European Journal of Applied Sciences 9 (3): 124-132, 2017
ISSN 2079-2077

DOI: 10.5829/idosi.ejas.2017.124.132

Performance Analysis of MPPT Algorithms for PV Array Fed Sepic Converter

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Abstract: This work deals with the application of Maximum Power Point Tracking (MPPT) Algorithm like Perturb and Observe and the Incremental Conductance algorithms for photovoltaic (PV) applications using MATLAB/SIMULINK. These algorithms are applied to a Single Ended Primary Inductor Converter (SEPIC) using a mathematical model. The proposed methodology algorithm can be expanded to a various class of converters which is capable for photovoltaic applications. The SEPIC converter provides the close loop characteristics. The mentioned algorithms i.e. Perturb and Observe and Incremental Conductance algorithms are compared in terms of their fastness and error for the proposed Single Ended Primary Inductor Converter.

Key words: Photovoltaic (PV) · Maximum power point tracking (MPPT) · SEPIC converter · Perturb and Observe (P&O) · Incremental Conductance (INC).

INTRODUCTION

Now a day, Renewable energy resource are becoming popular as they provide major part energy to energy of less consuming building [1]. Between the all renewable energy resource, solar power systems plays a vital role since they gives better opening to generate power and continues to grow in popularity [2, 3].

Photovoltaic (PV) array has variety of applications such as the power house appliances, solar car and aircrafts. The solar panel output power changes in fraction of seconds due to rapid climatic changes like weather condition rises or reduce in ambient temperature [4].

In the lower efficiency of solar module, various techniques are introduced, the recent idea known as "maximum power point tracking" (MPPT). The MPPT algorithms are used to improve the output power of the PV panel. In the development of solar panels, maximum power point tracking algorithm is the electronic method of electrical load to attain the highest obtainable power, during second to second changes in sun light, shadow, heat from the sun and solar PV system features. The single ended primary inductor converter (SEPIC converter) is used. The converter is used to avoid the fluctuation that is obtained by the solar panel output. This converter is connected between the load and the PV panel [5, 6]. The controller is used to trace the peak power of PV panel and control action is taken in the PV systems thereby improving efficiency of the overall systems.

This paper proposes a control scheme, how hill climbing and incremental conductance algorithms are used to track peak power obtained from solar panel that can be used to operate the load using SEPIC converter.

Proposed Methodology: The proposed system block diagram is shown in Fig. 1. This strategy of power production contains of PV panel, SEPIC converter, perturb and observe/incremental conductance controller. The PV array converts the sun light into electrical power. The generated power is fed to the SEPIC converter and the activating pulse to the converter is given by perturb and observe algorithm or incremental conductance algorithm. The MPPT algorithm will continue until maximum power obtained from PV panel. Hence the load is sustained to operate at peak power.

Photovoltaic Model: Photovoltaic array is designed in series/shunt combination of solar cells [7], the circuit representation is shown in Fig. 2.

The current cell equation is given by,

$$I = I_L - I_D \quad (1)$$

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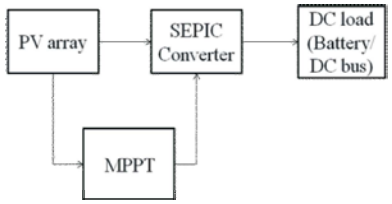

Fig. 1: Block diagram of the proposed methodology

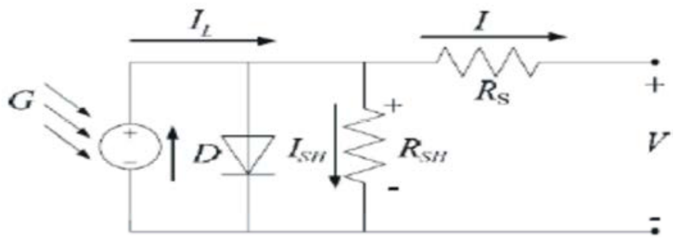

Fig. 2: Simplified circuit of PV panel

The current diverted through diode is given by,

$$I_D = I_o\left[\exp\left(\frac{V + IR_s}{nkT/q}\right) - 1\right] \quad (2)$$

The current source that delivers short circuit current. The resistance is connected in series and parallel with the current source. The diode is connected parallel with the source that provides the p-n junction. That will provide either voltage or current. The current I_d is produced which is called diode current or dark current.

where the symbol are given as follows,

I_o – Reverse saturation current, A
n – Diode ideality factor
T – Absolute temperature
e – Electron charge (1.602*10-19 C)
q – Elementary charge
k – Boltzmann constant (1.38*10-23 J/K)
I_D – Diode current, A
I_L – Photo generated current, A
R_s – Series resistance of cell

Proposed Converter: While choosing an MPPT algorithm, the important thing is to select and design a very good converter, which is operated as the major part of MPPT. The switching mode supply DC-DC converter efficiency is mostly used. The high efficiency is obtained by using switching mode power supply [8].

Among the entire converters available, single ended primary inductor converter (SEPIC) is a DC-DC converter which is most efficient and popularly used. It can be work in all modes such as continuous, discontinuous, or boundary condition mode. The duty cycle of the SEPIC converter is controlled by the control transistor [9-12]. SEPIC converter has low ripple and no pulsating. It improves the tracking efficiency of the solar PV array. SEPIC's are useful in battery voltage that can vary the regulator's calculated output. A SEPIC converter consists of a coupling capacitor, C_1 and output capacitor, C_2, coupled inductors L_1 and L_2 and diode as shown in Fig. 3.

Fig. 4 shows the converter when switch is on. The input voltage source is obtained by charging the inductor L_1 at this time. The energy is drawn from the inductor L_2 through the capacitor C_1 and the output capacitor is obtained by the load current. The load capacitor does not supply energy at that time. The polarity of the Inductor current and capacitor voltage are also decided.

Fig. 5 shows the converter when the switch is off, the current given to load system is obtained by charging the capacitor C_1 by inductor L_1. The load will be connected to the inductor L_2 at that time. This operation is done when the output capacitor will capture a current pulse, basically noisier than a buck converter. The SEPIC converter is most efficient and it will track maximum efficiency in solar array.

The duty cycle is formulae by,

$$Dmin = \frac{Vout + Vd}{Vin(max) + Vout + Vd} \quad (3)$$

$$Dmax = \frac{Vout + Vd}{Vin(min) + Vout + Vd} \quad (4)$$

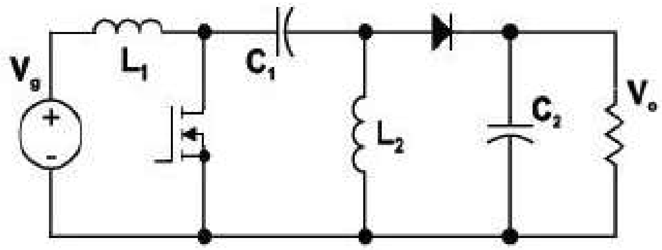

Fig. 3: SEPIC converter circuit diagram

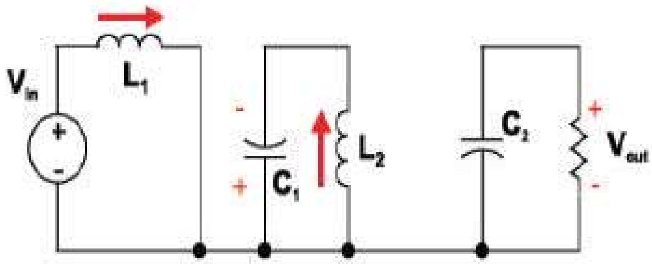

Fig. 4: SEPIC converter when switched ON

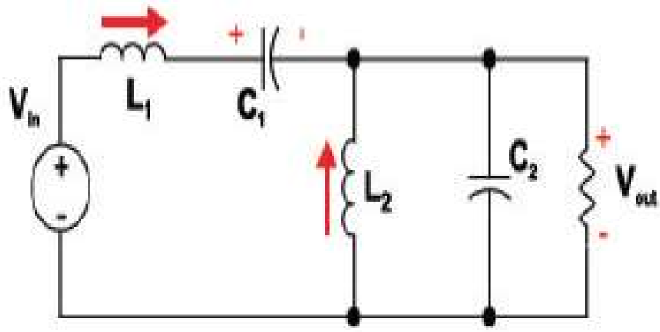

Fig. 5 SEPIC converter when switched OFF

Proposed Algorithm: There are wide number of algorithms used to trace maximum power. Some of the algorithms are simple and easy, such as current and voltage method and some are more difficult, like hill climbing (P&O) and incremental conductance (INC) method. These algorithm changes in steady state, sensor essential, occurrence of speed , price, range of performance, acceptance, to perform more versatile and its uses [10, 11].

P&O algorithm is the easier method. In this only one sensor is used, i.e. voltage sensor, to sense the solar panel voltage and the price of operation is lower. So it is easily implemented.

INC conductance method is the one which is widely used in all type of weather conditions. In this topology, the output voltage of the solar cell is varied depend upon the peak power voltage. According to the incremental and instantaneous conductance the PV system is established.

Perturb and Observe MPPT: The P&O algorithm is also called as hill climbing method. This method is most widely used. The implementation of this method is easy and cost is less. This method will do track sudden changes and it will not reach maximum power. At the maximum power it rises or reduced repeatedly depends upon the reference voltage and current.

During $dP/dV>0$ the MPPT algorithm will trace maximum power available in solar cell. This method will continue to track in the same direction. During $dP/dV<0$ it will track above the maximum power obtained in solar cell. This topology will reverse the direction of search. This topology results in unstable output power. The algorithm is obtained in MATLAB/Simulink.

Incremental Conductance MPPT: The output power from the solar PV is obtained by the incremental conductance method in reference to the voltage and the peak power will be equivalent to zero.

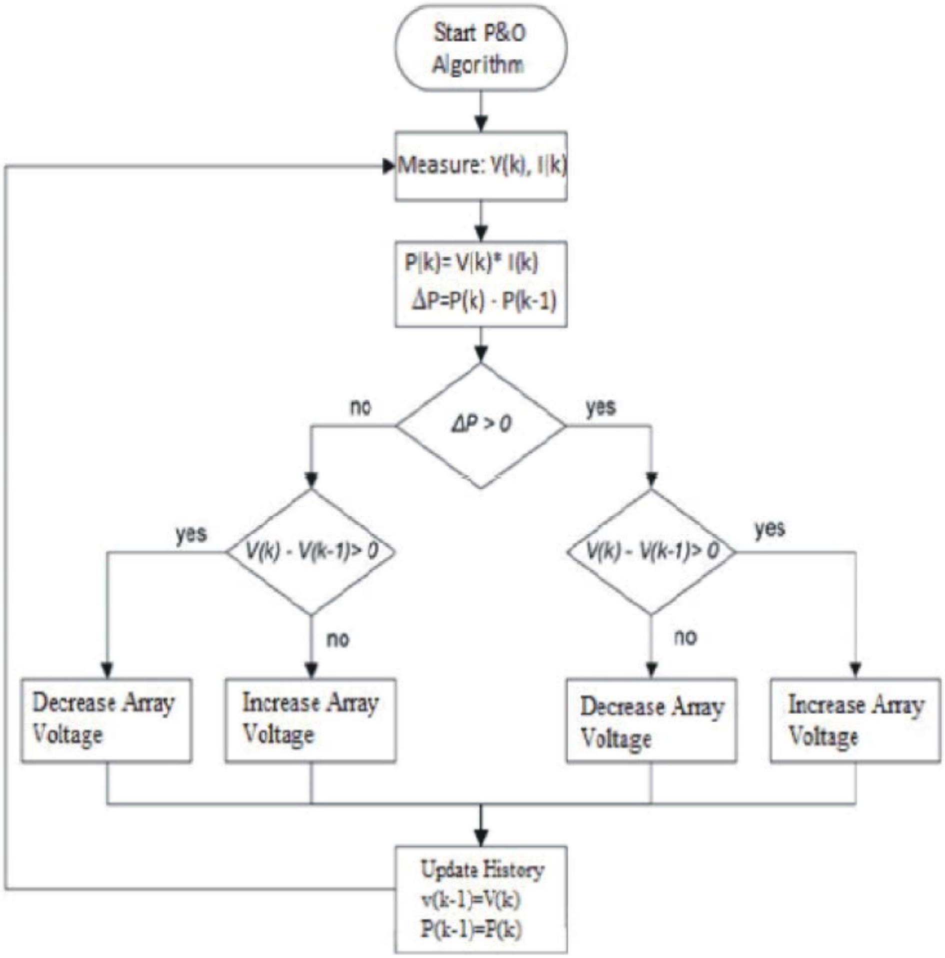

Fig. 6: Flowchart of P&O MPPT method

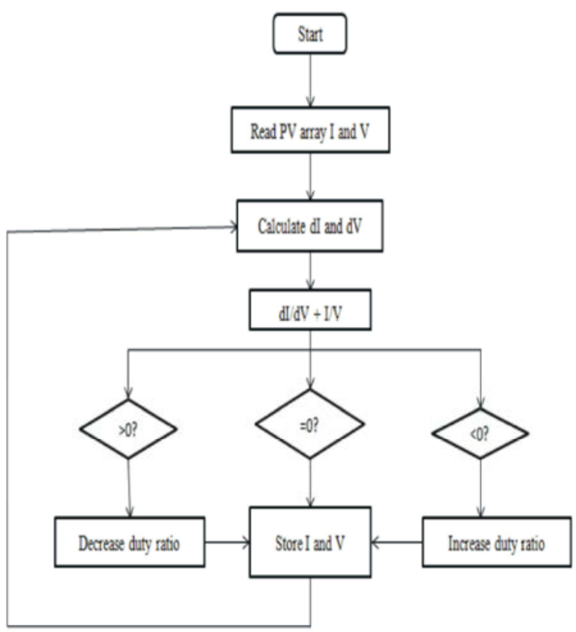

Fig. 7: Flowchart of INC MPPT method

$$\frac{dP}{dV} = \frac{(dIV)}{DV} = 1 + V\frac{dI}{dV} = 0 \quad (5)$$

$$\frac{-1}{V} = \frac{dI}{dV} \quad (6)$$

The Eqn. (5) denotes the instantaneous and incremental conductance of PV array. In peak power, the parameters should be same in magnitude, but different polarities. The eqn. (6) that indicates the peak power voltage will be higher or lower the operating voltage. This relation is shown in eqns. (7, 8, 9).

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V} \text{ at the MPP} \quad (7)$$

$$\frac{\Delta I}{\Delta V} > -\frac{I}{V} \text{ Left of the MPP} \quad (8)$$

$$\frac{I}{\Delta V} < -\frac{I}{V} \text{ Right of the MPP} \quad (9)$$

The present and earlier value is calculated using dI and dV of the PV voltage and current. This incremental conductance method has an advantage that it can achieve the peak power and it also find out when it reaches the peak power. This method does not oscillate around the peak power point.

Simulation Result: The proposed system consists of the PV circuit model, SEPIC converter, MPPT algorithm and it is designed using MATLAB as shown in Fig. 8. The PV panel output power is determined by the electrical circuit model of solar array. The PV array that provides voltage and current is given to the converter and controller simultaneously. The SEPIC converter will adjust the duty cycle directly.

Simulation Result for P&O Method: The simulink for P&O algorithm is shown in Fig. 9. The PV panel voltage and current is given to MPPT, that will track maximum peak power and the pulse is given to SEPIC converter.

The algorithm is verified by using the temperature and irradiance. The MPPT output and output power waveforms will be obtained according to its temperature and irradiance. The waveforms are shown below.

- At constant temperature (T=25°) with the changes in irradiation (S=800 to 600w/m^2)

Fig. 10 shows two waveforms i.e. MPPT output and output power. If the temperature is reduced means, power will start to increase. Here T=25° so power starts to increase. If the irradiation increase means, the output power will increase. In P&O, the output power will not be steady.

- At constant temperature (T=70°) with the changes in irradiation (S=800 to 600w/m^2)

Fig. 12 shows two waveforms i.e. MPPT output and output power. If the temperature is increased means, power will starts to reduce. Here T=70° so power starts to reduced when compared to Fig. 10. If the irradiation increase means, the output power will increase.

Simulation Result for Inc Method: The simulink for INC conductance algorithm is shown in Fig. 10. The first step is to read the PV array voltage and current. The next step is to calculate present and previous voltage and current in maximum peak power (MPP). By summing the present value and previous value, if it is greater than zero means duty ratio is reduced, if it is less than zero means duty ratio is increased, if it is equal to zero means voltage and current will be stored. This process is done until it gets maximum power output.

- At constant temperature (T=25°) with the changes in the irradiation (S=800 to 600w/m^2)

Fig. 15 shows two waveforms i.e. MPPT output and output power. If the temperature is reduced means, power will starts to increase. Here T=25° so power starts to increase. If the irradiation increase means, the output power will increase. In INC, the output power will be steady.

- At constant temperature (T=70°) with changes in the irradiation (S=800 to 600w/m^2)

Fig. 17 shows two waveforms i.e. MPPT output and output power. If the temperature is increased means, power will start to increase. Here T=70° so power starts too reduced when compared with Fig. 15. If the irradiation increase means, the output power will increase.

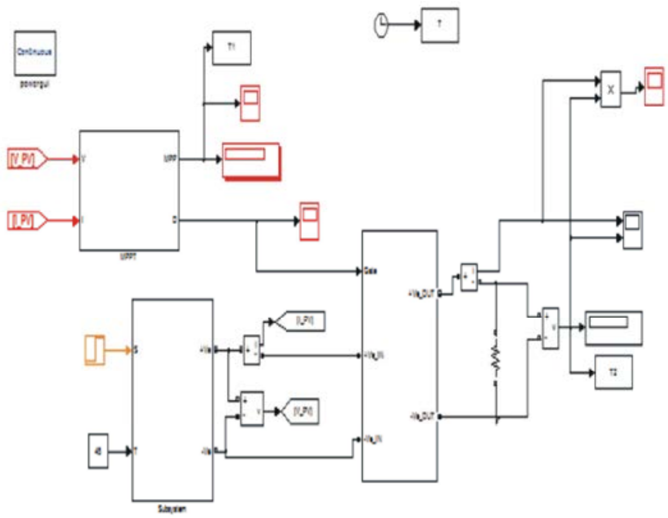

Fig. 8: Simulink diagram for proposed system

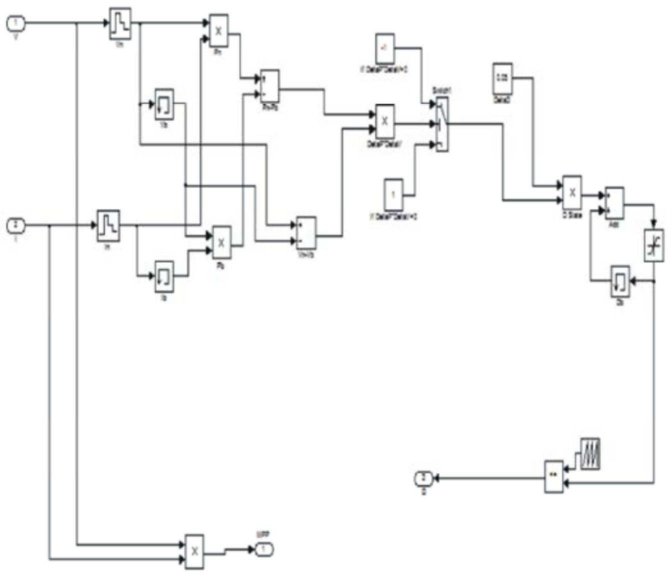

Fig. 9: Simulink of P&O algorithm

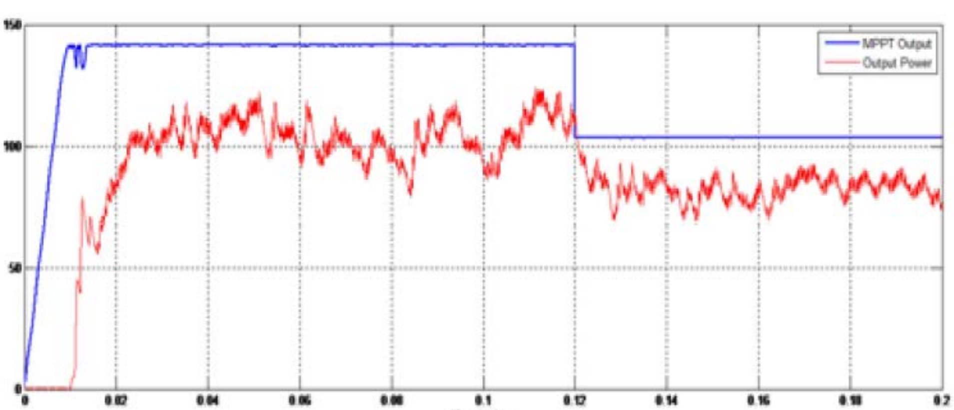

Fig. 10: MPPT output and output power waveform (T=25° and S=800 to 600w/m^2)

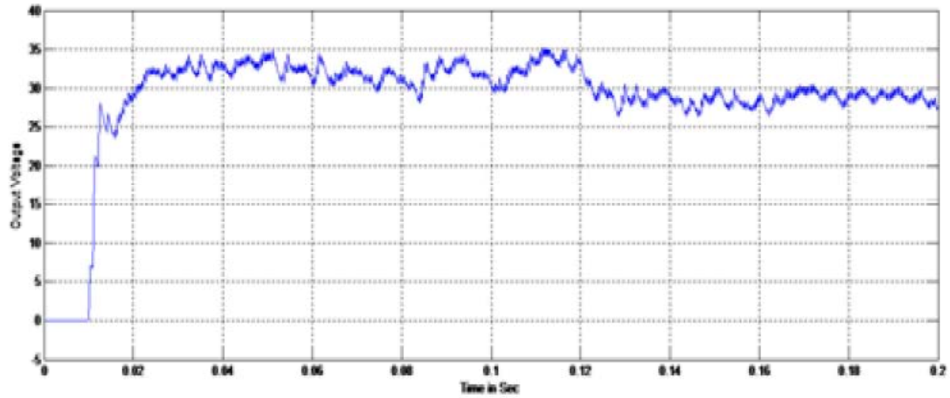

Fig. 11: Output voltage waveform (T=25° and S=800 to 600w/m^2)

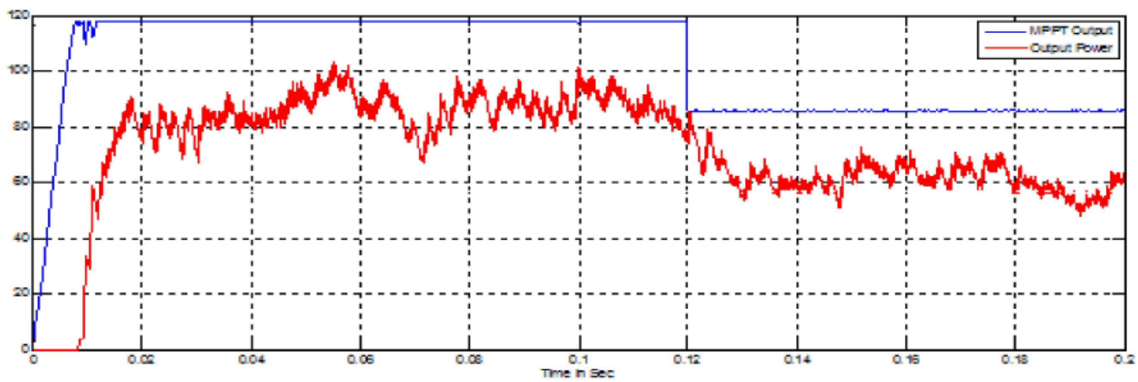

Fig. 12: MPPT output and output power waveform (T=70° and S=800 to 600w/m^2)

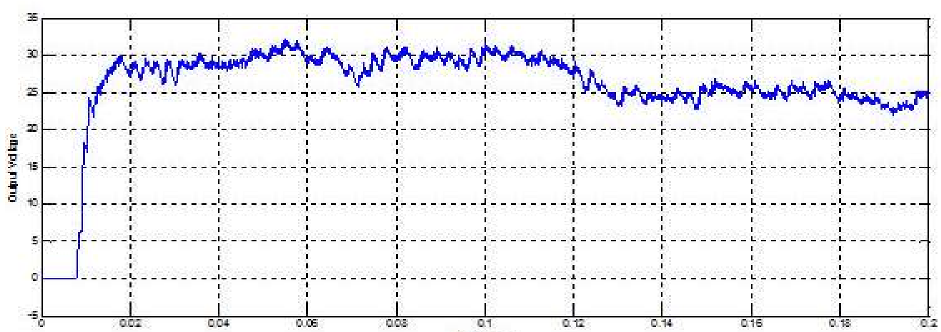

Fig. 13: Output voltage waveform (T=70° and S=800 to 600w/m^2)

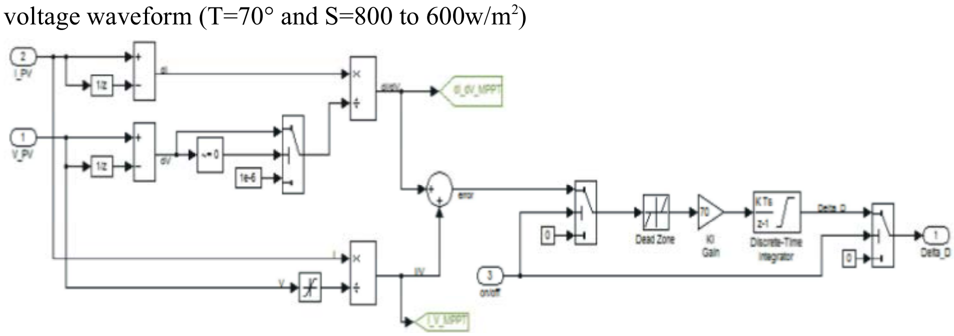

Fig. 14: Simulink of the INC algorithm

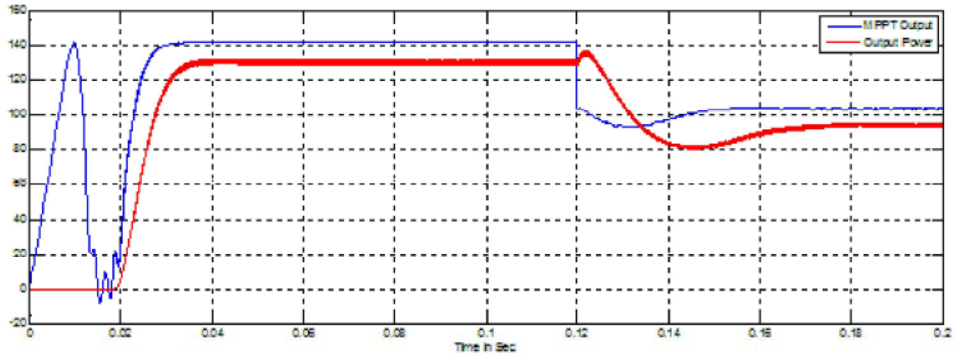

Fig. 15: MPPT output and output power waveform (T=25° and S=800 to 600w/m^2)

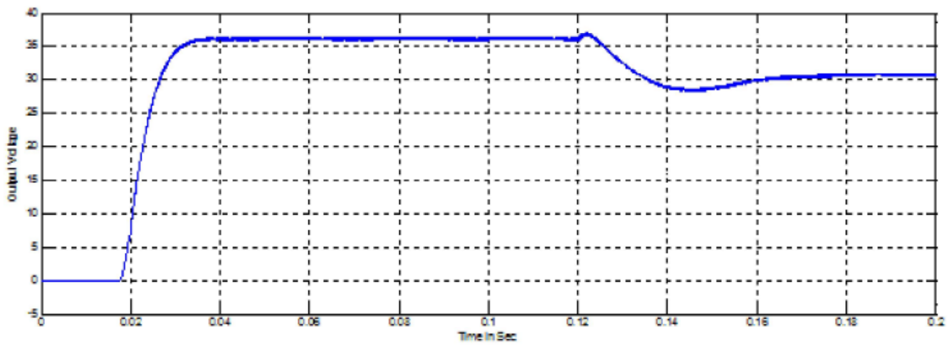

Fig. 16: Output voltage waveform (T=25° and S=800 to 600w/m^2)

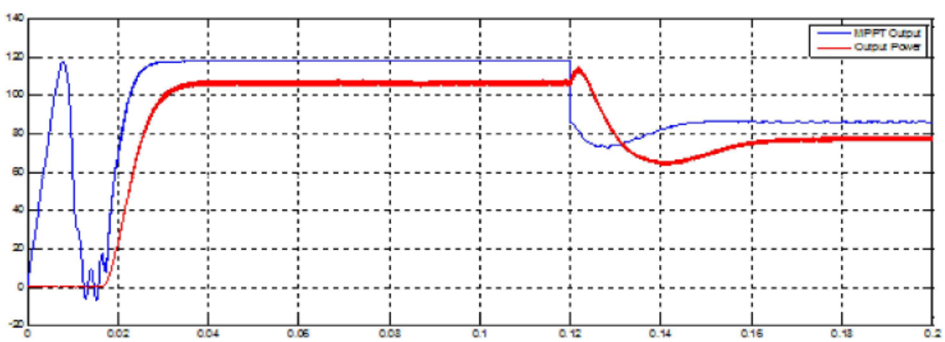

Fig. 17: MPPT output and output power waveform (T=70° and S=800 to 600w/m^2)

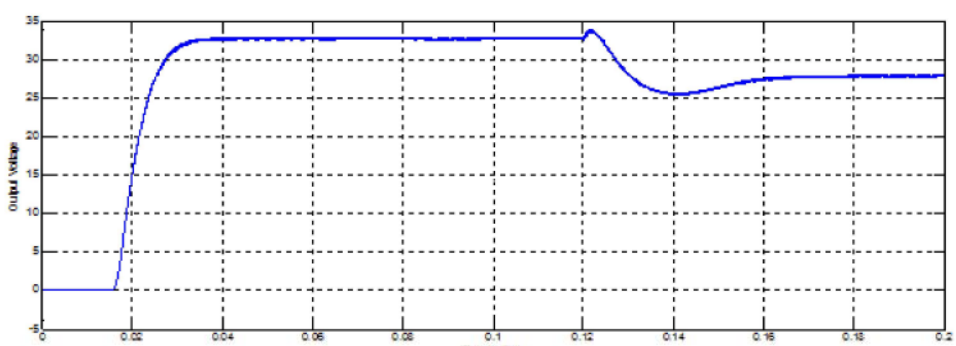

Fig. 18: Output voltage waveform (T=70° and S=800 to 600w/m^2)

CONCLUSION

This project presented the application of various Maximum Power Point Tracking (MPPT) like Perturb & Observe and Incremental Conductance Algorithms for photovoltaic (PV) applications using MATLAB/ SIMLINK. These algorithms are applied to a Single Ended Primary Inductor Converter (SEPIC) using a mathematical model. The above algorithms i.e. Perturb & Observe and Incremental Conductance Algorithms are compared in terms of their fastness and error for the proposed Single Ended Primary Inductor Converter.

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