

MPPT control of Photovoltaic using SEPIC converter to reduce the input current ripples

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ABSTRACT

This paper presents P&O control method for maximum power point tracking(MPPT) of PV system under varying irradiation and temperature conditions. This algorithm will identify the suitable duty ratio in which the DC/DC SEPIC converter should be operated to maximize the power output. In this paper, the SEPIC converter has been compared with conventional boost converter about reducing the input current ripple. Also, both converters and their control strategies have been analyzed and simulated using Simulink/Matlab software. Simulation results show that the SEPIC converter reduces input current better than conventional boost converter.

Keywords-Solar Cell – DC/DC Converter – P&O Algorithm – MPPT

I. INTRODUCTION

Solar photovoltaic energy has gained recognition as an alternative source of energy. "Photovoltaic panel maximum power point tracker" As the name implied, it is a photovoltaic system that uses the photovoltaic array as a source of electrical power supply and since every photovoltaic (PV) array has an optimum operating point, called the maximum power point, which varies depending on cell temperature, the insolation level and array voltage. A maximum power point tracker (MPPT) is needed to operate the PV array at its maximum power point[1],[2].

In this paper a technique for efficiency extracting the maximum output power from a solar panel under varying meteorological conditions is presented. The methodology is based on connecting a pulse width modulated dc/dc SEPIC converter, which is controlled by MPPT unit[3]. The main difference between the method used in the proposed MPPT systems and other technique used in the past is that PV array output power is used to directly control the dc/dc converter thus reducing the complexity of the system. The resulting system has high efficiency, low cost and can be easily modified.

II. PV MODEL

One of the most popular models that are used for photovoltaic modules, is single-diode model.the current source (I_{ph}) in parallel with a single-diode (D) and resistance (R_{sh}) and in series with a resistance (R_s) [4]. The PV emulator will be using the simplified model to simulate a solar cell. The practical mode will not be used since shunt

resistance is negligible in modules and calculations become equations that were used to model a solar cell. In this model the output current called I_{pv} and the output voltage called V_{pv} . we using the simplified model to simulate a PV module. the model is shown in

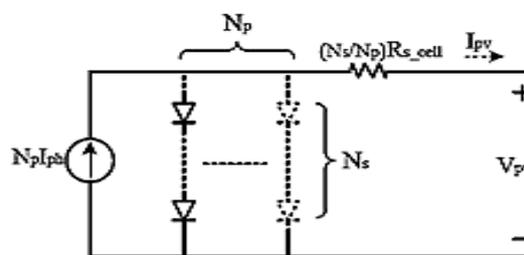


Fig.1: PVmodulesingle-diode model

N_s is the number of cells connected in series and N_p is the number of cells connected in parallel.

Most manufacturers Module PV, due to the high current produced by each cell, N_p amount equal to 1 and N_s are considered to be standard 36 or 72 .The values of I_{ph} represent photo current and I_o represents the reverse saturation current of diode, Using equations(1) and (2), respectively, and selected module characteristics are calculated. The equations I_{ph} and I_o Simulation environment Written obtained [5], [6].

$$I_{ph} = [I_{scr_cell} + k_i(T - T_r)] \frac{G}{G_r} \quad (1)$$

$$I_o = I_{rs} \left(\frac{T}{T_r} \right)^3 e^{\frac{qE_g}{AK} \left(\frac{1}{T_r} - \frac{1}{T} \right)} \quad (2)$$

Where: k_i the short circuit temperature coefficient (A/K), T is the cell temperature (K), T_r is the reference temperature (298K), G is the solar

radiation, G_r is the reference radiation($1000W/m^2$), q is the charge of an electron, E_g is the band gap energy of the semiconductor and its value is obtained from Table I, K is the Boltzman's constant in j/k , A the p-n junction ideality factor and its value is obtained from Table I, [7], [8].

Table I: Diode ideality factor and Band Gap energy

A	E_g	Cell type
1.2	1.12	Single Crystal Silicon
1.3	1.14	Multi Crystal Silicon
1.8	1.65	Amorphous Silicon
1.5	1.48	CdTe
1.5	1	CIS
1.3	1.43	AsGa

I_{scr_cell} is the cell short circuit current at the standard testing conditions(STC), where the STC is referred to the conditions with the reference solar radiation G of $1000W/m^2$ and solar cell reference temperature T of $25^\circ C$ and calculated from equation(3):

$$I_{scr_cell} = I_{scr_mod} \times \frac{1}{N_p} \quad (3)$$

I_{scr_mod} is the PV module short circuit current at reference temperature and radiation(A). E_g calculated from equation(4):

$$E_g = [1 - 0.0002677(T - T_r)] E_{gr} \quad (4)$$

E_{gr} is the constant by type of crystal constitutive[8]

I_{rs} is the reverse saturation current (A) is given by equation(5):

$$I_{rs} = \frac{I_{scr_mod}}{N_p \left(e^{\frac{qV_{oc_mod}}{N_s AKT}} - 1 \right)} \quad (5)$$

V_{oc_mod} is the greatest value of the voltage at the module terminals. The I-V characteristics of the PV module with single diode are given by:

$$I_{pv} = N_p I_{ph} - N_p I_0 \left(e^{\frac{q(V_{pv} + R_s I_{pv})}{N_s AKT}} - 1 \right) \quad (6)$$

R_{s_mod} is the series resistance and normally is small.

The series resistance effects the diode saturation current. The effects of changing R_s on the moduls I-V curve. As the series resistance is increased, the slope between the voltage at maximum power (V_{mp}) and the open circuit voltage (V_{oc}) decrease. Parameters R_s are obtained through iteration. Several researchers have estimated these two parameters independently, but the results are unsatisfactory. In this work, R_p and R_s are calculated simultaneously, similar to the procedure proposed in [9],[10]. I_{pv} is the output current and V_{pv} is the terminal voltage, here are two ways to get output photovoltaic module will be:

Get the PV module output as a current source and second, get a PV module output as a voltage source. Here, as shown in Fig.2, the output of a photovoltaic module is intended as a current source.

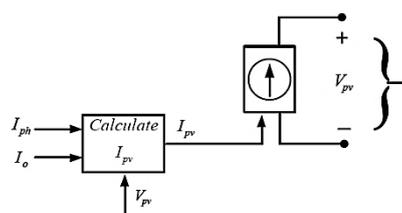


Fig.2: The calculated values of I_{pv} blocks

The completed model of photovoltaic module can see in Fig.3:

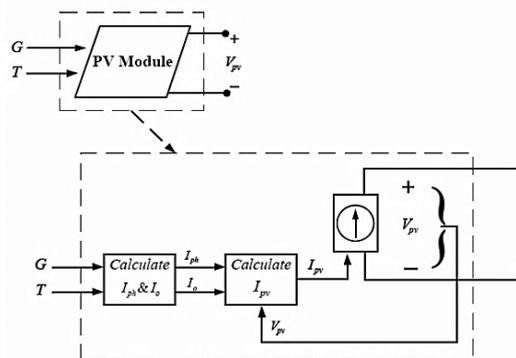


Fig.3: The completed model of PV module

In this section the physical equations governing the PV module (also applicable to PV cell) is elaborately presented with numerical values of module saturation current at various temperatures. Hence, this circuit model presents the relationship between module parameters and circuit performance. This involves the step-by-step method for the PV modeling in Matlab Simulink. The model of the PV module was implemented using a Matlab Simulink model. The model parameters are evaluated during execution using the equations listed as in the previous section. In this section the modeling of the VBHN235SE10 module has been [11]. PV module modeling in Simulink environment and with series resistance were implemented in Matlab/Simulink is shown in Fig.4.

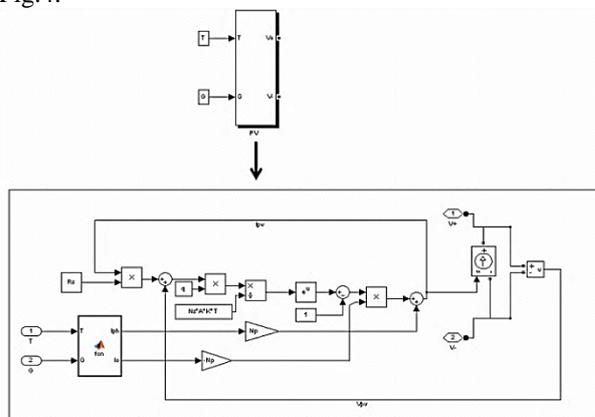


Fig.4: The VBHN235SE10 module modeling in Simulink environment

As the fig.4 shows, the output as a current source and the input is connected to a current source dependent. Two of the current

source, as PV module voltage, are returned into the Module, to affect the equations. The I_{pv} - V_{pv} and P_{pv} - V_{pv} characteristics for a radiation variation between $400 \frac{W}{m^2}$ and $1600 \frac{W}{m^2}$ and considering the constant temperature ($T=298^\circ K$) are shown in fig. 5.

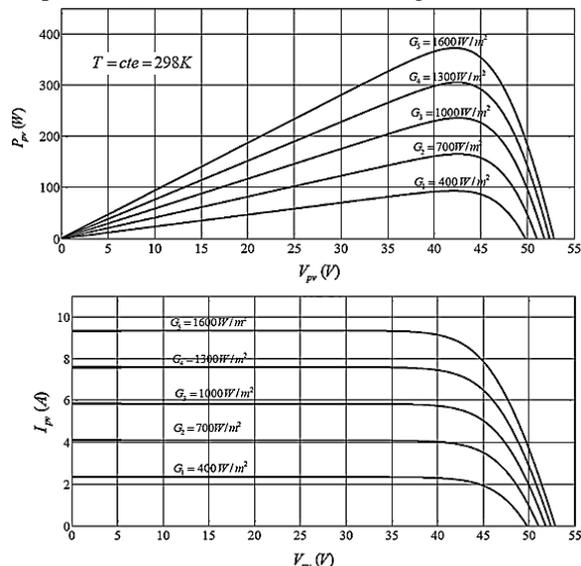


Fig.5: The VBHN235SE10 module I_{pv} - V_{pv} and P_{pv} - V_{pv} curve for various of solar radiation and constant temperature

From the graphs when the irradiance increases, the current and voltage output also increases. This result shows the net increase in power output with an increase in irradiance at the constant temperatures. Furthermore, it is well known that for a certain PV panel, the voltage-power characteristics are fixed for each insolation without intersection, as shown in fig.5. Hence, for any given PV voltage and power, the corresponding insolation can be estimated.

The I_{pv} - V_{pv} and P_{pv} - V_{pv} characteristics for a temperature variation between $273^\circ K$ and $313^\circ K$ and considering the constant solar radiation ($G = 1000 \frac{W}{m^2}$) are shown in fig.6.

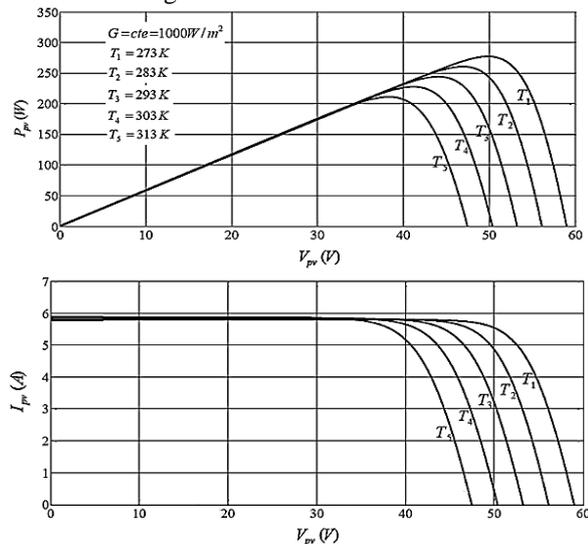


Fig.6: The VBHN235SE10 module I_{pv} - V_{pv} and P_{pv} - V_{pv} curve for various of temperature and constant radiation

The I_{pv} - V_{pv} and P_{pv} - V_{pv} characteristics under constant irradiance with varying temperature are presented in fig.6, respectively. When the operating temperature increases, the current output increases marginally but the voltage output decreases drastically, which result in net reduction in power output with a rise in temperature.

III. DC/DC CONVERTER

SEPIC (Single Ended Primary Inductance Converter) -type dc/dc converters make it possible to efficiently convert a DC voltage to either a lower or higher voltage and maintains the same polarity from input to output. The drawback to this converter is the additional pole created with additional LC network which makes the control loop more complicated than a simple buck, boost or buck/boost topology. It also has the same (buck/boost) $V_{out} = \frac{DV_{in}}{1-D}$ conversion ratio as the SEPIC converter. A SEPIC converter is used to interface the PV module output to the load and to track the maximum power point of the PV module[2]. The SEPIC converter is made up of two capacitors, two inductors, a power switch consists of one IGBT, the fly back diode is of a fast switching type. The transistor operates as a switch, it is turned on and off depending on pulse width modulated (PWM) control signal. PWM operates at constant frequency and in this paper is 10KHz and D can be varied from 0 to 1.

The SEPIC converter connected to the PV module is shown in fig. 7.

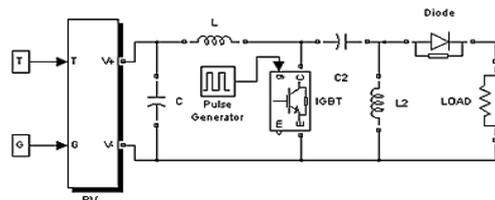


Fig. 7: SEPIC converter connected to the PV module

The power conversion stage, which is connected between a PV module and a load, is a pulse width-modulated (PWM) dc/dc SEPIC converter operating in continuous current mode (CCM)[2].

In the PV applications, it is desirable that i_{L1} ripple has the lowest and PowerCurvePV module should be at its maximum. The equation for the determination of the input current ripple is the same for all converters. The input current ripple (Δi_L) during the conduction of the power switch is defined by the equation(7)[12]:

$$\Delta i_L = \frac{V_i D}{f L_1} = i_2 - i_1 \quad (7)$$

Where: f is the switching frequency, i_1 is the Inductor current at time t_1 , i_2 is the Inductor current at time t_2 .

The Inductor current at time t_1 from i_1 (initial value) to i_2 (secondary value) increases linearly and at time t_2 from i_2 to i_1 decreases linearly. This is shown in fig. 8.

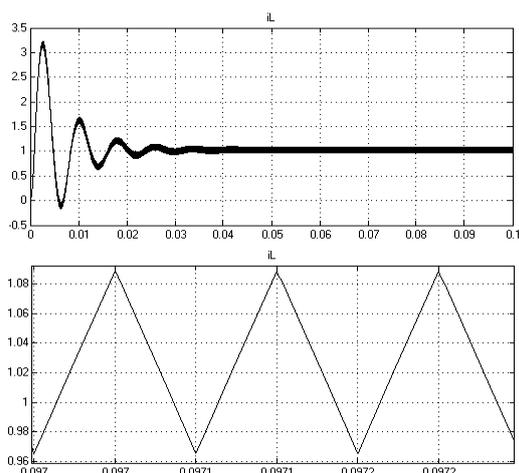


Fig.8:SEPIC input current Changes

The input current ripple considered is $\Delta i_L = i_2 - i_1$
 Therefore, the input current ripple is calculated as follows: $\Delta i_L = 1.0891 - 0.985 = 0.1041$

A BOOST converter is a step-up DC-DC power converter. fig.9 shows the boost converter circuit .

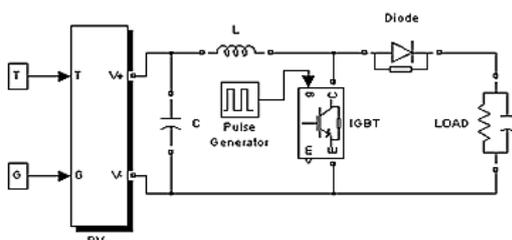


Fig. 9: BOOST converter connected to the PV module

The converter operation can be divided into two modes. Mode 1 begins when the transistor is switched ON, the current in the boost inductor increases linearly, and the diode is OFF state, mode 2 begins when the transistor is switched OFF, the energy stored in the inductor is released through the diode to the load[13]. The relationship between input and output voltages is given by $V_{out} = \frac{V_{in}}{1-D}$. The input current changes of BOOST converter is shown in fig.10.

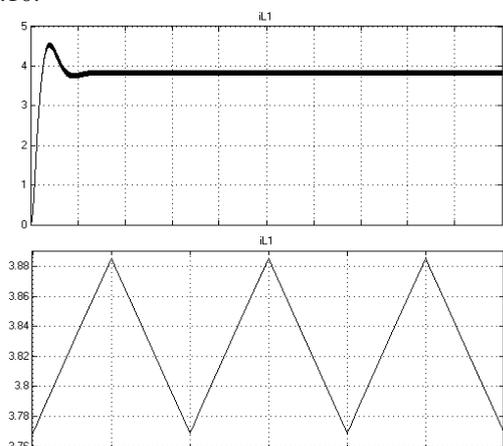


Fig. 10:BOOST input current Changes

For this converter the input current ripple (Δi_L) during the conduction of the power switch is calculated as follows:

$$\Delta i_L = i_2 - i_1 = 3.8855 - 3.7686 = 0.1169$$

IV. MPPT UNIT

For each PV module, two characteristic curves V-I and V-P are defined. With changing irradiance and temperature of PV modules, these curves are also modified accordingly. Namely, the output power of photovoltaic cells, due to the varying conditions of temperature and radiation. PV module power output can change for different current and voltage, yet there are only a maximum power point (MPP) for the module and at this point can be maximum power injection in the load. So, essentially, to increase efficiency power from PV modules at a time are at its maximum. This is done using the maximum power point tracking (MPPT) control system [14],[15]. Since the module output voltage is usually low, so a boost converter is used to connect to the load. In fig.11 the overall shape of solar modules, converters and systems to track the maximum power point is drawn.

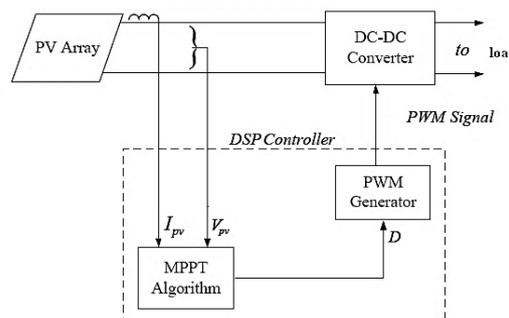


Fig.11: Connection solar modules, converters and MPPT

The Perturb and Observe (P&O) method is the most popular MPPT algorithm due to its simplicity. The flow chart of this method is shown in fig.12. P&O algorithm is based on the comparison of the change in voltage and power. In this algorithm PV output voltage and PV output current are sensed. Then power is calculated and compared with the power value calculated in the previous sample in order to get ΔP . If $\Delta P > 0$, then the operation continues in the same direction of perturbation and if $\Delta P < 0$ the operation reverses the perturbation direction. In the next perturbation cycle the algorithm continues in the same way. This process until ΔP is zero, or in other words the PV module MPP can reach continuously [16],[17].

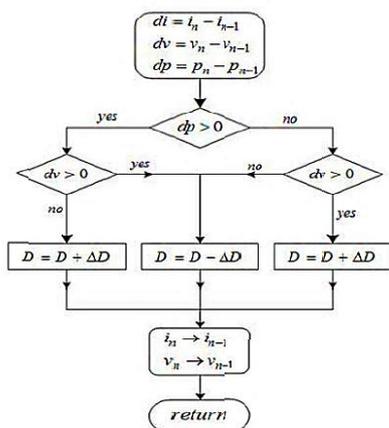


Fig.12:Flow chart of P&O algorithm

In the power voltage curve of the solar pv module, it is inferred that in the right hand side curve where the voltage is almost constant and the slope of power voltage is negative, whereas in the left hand side, the slope is positive (fig.13).Therefore the right side of the curve is for the lower duty cycle(nearer to zero) whereas the left side curve is for the higher duty cycle(nearer to unity).

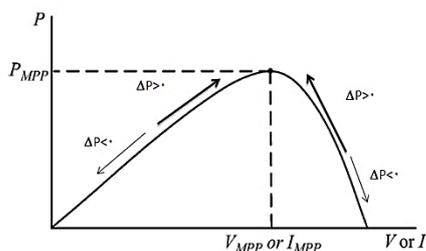


Fig.13:ΔP changes to the MPP

Depending on the sign of ΔP ($P(k+1) - P(k)$) and ΔV ($V(k+1) - V(k)$) after subtraction the algorithm decides whether to increase the D (duty cycle) or to reduce the D of the converter in order to force the working point of the PV module towards the MPP.D is the output block tracking algorithm, as the duty cycle converter is applied to the PWM block.

More, we will discuss the effect of MPPT unit on PV system. A MPPT has been proposed which works in conjunction with a power electronic converter to shift the operating point to obtain maximum power from a PV Panel under varying load, temperature and insolation conditions. MPPT first tracks the MPP and sets the operating point.

V. SIMULATION RESULTS

The final modeling is shown in fig.14.

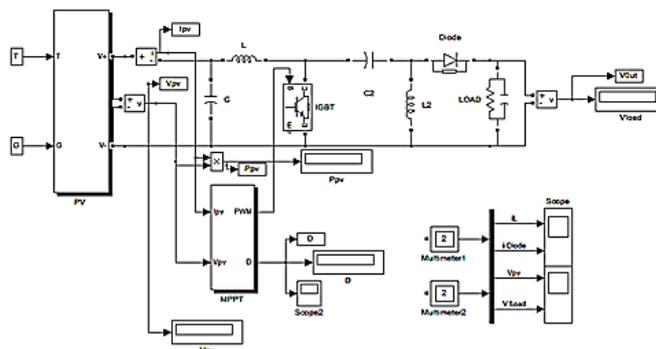


Fig. 14:The overall system

An extensive simulation for final model has been done using MATLAB.The following simulations were presented for different insolation levels at fixed temperature, and at different temperature levels at fixed insolation shown. Simulation was carried out up to 3 seconds for, $G = 400 \frac{W}{m^2}$, $G = 800 \frac{W}{m^2}$, $G = 1200 \frac{W}{m^2}$, $G = 1600 \frac{W}{m^2}$ (fig.15) and temperature $T=298K$ for load $R=50\Omega$ and $C=25\mu f$.

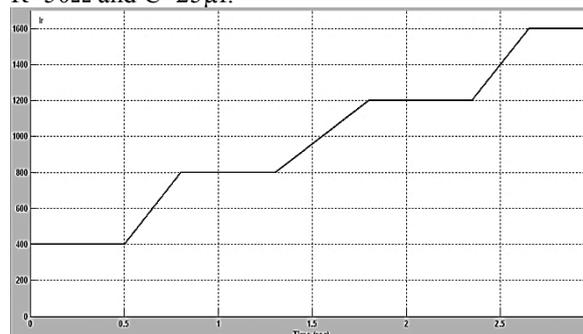


Fig. 15:changes in the radiation

The results are shown in the fig.16 and fig.17.

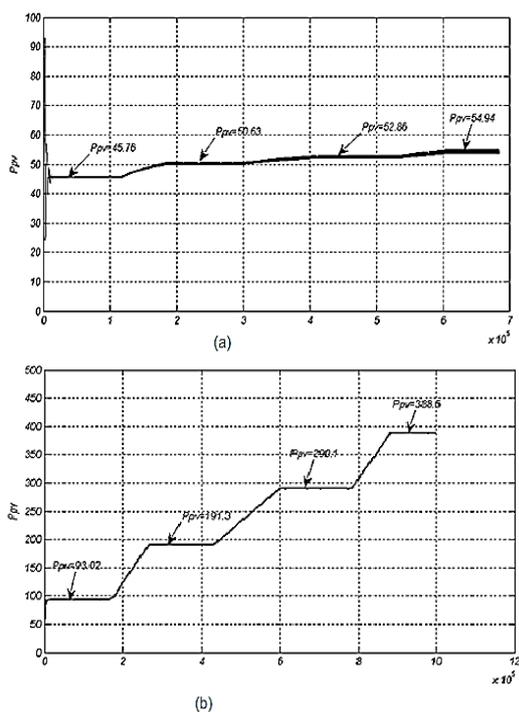


Fig. 16:changes in the P_{pv} - V_{pv} (G:variable , T:invariable)
 (a) without MPPT block (b)with MPPT block

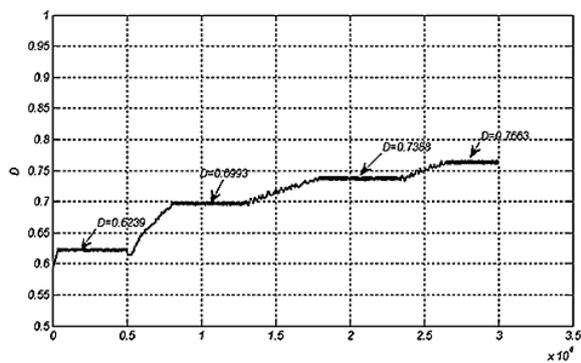


Fig. 17:changes in the duty-cycle produced by MPPT block
 (G:variable , T:invariable)

The next step the simulation was carried out up to 3 seconds for, insolation $G = 1000 \frac{W}{m^2}$ and temperature $T=290K, T=330K, T=315K, T=298K$ (fig.18) for load $R=50\Omega$ and $C=25\mu f$.

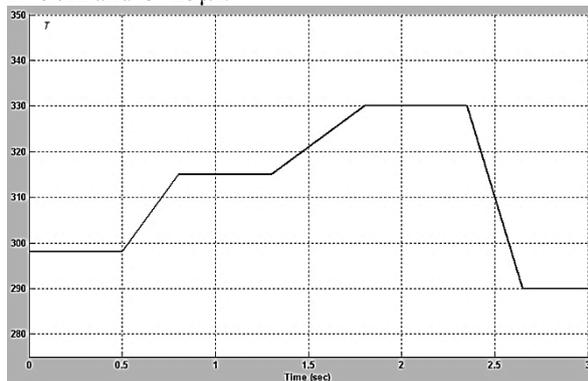


Fig. 18:changes in the temperature

The results are shown in the fig.19 and fig.20.

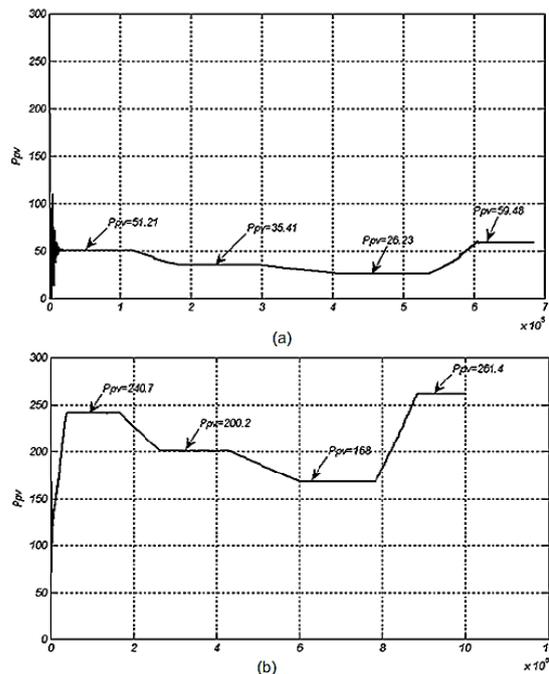


Fig. 19:changes in the P_{pv} - V_{pv} (G:invariable , T:variable)
 (a) without MPPT block (b)with MPPT block

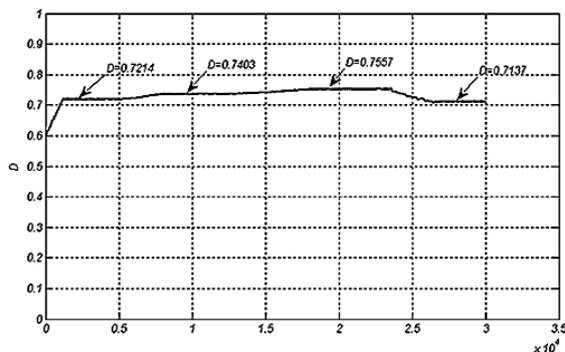


Fig. 20:changes in the duty-cycle produced by MPPT block
 (G:invariable , T:variable)

According to the results, we can say that the MPPT control block with continuous sampling of voltage and current and calculates the PV panel power , the DC-DC converter duty cycle is set to the output power to be maximum value.

VI. CONCLUSION

We can say the boost converter is designed for a narrow range of Line voltage and in the boost converter input current ripple is high ($\Delta i_L=0.1169$) to solve this problem, the SEPIC converters is propose which in fact, adding an LC network to BOOST converter is formed and generates high interest and like BOOST converter no casualties stress at lower voltages. In the SEPIC converter input current ripple is low ($\Delta i_L=0.1041$) and ripple current can be steered away from input, reducing the need for input noise filtering. Therefore, SEPIC converter is appropriate than BOOST converter in the solar

applications. Using the control block, the maximum power point is obtained at different conditions. This is possible by adjusting the duty cycle of the converter. As a result, the proposed system is optimized.

REFERENCES

- [1] D. Jc Mac Kay, *Sustainable Energy with out the Hot Air*, (UIT Cambridge, England, 2009).
- [2] R.B.Darla, Development of maximum power point tracker for PV panel using SEPIC converter, *Tele communications Energy Conference*, 2007, sept.30-oct.4.
- [3] D.Morales, *Maximum Power Point Tracking Algorithm for photovoltaic Applications*, Thesis for the Degree of Master of Science, Aalto University, Finland, 2010.
- [4] S.Poshtkouhi, V.Palaniappan and M.Fard, O.Trescases, *IEEE Transactions on Power Electronics*, Vol. 27, 2012, 4656-4666.
- [5] G.Walker, Evaluating MPPT converter topologies using a matlab PV model, *J. Elect. Electron. Eng.*, Vol. 21, 2001, 45-55.
- [6] D. Archer, R. Hill, *Clean electricity from photovoltaics, Series on Photoconversion of Solar Energy*, (Imperial College Press, 2001).
- [7] H.L. Tsai, Ci-Siang Tu and Yi-Jie Su, Development of Generalized Photovoltaic Model Using Matlab/Simulink, *The World Congress on Engineering and Computer Science*, USA, 2008, 22-24 October.
- [8] W. DeSoto, S.A.Klein and W.A.Beckman, Improvement and Validation of a model for photovoltaic Array Performance, *Elsevier Solar Energy*, 2006, Vol.80, No.1, 78-88.
- [9] M. G. Villalva, J. R. Gazoli, and E. R. Filho, Comprehensive approach to modeling and simulation of photovoltaic arrays, *IEEE Trans. PowerElectron*, Vol. 24, No. 5, 2009, 1198-1208.
- [10] M.villavla, J.Gazoli, and E.Filho, Comprehensive approach to modeling and simulation of photovoltaic Arrays, *IEEE Trans .on Power Electronics* , Vol.24, No.5, 2009, 1198-1208.
- [11] Panasonic, VBHN235SE10 specifications of photovoltaic module, *data released*, 2012, Mar.9.
- [12] K.Singh, A.N.Tiwari and K.P.Singh, Performance Analysis of Modified SEPIC Converter with Low Input Voltage, *IJRECT*, Vol.3, 2012, ISSUE1, ISSN: 2230-7109.
- [13] M.. H. Rashid, *Power Electronics Circuits Devices and Applications*, (New Jersey: Pearson Education, Inc, 3rd edition, 2004).
- [14] D.Rekious, E.Matagne, *Optimization of photovoltaic Power Systems*, (Springer, 2012).
- [15] M. Milosevic, *On the Control of Distributed Generation in Power Systems*, Thesis for the Degree of Doctor of Technical Science, Swiss Federal Institute of Technology, Switzerland, 2007.
- [16] S.A.KH.MozaffariNiapoure, S.Danyali, M.B.B.Sharifian, M.R.Feyzi, Brushless DC Motor Drives Supplied by PV Power System Based on Z-Source Inverter and FL-IC MPPT Controller, *Energy Conversion and Management*, Vol.52, 2011, Issues8-9, Pages 3043-3059.
- [17] T.Tafticht, K.Agbossou, M.L.Doumbia and A.Chériti, An Improved Maximum Power Point Tracking Method for Photovoltaic Systems, *Renewable Energy*, 2008, 1508-1516.