

HIGH GAIN DC-DC CONVERTER WITH LOAD REGULATION

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Abstract

High gain dc-dc converters are gaining importance due to the latest trends in extracting power from renewable energies. The most commonly available renewable energy resources are wind and solar. The voltage developed while tapping energy from these sources are very low. Often the load requires larger than the voltage developed by the renewable sources which necessitates a high gain DC-DC converter with moderate duty ratio. Conventional boost converter cannot achieve ultra high voltage gain at moderate duty ratio. The aim of designing engineers is to obtain converters with high gain with moderate duty ratio, reduced switch stress, and cost. Here a single switch non isolated dc-dc converter with capacitor-diode voltage multiplier topology is presented. A 30W prototype of the converter is designed and closed loop simulation is conducted to explain the effectiveness of the controller at different load condition to obtain regulated output.

Keywords: — Boost Converter, Single Switch Converter, PI-controller, Voltage Regulation.

1. INTRODUCTION

Recent trends in renewable energy technology motivate designing engineers to obtain boost converter with high gain. But the objective must be high gain at moderate duty ratio, current and voltage stress reduction on the active switches.

By reducing the switch stress it is possible to use MOSFET switch with low drain to source resistance. MOSFET with low R_{DS-ON} can reduce the power dissipation and correspondingly reduces the size of heat sink hence converter cost and size can be reduced. Inductors are main energy storing and transferring component in a boost converter. So the switching frequency must be a key factor for a converter. As the switching frequency increases the size of the inductor is reduced and the converter bulkiness can be reduced. But at higher switching frequency the switching loss will be high. So a compromise has to be made between switching losses and inductor size. Switching converters with transformer isolation can generate higher voltage from low-level input voltage but the efficiency is reduced due to transformer leakage inductance, and the size and cost proportionally increases. Converters with coupled inductor can also increase the boost level and reduce the switch stress, and size but the coupling coefficient cannot be ideal.

The outline of the paper is as follows:

In section 2 different converter topologies have been described. Section 3 gives brief description of the proposed converter. Converter design is presented in section 4 with

some assumptions Simulation parameters; simulation results are included in section 5. In section 6 the conclusion is given.

2. LITERATURE SURVEY

Many converter topologies have been introduced to negotiate the problems associated with traditional converters. The reverse recovery problem due to low off time can be recovered by fast recovery diodes. DC-DC converter presented in [1] with coupled inductor and clamping circuit helps in realizing high voltage gain at moderate duty ratio by the transformer action of coupled inductor. The circuit has improved efficiency by effectively recycling the inductor leakage energy using capacitor diode clamping circuit, the only demerit being the high resonating current through the magnetizing inductance and power switch. Boost converter with several voltage multiplier cells described in [2] can multiply the voltage to required value. But circuit complexity and cost is increased several folds.

In this paper a single switch non isolated dc-dc converter [3] is presented. The topology can have higher boost level and reduced switch stress without the use of transformer and coupled inductor. Basically there are two factors which affect the output of a converter. Firstly in renewable technology application the major source of input for a converter is the solar cell. The output voltage from solar cell varies with the intensity of solar radiation accordingly the converter output also changes. Secondly nature and requirements of the load affects the converter output. As per the standard the output of switching converter must be

within $\pm 1\%$ of the nominal value irrespective of changes in input voltage and load condition. So the output from these converters must be controlled by feedback controller, hence came the importance of PI-controllers

3. CONVERTER TOPOLOGY DESCRIPTION

The converter proposed in [3] is shown in fig: 1 which can be viewed as a single switch topology with capacitor diode voltage multiplier. The converter consists of one active switch (S) which is a power MOSFET. At the input section there are two identical inductors L_a , L_b and a capacitor C_{in} also there are two identical diodes D_{i1} and D_{i2} . The output section of the converter is a capacitor diode voltage multiplier which consists of two identical capacitors C_a , C_b and two identical diodes D_a , D_b . Also there is diode D_c a filter capacitor C_f and Load resistance R_o . The converter operation can be described as follows

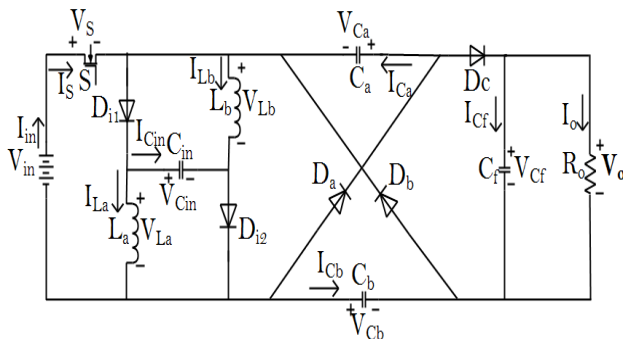


Fig- 1: high gain dc-dc converter

During the switch on period of the power switch (S) L_a , L_b and C_{in} are charged in parallel combination by source V_{in} , at the same time C_a and C_b discharges through source and load in series combination until V_{in} is greater than V_o . During switch off period the stored energy in L_a , L_b and C_{in} discharges the stored energy equally between C_a and C_b through D_a and D_b . The converter has a voltage gain of around 12 and the switch voltage is only one half of the output voltage during off condition.

4. CONVERTER DESIGN

The design of the converter is done under the assumption that

- 1). Converter is operating in continuous conduction mod
- 2). All the circuit components are ideal
- 3). Input voltage is constant
- 4). Output capacitor is large enough to keep the output voltage constant

Also let

- a) D is the duty ratio and T_s is the switching period
- b) $L_a = L_b$, $C_a = C_b$

In this paper a 30W prototype of the proposed converter is designed by considering an input of 12V, with switching frequency 80 kHz and duty ratio D as 0.692.

For $V_{in} = 12V$ with a conversion ratio of 12

The output voltage $V_o = 144V$

$$\text{Output current, } I_o = \frac{\text{Output power}}{\text{output voltage}} = \frac{30}{144} = 0.208A$$

Under the assumption of ideal condition we can take input power, $P_{in} = \text{output power}$, P_o

$$V_{in} \times I_{in} = V_o \times I_o$$

$$\text{Therefore } I_{in} = 12 \times I_o = 2.5A$$

$$\text{The load resistance, } R_o = \frac{V_o}{I_o} = \frac{144}{0.208} = 692.3\Omega$$

The value of inductance can be calculated as follows

$$\text{We have } V_{La} = L_a \frac{di_{La}}{dt} = V_{in}$$

$$L_a = V_{in} \times \frac{dt}{di_{La}} = V_{in} \times DT_s$$

Let inductor current ripple be 1A.

$$L_a = 12 \times 0.692 \times 12.5\mu = 103.8\mu H$$

So take $L_a = L_b = 103.8\mu H$

The capacitors can be designed as follows

Let the peak to peak ripple in output voltage be 0.05% of output voltage.

The proposed converter in Fig 1 is a boost converter with capacitor diode voltage multiplier. The formula for output capacitor can be written as

$$C_f = \frac{0.692 \times 12.5\mu}{692 \times 0.0005} = 24\mu F$$

Take $C_a = C_b = C_{in} = C_f = 33\mu F$

5. SIMULATION OF CONVERTER WITH FEEDBACK CONTROLLER

The closed loop simulation of the converter is done in MATLAB/Simulink environment. The simulation diagram and simulation waveforms are given in this section.

The simulation parameters are obtained from section 3 are given below

$$L_a = L_b = 103.8\mu H,$$

$$C_a = C_b = C_{in} = C_f = 33\mu F$$

Also let
 Proportional gain $k_p = 0.001$,
 Integral gain $k_i = 0.912$

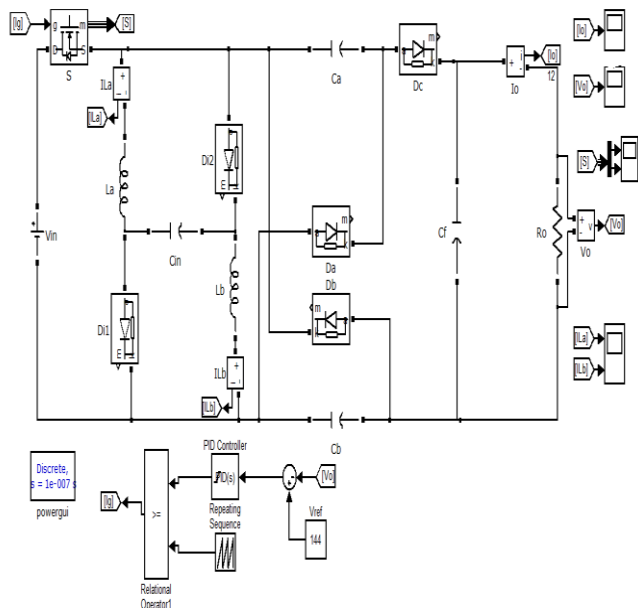


Fig -2: Feedback controlled converter schematic in MATLAB/Simulink

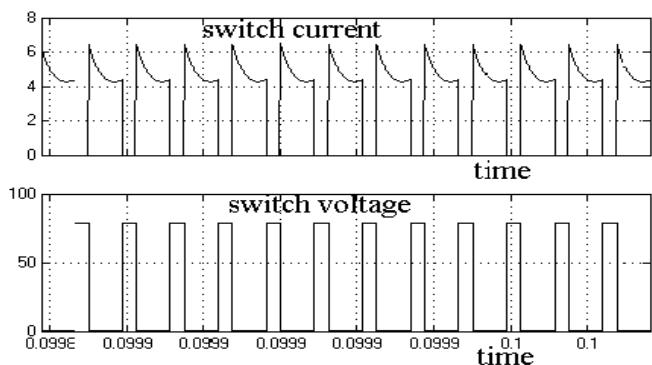


Fig -3: Switch current and voltage waveform for $R_o = 692.3\Omega$

In **Fig -3** the current flowing through the switch when it is closed and the reverse voltage across the switch is shown. From the simulation result it is clear that the voltage across the switch is only one half of the output voltage. The closed loop simulation of converter is done for an input of 12V and at two different loads. In each case the output voltage is almost constant (i.e. for 692.3Ω and 800Ω). The regulated output voltage for the two different load conditions is shown in **Fig 3** and **Fig 4**.

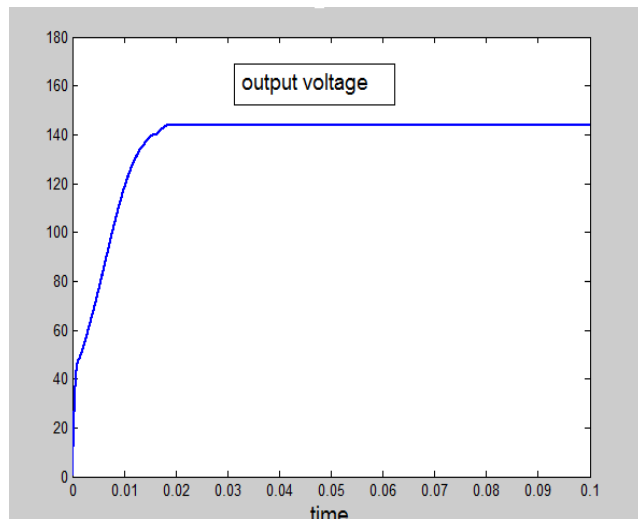


Fig -3: Output voltage waveform for $R_o = 692.3\Omega$

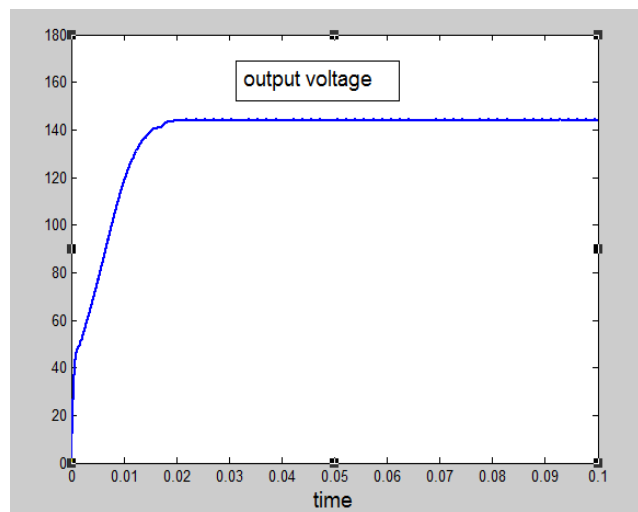


Fig -4: Output voltage waveform for $R_o = 800\Omega$

6. CONCLUSION

The converter is simulated in MATLAB/Simulink environment to get a regulated output voltage even though there are variations in load conditions. The simulation results justify that the controller selected is optimum for the design we considered. From the simulation result it is clear that the converter has higher voltage gain at moderate duty ratio.

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BIOGRAPHIES

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