ABSTRACT

This paper discusses the solar powered dc to dc buck boost converter which can work in both buck mode and in boost mode according to the requirement. It requires only two switches and by properly controlling the switches, buck or boost mode can be achieved. The MATLAB simulated model of the solar panel followed by the dc –dc converter is presented and waveforms obtained are discussed. The dc to dc converter model is programmed in MPPT mode using optimal duty ratio to achieve maximum output. The performance of the complete system model under varying insolation levels of solar panel is discussed.

KEYWORDS: DC-DC buck boost converter, PV panel, MPPT (maximum power point tracker), MATLAB, overvoltage protection, insolation level.

1. INTRODUCTION

In the recent years, with the growth in population, the demand for electrical energy has also increased. As a result, the research has been extended to generating power from solar energy. The key element required for producing electricity from sun is the solar panel or photovoltaic panel (PV panel). Research is going on to increase the efficiency of PV panel and to maximize the power output from the panel. This can be achieved by using the MPPT and also by minimizing losses in the dc to dc converter. The dc to dc converter can reduce the overall efficiency if large number of switches working at high frequency is used.

In this paper, a DC-DC buck boost converter is proposed with minimum number of switches which can work in MPPT mode to produce maximum output at all insolation levels of the solar panel. Also when the panel voltage is less than the set output voltage, then the DC-DC converter will work in boost mode and when panel voltage is greater than the set output voltage, it will work in buck mode.

The buck converter transforms the input voltage to a lower level, which can be given by the relation,

\[ V_{out} = V_{in} \times \delta \]

Where,

- \( V_{out} \) is the dc voltage output from the converter
- \( V_{in} \) is the dc voltage input to the converter
- \( \delta \) is the duty cycle

The boost converter transforms the input voltage to a higher level, which can be given by the relation,

\[ V_{out} = \frac{V_{in}}{1 - \delta} \]

2. DC-DC BUCK BOOST CONVERTER
The proposed DC-DC buck boost converter with minimal number of switches is shown, Fig.1.

![Proposed DC-DC buck boost converter](image)

**Fig1. Proposed DC-DC buck boost converter**

The DC-DC converter works in buck mode when switch S1 is operated and switch S2 is kept always in OFF mode. When S1 is closed, supply voltage appears across the load, and by the time inductor stores energy. Now when S1 is opened, the stored energy in the inductor freewheels through load and diodes D1, D2.

For operating in boost mode, switch S1 is kept always in ON mode and S2 is operated. When S2 is closed, inductor L stores energy and when S2 is opened, the supply voltage appears across the load and the energy in the inductor appears as the additive energy to the load, thus boost operation is performed.

Designing of L and C is an important part for both software and hardware implementation because both buck and boost operation depends on the energy of inductor which further depends on its value calculated. L and C can be calculated using the formulae given below,

\[
L = \frac{V_{\text{in}} \cdot \delta}{f \cdot dI}
\]
\[
C = \frac{I_{\text{out}} \cdot \delta}{f \cdot dV}
\]
\[
dI = 0.8 + I
\]
\[
\delta = \frac{(V_{\text{out}} + V_d)}{(V_{\text{out}} + V_{\text{in}} + V_d)}
\]

Where,

- \(V_{\text{out}}\) = output voltage
- \(V_d\) = diode forward drop

\(V_{\text{in}}\) = minimum input voltage
\(I\) = average inductor current = \(I_{\text{out}}/(1 - \delta)\)
\(I_{\text{out}}\) = average output current
\(f\) = switching frequency
\(dV\) = output ripple voltage
\(dI\) = ripple current
\(\delta\) = duty cycle

3. CONVERTER SIMULATION

The simulation model of DC-DC buck boost converter in MATLAB is shown in the Fig.2

![Simulation model of DC-DC converter](image)

**Fig2. Simulation model of DC-DC converter**

The simulation results for the DC-DC buck boost converter operating under boost mode for various duty cycles for R load is shown in Fig.3 and Fig.4.

![Simulation results](image)

**Fig3. Boost operation with load R=50ohm, input voltage \(V_i=12\)volts, and duty cycle=0.6**
input voltage $V_i=12$volts, and duty cycle=0.4

The simulated result for boost operation can be summarized in the Table 1, as given below. From the table, it could be inferred that the output voltage increases on increasing the duty cycle, while working in boost mode. Also, it could be seen that when RL load is taken instead of R load, the ripple in the output voltage reduces and the average output voltage improves. Thus, for the same duty cycle, the average output voltage with RL load is more than that with R load.

Table 1. Results for boost mode operation

<table>
<thead>
<tr>
<th>$V_i$(V)</th>
<th>$V_o$(V)</th>
<th>R load</th>
<th>RL load</th>
<th>duty cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>16</td>
<td>5ohm</td>
<td>-</td>
<td>0.4</td>
</tr>
<tr>
<td>12</td>
<td>23</td>
<td>5ohm</td>
<td>-</td>
<td>0.6</td>
</tr>
<tr>
<td>12</td>
<td>17</td>
<td>-</td>
<td>5ohm, 0.1mH</td>
<td>0.4</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>-</td>
<td>5ohm, 0.1mH</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Similarly, simulation for buck mode was done and the simulated result is presented in the tabular form for different duty cycles, as given below in Table 2. From the table, it could be inferred that, the output voltage increases on increasing the duty cycle, while working in buck mode. Also, it could be seen that when RL load is taken instead of R load, the ripple in the output voltage reduces and the average output voltage improves. Thus, for the same duty cycle, the average output voltage with RL load is more than that with R load.
4. SYSTEM SIMULATION

After the simulation of DC-DC buck boost converter separately, it was simulated with PV panel to test its performance when connected across the PV panel. The block diagram for the proposed system is shown in Fig. 7.

The MATLAB model of the PV panel is shown in Fig. 8 and the model of the complete system (the DC to DC Buck Boost converter working in MPPT mode with PV panel as the input) is shown in Fig. 9.

![Fig. 7. Block diagram of proposed System](image_url1)

![Fig. 8. MATLAB Model of PV panel subsystem](image_url2)

![Fig. 9. MATLAB model of DC-DC converter with PV panel subsystem](image_url3)

5. RESULTS

5.1. DC-DC Converter in MPPT Mode at different Insolation Levels (Boost mode)

The maximum power point is tracked with the combination of the solar panel and dc to dc converters with optimal duty ratio control using perturb and observe method. Fig 10 and Fig 11 shows that the DC-DC buck boost converter helps in tracking maximum power of the PV panel, and thus power output from DC-DC converter is more as compared to that from PV panel alone.

![Fig 10. Comparison of PV panel power and power output from DC-DC converter at insolation level of 700W/m²](image_url4)
5.2. DC-DC Converter in MPPT Mode at Different Insolation Levels (buck mode)

Now there are cases when insolation level is so high that it may cause dangerously high power across the load. Under such conditions, this DC-DC buck boost converter will automatically start working in buck mode. Now every time when the power crosses its upper limit, the DC-DC converter will switch to buck mode and when safe power is reached it will again perform the boost operation and this process will continue. Fig12 shows the operation of the DC-DC converter at high insolation level of 1200W/m², without incorporating any control scheme and Fig13 shows the working of this DC-DC buck boost converter with control. In Fig 12, without any control, the output power from DC-DC converter reaches to above 500W, for insolation level of 1200W/m². From the Fig13, it could be seen that when the upper power limit of 480W is reached, buck operation is performed, and when normal power level is reached, again boost operation is performed. Thus, the proposed converter starts working in buck mode as and when required.

Fig11. Comparison of PV panel power and power output from DC-DC converter at insolation level of 500W/m²

Comparison of output power from solar panel and output power from DC-DC converter at different insolation level is tabulated in Table 3. When insolation level is 300W/m² solar panel power output is 50 W, whereas the power output from DC-DC converter is 98W. Thus, for different insolation level the DC-DC converter follows the maximum power point tracking algorithm to track maximum power and then by adjusting the duty cycle of the MOSFETS used as switches, it outputs the maximum power.

Table3: Comparison of output power from solar panel and DC-DC converter at different insolation level

<table>
<thead>
<tr>
<th>INSOLATION (W/m²)</th>
<th>DC-DC converter output power (W)</th>
<th>solar panel power(W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>98</td>
<td>50</td>
</tr>
<tr>
<td>500</td>
<td>200</td>
<td>75</td>
</tr>
<tr>
<td>700</td>
<td>325</td>
<td>100</td>
</tr>
<tr>
<td>800</td>
<td>390</td>
<td>125</td>
</tr>
<tr>
<td>1000</td>
<td>483</td>
<td>150</td>
</tr>
</tbody>
</table>

Fig12. Output of DC-DC converter at 1200W/m² without any control
5.3. Constant Output Voltage Irrespective of the Input (Insolation Level)

The job of the DC-DC converters is to provide the constant level of output dc voltage for feeding the DC loads. Due to the problem of input variation there is an issue of poor dynamic stability. So, for this purpose the suggested DC-DC converter can be programmed to give the set output voltage, irrespective of the input. The output of the solar panel depends on insolation and temperature levels, so to overcome this problem, the DC-DC buck boost converter is programmed to give a set reference voltage of 18 volts, irrespective of the insolation levels.

Fig. 14, Fig 15 and Fig. 16 clearly shows DC-DC converter output voltage at different insolation level of 1000, 800 and 500W/m² respectively. It can be depicted that constant output voltage of about 18 volts is obtained at all the insolation levels. Thus, the proposed DC-DC converter can be programmed to achieve any set reference value, irrespective of the input.

6. CONCLUSION

The output voltage of the solar panel depends upon the insolation level and temperature and hence it varies during the day. It can be maintained constant with the help of proposed
DC-DC buck-boost converter, by properly controlling the duty cycle of the MOSFETs. The power obtained from the panel also varies with the insolation level and during early morning and late evening hours; the power obtained is very less. Applying the concept of MPPT and properly controlling the duty cycle of the MOSFETs, the solar powered DC-DC buck-boost converter successfully worked to extract maximum power from the panel.

REFERENCES


