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ANALYSIS AND PERFORMANCE EVALUATION OF P AND OMPPTFOR PVCONNECTEDDC-DCBOOST CONVERTER

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Abstract

The I-V characteristics of solar cell are affected due to solar irradiation and local temperature conditions. The solar cell array output power varies due to variations in radiation and cell temperature. Various maximum power point tracking (MPPT)algorithms are developed for extraction of maximum powerfrom a solar array when it operates at MPP which varies continuously whenever there is change in solar panels temperature or irradiance. The solar cell array is integrated with intermediate converter to utilize extracted maximum power from the solar panel. This integrated system operated at high efficiency and the low operating cost. This paper discusses about Perturb & observes algorithm implementation by considering only voltage profile of solar cell module. The integrated system comprising of solar array, boost converter along with MPPT is simulated using MATLAB/SIMULINK tool.

KeywordS : Solar cel, , MPPT algorithm, Perturb & obsurves algorithm, Boost converter

I. Introduction

The limited availability of non-renewable energy resources, cost of fossil fuel and environmental concerns leading to renewable energy resources to show an imperative role in power generation. Among a number of renewable resources solar PV system is more considerable owing to zero fuel cost, abundant in nature, inexhaustible, clean, and requires less maintenance [II]. However the solar PV system has less efficiency, which be governed bysolar insolation, cell temperature ,variations in load. The solar cell output power varies with cell temperature and solar irradiation. To rise the effectiveness of the solar PV system it is necessary to control the system at MPP. To operate the solar panels at maximum power point an algorithm is used which is called as Maximum power point tracking algorithm (MPPT) [I]. Various MPPT algorithms are designed and developed which differ in positions of sensors used, implementation. The aim of these algorithms is how quickly the maximum power point is reached with reduced disturbances around the MPP. Among several MPPT Algorithms, the more common are constant voltage (V_{OC}) and constant current (I_{SC}), Perturb &Observe (P & O), Incremental Conductance (INC).

Mostly used algorithm is perturb& Observe because of easy implementation [IV]. It is based on the operating voltage perturbation and the observation of the resulting power changes of solar panels. This algorithm involves the following steps when the perturbation in the output voltage of solar cell occurs then,

- If positive value of change in power occurs, the perturbation value is to be maintained constant to reach MPP
- If negative value of change in power occurs, then the perturbation value is reduced or reversed to reach the MPP value.

This algorithm can also be presented as:

- With increment in voltage value if the magnitude of power increases, then the MPP of solar array is present on left side of the I-V characteristics.
- With increment in voltage value if the magnitude of power decreases, then the MPP is present on right side of the I-V characteristics.

In this paper the system configuration in section 2, the modelling of solar cell, boost converter and the various MPPT techniques are presented in 3rd section. In 4th section the proposed system's simulation results are presented and conclusion is made in section 5.

II. System Configuration

The proposed system configuration block diagram is shown if fig.1 which shows solar PV array, MPPT system and dc/dc boost converter are main components. To obtain the required amount of output power with corresponding voltage and current values a solar PV array is designed with each individual cell are connected in series and parallel [V].

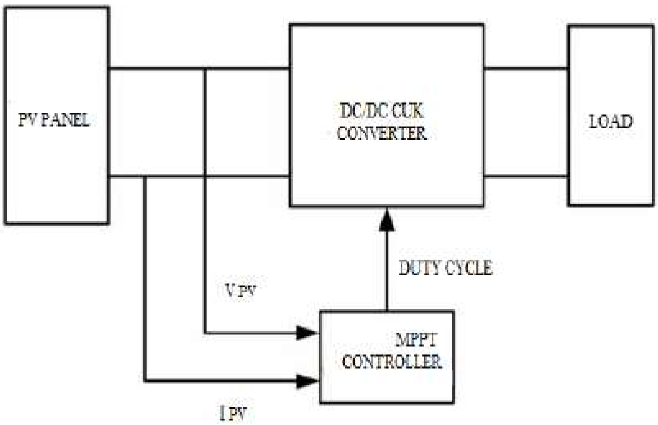

Fig: 1 Block diagram of solar system

The output voltage of solar PV array increases by series and parallel connection to get high values of output current. The output of solar PV array is given to dc/dc boost converter which produces higher values of output voltage by receiving series of pulses generated by MPPT [VI] block. The proposed system will operate at MPP when the switch in dc/dc boost converter is controlled by the pulses produced from the MPPT algorithm.

III. Description Of Proposed System Configuration

Mathematical Modelling of solar cell

The solar cell equivalent circuit is presented in fig.2. The characteristicsI_{PV}-$V_{PV}$of a solar cell are derived using equation 1 which is developed using the equivalent circuit.

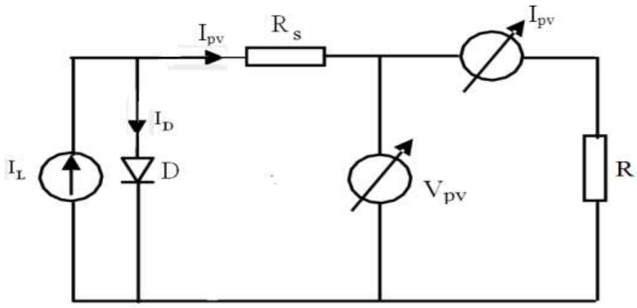

Fig.2: solar cell equivalent circuit

$$I_{PV} = I_L - I_D = I_L - I_O\left[\left(e^{\frac{V_{PV}+I_{PV}R_S}{\propto}}\right) - 1\right] \quad (1)$$

$$I_L = \frac{G}{G_{ref}}\left[I_{Lref} + \mu_{Isc}\left(T_C - T_{Cref}\right)\right] \quad (2)$$

$$I_O = I_{Oref}\left[\frac{T_{Cref}+273}{T_C+273}\right]^3 e^{\left[\frac{e_{gap}q}{N_S\propto_{ref}}\left(1-\frac{T_{Cref}+27}{T_C+273}\right)\right]} \quad (3)$$

Where V_{PV}output voltage and I_{PV}output current of solar cell.

I_L= Current produced due to Solar Irradiance, Io= Dark current; Rs = Series Resistance;Tc = Ambient cell temperature;Tref = Reference cell temperature in Kelvin; q = Electron Charge; egap = energy bandgapsilicon material;α= Completion factor;μ_{Isc} =shortcircuitcurrent temperature coefficient.

Fig.3 shows I_{pv}-V_{pv} and P-V_{pv} characteristics of solar module for specific solar irradiation and ambient cell temperature. From Fig. 3, it can be observed that output characteristics of solar module are not linear and has only one MPP for a specific irradiance and cell temperature. The solar module's output current is affected mainly due to variations in solar radiation. The solar module's voltage is affected by variations in temperature. In order to use the solar module efficiently, when there is a change in atmospheric conditions, a Maximum power point Tracker is to be integrated.

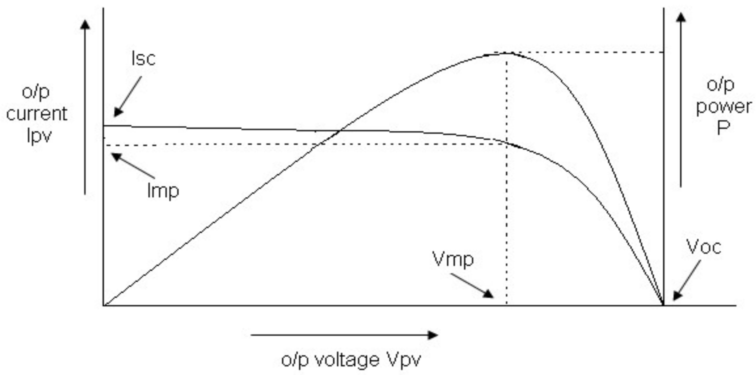

Fig.3: Characteristics of I_{pv}-V_{pv}& P-$V_{pv}$for a solar cell

Boost Converter

As the conversion efficiency of solar cells is low and in order to improve the system efficiency a high efficient intermediate power electronic converters with maximum power point trackers are to be integrated with solar modules. The converter should enhance the voltage of solar cell so a dc/dc boost converter is used which is used to control the average output fed to load. This paper presents dc/dc converter which boosts the voltage is coupled with solar array. The voltage and current equations for the converter under steady-state is derived using state space analysis for continuous conduction mode. The basic circuit for dc/dc boost converter is shown infig.4.

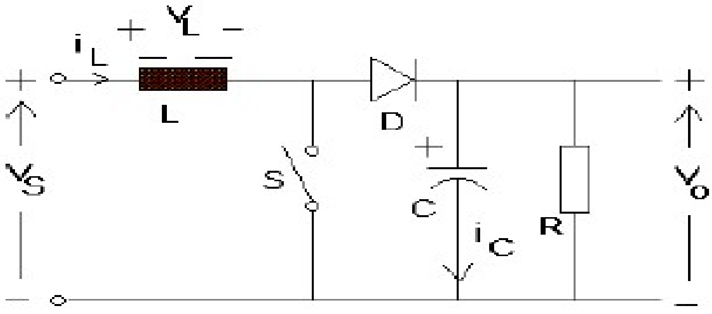

Fig. 4: Circuit Diagram for Boost Converter

The fig.5 shows the waveforms of dc/dc boost converter operating in above two modes under continuous current mode.

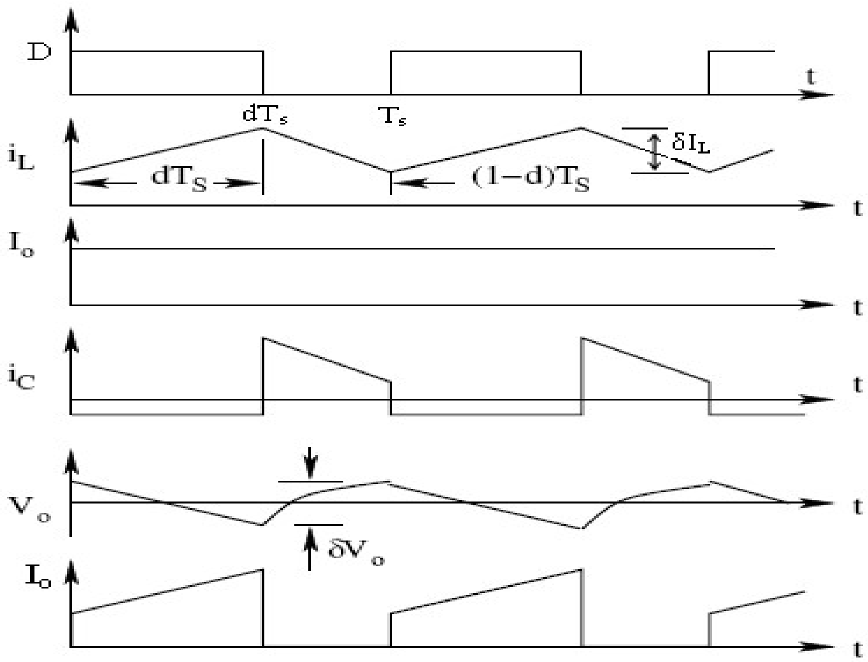

Fig.5: Waveforms for Boost Converter

Based on desired current ripple the inductor and on voltage ripple the capacitor values are determined.

$$\Delta I_L = \frac{V_S D T_s}{L} \quad (4)$$

$$\Delta V_C = \frac{V_o D T_s}{RC} \quad (5)$$

Output Voltage, $V_O = \frac{V_S}{1-D}$; Ts and D represents Switching period and Duty ratio.

The two modes of operation of boost converter is presented using state space analysis. After presenting these two modes in state space the generalized average modeling of state space for boost converter is obtained. When high output pulse is given to switch it is ON and diode is turned off. In this mode, state space equations are obtained as shown below:

$$\left.\begin{aligned} X^I &= A_1X + B_1V_S \\ V_O &= C_1^T X \end{aligned}\right\} \tag{6}$$

Where $X = \begin{bmatrix} I_L \\ V_C \end{bmatrix}$, $A_1 = \begin{bmatrix} 0 & 0 \\ 0 & -\frac{1}{RC} \end{bmatrix}$, $B_1 = \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix}$, $C_1^T = [0 \quad 1]$

When low output pulse is given to switch it is OFF and diode is turned on. In this mode, state space equations are obtained as shown below:

$$\left.\begin{aligned} X^I &= A_2X + B_2V_S \\ V_O &= C_2^T X \end{aligned}\right\} \tag{7}$$

Where $X = \begin{bmatrix} I_L \\ V_C \end{bmatrix}$, $A_2 = \begin{bmatrix} 0 & -\frac{1}{L} \\ \frac{1}{C} & -\frac{1}{RC} \end{bmatrix}$, $B_2 = \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix}$, $C_2^T = [0 \quad 1]$

Based on eq.6 and eq.7, the statespace equations are obtained as shown below:

$$\left.\begin{aligned} X^I &= AX + BV_S \\ V_O &= C^T X \end{aligned}\right\} \tag{8}$$

Where $X = \begin{bmatrix} I_L \\ V_C \end{bmatrix}$, $A = \begin{bmatrix} 0 & -\frac{(1-D)}{L} \\ \frac{(1-D)}{C} & -\frac{1}{RC} \end{bmatrix}$, $B = \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix}$, $C^T = [0 \quad 1]$

IV. MPPT Computational Techniques

Open circuit voltage algorithm

This open circuit voltage algorithm is easily implemented but there is difficulty in determining the accurate value of K [XIV]. Hence doesn't provide good result under varying physical conditions. Its tracking speed is fast but not exact. Powerloss during measurements occurs hence less efficient. MeasuringV_{OC}during operation is problematic as it can be done only by open circuiting the load.

Short circuit current algorithm

This algorithm is similar to the open circuit voltage algorithm and here also determining the accurate value of K is difficult. Measuring I_{SC} during operation is problematic as it can be done only by short circuiting the load [XII]. Using this algorithm, the output power is always less than the Maximum output power and the MPP is never matched perfectly.

Perturb and Observe algorithm

As the above mentioned two algorithms are not feasible an alternate MPP algorithm is developed which is called as perturb and observe method. This algorithm has the advantages of easy implementation, simple and is independent to PV array.At an instant K, If the PV output power and output voltage P(k) and voltage V (k) is more when compared with previous values of output power and voltage P(k-1) and V(k-1) the perturbation direction is maintained same or else the perturbation is reversed.The flowchart for the P & O algorithm is shown in fig.6.

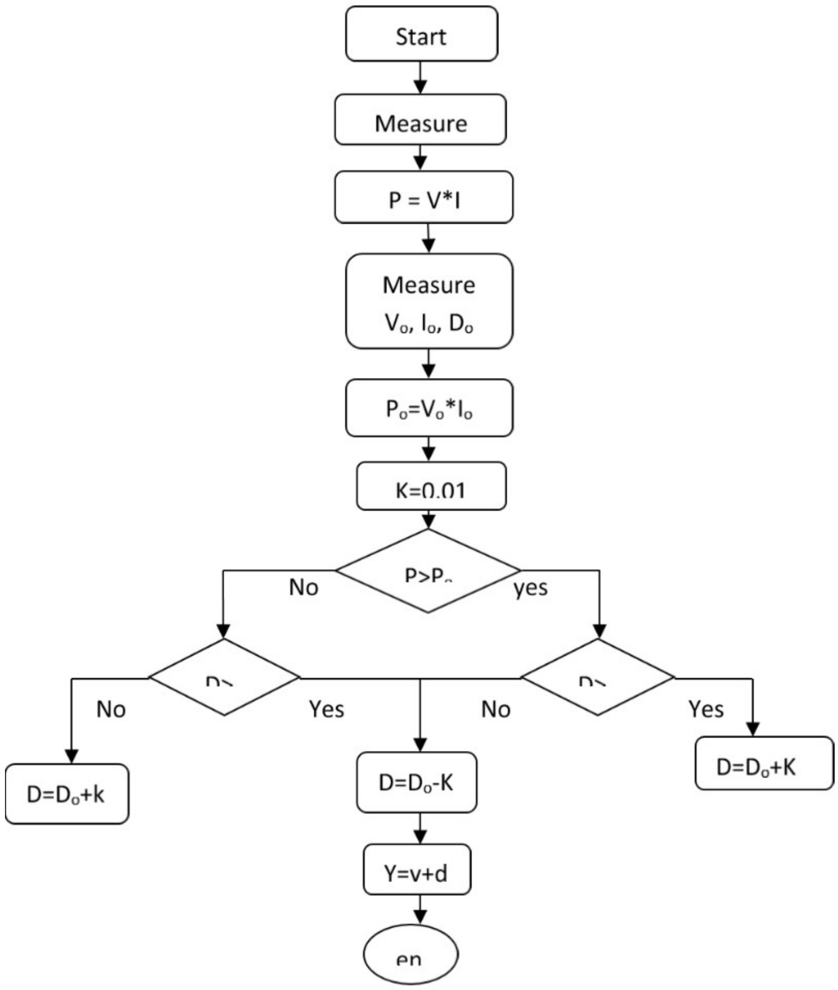

Fig 6:Flowchart of P&O MPPT

The requisite Maximum Power Point Tracking algorithm is that output power of solar module varies whenever the solar irradiance level and the ambient temperature changes. Due to the climatic variations the efficiency of solar panel is low. It is necessary to operate module at a specific point irrespective of climate variations to improve the efficiency and power delivered to the load is ample. The proposed algorithm continuously adjusts the width of the pulses given to the switch of boost converter till the partial derivative of $\partial P_{PV}/\partial V_{PV}$ is equal to zero which means that the solar panel is operating at its maximum power point[IX]. The operation of the algorithm is presented using the P_{PV}-V_{PV} characteristics of solar panel where P represents output power and V represents the output voltage as shown in fig.7.

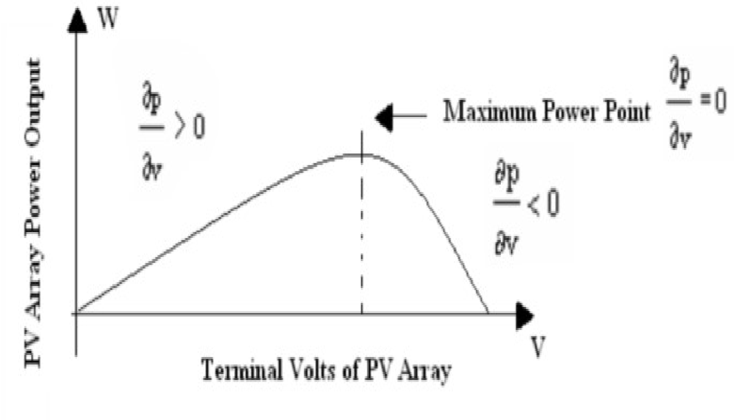

Fig.7Output Power(P_{PV}) vs Output Voltage(V_{PV}) of a module

$\partial P_{PV}/\partial V_{PV}$= 0 Then $V_{PV} = V_{MP}$ (9)

$\partial P_{PV}/\partial V_{PV}$>0Then $V_{PV} < V_{MP}$ (10)

$\partial P_{PV}/\partial V_{PV}$< 0 Then $V_{PV} > V_{MP}$ (11)

Simulation of Proposed System

In this section the validation of the proposed system is presented with simulation results using MATLAB/SIMULINK. The proposed system is an integration of solar array, boost converter and a MPPT controller which operates using P & O algorithm.The simulated waveforms of voltage,current and power of solar array at irradiances of 1000w/m^2 and 200 W/$m^2$with constant ambient temperature at 25^{o}C are shown.

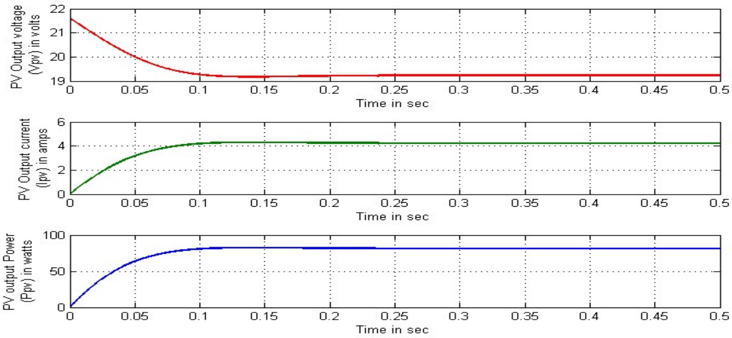

Fig.8. Simulated Waveforms of output voltage (V_{PV}), current (I_{PV}), power (P_{PV}) of solar Array for Irradiance and temperature of 1000 W/m^2, 25^{o}C

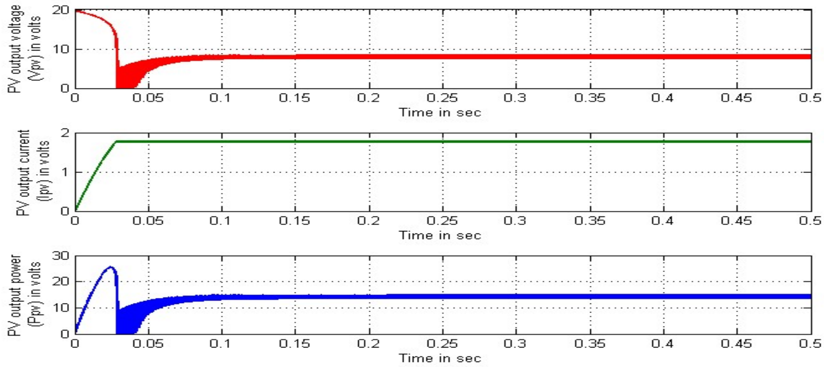

Fig.9. Simulated Waveforms of output voltage (V_{PV}), current (I_{PV}), power (P_{PV}) of solar Array for Irradiance and temperature of 00 W/m^2, 25^{o}C

The simulated waveforms of output voltage,current and power of converter at for irradiances of 1000 W/m^2 and 200 W/m^2 at temperature of 25^{o}C are shown.

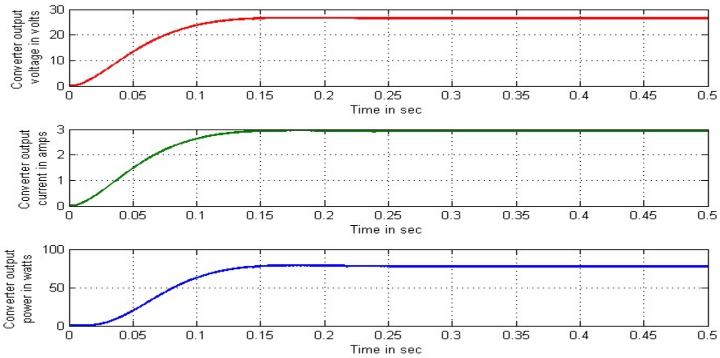

Fig.10. Simulated Waveforms of output voltage, current, power of converter for Irradiance 1000 W/m^{2}and Temperature of 25^{o}C

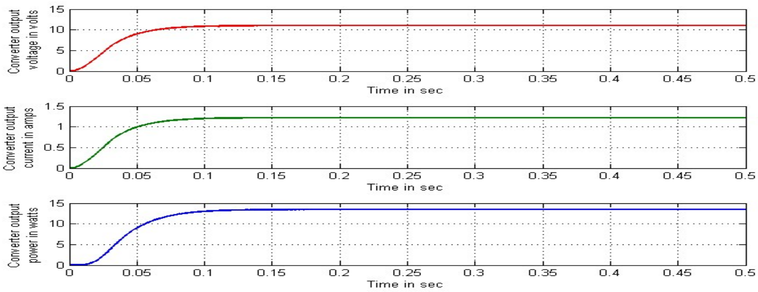

Fig.11. Simulated Waveforms of output voltage, current, power of converter for Irradiance 200 W/m^2 and Temperature of 25^{o}C

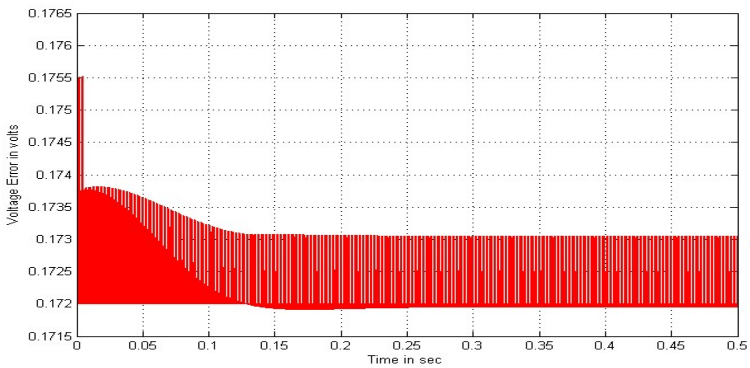

Fig.12. Input of the voltage controller (V_{ref} - V_{pv}) forIrradiance 1000 W/m^2 and Temperature of 25^{o}C

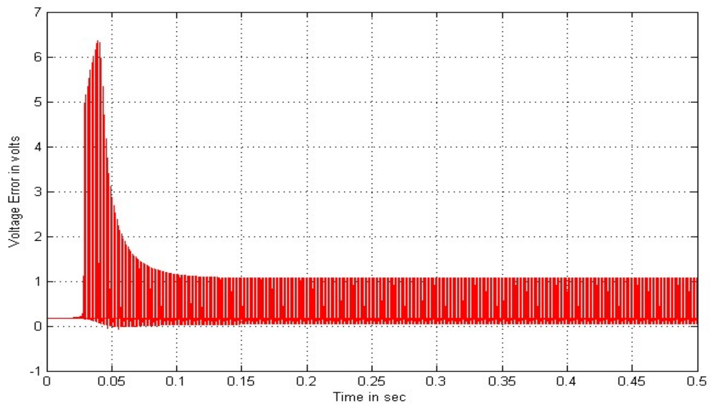

Fig.12. Input of the voltage controller (V_{ref} - V_{pv}) forIrradiance 200 W/m^2 and Temperature of 25^{o}C

The detailed performance analysis of MPPT and BOOST converter is given in the table 1.

Table.1

Performance Analytic of P&O MPPT Method and Boost Converter

Irradiance (W/m^2)	Temperature (^oC)	P&O Algorithm			Boost converter			Tracking Efficiency (%)	Conversion Efficiency (%)
		Voltage (V_{pv})	Current (I_{pv})	Power (P_{pv})	Voltage (V_{con})	Current (I_{con})	Power (P_{con})		
1000	25	19.23	4.232	81.41	26.44	2.924	77.30	81.41	94.95
800		18.29	4.017	73.45	25.09	2.775	69.63	73.45	94.79
600		16.33	3.573	58.35	22.32	2.468	55.09	58.35	94.41
400		11.88	2.560	30.41	15.99	1.768	28.27	30.41	92.96
200		8.479	1.767	14.98	13.47	1.221	11.04	14.98	73.69

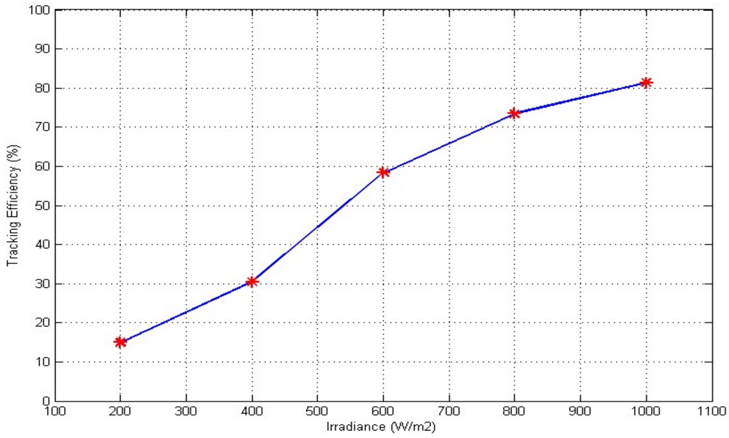

Fig.13. P&O MPPT Method: Analytical Evaluation of Irradiance vs. Tracking Efficiency

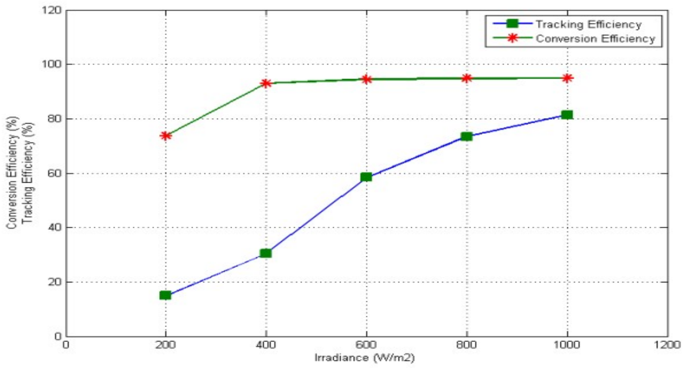

Fig.14. P&O MPPT Method: Analytical Evaluation of Irradiance vs. Tracking Efficiency and Conversion Efficiency

From the above simulation results and the graphs presented it is clear that for varying irradiance and constant temperature there is an increment in output power of solar array thereby tracking and conversion efficiencies also increased.

V. Conclusion

This paper presents a solar array integrated with boost converter and MPPT tracker which operates on perturb and observe algorithm. The tracking efficiency and complexity of proposed system is verified using MATLAB/Simulink. The conversion efficiency of the proposed MPPT algorithm is also validated and presented in the form of comparison and it is concluded that the system response is improved.

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