PERFORMANCE COMPARISON OF PV SYSTEM EMPLOYED WITH PERTURB & OBSERVE (P&O) AND INCREMENTAL CONDUCTANCE MPPT TECHNIQUES

Dr. S. P. Singh[1], Dinesh Kumar[2], Pankaj Kumar Gupta[3] , Ankit Kumar Srivastava[4], Dilip Kumar[5] Dr.A.S.Pandey[6]

[1]Associate Professor, Department of Electrical Engineering, REC, Ambedkar Nagar
[2,4,5], Assistant professor Department of Electrical Engineering, KNIT, Sultanpur
[3]M.tech Student Department of Electrical Engineering, KNIT, Sultanpur
[6]Professor Department of Electrical Engineering, KNIT, Sultanpur

***Abstract*— This paper introduces the comprehensive as well as comparative study on P&O and INC method for photo-voltaic systems. The photovoltaic (PV) module efficiency conversion is affected by DC-DC converter design and the MPPT algorithms have been implemented by taking converter into consideration. Here in this paper two algorithms are compared and to locate the maximum power points one by one and their performance comparison is based upon the waveforms of voltage, current and power across the load are recorded by using MATLAB/Simulink for constant irradiance and temperature.**

***Index Terms*— Photovoltaic cell , Sepic Converter, MPPT Techniques**

1. INTRODUCTION

The increase in use of renewable energy sources lead to use more of photovoltaic system which has higher advantages than others. [1].The photovoltaic panels are used to generate the power and the maximum power point tracking (MPPT) technology. PV system uses the photoelectric effect such that solar energy is directly converted into electric energy. This makes the system more convenient and reliable as compared to other methods of solar energy it uses the energy of visible and infrared regions of the solar radiations for conversion into electric power. It mainly consists of PV panel, DC-DC converter, and battery [2-3].

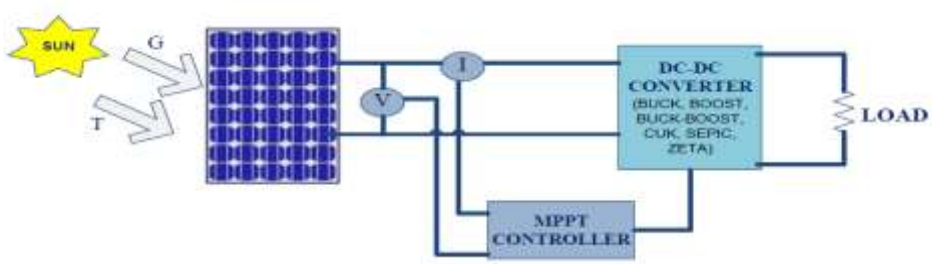

Fig. 1 Basic diagram of PV Energy Conversion System conversion.

Maximum power point tracking (MPPT) techniques are used in photovoltaic (PV) systems to maximize the PV array output power by tracking continuously the maximum power point (MPP) which depends on panel temperature and on irradiance conditions. The issue of MPPT has been addressed in different ways in the literature but, especially for low-cost implementations, the perturb and observe (P&O) maximum power point tracking algorithm is the most commonly used method due to its ease of implementation. A drawback of P&O is that, at steady state, the operating point oscillates around the MPP giving rise to the waste of some amount of available energy; moreover, it is well known that the P&O algorithm can be confused during those time intervals characterized by rapidly changing atmospheric conditions.

The simplest is to operate the PV array at constant voltage equal to the MPP voltage of the array at the standard test conditions (STCs) provided by the manufacturer. This value is used as a reference for a feedback control loop that usually employs a PI controller to adjust the duty ratio of the MPPT converter. The utilization efficiency, however, can be further improved by employing a hill-climbing MPPT technique such as perturb and observe (P&O) algorithm. This is a simple algorithm that does not require previous knowledge of the PV generator characteristics or the measurement of solar intensity and cell temperature and is easy to implement with analogue and digital circuits. The algorithm perturbs the operating point of the PV generator by increasing or decreasing a control parameter by a small amount (step size) and measures the PV array output power before and after the perturbation. If the power increases, the algorithm continues to perturb the system in the same direction; otherwise the system is perturbed in the opposite direction. The number of perturbations made by the MPPT algorithm per second is known as the perturbation frequency or the MPPT frequency[2], [6], [7], [8], [9], [11].

II. MODELING OF PV SYSTEM

It is a non-linear device and can be represented as a current source in parallel with diode as shown in the Fig. 2.3. The practical PV cell model includes the connection of series and parallel internal resistance, namely Rs and Rp which is expressed as the following equation[3],[5], [16], [17].

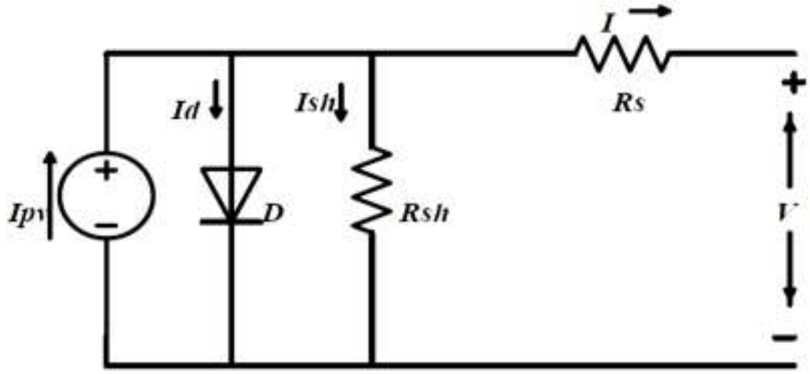

Fig. 2.The electrical equivalent circuit of a PV cell

$$I_{pv} = I_d + I_{sh} + I \text{..............................(1)}$$

$$I = I_{pv} - I_d - I_{sh} \text{...............(2)}$$

The Diode current is given by

$$I_d = I_o \left[\exp\left(\frac{V + R_s I}{V_t a} \right) - 1 \right] \text{....(3)}$$

$$I_{sh} = \frac{V + IR_s}{R_{sh}} \text{................(4)}$$

By eqns. 1, 2, 3 and 4

$$I = I_{pv} - I_o \left[\exp\left(\frac{V + IR_s}{V_t a} \right) - 1 \right] - \frac{V + IR_s}{R_p} \text{.....(5)}$$

The light generated current of the photovoltaic cell depends linearly on the solar irradiation and is also influenced by the temperature according to the following equation:

$$I_{pv} = \left[I_{sc,n} + K_t (T - T_n) \right] * \frac{G}{G_n} \text{................(6)}$$

The diode saturation current I_O and its dependence on the temperature may be expressed by

$$I_o = I_{rs} \left(\frac{T_n}{T} \right)^3 * \exp\left[\frac{qE_g}{ak} \left(\frac{1}{T_n} - \frac{1}{T} \right) \right] \text{.......(7)}$$

$$I_{rs} = \frac{I_{sc,n}}{\left[\exp\left(\frac{V_{oc,n}}{V_t a} \right) - 1 \right]} \text{............................(8)}$$

The reverse saturation current is given by

From eqns. (7) and (8), we can calculate the saturation current I_o easily. The photovoltaic model described in the previous section can be improved if eqn. (4) is replaced by:

$$I_o = \frac{I_{sc,n}}{\left[\exp\left(\frac{V_{oc,n} + K_v \Delta T}{V_t a} \right) - 1 \right]} \text{..................(9)}$$

Thus eqns. 5 can be change to

$$I = N_p I_{pv} - N_p I_o \left[\exp\left(\frac{1}{V_t a} \left(\frac{V}{N_s} + \frac{IR_s}{N_p} \right) \right) - 1 \right] - \frac{1}{R_{sh}} \left(\frac{V * N_p}{N_s} + IR_s \right) \text{..(10)}$$

III. MODELING OF SEPIC CONVERTER

Single ended primary inductance converter (SEPIC) is one type of non-isolated DC-DC converter. It gives a positive regulated output voltage corresponding to input voltage. It is similar to the Buck-Boost converter but the difference in SEPIC converter is to exchanges the energy between the capacitor and inductor in order to convert from one voltage to another voltage. Fig.3.6. shows the circuit diagram of SEPIC converter [1].

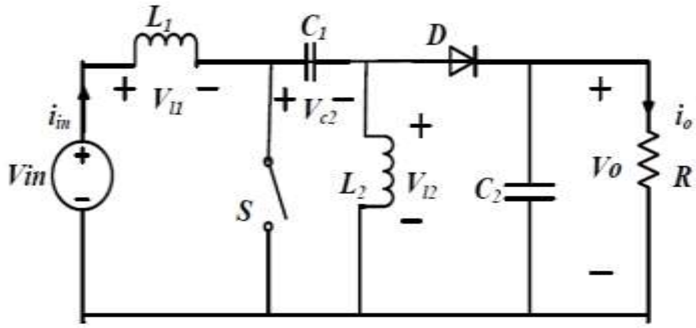

Fig. 3. Schematic Diagram of SEPIC Converter Designing steps of SEPIC Converter are as follows

$$L_1 = \frac{D*V_{in}}{\Delta I_{LI} f_s} \text{..........................(11)}$$

$$L_2 = \frac{D*V_{in}}{\Delta I_{L2} f_s} \text{.........................(12)}$$

$$C_1 > \frac{I_{out}*D}{\Delta V_{C1} f_s} \text{........................(13)}$$

$$C_2 > \frac{I_{out}*D}{\Delta V_{C2} * f_s} \text{.....................(14)}$$

IV.MPPT TECHNIQUES

There are different techniques used to track the maximum power point. The choice of the algorithm depends on the time complexity the algorithm takes to track the maximum power point (MPP), implementation cost and the ease of implementation. In this thesis work we are concentrated to mainly three types of MPPT Techniques which are used widely.

- Perturb and Observe Method
- Incremental Conductance Method
- Fuzzy Logic Control Technique
- Fractional Open-Circuit Voltage Technique
- Fractional short-Circuit Current Technique
- Constant Voltage Technique

Perturb and Observe (P&O) MPPT Technique Perturb and Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP [6], [8], [9], [19].It is dominantly used in practical PV systems for the MPPT control due to its simple implementation, high reliability, and tracking efficiency[13],[14],[15]. The present power Pk is calculated with the present values of PV voltage Vk and current Ik and is compared with the previous power P(K-1) .

Incremental Conductance (INC) MPPT Technique Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. At MPP the slope of the PV

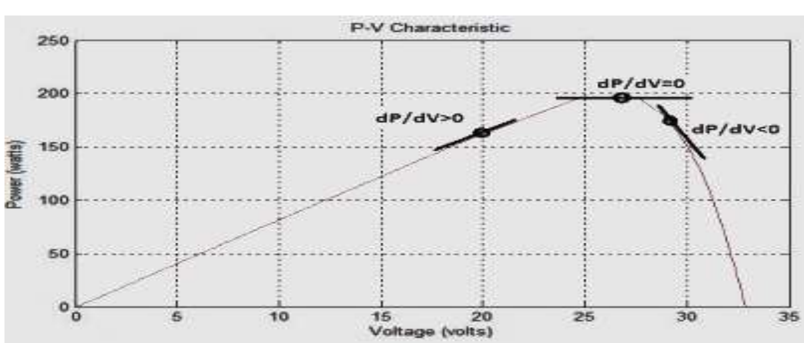

Fig.4 Solar panel P-V Characteristics for P&O Algorithm

curve is 0. The left hand side is the instantaneous conductance of the solar panel. When this instantaneous conductance equals the conductance of the solar then MPP is reached

$$\left(\frac{dP}{dV}\right)_{MPP} = \frac{d(VI)}{dV} \text{...........(15)}$$

$$0 = I + V\left(\frac{dI}{dV}\right)_{MPP} \text{.............(16)}$$

$$\left(\frac{dI}{dV}\right)_{MPP} = -\frac{I}{V} \text{..................(17)}$$

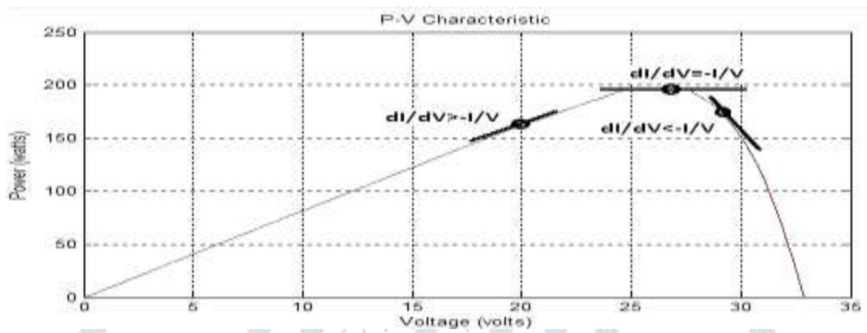

Fig.5. Solar panel P-V Characteristics for INC Algorithm

V. SIMULATION MODEL

PV system is simulated with following techniques:

- PV system with P&O MPPT technique
- PV system with INC MPPT technique

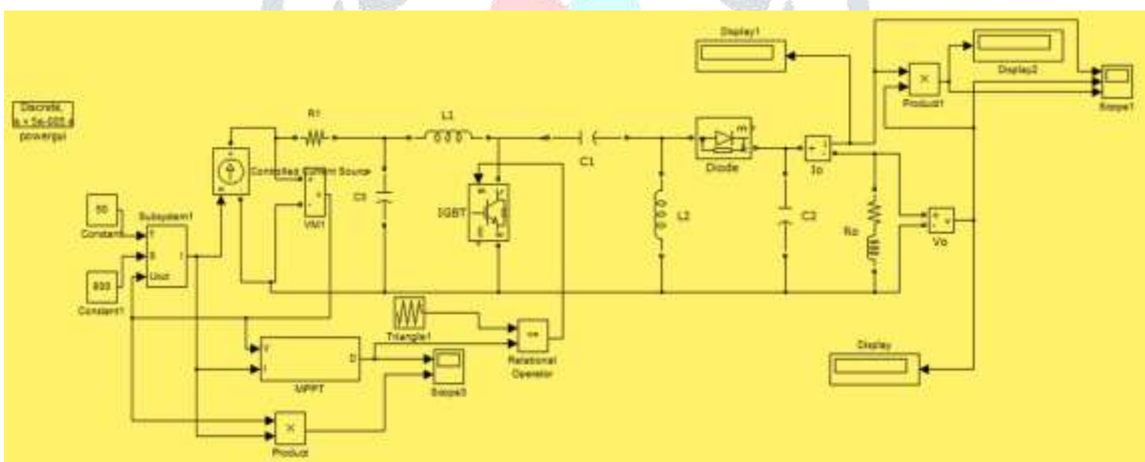

Fig.6 PV system with P&O MPPT technique developed in MATLAB/Simulink

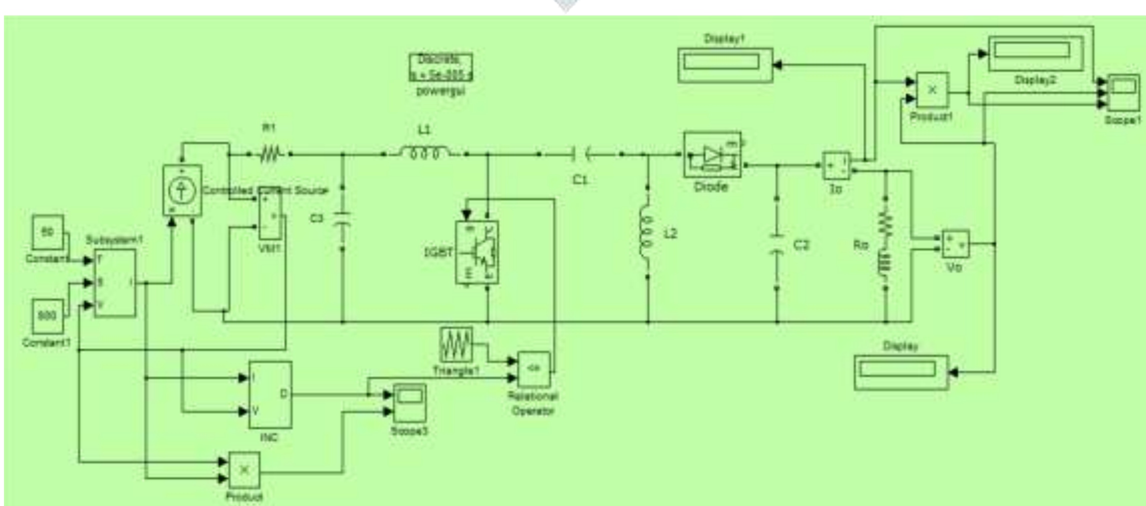

Fig. 7 PV system with INC MPPT technique developed in MATLAB/Simulink

TABLE: 1 Simulation Parameters of PV

Parameters	Variable	Value
Maximum Power	P_{max}	1260 W
Voltage at P_{max}	V_{max}	54.2 V
Current at P_{max}	I_{max}	23.25 A
Short-circuit Current	I_{sc}	25.44 A
Open-circuit Voltage	V_{oc}	66 V

TABLE: 2 Simulation Parameters of SEPIC Converter

Parameter	Variable	Value
Switching frequency of SEPIC Converter	f	5 kHz
Inductance	L_1	0.25 mH
Inductance	L_2	0.25 mH
Capacitance	C_1	300 µF
Capacitance	C_2	470 µF
Load(RL)	R	6.5 Ω
	L	0.10 mH

IV. Simulation Results

(a) Simulation Results of PV system with Perturb & Observe (P&O) MPPT Technique

Case: 1 Output at Irradiance constant (G)=1000W/m2 and Temperature (T)= 25oC
Case: 2 Output at Irradiance constant (G)= 800W/m2 and Temperature (T)= 25oC

Case: 1 Output at Irradiance constant (G)=1000W/m2 and Temperature (T)= 25oC

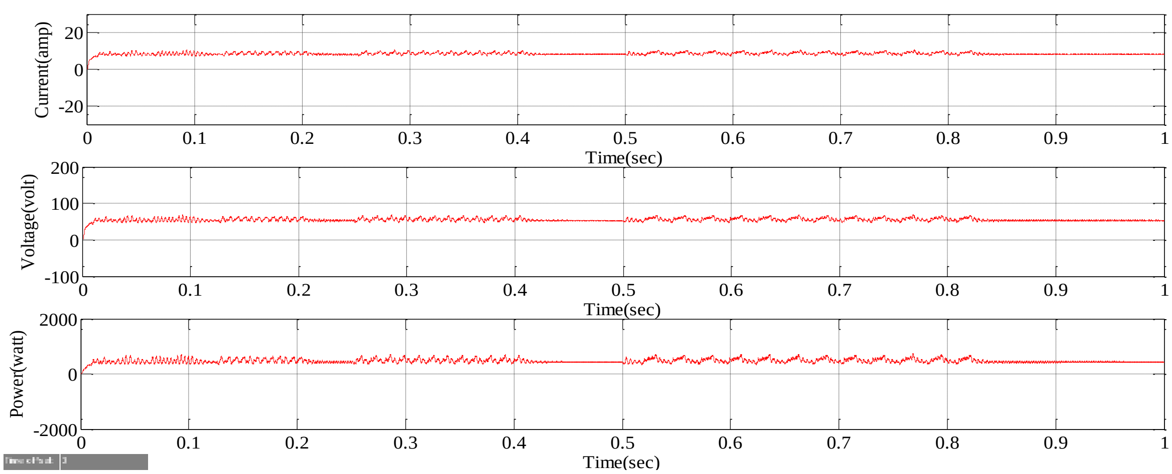

Fig. 8 System output at G=1000 W/m2 and T= 25oC with P&O MPPT

It clear from Fig. 5.3 at G=1000 W/m2 and T=25oC system gives 8.027 A current, 52.51 V voltage and 421.5 watt power to load.

Case: 2 Output at Irradiance constant (G)=800W/m2 and Temperature (T)= 25oC
It is clear from Fig. 5.4 at G=800 W/m2 and T=25oC system gives 6.598 A current, 43.16 V voltage and

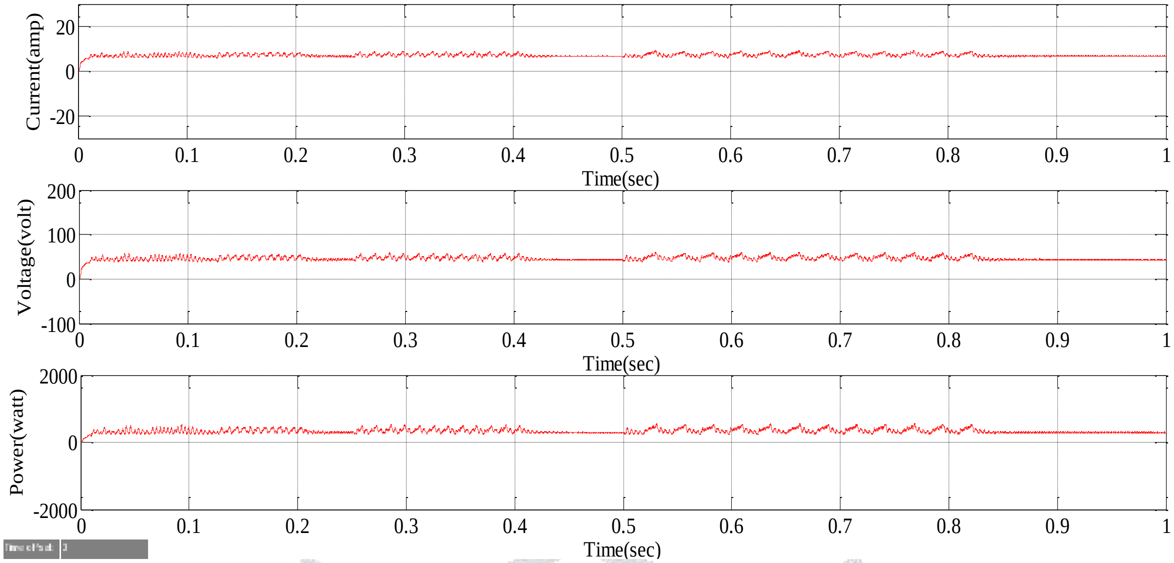

Fig. 9 System output at G=800 W/m2 and T= 25oC with P&O MPPT

284.8 watt power to load. It is concluded that power is decreased as irradiance is decreased.

(b) Simulation Results of PV system with Incremental Conductance (INC) MPPT Technique

Output at Irradiance constant (G)=1000W/m2 and Temperature (T)= 25oC
Output at Irradiance constant (G)= 800W/m2 and Temperature (T)= 25oC
Case: 1 Output at Irradiance constant (G)=1000W/m2 and Temperature (T)= 25oC

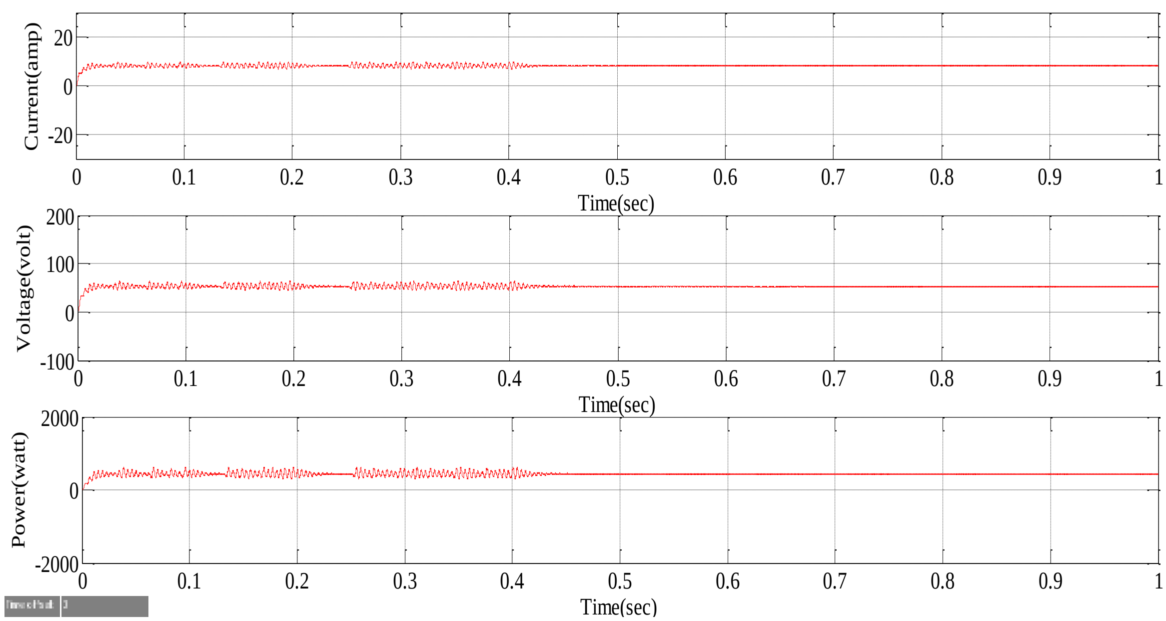

Fig. 10 System output at G=1000 W/m2 and T= 25oC with INC MPPT

It is clear from Fig. 5.10 at G=1000 W/m2 and T=25oC system gives current, voltage & power 8.084 A, 52.94 V and 428.0 watt respectively. Power increased in INC MPPT w.r.t. P&O MPPT at same conditions.

Case: 2 Output at Irradiance constant (G)=800W/m2 and Temperature (T)= 25oC

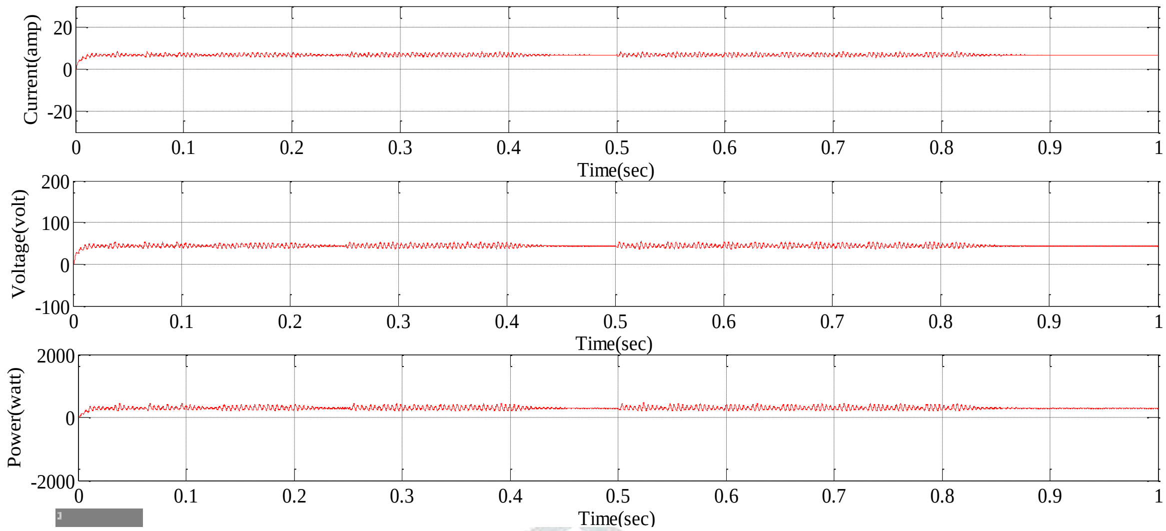

Fig. 11 System output at G=800 W/m2 and T= 25oC with INC MPPT

It is clear from Fig. 5.11 at G=800 W/m2 and T=25oC system gives current, voltage & power 6.631 A, 43.50 V and 288.4 watt respectively. It concluded that power decreased as irradiance decreased.

VI. Performance Comparison

From Results of Table it is clear that in each case of constant conditions outputs of INC MPPT are smother than that of P&O MPPT technique. It is clear from the Table 5.6 that in each case INC MPPT is giving more power than P&O MPPT and when irradiance is decreasing, INC MPPT is giving better result than P&O.

Table:3 Comparison Table under Constant environmental conditions

Case	**T(oC)**	**G(W/m2)**	**MPPT Technique**	**Output Results**			**% Power improvement with INC w.r.t. P&O**
				IL(A)	**VL(V)**	**P(W)**	
1.	25	1000	P&O	8.023	52.51	421.5	1.54
			INC	8.084	52.94	428.0	
2.		800	P&O	6.598	43.16	284.8	1.26
			INC	6.631	43.50	288.4	

VII. Conclusions

In this paper the simulation of SEPIC converter with the two MPPT methods of control: perturb and observe (P&O) and Incremental conductance (INC) MPPT technique has been done. All of them were applied on a chain of energy conversion supplied by SEPIC converter. It is clear that MPPT increases the output power of PV system. We compared the obtained simulation results, by subjecting the controlled system to the same environmental conditions. The simulations have shown that the use of INC method can improve the efficiency of the overall system by minimizing the energy losses when the change of irradiation is frequent rather than the perturb and observe technique.

REFERENCES

[1] Falin, Jeff. “Designing DC/DC converters based on SEPIC topology”, Texas Instruments. December, 2013.
[2] Tarun Kapoor, “Renewable Energy in India: Growth and Targets”, GOI, MNRE, 13 May, 2015.
[3] Tarak Salmi, Mounir Bouzguenda, Adel Gastli, and Ahmed Masmoudi, “MATLAB /Simulink Based Modeling of Solar Photovoltaic Cell”, International Journal of Renewable Energy research, vol. no. 2, 2012.
[4] Nisha Sharma, Dr. Fahim Ansari, and Pawan Kr. Panday, “Modeling and Simulation of Photovoltaic Cell using Matlab/Simulink”, International Journal of Scientific and Research Publications, vol. no. 3, July, 2013.
[5] G. R. Walker & P. C. Sernia, “Cascaded DC-DC Converter Connection of Photovoltaic Modules”, Power Electronics Specialists Conference IEEE, 2002.
[6] C. Thulasiyammal et al.., International Journal of Advance Research in Computer Science and Management Studies Volume 1, Issue 5, October, 2013 pg. 95-104.
[7] C. Jaen, C. Moyano, X. Santacruz, J. Pou, and A. Arias, “Overview of maximum power point tracking control techniques used in photovoltaic systems”, Electronics, Circuits and Systems, 2008. ICECS 2008. 15th IEEE International Conference, pp. 1099 - 1102.
[8] Fei Zhang & Jianping Xu, “A Novel PCCM Boost PFC Converter With Fast Dynamic Response”, Industrial Electronics IEEE Transactions, vol. 58, December, 2010.

[9] Samer Alsadi & Basim 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, December, 2012.

[10] M.Lokanadham & K.Vijaya Bhaskar, “Incremental Conductance Based Maximum Power Point Tracking (MPPT) for Photovoltaic System”, International Journal of Engineering Research and Applications, vol. 2, April, 2012.

[11] K. Irisawa, T. Saito, I. Takano, & Y. Sawada, “Maximum power point tracking control of photovoltaic generation system under non-uniform insolation by means of monitoring cells”, in Proc. 28th IEEE Photovoltaic Specialists Conf., vol.14 , pp. 1707–1710, Sep., 2000.

[12] Taiwo, A.S. & Oricha, J.Y. (2014) Modeling, “Steady-State Analysis of a SEPIC dc-dc Converter Based on Switching Function and Harmonic Balance Technique”, Journal of Power and Energy Engineering, 2, 704-711.

[13] Lashab Abderezak, Bouzid Aissa, & Snani Hamza, “Comparative study of three MPPT algorithms for a photovoltaic system control”, IEEE Trans. Conference, 9781-4673-6636-6/15/IEEE.

[14] Dr. S.P. Singh & Surya Prakash Tripathi, “Comprehensive Study of MPPT Techniques Used for Photo-Voltaic Energy Conversion System: A State of-Art Review”, International Conference on Advanced and Agile Manufacturing Systems (ICAM, 16-17thDecember“2015, ISBN: 978-9385777-03-05).

[15] Ahana Malhotra, Dr.Prema Gaur, “Comparative Study of DC-DC Converters in Solar Energy Systems”, IEEE conference 978-1-4799-3080-7114/IEEE.

[16] M. G. Villalva, J. R. Gazoli & E. Ruppert F., “Modeling and circuit based Simulation of Photovoltaic Arrays”, Brazilian Journal of Power Electronics, 2009 vol. 14, no. 1, pp. 35--45, ISSN 1414-8862.

[17] Marcelo Gradella Villalva, Jonas Rafael Gazoli, & Ernesto Ruppert Filho, “Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays”, IEEE Transactions on Power Electronics, vol. 24, no. 5, May, 2009.

[18] H.S Hung Chung & K.K.Tse “a novel maximum power point tracking technique for a solar panels using a SEPIC or CUK converter”, IEEE Trans power Electronic vol.18 no.3 may, 2003.

[19] Tadiparthi Ramki & L.N Tripathy, “Comparison of Different DC-DC Converter for MPPT Application of Photovoltaic System”, IEEE International Conference on Electrical, Electronics, Signals, Communication and Optimization (EESCO) – 2015, 978-1-4799-7678-2/15.