International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Evaluation of Optimum MPPT Technique for PV System using MATLAB/Simulink

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Abstract*: In day to day life the electrical demand is increased drastically, but the electrical power generation with the conventional sources is not in proposition with the demand, hence there is a great requirement to search about the alternative or renewable energy sources available in nature especially for solar energy source, which can be available abundantly throughout the year. In this paper we discus about how the solar energy can be converted into electrical energy effectively and efficiently with the help of various (Maximum Power Point Tracking) MPPT techniques according to dynamic changes occurring in temperature, radiance, Here we test Perturb and Observe (P&O) Method, Incremental Conductance method (ICM) and Fuzzy with PI Controller in MATLAB/Simulink to get the maximum power and voltage with the help of DC — DC Boost converter and find the optimum MPPT for PV (Photo voltaic) System.

Index Terms: PV, Renewable energy Sources, MPPT, P&O, ICM Fuzzy, and PI Controller

I. INTRODUCTION

The electrical energy plays a vital role in our daily routine life at the same time electrical load in the world is increasing day by day and 70% of the load is depended on conventional power only, which causes the environment pollution and the sources may exhaust if it used continuously, so we need to think about the renewable energy sources, which are available abundantly in nature irrespective of seasons and time. The best alternative energy source is Solar energy which converts the solar energy in to electrical power, but the power generation is dependent on temperature and radiance which dynamically changes, while comparing the I-V and P-V Curves of the PV cell, the power will be effected by changing the temperature, radiance and sudden effect of shadows due to cloud or any other reasons. To overcome all these problems, the various MPPT techniques are introduced, as the generated power is in terms of DC, it needs to be converted into AC to utilize in proper way and to connect to the grid, hence proper inverters with appropriate ratings are used to convert generated and boosted DC in to AC. in this paper the basic PV Model with Converter and controller is explained in section 2, the fundamental Working principle, Mathematical modeling, I-V, P- V Characteristics, Boost converter, Various MPPT techniques like P&O, ICM and Fuzzy controller in Section 3, in section 4 MATLAB/Simulation models are designed and tested for various results, compared different MPPT techniques and finds Optimal MPPT method. Section 5 follows with conclusion and future scope.

Manuscript published on 30 June 2019.
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II. BASIC BLOCK DIAGRAM

In PV System the power generation mainly depends on the radiation and temperature in nature which are varying frequently, the maximum power of any PV system can be extracted at only one point for every temperature and radiation, in this paper the maximum point extraction can be achieved by different MPPT techniques to improve the efficiency of the system. Figure 1 represents simple Block diagram which consists of the PV panel, DC to DC Converter, various MPPT techniques and the DC Load.

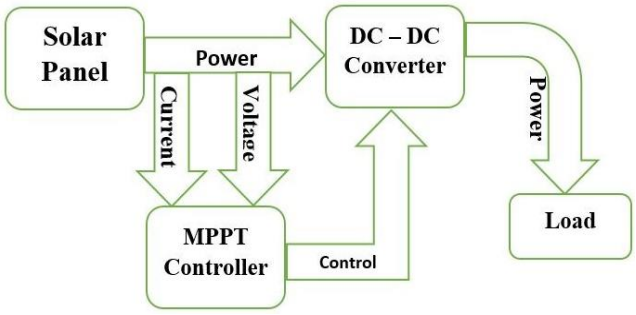

Fig.1. Basic Block Diagram of PV System with Controller

III. PV SYSTEM

A) Mathematical Modeling and Performance of PV Cell:

The basic working principle of PV System involves converting the sunlight energy into electrical energy, and the PV cell is basically a P-N junction diode when the radiance of sunlight with certain temperature hits the cell, the electrons crosses the barrier making it as short circuit hence the electrical power will be generated and further can be used [1] [2]

From the above Figure 2 the PV Current can be expressed as

$$I_{pv} = I_{ph} - I_d - I_{sh} \quad (1)$$

Where
Iph= Phase current of PV cell
Id = Diode current
Ish = Shunt branch current
Ipv = PV cell current

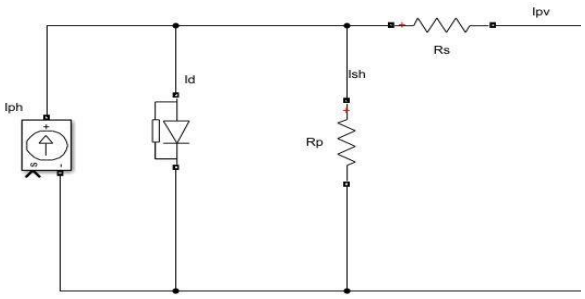

Fig.2. Equivalent Circuit of PV Cell

The phase current of PV cell can be expressed as

$$I_{ph} = [I_{sc} + K(T - T_{ref})\frac{G_{ref}}{G}] \quad (2)$$

Diode current is

$$I_d = \left[\exp\left(\frac{V + I_{pv}R_{se}}{KV_t\eta}\right) - 1\right] I_{sc}N_p \quad (3)$$

Shunt current

$$I_{sh} = \frac{V + I_{pv}R_{se}}{R_{sh}} \quad (4)$$

Reverse Saturation current of diode

$$I_{rs} = \frac{I_{sc}}{\exp\left(\frac{qV}{Kt\eta}\right) - 1} \quad (5)$$

Solar PV Cell Specifications:

Open circuit Voltage: 33.64 V
Short circuit current:8.21 Amp
Identity factor (A): 1.6
Boltzman Constant (K): 1.3805e-23 J/K
Electron charge (Q) : 1.6e-19 C
Series resistance of PV cell: 0.43854
Shunt resistance of PV Cell: 493.4216
Short circuit current temperature coefficient at Iscr (Ki) : 0.003 A/C0
Band gap for silicon Ego: 1.1 ev
No. of series cells: 54
Voltage at Maximum power Vmpp: 27.16 V
Current at Maximum Power Impp: 7.89 Amp
Power rating of panel: 215 W

The I-V and PV Curves of the PV panel with respect to different radiance and temperature are shown in Figure 3

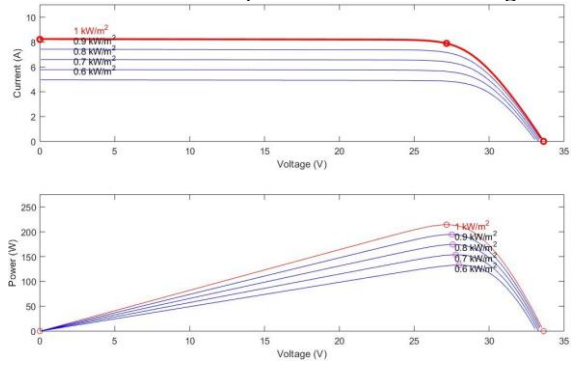

Fig.3. I-V and P-V Characteristics of PV Panel for given Specifications

A) Boost Converter:

Boost converter is mainly used to step up the generated dc voltage from the solar panel with a constant value by maintaining the power as constant. The basic boost converter Figure 4 mainly consists of Diode, IGBT used as switch and can be acted according to triggering The basic boost converter Figure 4 mainly consists of Diode, IGBT used as switch and can be acted according to triggering pulse provided and output capacitor is to remove the ripples which are generated in the output DC Voltage. Here in this boost converter the required output voltage can be obtained by changing the triggering pulses, which can controlled either fixed or automatic as like closed loop with proper controllers, and the basic calculations to obtain triggering pulse can be obtained using following equations [3] [4]

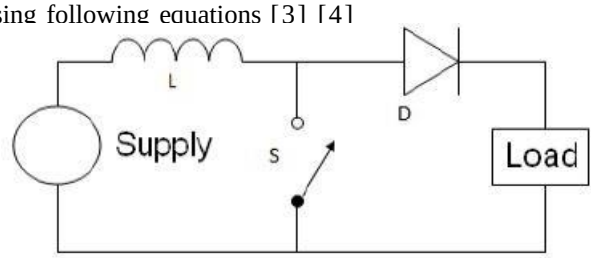

Fig.4. Basic Boost Converter

Duty Cycle of the Switch or IGBT is

$$D = [1 - \frac{V_{in(\min)} * \eta}{V_{out}}] \quad (6)$$

Where D = Duty Cycle

Vin: Input voltage to the converter which is coming from PV Cell
$\acute{\eta}$: Efficiency of Converter
Vout: Output Voltage to the converter Change in ripple current

$$di = I_{ripple} * I_{out} * \frac{V_{out}}{V_{in}} \quad (7)$$

The output current of Boost converter

$$I_{out} = \frac{Power\ Rating}{Output\ Voltage} \quad (8)$$

Inductance of boost converter

$$L = \frac{[V_{in} * (V_{out} - V_{in})]}{di * f_s * V_{out}} \quad (9)$$

Acceptable change in Voltage

$$DV = \frac{V_{out}}{dv\ Percent/100} \quad (10)$$

Output Capacitor to reduce the ripples

$$C = \frac{I_{out} * D}{f_s * dv} \quad (11)$$

Output Resister

$$R = \frac{V_{out}}{I_{out}} \quad (12)$$

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C) Maximum Power Point Tracking (MPPT) Techniques:
MPPT techniques are used to generate the firing pulses to DC – DC converter to obtain maximum power, we have different MPPT techniques for PV System,

i) Perturb & Observe Method:
In this method the Instant power is calculated at t=k and k-1 sec, by measuring the voltage and current from the PV panel, if the power at t=k is greater than t=k-1 then it checks the voltage for same times again if the voltage maintained same then the duty cycle will be updated like δ + Δδ otherwise it will be δ - Δδ and the same procedure will be continued till it reaches the maximum power point., at that particular point the voltage, current and power will be updated as final values for that particular radiance and temperature [5] [6] [7] [8] .the following Figure 5 shows that basic algorithm for P & O Method

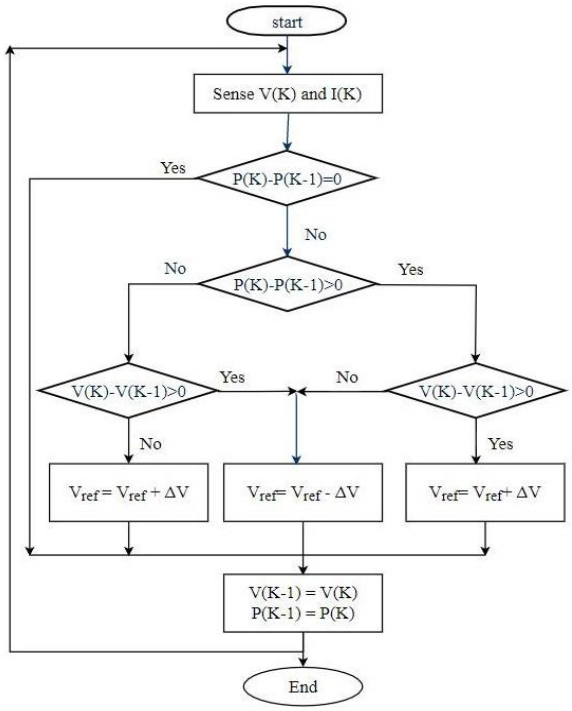

Fig.5. P & O Algorithm Flowchart

ii) Incremental Conductance Method:
In this method the main concentration is about the output admittance of the boost converter [9], Power from the boost converter is given as

$$P = VI \tag{13}$$

to get the maximum power from the PV cell differentiate the power with respect to voltage and equate it to zero.

$$\frac{\partial P}{\partial V} = \frac{\partial (VI)}{\partial V} = 0 \tag{14}$$

By simplifying the above equation

$$\frac{\partial I}{\partial V} = -\frac{I}{V} \tag{15}$$

in this method change in conductance and conductance at an instant of time are compared and the duty cycles is either increased or decreased according to the condition of conductance value [10] [11]. The basic Incremental conductance method algorithm flow chart is shown in below Figure 6

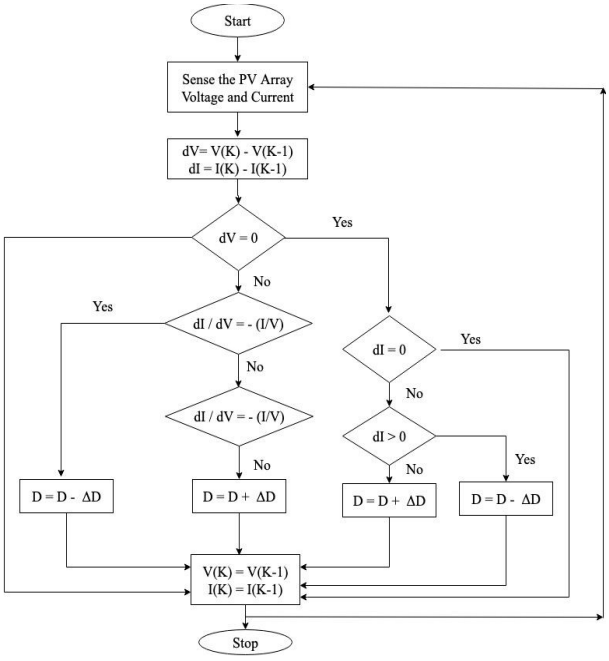

Fig.6. Incremental Conductance Method Algorithm Flowchart

iii) Fuzzy Logic Controller (FLC):
The biggest advantage of fuzzy logic control is that it can understand the in accurate input which doesn't have mathematical modeling and it can be work for nonlinear functions also, where the other systems can understand only the Boolean 0 or 1, but this system can understand all the conditions in between 0 and 1 also [6].

The fuzzy logic control mainly consists of three stages 1. Fuzzification, inference system (rule base lookup table) and Defuzzification. In fuzzification the numeric crisp inputs can be converted into linguistic variables depending on membership functions. In the interference system the rule base is created in Madani's table method and in Defuzzification the outputs of FLC are converted into duty cycle [12]

The basic fuzzy logic control block diagram is shown in following Figure 7

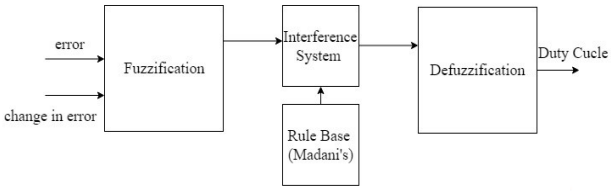

Fig.7. Fuzzy Logic Control Block diagram

In fuzzy control System power and change in power are calculated by taking the voltage and current from the PV panel, the error and change in errors are taken as ratio of change in power to change in voltage and small change in this value, these values are taken as crisp values for fuzzification.

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IV. PROPOSED SYSTEM & RESULTS

The proposed system comprises a PV system of 33 Volts, 8 amps and 200 watts of power rating with boost converter converting 33 volts to 50 Volts by maintaining power as same, and different MPPT techniques like P & O Method, Incremental Conductance method and fuzzy control method to get the maximum output. The simulation model of total system with output wave forms of each MPPT techniques are shown in the below Figure 8, Figure 9, Figure 10, Figure 11

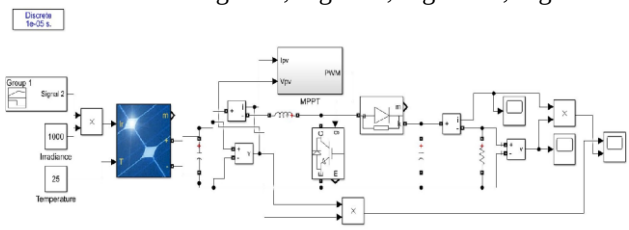

Fig.8. Simulation Model of PV System with Boost Converter and MPPT Controller

The PV system with Boost converter is controlled with respect to P & O, Incremental Conductance method and Fuzzy control method separately. Here the Output Voltage and Power of each method are compared with respect to time response analysis also. The following Figure 9, Figure 10, Figure 11 shows the Simulation model of P & O, ICM and Fuzzy Control Method.

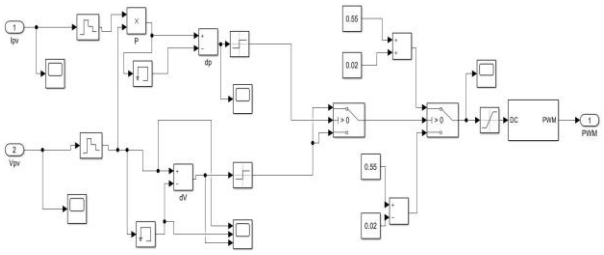

Fig.9. Simulation model of P & O MPPT Method

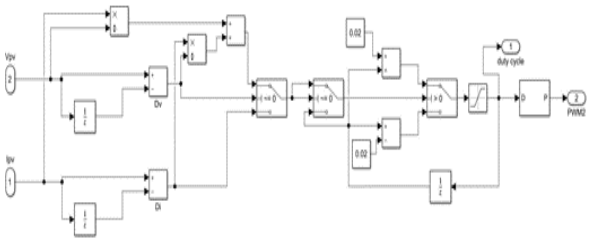

Fig.10. Simulation Model of Incremental Conductance method

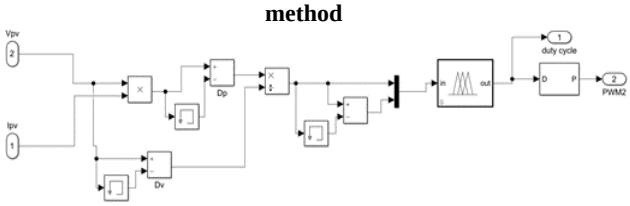

Fig.11. Simulation Model of Fuzzy Logic Control Method

For the fuzzy control the inputs are takes as error (DP/DV) and change in error (i.e. change in DP/DV) and the membership values for input and output are shown in Figure 12 , Figure 13 ,Figure 14

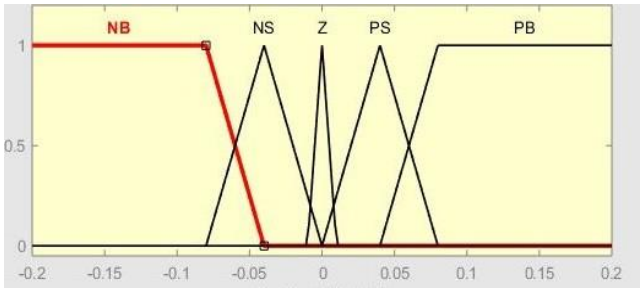

Fig.12. Membership function of DP/DV

The rule base in Mamdani fuzzy control method to get the maximum power for a given PV System with different radiance and temperature is as shown in Table I

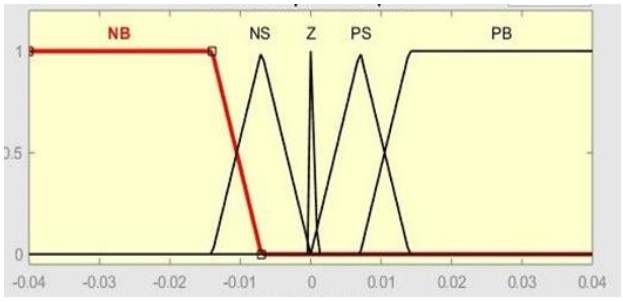

Fig.13. Membership function for change in DP/DV

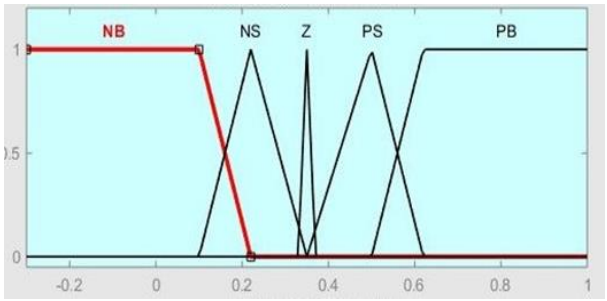

Fig.14. Membership function for output of fuzzy control

TABLE I
RULE BASE FOR PV FUZZY CONTROL

$\frac{Dp}{Dv}$ Change in $\frac{Dp}{Dv}$	NB	NS	Z	PS	PB
NB	PB	PS	NB	NS	NS
NS	PS	PS	NB	NS	NS
Z	NS	NS	NS	PB	PB
PS	NS	PB	PS	NB	PB
PB	NB	NB	PB	PS	PB

The voltage, Current and power wave forms of PV model with Boost converter with different MPPT techniques are shown in Figures 15, Figure 16,Figure 17

With the above results we can observe that the voltage, Current and Power of a PV system with Boost converter is increased in Fuzzy control method when it is compared with P & O and ICM The time response analysis can be observed from the following Figure 18, where the voltages of all the MPPT methods are analyzed.

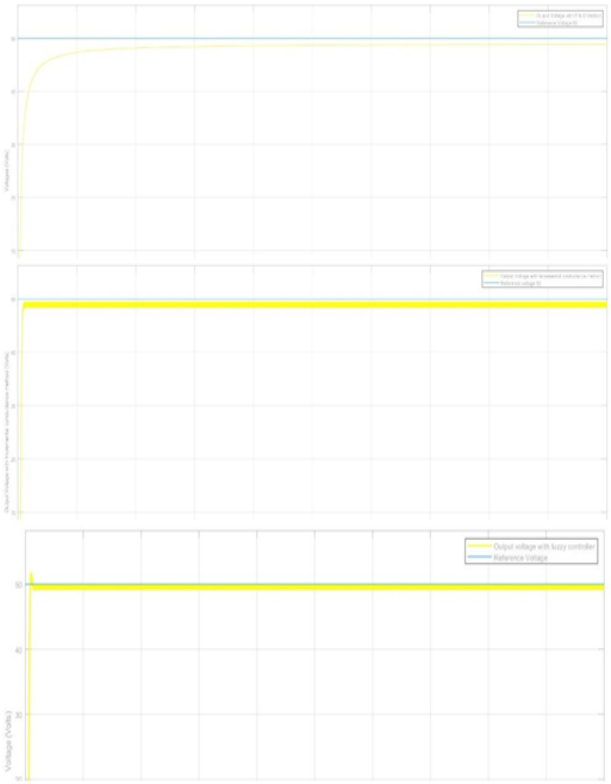

Fig.15. Output Voltage of boost converter with P & O, ICM and Fuzzy control method

Fig.16. Output current of boost converter with P & O, ICM and Fuzzy control method

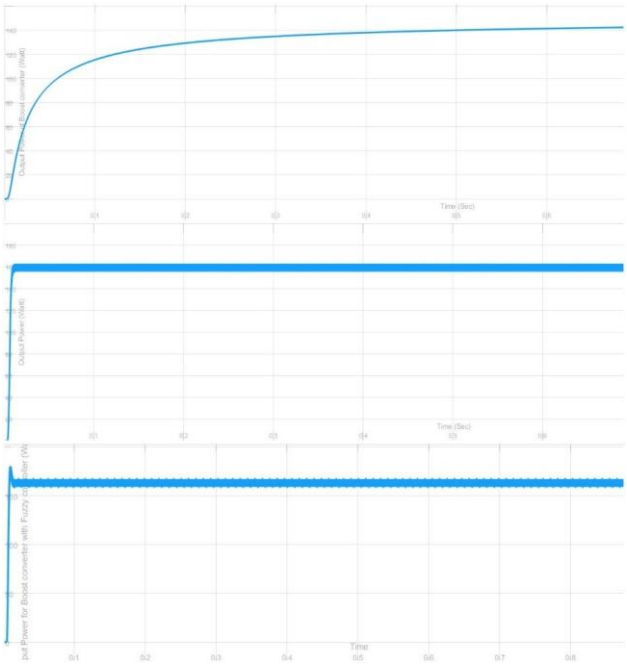

Fig.17. Output power of boost converter with P & O, ICM and Fuzzy control method

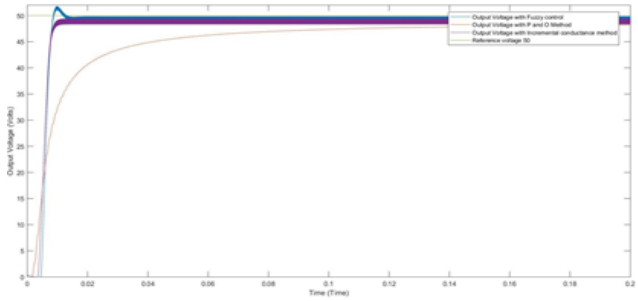

Fig.18. Time response of boost converter output voltage with P & O, ICM and fuzzy control method

The following Table 2 shows the comparison among the three MPPT techniques in all aspects

S. No.	MPPT Method	Peak Time (Sec)	Settle Time (Sec) (5%)	Settle Time (Sec) (2%)	Voltage (Volts)	Current (Amp)	Power (Watt)
1	Perturb & Observe Method	0.14 Sec	0.16 Sec	Not settled with 2%	46 Volts	3.1 Amp	144 Watt
2	Incremental Conductance Method	0.005 Sec	0.01 Sec	0.012 Sec	47.5 Volts	3.3 Amp	160 Watt
3	Fuzzy Logic Control	0.003	0.008 Sec	0.01 Sec	49 Volts	3.4 Amp	170 Watt

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V. CONCLUSION

In this paper different MPPT techniques are compared with respect to Simulation results to get the maximum output Voltage, Current and power, and from the results it is observed that the Voltage, current and power of PV System with Boost converter using Fuzzy logic control method is better than the results of PV system with Perturb and Observe method and Incremental conductance method.In future the same PV system can be compared with respect to Neuro Network Method, Neuro Fuzzy Control method and ANT colony method.

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