INCREMENTAL CONDUCTANCE BASED MPPT FOR PV SYSTEM USING BOOST AND SEPIC CONVERTER

Rahul Pazhampilly, S. Saravanan and N. Ramesh Babu
School of Electrical Engineering, VIT University, Vellore, Tamil nadu, India
E-Mail: rahul.pazhampilly@gmail.com

ABSTRACT

Maximum power point tracking (MPPT) algorithm increases the solar energy efficiency of a solar PV systems. Incremental conductance based MPPT technique is used to track maximum power point exactly with fast response. The Incremental conductance method search the exact MPP based on the feedback voltage and current but does not depend on the characteristics of PV array. The MPPT algorithm is implemented in PV based power generation systems along with two different DC-DC converters to boost up the output voltage. The working of proposed algorithm is checked by simulation using Matlab/Xilinx system generator. The performance of the algorithm with boost converter is validated and compared with SEPIC and the conclusions were drawn at the end of this paper.

Keywords: maximum power point tracking (MPPT), photovoltaic (PV), incremental conductance (IncCond), boost converter, SEPIC.

1. INTRODUCTION

The major concern in the power sector is the increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard.

Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power rural areas where the availability of grid is very low. Another advantage of using solar energy is the portable operation whenever and wherever necessary.

In order to tackle the present energy crisis one has to develop an efficient manner in which power has to be extracted from the incoming solar radiation. The use of the newest power control mechanisms called the Maximum Power Point Tracking (MPPT) algorithms leads to the increase the efficiency of operation of the solar modules and is effective in the field of utilization of renewable sources of energy. MPPT algorithm controls the power converters to continuously detect the instantaneous maximum power of the PV array [1-2].

2. PV PANEL MODELING

A photovoltaic cell is a device which converts light energy to electrical energy. If band gap is less than energy of photon of light, electron is emitted and creates current. Photovoltaic cell is forward biased [3]. A group of photovoltaic cell is called as PV module. PV modules are arranged in series and parallel to get modules different sizes that ranges from 60W to 170W. In this paper the solar panel is designed for 60W.

A PV array consists of a number of photovoltaic cells in series and parallel connections. Series connections increases the voltage of the module, and in parallel increases the current in the array [4]. Considering only a single solar cell; it can be modeled by utilizing a current source, a diode and two resistors. This model is known as a single diode model of solar cell which is shown in Figure-1.

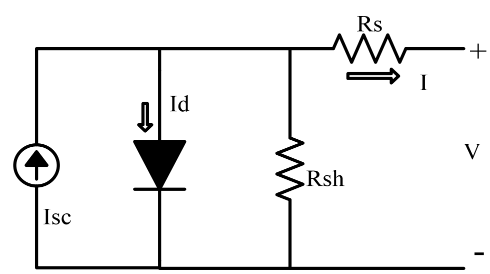

Figure-1. Circuit diagram of the PV model.

The characteristic equation for a photovoltaic cell is given by
eqn(7)

$$I = I_{pv} - I_s\left(\exp\frac{q(V+R_sI)}{N_skTa} - 1\right) - \frac{V+R_sI}{R_p} \quad (1)$$

Where

I_{pv} = PV Current (A)
I_s = Saturation Current (A)
q = Electron Charge (1.60217×10-19 C)
k = Boltzmann constant (1.38065×10^{-23} J/K)
a = Diode ideality constant
R_s = Series Resistance of cell (Ω)
R_p = Parallel Resistance of cell (Ω)
N_s = No. of Cells in series
T = Temperature (K)

To model the solar panel correctly two diode model is relevant [5]. But here it is limited to single diode model. Figure-2 shows IV curve of solar and also the P-V characteristics, when voltage and current characteristics are multiplied as shown in Figure-3. Panel power output reaches its peak at point mentioned as MPP.

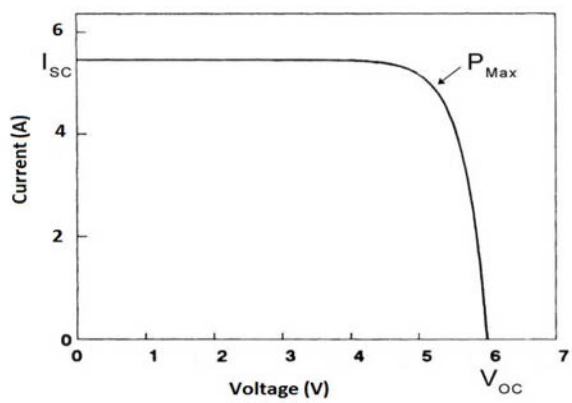

Figure-2. I-V Characteristics of a solar panel.

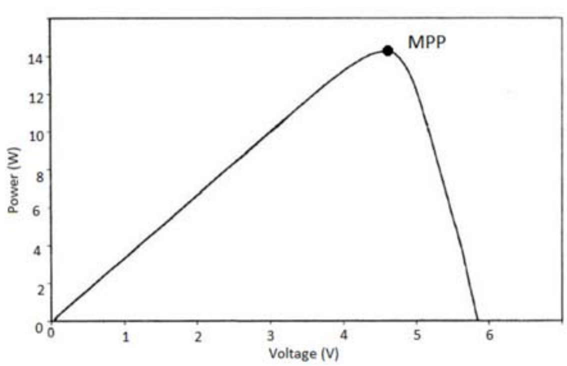

Figure-3. P-V Characteristics of a solar panel.

3. MAXIMUM POWER POINT TRACKING

MPPT increases the efficiency of the solar panel. A normal solar panel can convert nearly 40% of incident solar energy into electrical energy. The MPPT is done by matching source impedance with the load impedance. So impedance matching should be clearly done to get maximum power point [5, 6]. We are using boost converter connected to a solar panel to increase the output voltage which has to be given to load side. There are different methods to implement the MPPT algorithm and the incremental conductance is the simplest method among all.

A) Incremental conductance method

This method uses the incremental conductance dI/dV to compute the sign of dP/dV [6-10]. When dI/dV is equal and opposite to the value of I/V the algorithm knows that maximum power point has reached and there it ends and returns the corresponding value of operating voltage for MPP. One problem is that it requires many sensors like voltage and current to operate. The proposed algorithm is shown in Figure-4, and Figure-5 shows the implementation of the algorithm in Xilinx system generator tool. The power of the panel is,

$$P = V * I \tag{2}$$

Differentiating with respect to voltage

$$\frac{dP}{dV} = d(V * I) \tag{3}$$

$$\frac{dP}{dV} = I + V * \frac{dI}{dV} \tag{4}$$

When the maximum power point reaches zero then the condition will be:

$$\frac{dP}{dV} = 0 \tag{5}$$

Substitute Equation (4) in (5)

$$I + V * \frac{dI}{dV} = 0 \tag{6}$$

$$\frac{dI}{dV} = -\frac{I}{V} \tag{7}$$

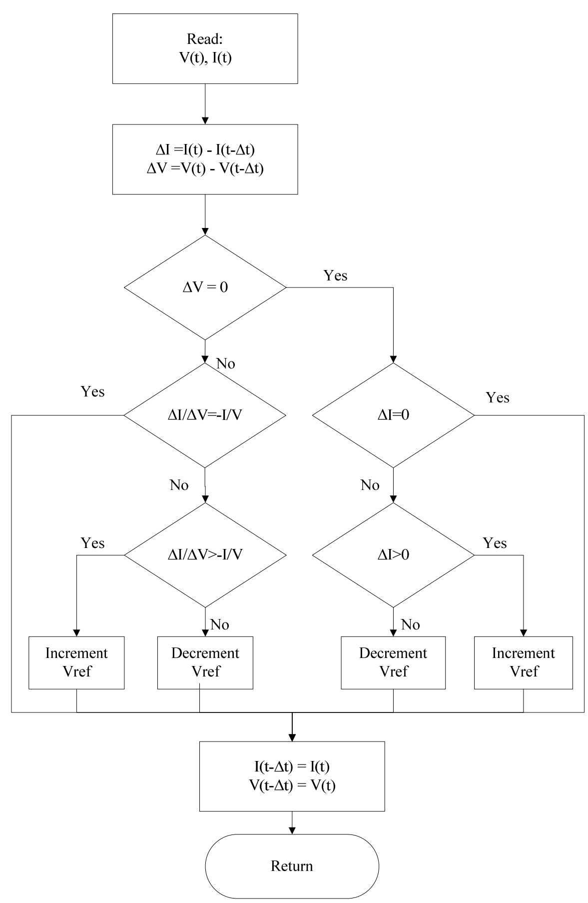

Figure-4. Incremental conductance algorithm.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

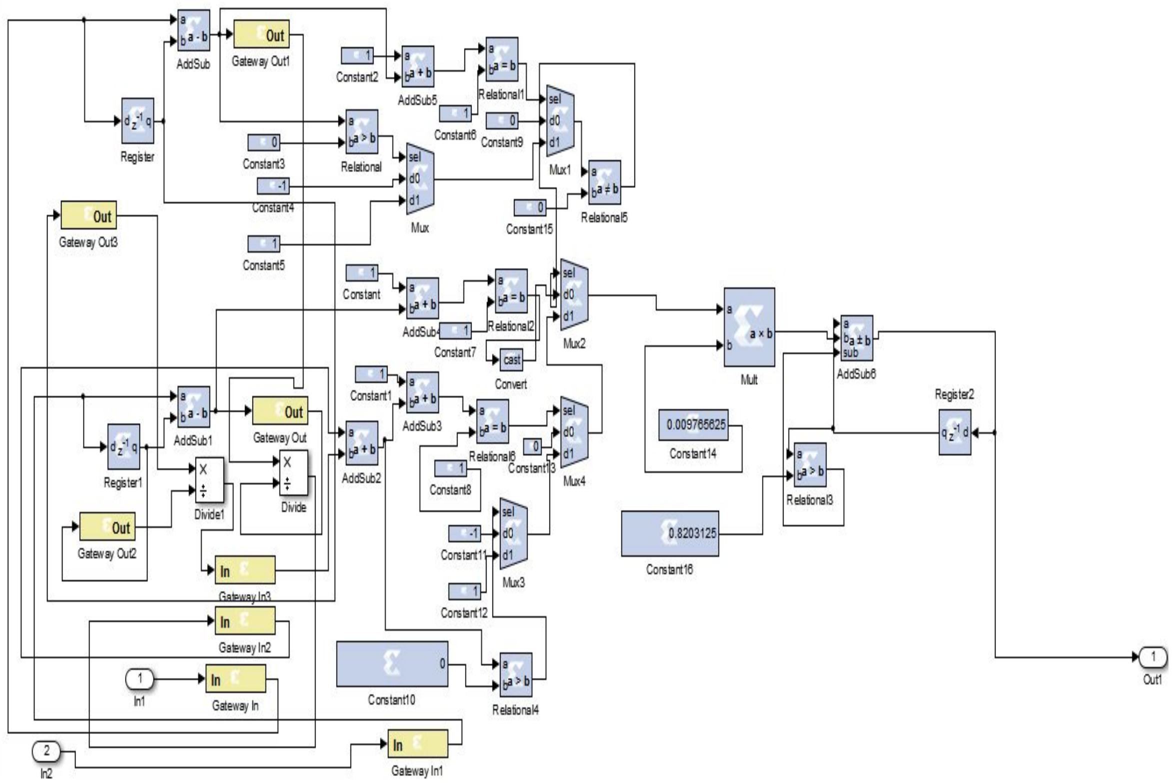

Figure-5. Implementation of Incremental conductance algorithm in Xilinx system generator toolbox.

In this method the MPP is reached by comparing incremental conductance with instantaneous conductance. In this flowchart (Figure-4) if change in voltage is not equal to zero then incremental conductance is compared with instantaneous conductance. If both are equal, then it gets terminated and returns the desired value. If not, both are made equal by increasing or decreasing reference voltage. Once the MPP is reached, the point is maintained until change in irradiance, temperature occurs.

The problem with Incremental conductance method is that the operating point keeps on oscillating for larger increment and for smaller increment time to track MPP is longer.

4. DC/DC CONVERTER

The performance of the PV system is compared between boost converter and SEPIC converter. The performance is checked under the temperature and irradiance changes. Both the converters are used to step up the output voltage.

A. Boost converter

A DC to DC converter is required to vary the duty cycle in order to change the input resistance of the panel to match the load resistance [11]. In this study we use boost converter as shown in Figure-6.

At first stage, when the switch is closed inductor gets charged through the battery and stores the energy. Generally the current in the inductor rises exponentially, but to make it simple we consider charging and discharging of the inductor are linear. Here the load current remains constant which is being supplied due to discharging of the capacitor.

In second stage switch is opened. Here the diode becomes short circuited. The capacitor gets charged through the energy stored in the inductor which is discharged through opposite polarities. Throughout the operation the load current remains constant.

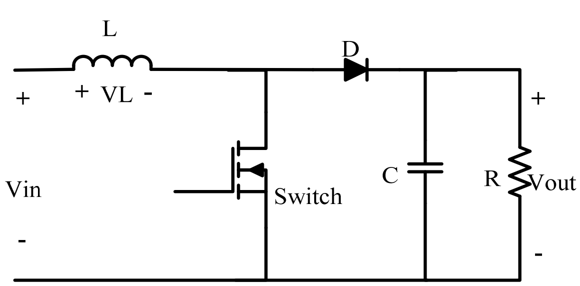

Figure-6. Circuit diagram of Boost converter.

VOL. 10, NO. 7, APRIL 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

B. SEPIC converter

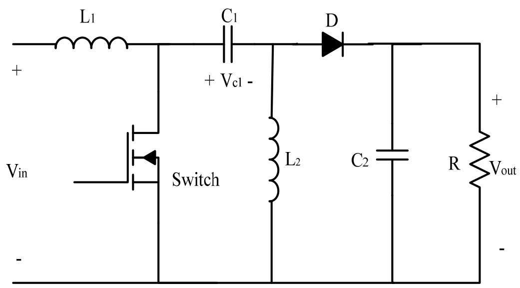

Figure-7. Circuit diagram of SEPIC converter.

The circuit diagram of the SEPIC converter is shown in Figure-7. It can produce input voltage which is greater or lesser than output voltage with no polarity change. The duty cycle of converter is given by the equation (8).

$$D = \frac{V_0}{V_0 + V_S} \tag{8}$$

The inductors value for L_1 and L_2 are given by the Equation (9, 10),

$$L_1 = \frac{V_S D}{\Delta i_{L1} . f} \tag{9}$$

$$L_2 = \frac{V_S D}{\Delta i_{L2} . f} \tag{10}$$

The capacitances values are given by,

$$C_1 = \frac{D}{R(\Delta V_{C1} / V_0) f} \tag{11}$$

$$C_2 = \frac{D}{R(\Delta V_0 / V_0) f} \tag{12}$$

Where
V_S = Output Voltage
V_0 = Input Voltage
D = Duty Cycle
f = Switching Frequency
□iL = Inductor ripple current
□V0` = Ripple Voltage

5. RESULTS AND DISCUSSIONS

Figure-8 shows the basic block diagram of the whole PV based power generation system. In this we have PV panel, MPPT algorithm, DC/DC converters and finally connected with the load. As mentioned above in the previous section, the controller is designed in XILINX system generator and the results are validated using two converters; boost converter and SEPIC converter. The converter output voltage and the PV panel voltage of both the converters are shown in Figure-9 and Figure-10 respectively. The results are validated using temperature and irradiance change. Figure-9 and Figure-10 shows how the controller responses during irradiance change in both boost and SEPIC respectively. Comparing the outputs, the boosted voltage is more in SEPIC converter than that of normal boost converter. Moreover rising time is less, i.e. time to reach maximum voltage is less for the same than normal boost converter. During the period of 0.3 sec to 0.4 sec the irradiance values have been varied in both boost and SEPIC converter to check the tracking of controller. The result shows the voltage of SEPIC converter drops more and settles quickly when compared to boost converter.

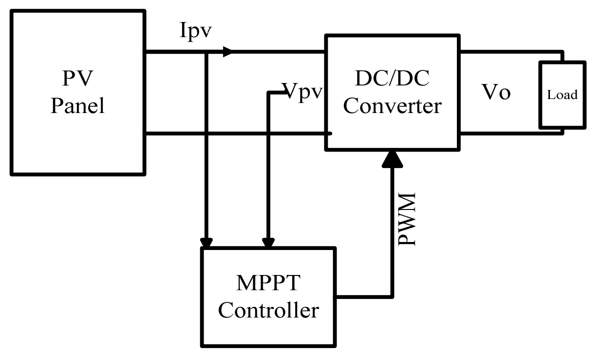

Figure-8. General overview of simulation model.

Table-1. Numerical value of simulation results.

Parameters	Normal condition		Irradiance change period (0.3-0.4 sec)	
	Boost	SEPIC	Boost	SEPIC
V_{in} (V)	20	20	15-19	13-19
V_{out} (V)	90	95	79-90	70-94
I_{in} (A)	7	5.5	6.1	4.1
I_{out} (A)	.55	.59	.55-0.49	.59-0.42

Table-2. Numerical value of system design.

Parameters	Design values	
	Boost	SEPIC
Inductance	63.75e-6	L_1=144.933e-6 L_2=144.933e-6
Capacitance	21.23e-6	C_1=1.859e-6 C_2=21.54e-6
Resistance	166.67	166.67

VOL. 10, NO. 7, APRIL 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

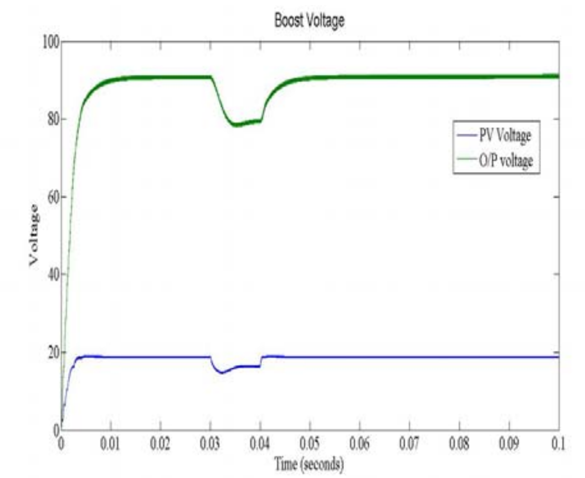

Figure-9(a). Output voltage of Boost converter during changing condition.

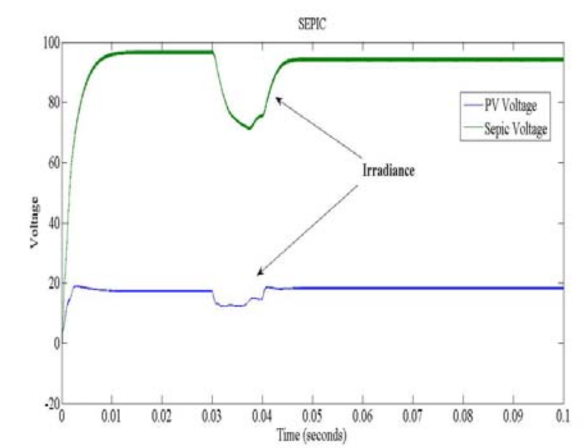

Figure-9(b). Output voltage of SEPIC converter during changing condition.

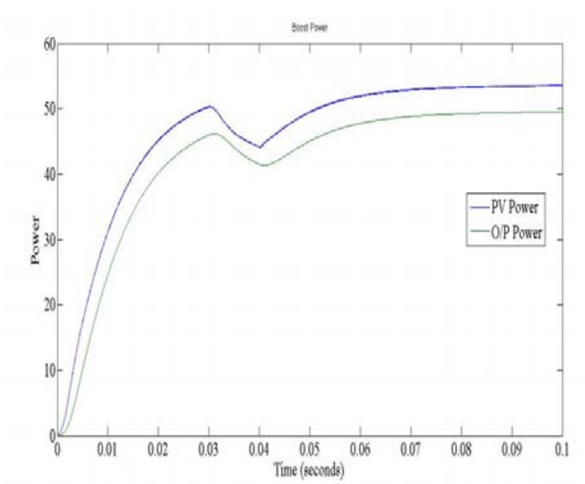

Figure-10(a). Output power of Boost converter during changing condition.

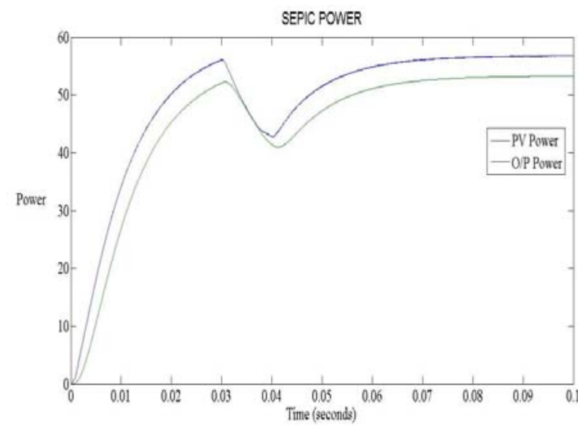

Figure-10(b). Output power of SEPIC converter during changing condition.

6. CONCLUSIONS

When comparing the voltage graph of the two converters, SEPIC converter gives more voltage with lesser time compared to normal boost converter, and also output power is more in the case of SEPIC converter. The MPPT algorithm is designed using Xilinx system generator and implemented for validation. From the discussions it can be concluded that the SEPIC converter based PV power generation along with the MPPT algorithm is more efficient than boost converter based power generation unit. In future, it is planned to implement the algorithm in hardware.

REFERENCES

[1] A.Mellit, H.Rezzouk, A.Messai, and B.Medjahed, "FPGA-based real time implementation of MPPT-controller for photovoltaic systems," Renewable Energy. vol. 36, pp. 1652-1661, 2011.

[2] Chekired, F., Larbes, C., Mellit, A., "Comparative study between two intelligent Mppt-controllers implemented on Fpga: application for photovoltaic systems", Int. J. Sustain. Energy. 31, pp. 1-17, 2012.

[3] Villalva, M.G., Gazoli, J.R.: "Comprehensive approach to modeling and simulation of photovoltaic arrays", IEEE Trans. Power Electron. 24(5), pp. 1198-1208, 2009.

[4] S.Saravanan, and N.Ramesh Babu, "Performance Analysis of Boost and Cuk Converter in MPPT based PV System," IEEE Int. Conf. on Circuit, Power and Computer Technology (ICCPCT), 2015.

[5] Mellit, A., Rezzouk, H., Messai, A., Medjahed, B.: "Fpga-based real time implementation of Mppt-controller for photovoltaic systems", Renew. Energy. 2011, 36(5), pp. 1652-1661.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

[6] Y. C. Chang, C. L. Kuo, K. H. Sun, and T. C. Li, “Development and operational control of two-string maximum power point trackers in dc distribution systems”, IEEE Trans. Power Electron. 28(4), pp. 1852-1861, 2013.

[7] Lin, C.-H., Huang, C.-H., Du, Y.-C., Chen, J.-L.: “Maximum photovoltaic power tracking for the Pv array using the fractional-order incremental conductance method”, Appl. Energy. 88(12), pp. 4840-4847, 2011.

[8] Farivar, G., Asaei, B., Rezaei, M.A.: “A novel analytical solution for the Pv-arrays maximum power point tracking problem”, IEEE Int. Conf. on Power and Energy (PECon), 2010.

[9] Mei Qiang, Shan Mingwei, Liu Liying, Guerrero Josep M., “A Novel Improved Variable Step-Size Incremental-Resistance MPPT Method for PV Systems”, IEEE Trans Ind Electron. 58(6): 2427-34, 2011.

[10] Kish, G., Lee, J., Lehn, P. “Modelling and control of photovoltaic panels utilising the incremental conductance method for maximum power point tracking”, IET Renew. Power Gener. 2012, 6(4), pp. 259-266.

[11] Leedy, A.W., Guo, L., Aganah, K.A. “A constant voltage Mppt method for a solar powered boost converter with dc motor load”, Proc. of IEEE Southeastcon, 2012.