HIGH STEP-UP CONVERTER WITH DIODE CAPACITOR TECHNIQUE FOR RENEWABLE ENERGY APPLICATIONS

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ABSTRACT

This paper presents a high step-up boost converter with diode capacitor technique. In this topology an additional stage of voltage multiplier cells (diodes and capacitors) is incorporated into the conventional boost converter which will increase the voltage gain and efficiency of the converter. The peculiarity of this new method is that the switching losses, ripples and the stresses are low. Another important feature of this converter is the lower blocking voltage across the controlled switches compared to the other existing circuits. By using the metal oxide semiconductor field effect transistors (MOSFETs) with reduced on-resistance further minimizes the conduction losses. The simulation is done using PSIM and the simulation results prove that the converter can be applied to high performance, high voltage applications.

Keywords: Boost Converter, High Voltage Gain, Three State Switching Cell, And Voltage Multiplier Cells.

I. INTRODUCTION

The use of fossil fuels contributes high amount of pollution which ultimately results in ozone depletion, global warming, climatic changes etc. Thus the life on earth is affected. Therefore the renewable resources has to be exploited which are pollution free and eco friendly. Till now there are many ways to acquire these energy sources. But they have certain limitations since they are derived from the natural resources. Their performance can be affected by the varying climatic conditions. Therefore we incorporate the power electronics technology to improve the efficiency of these systems. The most popular and often used renewable energy sources are solar energy, wind, fuel cells etc. Considering the overall cost of renewable energy system and its low output, the use of high efficiency power electronics converters is a must. Therefore it is essential to place a boost converter at the output of the renewable energy systems. Then only this energy can be properly utilized for high power applications. One such efficient boost converter topology is discussed here.

The literature shows the advantages and disadvantages of many types of dc-dc step up converters. Theoretically, the static gain of a boost converter tends to infinite when the duty cycle tends to unity. However this is not possible in practical, because there will be conduction losses in the semiconductor devices which limit such high gain [1].

A boost converter with switched capacitors is shown in paper [2] for obtaining high voltage gain. Here the output voltage of the converter is increased by adding capacitors. The high component count is a major drawback in this topology. The interleaved structure is another effective solution to increase the power level [3]. Thus it can be used for high power high voltage applications. Interleaving can minimize the current ripple and doubles the switching frequency. The use of voltage multiplier cells can provide high voltage gain and reduce the voltage stress across the semiconductor elements. However the high component count increases the conduction losses and snubber circuit is required due to the reverse recovery currents through the multiplier diodes [4]. The converter that is presented in [5] is based on the three
state switching cell along with the voltage multiplier cells. This converter can provide high voltage gain in high power applications, the input current ripple is low, and the input inductor is designed for twice the switching frequency and the voltage stress across the switches are low. But the main drawbacks are, a snubber circuit is necessary for each switch and an additional winding per cell is required for the autotransformer.

Within this context this paper describes a boost converter for high voltage step-up applications with two cells using diode capacitor technique. The duty ratio is taken greater than 0.5, duty ratio less than 0.5 can lead to poor performance of the transformer.

II. CIRCUIT DESCRIPTION

The topology that uses the three state switching cell and voltage multiplier cells are shown in Fig. 1.

![Fig.1: Boost converter using two voltage multiplier cells (mc=2)](image)

The assumptions that are made in this topology are1) the input voltage is less than the output voltage, 2) the behaviour of the semiconductors and magnetic components are ideal, 3) the switching frequency is constant, 4) the autotransformer turns ratio is one, 5) the drive signal to the switches are 180° apart and 6) the converter under steady state operation is considered. From the Fig.1 we can see that the circuit is formed by a voltage source $V_i$, input inductor $L$, autotransformer $T_r$, two controlled switches $S_1$ and $S_2$, the multiplier cells consists of the capacitors and diodes which are respectively $C_1$, $C_2$, $C_3$, $C_4$, $D_1$, $D_2$, $D_3$, and $D_4$, the rectifier diodes are $D_5$ and $D_6$, the output capacitor $C_0$ and the load resistor $R_0$. The efficiency can be increased by the use of the three state switching cells. The claimed advantages are: the input current is continuous with low ripple; the input inductor is designed for twice the switching frequency, the voltage stress across the switches is low, reduced weight and size of the components. Hence the use of 3SSC leads to the use of switches with reduced current rating, which is desirable in high-power high-current applications.

An autotransformer is used to achieve high voltage conversion ratio, either in step-up or step-down applications. The gain can be increased by adjusting the turns ratio of the transformer without affecting the voltage stress across the main switches. But the main disadvantages are the losses caused due to increased size and weight associated with the transformer. The use of voltage multiplier cells is not new and has already been reported in literature. For example, in [6] employs multiplier capacitors to achieve high voltage gain. The multiplier cells are formed by the diodes and capacitors. The charging of capacitors at regular intervals of time period associated with the turn on of the diodes is the reason for voltage step up. The number of multiplier cells used in the converter is based on the application. The input inductor is also designed for twice the switching frequency, implying reduction of weight and size. The voltage stress across the switches is less than half of the output voltage. A metal oxide semiconductor field effect transistor (MOSFETs) with reduced on-resistance is used to further minimize the conduction losses. However, the converter cannot operate adequately when duty cycle is lower than 0.5 due to magnetic induction issues.

The study carried out in this scheme only considers the operation of the converter with duty cycle, $D > 0.5$. This is a significant improvement as compared to the other topologies presented in the literature survey. The operation of the converter with duty cycle lower than 0.5 leads to poor performance of the transformer. Thus it is not possible to step up the output voltage to the desired value. The conduction losses are less compared to other existing boost topologies. The specifications of the parameters are as follows:
III. DESIGN

The gain $G_v$, of the converter is given by:

$$G_v = \frac{V_0}{V_i} = \frac{mc+1}{1-D} \quad (1)$$

where, $V_0$ is the output voltage, $V_i$ is the input voltage, $mc$ is the multiplier cell and $D$ is the duty cycle.

The input inductor is designed based on the equation:

$$L = \frac{V_0}{16f_s(mc + 1)\Delta I_L} \quad (2)$$

where, $L$ is the inductor, $f_s$ is the switching frequency, $mc$ is the multiplier cell and $\Delta I_L$ is the ripple current.

The output current is given by:

$$I_o = \frac{I_i(1-D)}{(mc + 1)} \quad (3)$$

where, $I_i$ is the input current, $D$ is the duty cycle, $mc$ is the multiplier cell.

The expression for output capacitor is:

$$C_o = \frac{I_o(1-D)}{2\Delta V_c f_s} \quad (4)$$

where, $\Delta V_c$ is the voltage ripple.

IV. ANALYSIS AND RESULTS

Table 1: Converter specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input battery voltage</td>
<td>48 V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>400 V</td>
</tr>
<tr>
<td>Power</td>
<td>1000 W</td>
</tr>
<tr>
<td>Frequency</td>
<td>25 kHz</td>
</tr>
</tbody>
</table>

![Fig2: PSIM model of a boost converter with diode–capacitor technique](image)
Fig 3: Output and input voltage waveforms

Fig 4: Input inductor current waveform

Fig 5: Voltage across diode D₁

Fig 6: Voltage across diode D₃
V. CONCLUSION

The important characteristic of the new generalized non isolated boost converter with high voltage gain is the reduced blocking voltage across the controlled switches. The main advantages of this topology are:

- Reduced size, weight and volume of the magnetic components
- The current stress through the switches is low
- Conduction losses are less compared to other boost topologies.
REFERENCES


