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

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Abstract

Solar Energy is seen as the most reliable source among renewable energy sources (RES). Solar Photovoltaic (PV) is used to convert solar energy into unregulated electrical energy. Maximum Power Point Tracking (MPPT) algorithm is used to extract maximum power from solar PV. Power electronics DC – DC converter plays a very important role in implementing MPPT algorithm. The objective of this work is to analyze the working of MPPT technique with boost DC – DC converter. The simulation work is done by using PSIM simulation software.

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

I. INTRODUCTION

Energy Crisis and climate change threats leads the researchers to look for alternate sources of energy [1-3]. The world is virtually on the hunt of promising renewable and sustainable sources of energy. In recent years, renewable energy sources like solar, wind, tidal, have attracted the researchers, as it is limitless, non-pollutant and available free of cost. Solar energy is considered as the most reliable source among RES. Due to technological advancement in power electronics and reduction in the manufacturing cost of PV cell, solar energy is becoming more promising source of energy [4-8]. 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 boost dc-dc converter is used and the performance of MPPT is evaluated.

II. SOLAR PV CHARACTERISTIC

Fig. 1: Equivalent model of PV Cell

Fig. 2: Solar PV Power Characteristics with different Solar Irradiation level
PV cells are the basic element of solar PV system. Modules are formed using these 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].
\[
I = I_{ph} - I_{os} \left\{ \exp \left[ \frac{q}{AKT} \left( V + I_{R} \right) - 1 \right] - \frac{V + I_{R}}{R_{p}} \right\} \tag{1}
\]
\[
I_{os} = I_{sc} \exp \left[ \frac{q E_{GO}}{B k} \left( \frac{1}{T_{r}} - \frac{1}{T} \right) \right] \tag{2}
\]
\[
I_{ph} = S \left[ I_{sc} + K I \left( T - 25 \right) \right] / 100 \tag{3}
\]
Where I is 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-circuit 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 (ΔY) 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>
<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
IV. Boost DC–DC Converter

Fig. 4: Schematic of Boost DC–DC converter

Table 2: Parameters of DC-DC Boost 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>$V_{MPP}$ 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>$L_{boost}$</td>
<td>1mH, 15A Saturation</td>
</tr>
<tr>
<td>5</td>
<td>$C_{boost}$</td>
<td>1000 uF</td>
</tr>
<tr>
<td>6</td>
<td>$V_o$</td>
<td>Based on duty cycle expression</td>
</tr>
<tr>
<td>7</td>
<td>$R_{LOAD}$</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:

$$V_o = \frac{V_{in}}{(1-D)} \quad (4)$$

V. MPPT with Boost DC-DC Converter

Fig. 5: Block Diagram of Boost DC–DC converter

Fig. 6: MPP Zone on I-V Curve
The block diagram of boost dc-dc converter with MPPT is shown in Fig. 5. The MPP zone for 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 boost converter between B and C in Fig. 6, where R_{load} \gg R_{MPP}. The MPPT will not be working between A and B. These zones are decided by equation 5.

\[ \text{R}_{\text{in}} = \text{R}_{\text{o}} (1 - D^2) \]  

(5)

VI. RESULT AND DISCUSSION

Fig. 8: MPP Working for BOOST Converter when R_{LOAD} \gg R_{MPP}.

Fig. 9: MPP Failed for BOOST Converter when R_{LOAD} < R_{MPP}.
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 failed when $R_{LOAD} < R_{MPP}$. The power is much lower than MPP power of solar PV. These results shows that entire PV characteristic cannot be MPPT working zone with boost DC – DC converter.

VII. CONCLUSION

The main objective of the paper is to evaluate the performance of MPPT with boost DC – DC converter in terms of MPPT working zone. The MPPT with boost dc-dc converter is analyzed and simulation results are presented. It is evident that MPPT is not function in the entire zone of PV characteristic curve.

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REFERENCES