed that when the operating voltage is decreased, the PV power is increased. In order to identify the MPP operating point, reduction of ΔV should be made on the present PV operating voltage and the parameters P_k and P_{k-1} are compared. If the condition $P_k > P_{k-1}$ is fulfilled, the decrement of ΔV will be continued until the MPP is successfully spotted.

Case III where $P_k < P_{k-1}$ and $V_k > V_{k-1}$ can be described as path β in Fig. 6. In this case, the PV power is decreasing as the increased of PV operating voltage. Thus, it should have a reduction of ΔV on the present PV operating voltage.

Case IV where $P_k < P_{k-1}$ and $V_k < V_{k-1}$ is illustrated as path α in Fig. 6. The PV power is reducing

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as the decreasing of PV operating voltage. Thus the PV operating voltage should have an increment of ΔV to track the PV maximum power point.

The main weakness of P&O MPPT algorithm is the PV module's operating voltage is perturbed every cycle. The algorithm will always perform an increment or decrement of ΔV to the PV operating voltage.
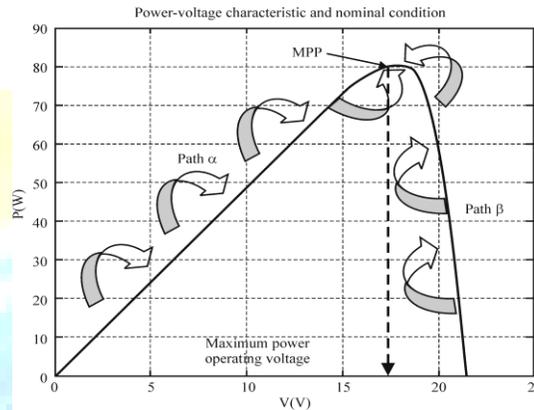

Fig. 6: Principle for MPP tracking

V. The Proposed MPPT Fuzzy Logic Base Method

A Fuzzy Logic Controller (FLC) is designed to work as an MPPT controller. Fig. 7 shows the FLC.
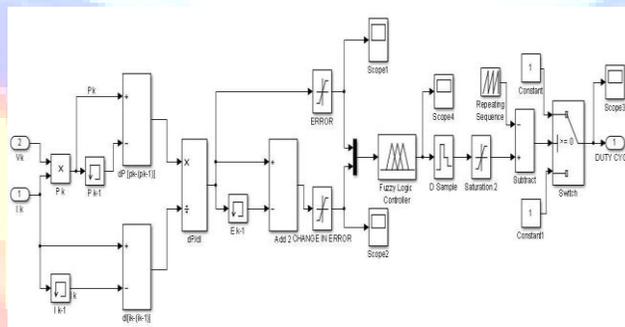
Fig. 7: Fuzzy logic controller

The FLC contains a Fuzzy Inference System (FIS) whose structure is shown in Fig. 7. The FIS inputs, error (E) and change in error (CE), are obtained using the following equations:[10]

$$E(k) = \frac{P_{PV}(k) - P_{PV}(k-1)}{I_{PV}(k) - I_{PV}(k-1)} \quad ....(10)$$

$$CE(k) = E(k) - E(k-1) \quad ....(11)$$

Where:

P_{PV}: The power of the PV system

I_{PV}:   The current of the PV system
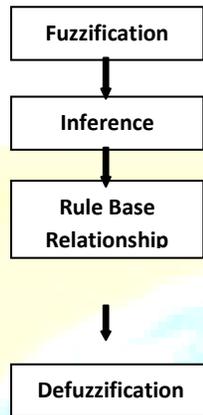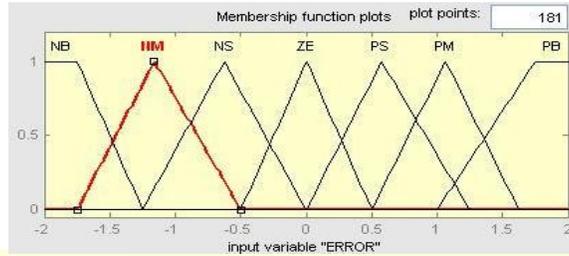
E: Error

CE: Change in error

Fig. 8: Fuzzy Interface System

A. Fuzzification

1) Fuzzification of Error-Signal: The range of error-signal is partitioned into seven regions with triangular and trapezoidal membership functions labelled as: Negative Big, Negative medium, Negative small, Zero error, positive small, positive Medium and positive big over Universe of Discourse (UoD) of -0.8 to 0.8 as shown in fig.9.

2) Fuzzification of Change in Error-Signal: The second input parameter is Change in Error-Signal. The range of signal is partitioned into seven regions with triangular membership functions labelled as: Negative Big, Negative medium, Negative small, Zero error, positive small, positive Medium and positive big over UoD of -3 to 3 same as shown as eroor signal.

3) Fuzzification of PWM Duty cycle-Signal: Defuzzification converts membership functions into Crisp value for PWM signal. Seven regions with triangular and trapezoidal membership partitions are labelled as: Negative Big, Negative medium, Negative small,
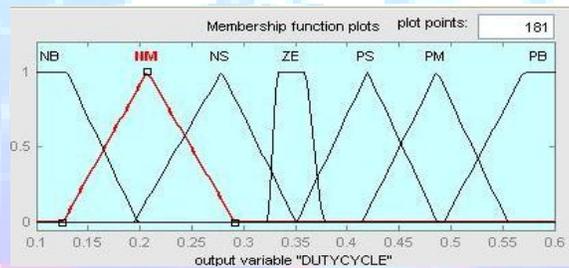
Zero error, positive small, positive Medium and positive big over UoD of 0.1 to 0.7 counts.

(a)
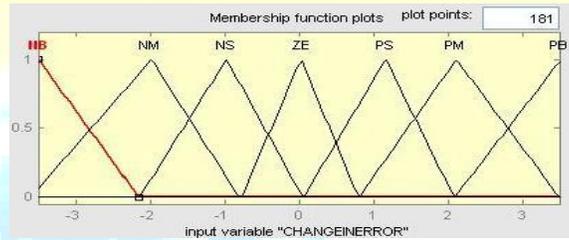
(b)

(c)

Fig.9: Graphical view of the membership function error signal

B. Fuzzy Inference System

The Fuzzy Inference forms a key part of Fuzzy Logic Control. The Fuzzy IF-THEN rule base matrix is in

Table 1: Rule Based Matrix

E/CE	NB	NM	NS	ZE	PS	PM	PB
NB	ZE	ZE	ZE	NB	NB	NB	NM
NM	ZE	ZE	ZE	NS	NM	NM	NM
NS	NS	ZE	ZE	ZE	NS	NS	NS
ZE	NM	NS	ZE	ZE	ZE	PS	PM
PS	PS	PM	PM	PS	ZE	ZE	ZE

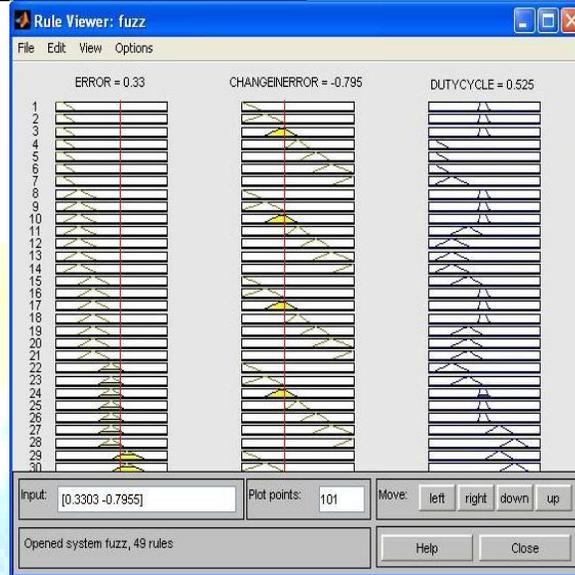| PM	PM	PM	PM	ZE	ZE	ZE	ZE
PB	PB	PB	PB	ZE	ZE	ZE	ZE

Fig.10: Rule Viewer

C. Defuzzification:

The Fuzzy Inference based on Mamdani's scheme is shown in fig.10 for present Error of 0.33, change of error is -0.79 thereby suggesting a PWM duty cycle of 0.525.

VI. Experimental Result

In order to verify the MPP tracker for the photovoltaic simulation system with step decay in solar irradiance, the proposed fuzzy MPPT method can effectively and accurately tracks the maximum power. The simulation is done using MATLAB/STMULINK and comparison study of the results are taken from P&O and Fuzzy MPPT. The output of the fuzzy MPPT control block is the gating signal which is used to drive the MOSFET. With further tuning of fuzzy sets and fuzzy rules the process of output power can be more and more power efficient. Results are shown in fig. 11.

VI. Conclusion

Fuzzy MPPT model using Matlab/SIMULINK and design of appropriate DC-DC buck-boost converter with a maximum power point tracking facility are presented in this paper. A new method for MPPT based fuzzy logic controller is presented. The model is tested under $1200W/m^2$ to 540 W/m^2 solar radiation and 25^0C photovoltaic temperature. Simulation results show that the proposed method effectively tracks the maximum power point as compared to

P&O MPPT technique. The oscillation around MPP is decreased and the response is faster in compared with the conventional methods.
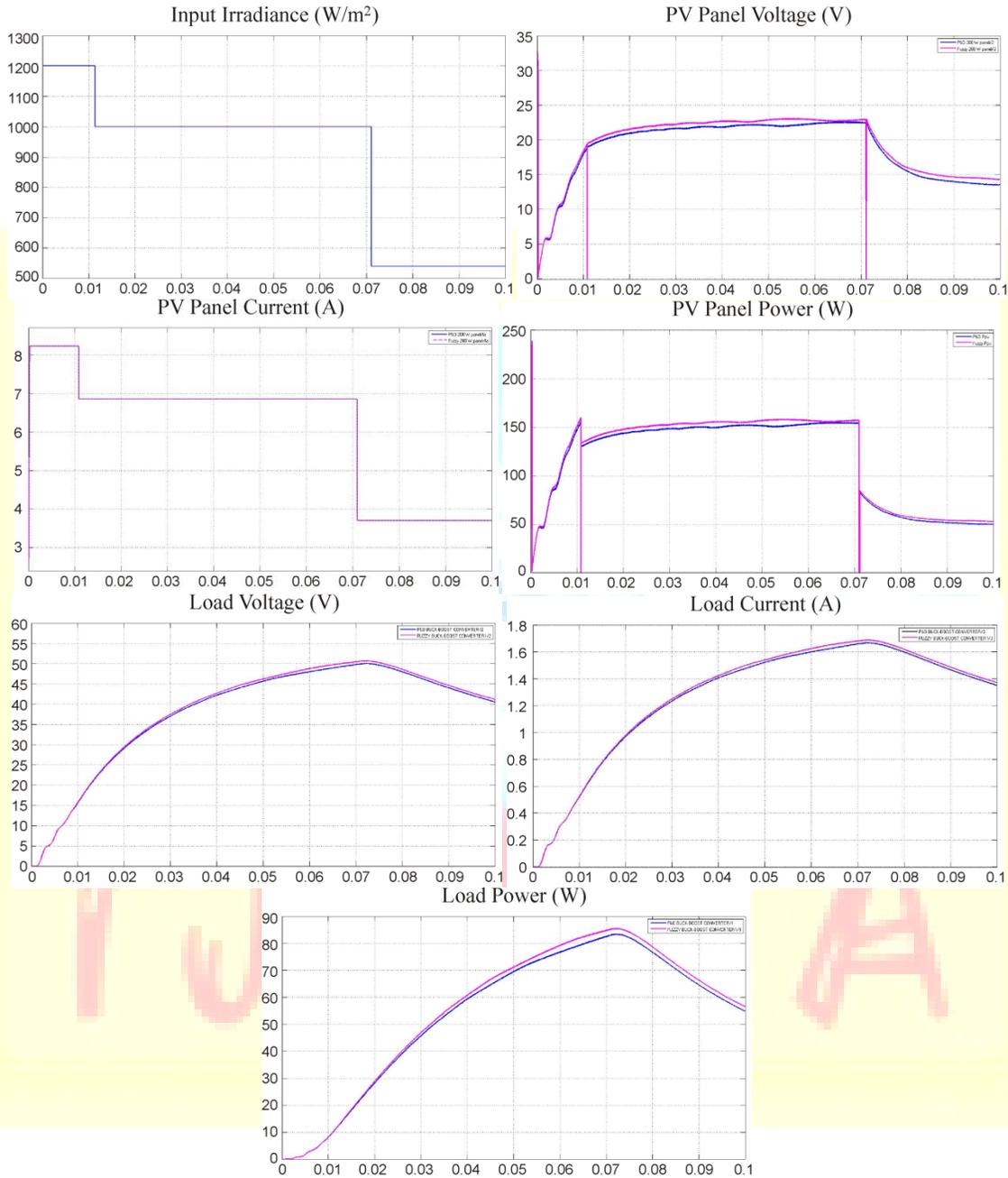

Fig. 11: Performance of Fuzzy MPPT over P&O MPPT

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