International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Comparative Studies of DC-DC Boost Convertor and SEPIC Convertor for Global Maximum Power Point Tracking Technique in a PV Array under Partial Shaded Condition

Baljindra Kaur[1], Vaibhav Gaur[2]

[1, 2]Mewar University

Abstract: ***This thesis portray a validation and design of a Maximum Power Point tracking (MPPT) capable of tracking the true global Maximum Power point (GMPP) in the present of other local maxima. The proposed system tracks Maximum Power point (MPP) without the use of costly components such as single concreters and microprocessors thereby the compactness of the system. In this paper we are using DC-DC Boost convertor and SEPIC Convertor and perform comparison between both. This paper also discusses about an improved technique for tracking global maximum power point of photovoltaic arrays that has better performance under partial shading conditions. The first stage in this method is to find out global maximum power point among the local maxima. Once the global maximum power point is found then by adjusting the duty ratio, the voltage corresponding to maximum power can be found out. The control is then transferred to perturb and observealgorithm stage. This technique could be applied for both stand alone and grid connected PV system. A comparison study between a SEPIC converter and a buck boost converter with the above mentioned algorithm has also been carried out in order to verify the performance of both the converters. Modified algorithm has been simulated using MATLAB/Simulink and results are obtained. Partial shading condition was modelled in MATLAB/Simscape and analyzed the solar array characteristics under various shading conditions. From the simulation results it was found that the SEPIC converter is much more efficient and is highly suitable for photo voltaic applications.***

Keywords: PV system, DC-DC Convertor, Maximum Power Point tracking (MPPT), SEPIC Convertor

1. Introduction

Efficiency of the any PV module can be improved by operating at its peak power point so that the maximum power can be delivered to the load under varying environmental conditions. This paper is mainly focused on the maximum power point tracking of solar photovoltaic array (PV) under partial shaded conditions. A maximum power point tracker (MPPT) is used for extracting the maximum power from the solar PV module and transferring that power to the load. The problem of maximum power point (MPP) tracking becomes a problem when the array receives non uniform insolation. Cells under shade absorb a large amount of electric power generated by cells receiving high insolation and convert it into heat which may damage the low illuminated cells. To relieve the stress on shaded cells, bypass diodes are added across the modules. In such a case multiple peaks in voltage power characteristics are observed. Classical MPPT methods are not effective due to their inability to discriminate between local and global maximum. In this paper, Global MPPT algorithm is proposed to track the global maximum power point.

Photovoltaic cells when connected together form a panel and a number of panels contribute to form a solar array. The PV array consists of a number of panels connected in series and parallel topologies. With varying levels of irradiation during the day, the array output can vary in a wide range. This effect is expected. But unexpected shading effects due to dusts, clouds, leafs, branches of trees and buildings causing shading on cells or part of modules or panels. Under these partial shading conditions, the Power versus voltage characteristics of the solar array will contain one global maximum along with many local maxima. The global maxima correspond to maximum power while the others correspond to much lower powers [2]. Around 30% power loss will take place even though only one cell in the PV module is shaded. As the number of shaded cells increases, the amount of power loss also will be increases (nearly 80%). Under partial shading conditions, conventional MPPT methods may not be able to track maximum power irrespective of the change in irradiance conditions. At the local maximum power point it may converge resulting in reduction of PV panel output. Due to this reason the overall PV system efficiency gets degraded [3]-[4]. An efficient MPPT system which can be used even under partial shading conditions efficiently is discussed in this paper.

Organization of this paper is as follows: a description about the MPPT system is given in Section II, SEPIC converter characteristics is dealt in section III, section IV presents the implementation of partial shading effect, Global MPPT is described in section V and simulation results are presented in section VI.

2. System Description

Basic Block diagram of photovoltaic maximum power point tracking system implemented using SEPIC Converter is shown in Fig1. System load is supplied from solar panel with the help of SEPIC convertor. The array voltage ph and current Ipv is sensed by suitable sensors and is given as input to the MPPT controller. The basic idea of MPPT technique is to adjust the load impedance of panel there by forcing the panel to operate as the maximum power point of P-V curve. Load impedance is adjusted by changing the duty ratio of the converter which is connected as an interface between the panel and the load.

In this work SEPIC serves as the DC-DC converter and its duty ratio is adjusted to track maximum power transfer from P-V array to the load.

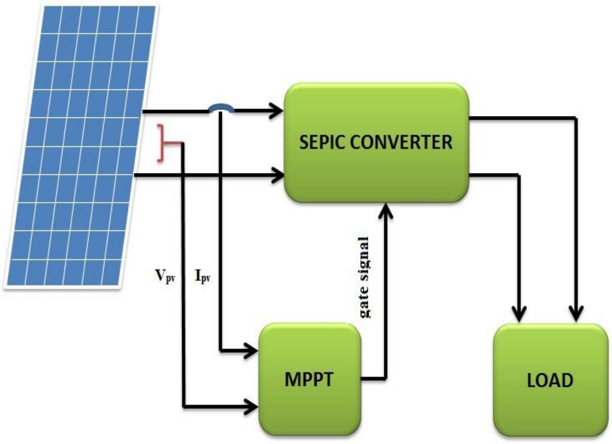

Figure 1: Block diagram of an MPPT system

Under partial shading conditions multiple local maxima will appear on the power-voltage characteristics of solar PV system in that only one will be global maximum power point. The above mentioned situation is shown in the power-voltage curve of partially shaded array in Fig.2. The conventional MPPT methods converge at local maximum power points and the

The above mentioned MPPT system can be applied to either grid connected solar PV applications or standalone applications. Here Single Ended Primary Inductor (SEPIC) converter is used as DC-DC boost power converter so that the output voltage can be made constant irrespective of the input voltage variations.

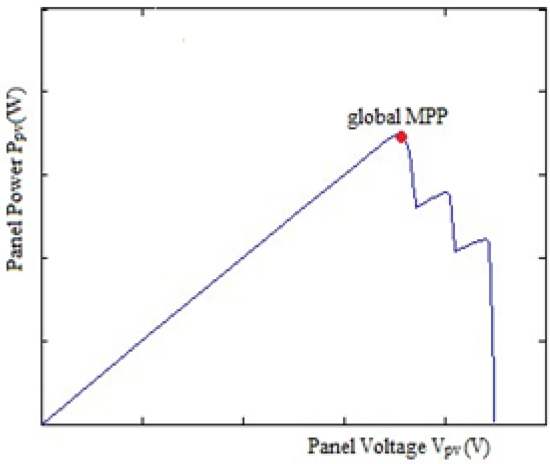

Figure 2: Power vs Voltage for a partially shaded PV array

The global MPPT (GMPPT) technique used here is performed in three consecutive steps,
a) Constant input Power mode
b) PV array Voltage regulation
c) Perturb and Observe (P&O) Stage

The switch is controlled by either PWM_1 or PWM_2 control signals provided from the MPPT controller. This aspect is explained in the following section.

3. SEPIC Converter

Since the SEPIC converter is a modified form of an ordinary buck-boost converter, it has some advantages [5]-[6] over conventional buck boost converters. The circuit diagram of single-ended primary inductance converter as shown in Fig.3

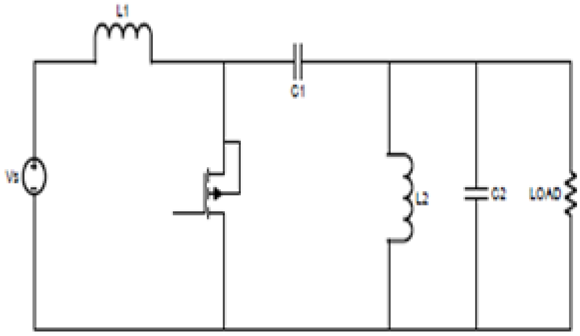

Figure 3: Circuit diagram of SEPIC convertor

The output of a SEPIC converter is non-inverting but the output of a buck boost converter is inverting. In this SEPIC converter, MPP tracking is much easier because the amount of input current ripple present is non-pulsating. Since the switch present in SEPIC converter is directly connected to ground only low side driving is required which is easier than high side driving used in buck-boost converter. Additionally, the SEPIC converter is highly efficient compare to buck boost convertor.

The voltage gain of a SEPIC converter is given by

$$V_o = \frac{D}{1-D} \times V_{pv}$$

Where $D=t_{on}/T_s$ is the duty ratio of converter switch, V_o is the output voltage of the convertor and V_{ph} is the input voltage which is fed from the solar array. The control signal of PWM1 is produced by comparing the panel current I_{pv} with a control signal which is a saw tooth wave derived from the basic equations of SEPIC Convertor.

For stand-alone applications, the output voltage V_o has to be constant even if it is connected to the grid or to the battery bank. For stand-alone battery charging application [7]-[8], the SEPIC converter acts in buck mode for reducing the panel voltage to constant value. But for grid interface, the SEPIC converter has to work in the boost mode. The input power of the converter can be controlled by varying the amplitude of the control signal and it is called constant input power mode operation.

4. Implementation of Partial Shading Effect

A Solar panel has been simulated in MATLAB/Simscape and is discussed in this section. Twenty solar cells are connected in series to form a string which acts as a module. Each cell having an open circuit voltage V_{oc}= 0.9 V and short circuit current I_{sc} = 0.63 A. The combination of such modules forms a solar panel. A number of panels interconnected forms solar array, of maximum power 39.2 W at V_m =65.6 V and I_m=0.59A. In order to create partial shading effect using Simulink , a diode is connected in anti parallel to each cell. This is done to avoid avalanche breakdown which would create hot spots on the solar cell which may lead to the damage of entire solar cell.

At a standard irradiance condition of 1000W/m^2 the solar cell produces rated power which can be observed from volt-current and volt-power characteristics. Fig.4 shows the solar cell modeling for partial shading conditions.

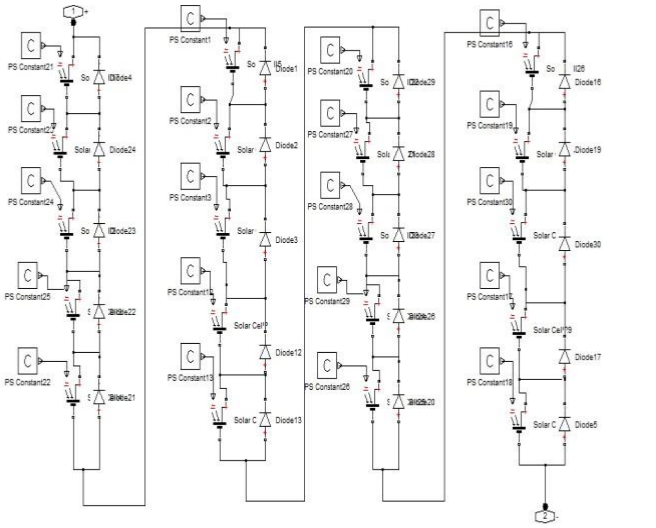

Figure 4: Modeling of solar cell for partial shading condition

The irradiance value can be changed manually and the corresponding variation in irradiance can be seen. As the irradiance value decreases from 1000W/m^{2}the panel voltage and current also reduces considerably which further results in the reduction of panel power output. In order to overcome this condition, modified maximum power point tracking method as explained in this paper can be used to track available maximum power from the panel. Fig.5 shows the Simulink model of the solar panel under partial shading conditions.

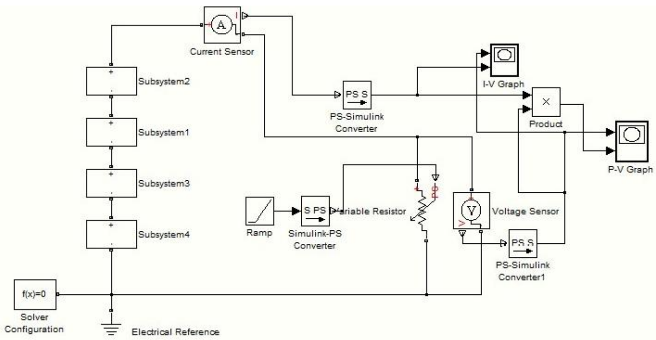

Figure 5: Simscape model of solar panel

Fig. 6 shows the Power - Voltage characteristics under normal irradiation conditions (1000W/ m^2) without partial shading. The magnitude of voltage (V_M) corresponding to maximum power (P_M) is also shown.

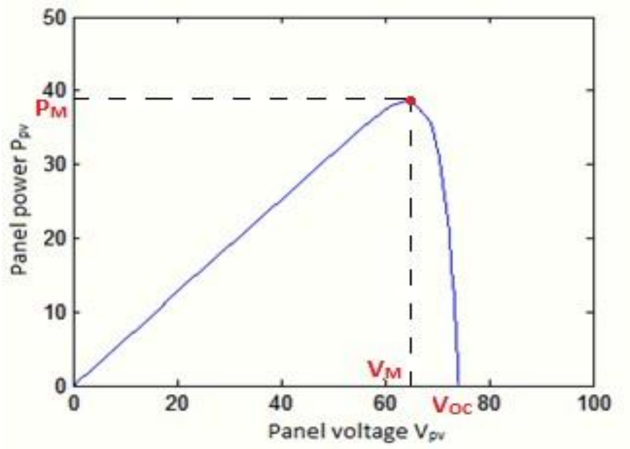

Fig-6: Power-voltage curve under 1000 W/m2

The current –voltage characteristics of the designed panel are shown in Fig.7 at 1000W/m^2. Current and voltage magnitudes corresponding to maximum power is represented as I_M and V_M respectively.

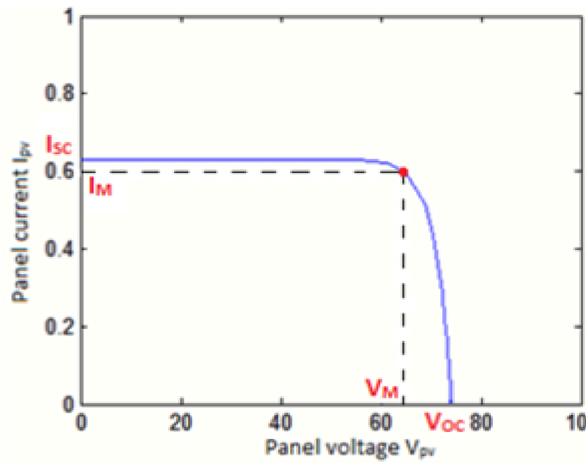

Figure 7: Current-voltage curve under 1000 W/m2

The Power-Voltage characteristics of the designed solar panel under Partial shading condition created using Simulink is shown in Fig.8.

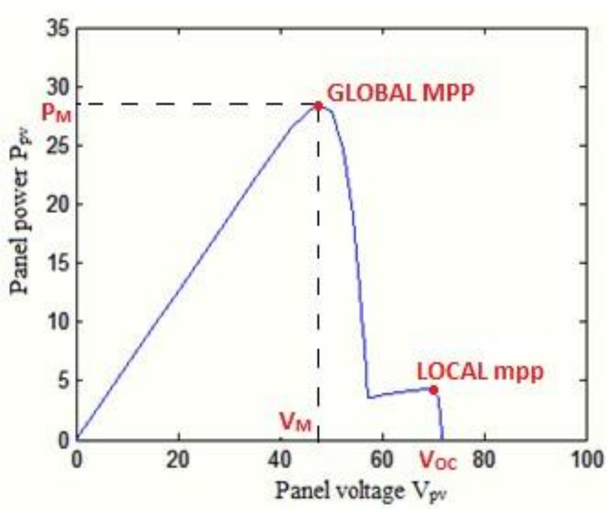

Figure 8: Power-voltage curve under partial shading condition

Positions of global and local maximum power points are marked in the figure. Similarly current voltage characteristics of panel under partially shaded condition are shown in Fig.9 with global and local maximum power points marked in it.

It can be observed that under partial shading condition, multiple maximum power points has been created. Out of these maximum power points only one will be global maximum power point and the remaining power points will be local maximum power points

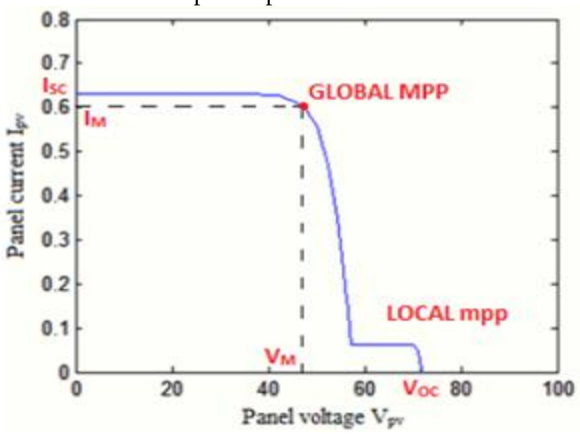

Figure 9: Current-voltage curve under partial shading condition

5. MPPT and Algorithms

The MPPT under partial sheded condition is described under two algorithms [9] i.e.
a) Global search algorithm
b) Local search algorithm

Initially the global tracking process is performed and the voltage magnitude corresponding to each maximum power point is identified. There will be one global maximum power point among the local maximum power points. The value of voltage magnitude corresponding to maximum power is stored in microcontroller memory. The control algorithm adjusts the duty cycle to adjust the converter input impedance to make it operate at global maximum power point. Once the global maximum power point has been reached then the control is moved from global loop and enters to local loop.

The local loop contains some ordinary MPP tracking method such as Perturb & Observe, Incremental Conductance etc. The SEPIC converter is switched by using either PWM_1 or PWM_2. PWM_1 signal is generated with the help of global tracking loop and PWM_2 signal is generated using local tracking loop

According to Perturb and Observe algorithm [10] due to a perturbation in output voltage by a small increment, if the resulting changes in power ΔP is positive, then we can move in the direction of MPP and we keep on perturbing in the same direction. If the value ΔP is negative, we are going away from the direction of MPP and the sign of perturbation supplied has to be changed. The P&O algorithm operates by periodically perturbing the operating voltage and comparing it with the previous instant. If the power difference ΔP and the voltage difference ΔV, both in the positive direction then there is an increase in the array voltage. If either the voltage difference or the power difference is in the negative direction then there is a decrease in the array voltage. If both the voltage and power difference are in the negative direction then there is a increase in the array voltage.

6. Simulation

Design parameters and ratings of the SEPIC and Buck-Boost converter is as per table 1.

Table 1: Converter Parameters

Parameter	Value	
	SEPIC	Buck-boost
L_1	1107μH	864μH
C_1	518μF	69μF
L_2	1107μH	
C_2	518μF	
Power	150 W	150 W
V_S	30 to 40 V	30 to 40 V
V_O	36 V	36 V
f_S	10 KHZ	10 KHZ

6.1 Simulation Model

6.1.1 Using Buck Boost Converter

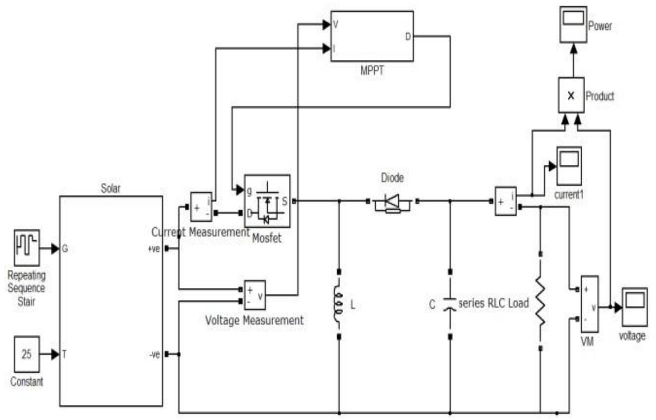

Figure 10: Simulink model of the MPPT controller using Buck- Boost converter

6.1.2 Using SEPIC Converter

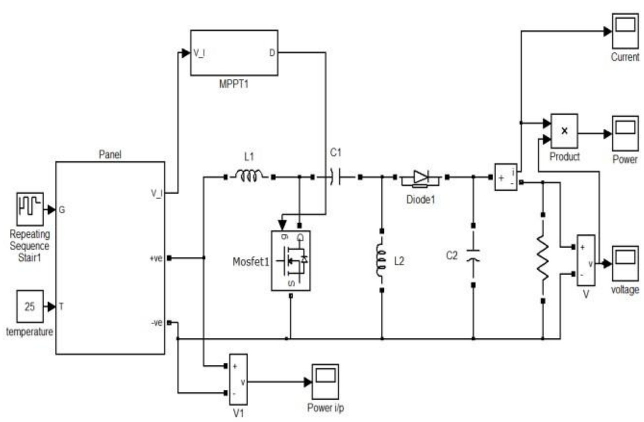

Figure 11: Simulink model of the MPPT controller using SEPIC

7. Simulation's Results

From the simulation results first difference which was observed is in the output voltage of the converters. Buck- Boost Converter produces an inverted output voltage while the SEPIC has non inverted output. The output voltage waveforms of both converters are shown in Fig.12.

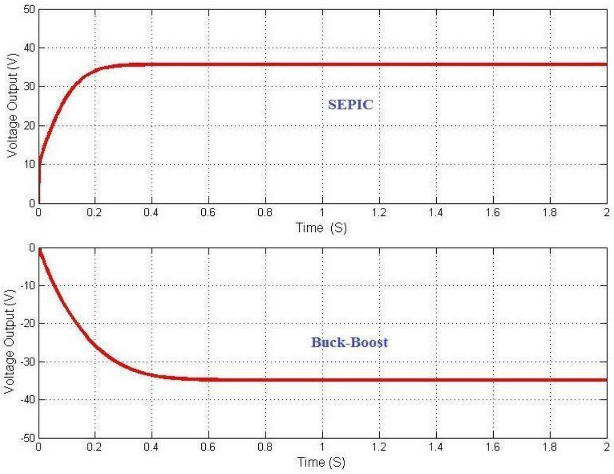

Figure 12: Output voltages of SEPIC and Buck-Boost converter

Similarly the converters were also compared for efficiency by measuring their output power. For 1000 W/m^2 irradiance and 25^{O}c ambient temperature, the output power obtained is 138.5W in the case of a SEPIC converter as shown in Fig.13. Similarly for a buck boost converter, the output power is only133W. Thus from Fig.13 it is clear that maximum power tracked using SEPIC converter is greater than buck-boost converter. Hence the efficiency of SEPIC converter is higher than buck-boost converter.

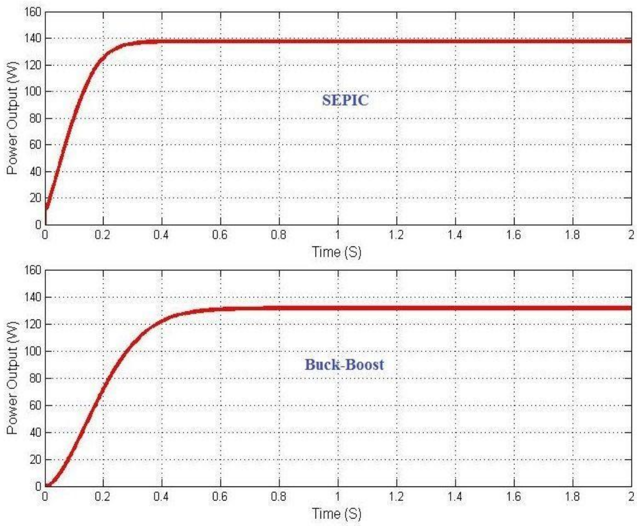

Figure 13: Output power of SEPIC and Buck-Boost converter

In Fig.14, different irradiance condition and the corresponding power using MPPT technique is shown. Different irradiance values have also been shown in Fig.14.

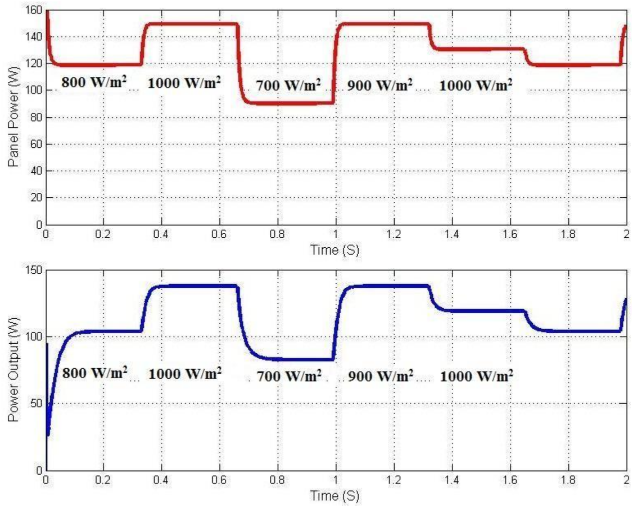

Figure 14: Maximum panel power and tracked maximum power under different irradiance conditions at 298 K

8. Conclusion

Under partial shading conditions and rapidly varying irradiance conditions conventional MPPT methods fail to track real maximum power point. To overcome this situation, an improvement in conventional MPP tracking algorithm is done and integrated with SEPIC converter. The above mentioned MPPT system is able to track the real maximum power point under constant and varying weather conditions. The comparative study with buck-boost converter shows the added advantage of SEPIC converter for photo voltaic applications.

References

[1] "Trends in photovoltaic applications. Survey report of selected IEA countries between 1992 and 2006," Int. Energy Agency Photovoltaic Power Syst.,Paris, France, Tech. Rep. IEA-PVPS T1-16:2007, 2007

[2] H. Patel and V. Agarwal, "Maximum power point tracking scheme for PV systems operating under partially shaded conditions," IEEE Trans. Ind .Electron., vol. 55, no. 4, pp. 1689–1698, Apr. 2008.

[3] E.V. Paraskevadaki and S. A. Papathanassiou, "Evaluation of MPP voltage and power of mc-Si PV modules in partial shading conditions," IEEE Trans. Energy Convers. vol. 26, no. 3, pp. 923–932, Sep. 2011.

[4] Y. H. Ji ,Suwon, D.Y. Jung , C. Yue Won , B. K Lee "Maximum Power Point Tracking Method for PV Array under Partially Shaded Condition", IEEE International Conference on, Sept. 2009 , Page(s):307 – 312

[5] D. W. Hart "Power Electronics" 1ST ed., New York: 2011.

[6] J. Betten, "Benefits of a coupled-inductor SEPIC converter", Power Management.

[7] S. J. Chiang, H.J. Shieh, and M.C. Chen, "Modeling and Control of PV Charger System with SEPIC Converter", IEEE Trans. Ind. Electron, vol.56, no. 11, pp.4344-4353, Nov. 2009.

[8] N. Mohan, T. Undeland, and W. Robbins, Power Electronics: Converters, Applications and Design, 2nd ed., New York:Wiley, 11995, pp. 164–172.
[9] E. Koutroulis, ”A New Technique for Tracking the Global Maximum Power Point of PV Arrays Operating Under Partial-Shading Conditions”,IEEE journal of Photo volt, vol. 2, no. 2, april 2012.
[10] S. Alsadi, B. Alsayid, "Maximum Power Point Tracking Simulation for Photovoltaic Systems Using Perturb and Observe Algorithm" International Journal of Engineering and Innovative Technology (IJEIT) vol. 2, Issue 6, Dec. 2012
[11] Sreekumar A.V**,** Arun Rajendran "maximum power point tracking of PV arrays under partial shading condition using SEPIC converter" International Journal of Research in Engineering and Technology (IJRET), Volume: 03 Special Issue: 07, May-2014

Author Profile

Baljindra Kaur received her B.E degree in Electrical Engineering from University of Rajasthan. She is currently pursuing her M.Tech at Mewar University, Her areas of interest are Power Systems and renewable energy.

Vaibhav Gaur received his B.E degree in Electrical Engineering from University of Rajasthan,. He is currently pursuing his M.Tech at Mewar University . His areas of interest are Power Systems and renewable energy.