Performance Evaluation of Maximum Power Point Tracking Algorithm with Buck-Boost DC-DC Converter for Solar PV System

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Abstract

Maximum power point tracking is used in solar PV energy conversion system to extract maximum power from solar PV (Photovoltaic). MPPT algorithm is implemented in the control circuit of Power electronics DC-DC converters. The behavior of MPPT depends upon the type of the type of DC – DC converter used. The objective of this paper is to analyze the working of MPPT with buck-boost DC – DC converter. The simulation is study is done by using PSIM simulation software.

Keywords: MPPT, Solar PV, Power Electronics, Buck-Boost Converter, PSIM

I. INTRODUCTION

Global Energy Crisis and climate change threats leads the researchers to look for alternate sources of energy [1-2]. Solar Energy is considered as the most reliable source among all renewable energy sources (RES) [3-8]. Solar PV is used to convert solar energy into electrical energy. Solar PV exhibits nonlinear characteristics and its efficiency is also low. It becomes essential to extract maximum power from solar PV under all ambient conditions. MPPT (Maximum Power Point Tracking) algorithm is used to extract maximum power from solar PV [9-10]. The MPPT is implemented in the control circuit of Power electronics converters. A converter without MPPT system only regulates the output voltage of PV module, but it does not ensure that PV system is operating at the maximum power point MPP [11]. The operation of MPPT depends on the type of converter used [12-14]. In this paper a buck-boost dc-dc converter is used and the performance of MPPT is evaluated.

II. SOLAR PV CHARACTERISTIC

![Fig. 1: Equivalent model of PV Cell](image1)

![Fig. 2: Solar PV Power Characteristics with different Solar Irradiation level](image2)
The basic element of solar PV system is PV cells. These cells are connected to form modules. It is further expanded in the form of arrays as per the power requirements. These PV cells exhibit nonlinear characteristics. The output of the PV cell varies with solar irradiation and with ambient temperature. The equivalent circuit model of PV cell given in Fig (1). The characteristic equation of PV cell based on this model is given by equation 1, 2 and 3 [3].

\[
I = I_{ph} - I_{os} \{\exp \left[\frac{q}{AKT} \left( V + IR_s \right) \right] - 1\} - \frac{(V + I*R_s)}{R_p} \tag{1}
\]

\[
I_{os} = I_{or} \exp \left[\frac{q E_{GO}}{Bk} \left( \frac{1}{T_r} - \frac{1}{T}\right)\right] \frac{T}{T_r} \tag{2}
\]

\[
I_{ph} = S \left[I_{sc} + KI (T - 25)\right] / 100 \tag{3}
\]

Where I am the PV module output current, V is the PV cell output voltage, \(R_p\) is the parallel resistor, \(R_s\) is the series resistor. \(I_{os}\) is the PV module reversal saturation current, A, B are ideality factors, T is temperature (°C), k is boltzmann’s constant, \(I_{ph}\) is the light-generated current, q is electronic charge, \(K_I\) is short-circuiting current temperature coefficient at \(I_{sc}\), S is solar irradiation (W/m²), \(I_{sc}\) is short-circuit current at 25°C and 1000 W/m², \(E_{GO}\) is bandgap energy for silicon, \(T_r\) is reference temperature and \(I_{or}\) is saturation current at temperature \(T_r\). The plot of solar PV output power is shown in Fig (2). It can be seen that the power and current varies non-linearly with the variation in solar irradiation and with ambient temperature.

### III. P&O MPPT TECHNIQUE

Perturb and observe (P&O) method is a MPPT scheme proposed by researchers. In perturb and observe method the perturbation is applied either in the reference voltage or in the reference current signal of the solar PV. The flow chart of the P&O method is shown in Fig 3. In this chart Y is shown as the reference signal. It could be either solar PV voltage or current. The main aim is to reach to the MPP. To achieve it the system operating point is changed by applying a small perturbation (\(\Delta Y\)) in solar PV reference signal. After each perturbation the power output is measured. If the value of power measured is more than the previous value then the perturbation in reference signal is continued in the same direction. At any point if the new value of solar PV power is measured less than the previous one then perturbation is to apply in the opposite direction. This process is continued till MPP is reached. In [8] the P&O method uses the solar PV panel current as a reference signal. The issue with this method is it becomes oscillatory around MPP. Table 1 gives the summary of P&O MPPT method.

**Table 1: Summary of the Perturb & Observe MPPT Method**

<table>
<thead>
<tr>
<th>Perturbation</th>
<th>Change in Power</th>
<th>Next Perturbation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Positive</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Negative</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
</tr>
</tbody>
</table>

![Fig. 3: Flowchart Diagram of the conventional Perturb & Observe MPPT method](image-url)
IV. BOOST DC – DC CONVERTER

![Schematic of Boost DC – DC converter](image)

**Fig. 4: Schematic of Boost DC – DC converter**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of the Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vin</td>
<td>$V_{\text{MPP}}$ : when MPP is working</td>
</tr>
<tr>
<td>2</td>
<td>MOSFET</td>
<td>20A, 600V</td>
</tr>
<tr>
<td>3</td>
<td>DIODE</td>
<td>12A, 1000V</td>
</tr>
<tr>
<td>4</td>
<td>$L$</td>
<td>1mH, 15A Saturation</td>
</tr>
<tr>
<td>5</td>
<td>$C$</td>
<td>1000 uF</td>
</tr>
<tr>
<td>6</td>
<td>$V_0$</td>
<td>Based on duty cycle expression</td>
</tr>
<tr>
<td>7</td>
<td>$R_{\text{LOAD}}$</td>
<td>Variable</td>
</tr>
<tr>
<td>8</td>
<td>Frequency</td>
<td>20 kHz</td>
</tr>
<tr>
<td>9</td>
<td>Power Output</td>
<td>40W</td>
</tr>
</tbody>
</table>

The schematic of boost converter is shown in Fig. 4. The specifications of components are shown in Table I. The boost converter is designed to work in continuous conduction mode. The relationship between boost converter input and output is given by:

$$V_0 = D \frac{Vin}{1-D}$$  \hspace{1cm} (4)

V. MPPT WITH BOOST DC-DC CONVERTER

![Block Diagram of Buck-Boost DC – DC converter](image)

**Fig. 5: Block Diagram of Buck -Boost DC – DC converter**

![MPP Zone on I-V Curve](image)

**Fig. 6: MPP Zone on I-V Curve**
The block diagram of buck-boost dc-dc converter with MPPT is shown in Fig. 5. The MPP zone for buck-boost converter is shown in Fig. 6. The variation of input impedance with duty cycle is shown in Fig. 7. Equation 5 is the relationship between input and output impedances with duty cycle. The MPPT will be working with buck-boost converter between B and C in Fig. 6, where $R_{load} >> R_{MPP}$. The MPPT will be working between A and B. The MPPT will be working for the entire range on solar PV characteristic.

### VI. RESULT AND DISCUSSION

![Fig. 8: MPP Working for Buck-Boost Converter when $R_{LOAD} > R_{MPP}$](image8)

![Fig. 9: MPP Failed for Buck-Boost Converter when $R_{LOAD} < R_{MPP}$](image9)
Fig. 8 and 9 are simulation results. Fig. 8 shows that MPPT is working $R_{LOAD} > R_{MPP}$. The maximum PV power and Load power is almost same. Fig. 9 shows that MPPT is working when $R_{LOAD} < R_{MPP}$. The power is same as MPP power of solar PV. These results shows that entire PV characteristic is MPPT working zone with buck - boost DC – DC converter.

VII. CONCLUSION

The main objective of the paper is to evaluate the performance of MPPT with buck-boost DC – DC converter in terms of MPPT working zone. The MPPT with buck-boost dc-dc converter is analysed and simulation results are presented. It is evident that MPPT is functional in the entire zone of PV characteristic curve.

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REFERENCES