

Performance Analysis of MPPT Based Boost Converter using MATLAB Simulink

Priyansh Gupta¹, Sudhir Sharma², Deepti Jain³

¹M.E. Scholar, Samrat Ashok Technological Institute, Vidisha

²Assistant Professor, EED, Samrat Ashok Technological Institute, Vidisha

³Assistant Professor, EED, Samrat Ashok Technological Institute, Vidisha

Abstract- In this paper, Importance of I-V Characteristics of PV array firstly described having varying value of Load resistance. Importance of boost converter in extracting the maximum power from PV array then presented.

Normal operation of Boost converter explained with mathematical equations. Use of Solar PV array having Maximum Power Point Tracking explained using MATLAB simulink.

Combining the MPPT and solar PV array, MATLAB simulation of Solar PV array fed Boost converter having the achievement of Maximum power operating point is done. The performance and result analysis of both the test circuit presented and compared in detail.

I. INTRODUCTION

The Solar PV arrays are the best source of renewable electrical energy in modern time. The electrical energy generated from the solar PV array is actually in the form of constant current up to a certain voltage level, after that particular voltage level, the current will drop to zero. Around this particular voltage, the solar PV array will give the maximum power. This point is also called the MPP Maximum power point, the same is explained in the upcoming section of this paper.

While using the Solar PV array as the source of electrical energy, the best way to take the maximum power from solar PV array is to interface the PV array with the Boost converter.

By changing the duty cycle of Boost converter depending upon the MPPT algorithm, one can achieve the Maximum Power point of PV array with the varying load resistance value.

Boost converters are the dc to dc converters having the constant dc voltage input and having the step up output voltage higher than the input voltage.

In the proposed strategy, Performance of Solar PV fed

Boost converter is analyzed in detail under varying load condition.

II. I-V CHARACTERISTICS OF SOLAR PV ARRAY & ITS LIMITATION

The renewable source of energy i.e. solar PV array is constant current dc source having the I-V characteristic shown in fig. 1. In the proposed strategy, the same solar PV array is used for complete simulation work.

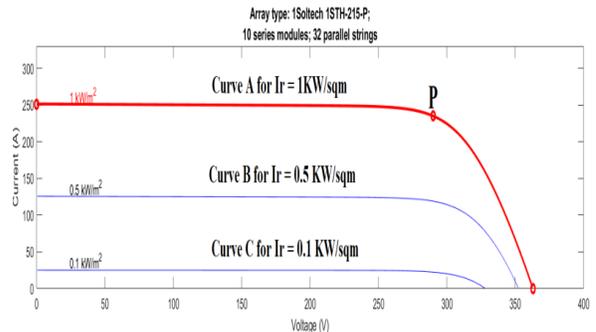


Fig.1: Graph showing the I-V characteristics of Solar PV array
 In the above shown graph, Point P is the maximum power point having value of V & I co-ordinate is 290 Volts & 235.2 Amps respectively and Maximum power is 68,208 Watts. The three curves A, B & C are applicable for same solar PV array at one temperature of 25 °C, but for different value of irradiation i.e. 1KW/m², 0.5 KW/m², 0.1KW/m² respectively. The important observation from the Fig.1, is that source can deliver the rated current of 250 Amps from 0 Volts to the voltage around 290 Volts or we can also say that for the value of load resistance varying from 0 Ohm to (290V/250A) = 1.16 Ohms, it will deliver the constant current of 250 Amps independent of load resistance value, and above that value of resistance i.e.1.16 Ohms, the I-V curve has parabolic shape hence the output voltage, current and power has two value and

the MATLAB simulation reveals that the voltage current & power fluctuates above that value of resistance. Hence the solar PV cell can be used only in the constant current region and most preferably at maximum power point i.e. point P in fig.1.

Due to above limitation in the Solar PV array related to load resistance value; the solar PV array cannot be used directly to feed the dc load. Generally Boost converter with MPPT (Maximum power point tracking) is used to extract the maximum power from the solar PV array.

III. MATLAB SIMULATION OF CONVENTIONAL BOOST CONVERTER

For the proper analysis of MPPT controlled Boost converter, it is necessary to simulate the normal boost converter circuit. The most common circuit of boost converter is shown in fig.2.

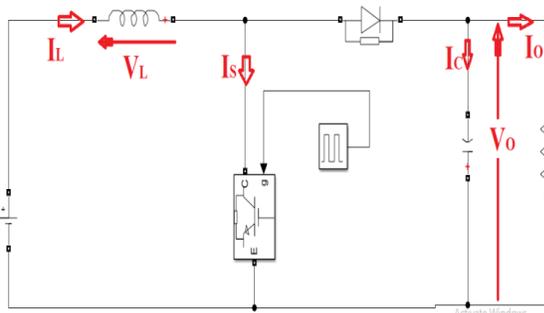


Fig.2: Boost converter Simulation Circuit

As from the normal working of the boost converter, following equations are well known for continues conduction mode of boost converter and mentioned below:

$$V_o = V_s / (1 - D) \quad \{ \text{where } 0 < D < 1 \} \dots \dots \dots \text{eq.1}$$

$$L_{min} = (1 - D)^2 DR / 2f \quad \{ L > L_{min} \} \dots \dots \dots \text{eq.2}$$

$$C_{min} = DV_o / VrRf \quad \{ C > C_{min} \} \dots \dots \dots \text{eq.3}$$

$$I_{\Delta L} = V_s D / FL \dots \dots \dots \text{eq.4}$$

$$R_{in} = R_o (1 - D)^2 \dots \dots \dots \text{eq.5}$$

The boost converter used is firstly simulated with the help of normal dc voltage source. The values of parameters selected used for simulation of boost converter are mentioned in table 1 and mentioned below:

Table 1: Values of parameters selected for Conventional Boost converter

S. No.	Name of parameter /element	Value selected for simulation
1	Vs(Input Voltage)	289 Volts
2	D(Duty ratio)	0.6
3	f(Switching frequency)	5000 Hz

4	Ro(Load Resistance)	10 Ohms
5	Allowed Output Ripple factor (Vr/Vo in %)	1%
6	Boost inductor, Lmin (minimum value for continues conduction) from eq.2	96 μH
7	Boost capacitor Cmin (minimum value for continues conduction mode) from eq.3	1200 μF

IV. SIMULATION RESULTS OF CONVENTIONAL BOOST CONVERTER

On the application of values given in table 1 in boost circuit diagram of fig.1. The waveform of voltage and current at different parts of circuit is shown in fig. 3.

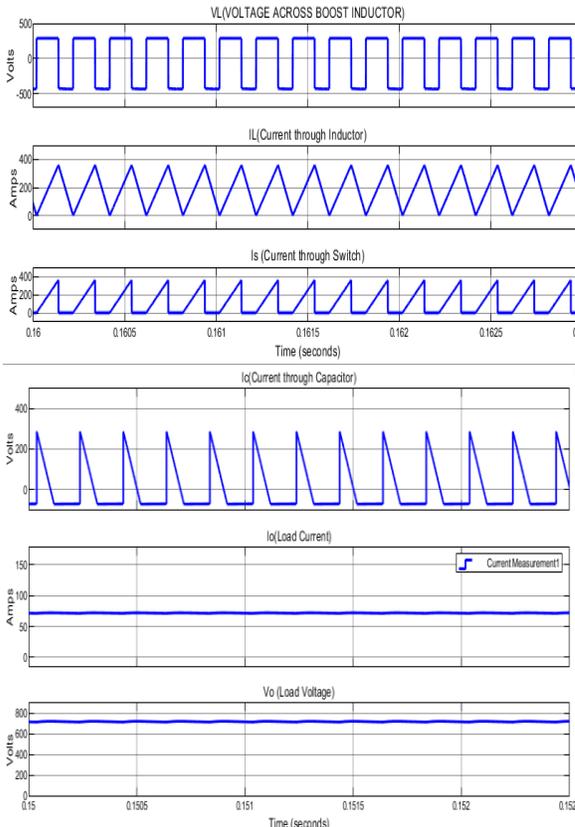


Fig.3: Voltage & Current at different parts of boost circuit at the boundary of continues and discontinues mode of conduction

The average value of Voltage and Current at different parts of boost converter is mentioned in table 2 & mentioned below:

Table 2: Values of parameters after simulation of boost converter circuit

S. No.	Average Voltage / Current as per boost circuit mentioned in fig.2	Value

1	Voltage across inductor (VL)	0 Volts
2	Input Current through Inductor (IL)	180.9 Amps
3	Current through IGBT (Is)	108.5 Amps
4	Current through Capacitor (Ic)	0 Amps
5	Current through Load (Io)	71.94 Amps
6	Voltage across Load (Vo)	722.7 Volts
7	Rin (Input resistance of boost converter)	1.6 Ohms
8	Power input to boost converter	5.214 KWatts
9	Power delivered to load	5.176 KWatts
10	Power loss in the boost converter	380 Watts
11	Power Efficiency of boost converter	99.27%

V. PROPOSED STRATEGY OF MPPT CONTROLLED BOOST CONVERTER

The main purpose of MPPT (Maximum Power Point Tracking) controller is to achieve (set) the duty ratio in such a way that the voltage output of PV array (or input voltage of boost converter) should be at a point in the P-V characteristic as shown in fig.4, such that PV array will deliver the maximum power to load.

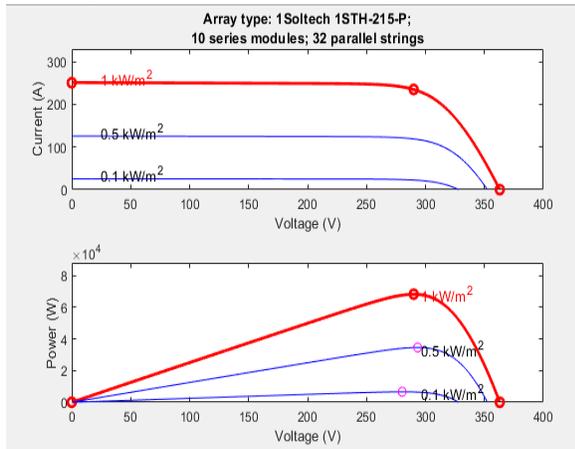


Fig.4: I-V & P-V Characteristics of PV array used as a source of boost converter

The simulation circuit of MPPT controlled Boost converter is shown in fig.4. In this circuit, Solar PV array is used in place of dc source, the voltage and current of solar PV array is used as input of MPPT controller, the output of which is the duty ratio. The value of duty ratio will drive the PWM generator and the output of PWM generator will follow the value of duty ratio.

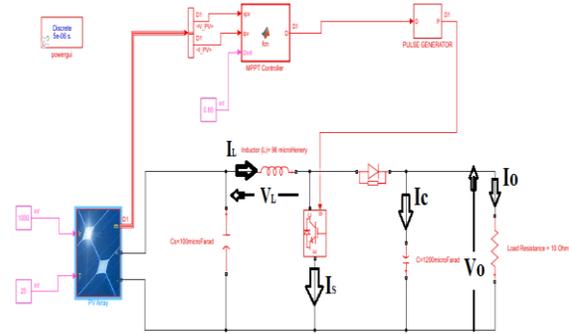


Fig.5: Simulation circuit of MPPT controlled Boost converter

For the comparison purpose, the value of elements for simulation of MPPT controlled boost converter is same as that in the previous section i.e. conventional boost converter, the value of those elements are mentioned below in table 3. Here the value of duty ratio will be selected by the MPPT controller depending on the load resistance maximum power point and other circuit parameters.

Table 3: Values of parameters selected for MPPT controlled Boost converter

S. No.	Name of parameter /element	Value selected for simulation
1	Vs(Input Voltage)	As per graph of solar PV array as in fig. 4.
2	Maximum power point of Solar PV array	68210 Watts @ 290 Volts
3	D(Duty ratio)	Automatically decided by the MPPT controller
4	f(Switching frequency)	5000 Hz
5	R(Load Resistance)	10 Ohms
6	Allowed Output Ripple factor (Vr/Vo in %)	1%
7	Boost inductor, Lmin (minimum value for continues conduction) from eq.2	96 µH
8	Boost capacitor Cmin (minimum value for continues conduction mode) from eq.3	1200 µF

VI. SIMULATION RESULTS OF MPPT CONTROLLED BOOST CONVERTER

On the application of values given in table 3 in MPPT controlled boost circuit diagram of fig. 5. The waveform of voltage and current at different parts of circuit is shown in fig. 6.

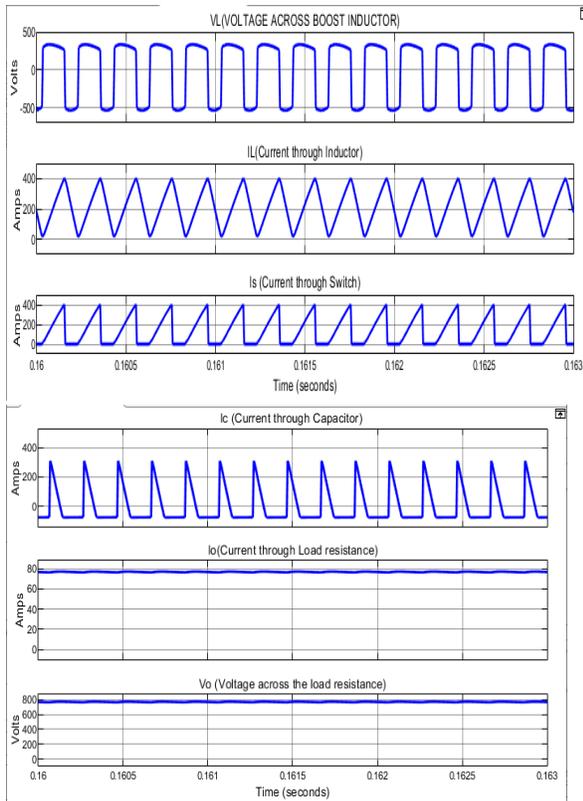


Fig.6: Voltage & Current at different parts of MPPT controlled boost circuit at the boundary of continues and discontinues mode of conduction.

The value of average voltage and current comes after the simulation at different parts of the circuit is tabulated in table 4. The duty cycle will be governed by the MPPT controller and the input of MPPT controller is the output voltage & current of solar PV array.

Table 4: Values of parameters after simulation of MPPT controlled boost converter circuit for minimum value of boost inductor and capacitor as mentioned in table 3.

S. No.	Average Voltage / Current as per boost circuit mentioned in fig.2	Value
1	Voltage across inductor (VL)	~0 Volts
2	Voltage input of Solar PV array	289 Volts
3	Input Current through Inductor (IL)	210 Amps
4	Current through IGBT (Is)	133.9Amps
5	Current through Capacitor (Ic)	~0 Amps
6	Current through Load (Io)	76.83 Amps
7	Voltage across Load (Vo)	768.3 Volts
8	Duty cycle set by the MPPT controller for extracting maximum power from PV array	0.6248
9	Rin (Input resistance of boost converter)	1.4 Ohms
10	Power input to boost converter	59.55 KWatts

11	Power delivered to load	59.03 KWatts
12	Power loss in the boost converter	520 Watts
13	Power Efficiency of boost converter	99.12%

VII. ANALYSIS OF SIMULATION RESULTS OF MPPT CONTROLLED BOOST CONVERTER AND COMPARED IT WITH THE CONVENTIONAL BOOST CONVERTER

As firstly, the conventional boost converter is simulated for the boundary condition of continues conduction mode having minimum value of boost inductor and capacitor for $V_{dc}=289$, $D=0.6$ and $R_o=10$ Ohms, $L=96 \mu H$ and $C=1200 \mu F$. The simulation results in fig.3 reveals that the boost converter operates at boundary between the continues and discontinues mode of conduction and hence the ripple of current through the boost inductor will be equal to maximum current.

After that taking same value as used in the conventional boost converter, the simulation of MPPT controlled boost converter was done for extracting the Maximum power from the PV array, it was observed that maximum power point cannot be achieved at same value of load resistance i.e. $R_o = 10$ Ohms and also at R_o in between 1 Ohms to 100 Ohms.

Simulation was again done by increasing the value of boost inductor as per eq.4 such that the ripple in the inductor current is 3%. It was then seen from simulation that the boost converter achieves the maximum power point. By increasing the value of inductor for achieving the MPP point and reducing the ripple in the inductor current within 3%. The following are the values of average current and voltage at different parts of circuit and the same in mentioned in table 5.

Table 5: Values of parameters after simulation of MPPT controlled boost converter circuit for $L=5000 \mu H$ and $C=C_{min}$ i.e. $1200 \mu F$

S. No.	Average Voltage / Current as per boost circuit mentioned in fig.2	Value
1	Voltage input of Solar PV array	289.4 Volts
2	Input Current through Inductor (IL)	235.4Amps
3	Current through IGBT (Is)	153.4 Amps
4	Current through Load (Io)	82.14Amps
5	Voltage across Load (Vo)	821.4Volts
6	Duty cycle set by the MPPT	0.6304

	controller for extracting maximum power from PV array	
7	Rin (Input resistance of boost converter)	1.366 Ohms
8	Power input to boost converter	68.13 KWatts
9	Power delivered to load	67.47 KWatts
10	Power loss in the boost converter	660 Watts
11	Power Efficiency of boost converter	99.03%

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VIII. CONCLUSION

It is concluded from the proposed strategy that

- 1) The maximum power point can be obtained only when the boost converter operated well within the continuous conduction mode, such that the ripple in the current through boost inductor should be within 3%.
- 2) By increasing the value of boost inductor much higher than the critical value such that current ripple of boost inductor is 3%, stability of output voltage and current will not get affected.
- 3) The duty ratio was not being changed.
- 4) The current input to boost converter changed from 210.6 Amps to 235 Amps
- 5) Power output of boost converter increases by 14%

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