

Study of Boost Type Isolated DC-DC Converter

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ABSTRACT: This paper presents the simulation study of three switch isolated dc-dc boost converter which consists of the following features 1)Continuous input current, 2) Removal of snubber circuit, 3)reduced one active switch, one additional diode, one additional capacitor , 4)unchanged primary and secondary voltage waveforms of the transformer when the duty cycle is changed. This paper presents the proposed converter advantages, operation, modes of operation and detailed simulation analysis. The simulation model of the proposed converter has been developed for 40V dc input using MATLAB Simulink. The theoretical predictions and the performance of the proposed converter have been successfully validated with the help of simulation results.

KEYWORDS: DC–DC power conversion, Current-Fed Full-Bridge (CFFB) converter, Voltage Double Rectifier (VDR), step-up transformer.

I. INTRODUCTION

Many high step-up dc–dc converters have been proposed and investigated to convert low voltages into a constant dc bus voltage. For isolated topologies that provide galvanic isolation, voltage-fed full-bridge (VFFB) and current-fed full-bridge (CFFB) dc–dc converters are widely used. The CFFB dc–dc converters are suitable for applications with a high step-up voltage gain since they have the boost function [1]. Whereas in VFFB dc–dc converters, because of the buck function the major voltage gain is provided by a high-frequency transformer with a large turn ratio.

To improve the voltage boost ability, a boost converter is attached to the secondary side of the VFFB dc–dc converter. The current ripple and turn ratio of the high-frequency transformer in CFFB converters are lower than those in VFFB dc–dc converters. Hence current-fed full-bridge (CFFB) dc–dc converters are widely used [9].

The resonance between the leakage inductor of the transformer and the output capacitance of the primary switches causes voltage spikes where passive snubber is used

to absorb the switch turn-off voltage spike in CFFB converters. Further for the energy recovery of the snubber, active clamping circuits with increasing size and cost have been proposed [9].

A variety of topologies have been proposed to avoid the use of the active clamping circuits [3]. They are soft-switching snubberless naturally clamped CFFB converters, interleaved CFFB converter to reduce the input current ripple, a dual-input CFFB converter based on a distributed multi transformer structure and so on. However, the types of CFFB converters proposed use a greater number of transformers and switches, which increases the loss and cost of the overall system.

This paper describes a three-switch isolated boost dc–dc converter which uses one less active switch, one extra diode, and one extra capacitor. The proposed three switch dc dc boost converter is shown in figure.1 [4].

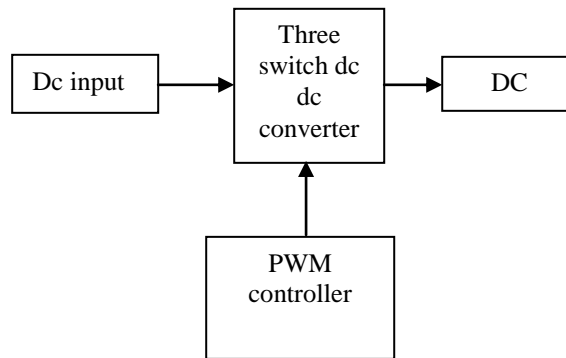


Fig.1. Three switch isolated dc dc boost converter

Dc input is fed into the DC-DC converter [7]. The embedded controller is used to generate gate pulses. The generated pulse is fed into the PWM generator. The PWM method is used to change the duration of the pulse with respect to the analog input. This PWM can be implemented by Time-based topology. The output of the PWM is fed to the DC-DC converter which is further fed into load [6].

The converter used in the power stage offers a significant enhancement in terms of lower component count and condensed design complexity when compared with the other existing converter. In the control circuit, the embedded controller can provide all essential switching pulses for power switches, resulting another significant drop in cost and circuit complexity [5].

This paper is organized as follows. First, the power circuit advantages and its configuration presented in section II. Then, the power circuit operation includes the modes of operation in detail is discussed in section III. Section IV describes the simulation results and functionality verification of the three switch isolated dc dc boost converter using time based PWM technique. Last section concludes and the scope for further work is presented [2].

II. POWER CIRCUIT

A. Power Circuit Advantages

The three switch isolated dc dc boost converter has the following merits over other existing conventional converter topologies.

- 1) The input dc current is continuous with low ripple, whereby an LC input filter at the front end (typically used to protect the energy source such as the FC) is unnecessary [1].
- 2) It uses one less active switch, one extra diode, and one extra capacitor than the conventional isolated boost dc–dc converter [1].
- 3) The primary- and secondary-side voltage waveforms of the high-frequency transformer are unchanged when the output voltage is controlled; this facilitates the ease of the design of the high-frequency transformer [9].
- 4) The snubber circuit is not used [2].

B. Power Circuit Description

The proposed three switch isolated dc dc boost converter contains three semiconductor switch which is shown in figure. 2. The low-voltage side consists of a boost inductor (L1), three switches (S1, S2 and S3), a capacitor (C1), a diode (D1), and the primary winding of the transformer (TR). The high-voltage side consists of the load (R) and the secondary winding of the transformer (TR) connected to the VDR implemented by two diodes (D2 and D3) and two capacitors (C2 and C3) [1].

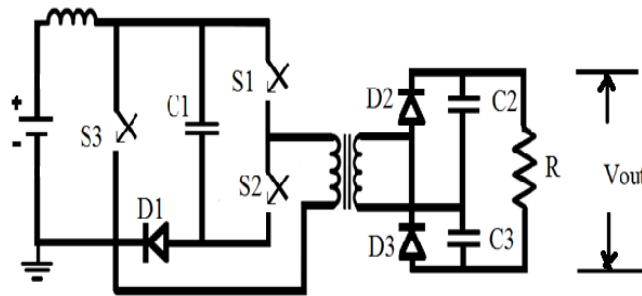


Fig.2. Three switch isolated boost dc dc converter power circuit

DA is the minimum value of D, where D is the duty cycle of switch S3. DA is set to 0.3 in order to maintain the ac pulse primary and secondary-side voltage waveforms of the high-frequency transformer at 30% positive, 20% zero, 30% negative, and 20% zero sequentially, respectively. DA should be in the range of [0.25, 0.5] for the optimal utilization of the high-frequency transformer. The selection of DA depends on the minimum voltage gain of the converter [8].

The simplified converter topology is obviously cost-effective compare to other topologies, i.e., it uses one less active switch, one extra diode, and one extra capacitor than the conventional isolated boost dc dc converter[3].

III. POWER CIRCUIT OPERATION

A. Mode I Operation

S1 is turned “ON”, s2 and s3 are turned “OFF”. The inductor L1 is discharged, while the leakage inductor of the transformer and the capacitor are charged. The D1 and D2 diodes are forward-biased, while the D3 diode is reverse-biased. The primary voltage of the transformer is V_{c1} . The secondary side of the transformer generates a positive voltage.

B. Mode II Operation

S1 and s3 are turned “ON”, s2 is turned “OFF”. All diodes are reverse biased.

C. Mode III Operation

S1 and s3 are turned “OFF”, s2 is turned “OFF”. If s2 is turned “ON”, D2 and D3 are reverse biased.

D. Mode IV Operation

S3 and s2 is turned “ON” and s1 is turned “OFF”. D1 and D2 are reverse biased and D3 is forward biased

E. Mode V Operation

S3 and s1 is turned “OFF”, s2 remains “ON”.s2 is turned “OFF”.s1 and s3 are turned “ON” and s2 is turned “OFF”.

IV. SIMULATION RESULTS

The MATLAB Simulink model of the three switch isolated DC DC boost converter is shown in Fig.3. This model, developed using the Simulink power system block set, comprises of components such as power electronic devices (MOSFETs) and elements such as capacitors and resistors.

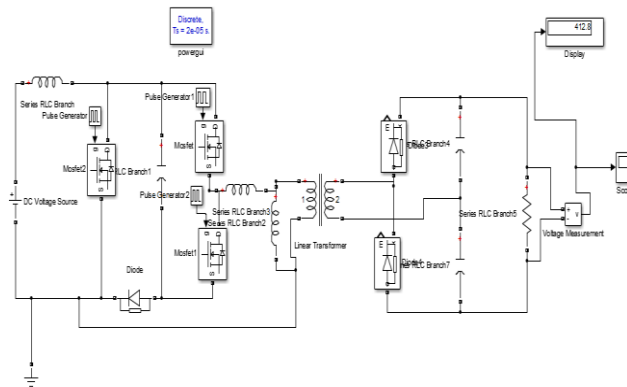


Fig.3. Converter simulation circuit

The PWM signals for each of the switching devices in the power circuit come from the PWM generator block. This block includes all the PWM signals required for switching. The waveform for the three switch dc dc boost converter based on PWM technique and the output voltage. The input voltage of the converter is shown in figure 4.

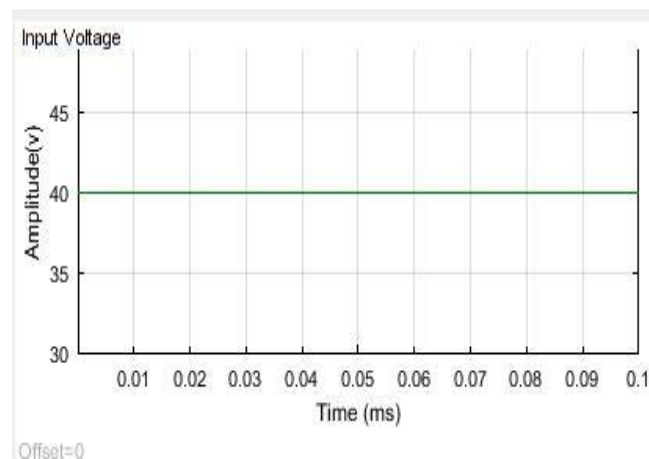


Fig. 4. Waveform of input Voltage

The primary voltage of the converter transformer is shown in figure.5.

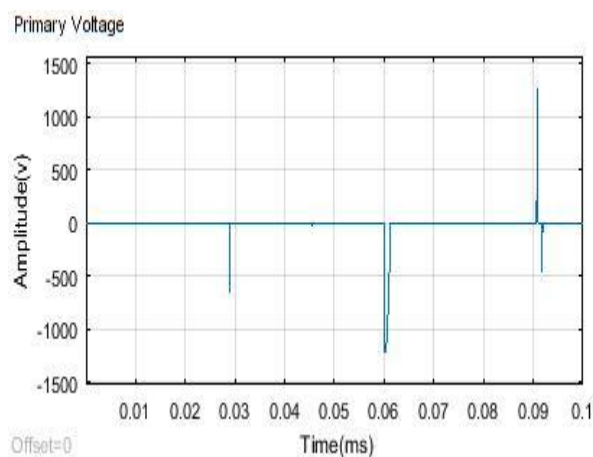


Fig.5. Waveform of Primary Voltage

The drain source current of switch S1 is shown in figure 6.

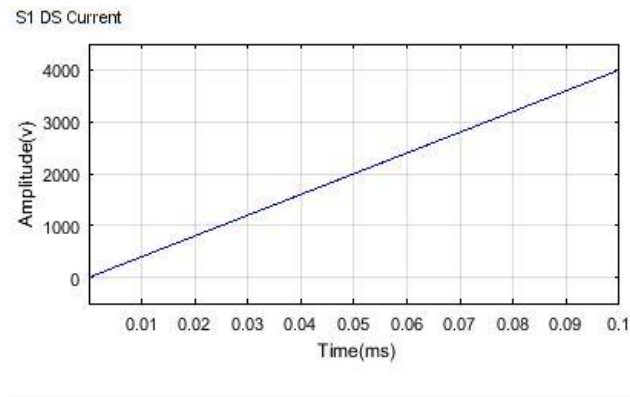


Fig.6. S1 drain source current

The drain source voltage of switch S1 is shown in figure 7.

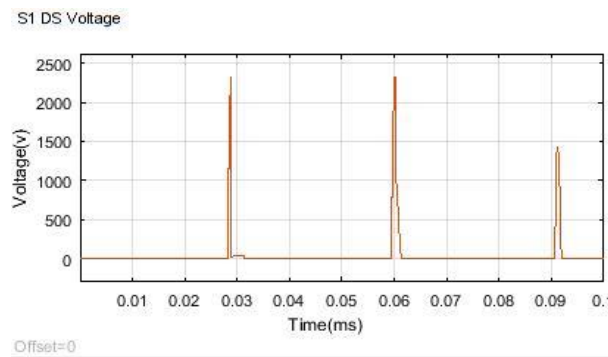


Fig.7. Waveform of S1 drain source voltage

The drain source voltage of switch S2 is shown in figure 8.

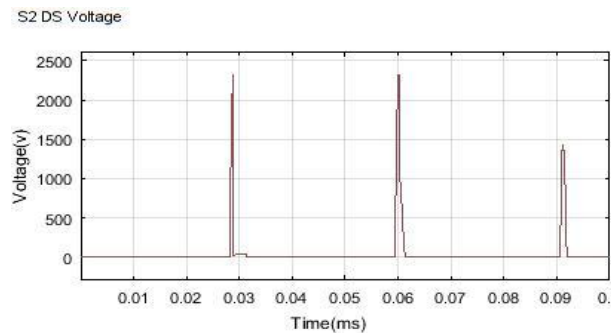


Fig.8. Waveform of S2 drain source voltage

The secondary voltage of the converter transformer is shown in figure.9.

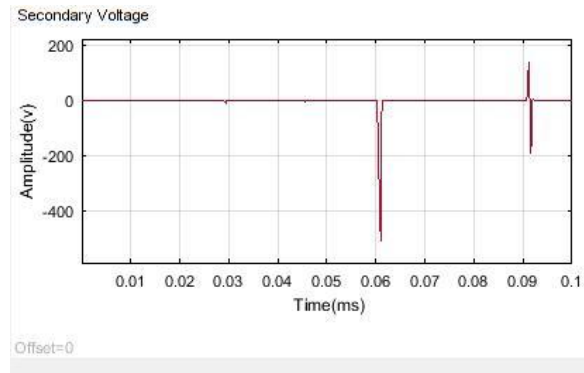


Fig.9. Waveform of Secondary voltage.

The primary and secondary voltage waveforms of the transformer are unchanged, even though the input voltage changes from maximum to minimum .

To verify the operating principle of the proposed converter, MATLAB simulation was performed with the following parameters: $L_1 = 1\text{mH}$, $C_1 = 220\mu\text{F}$, $C_2 = C_3 = 150\mu\text{F}$, and $R = 600\Omega$. The drain-to-source on-resistance of Metal-Oxide-Semiconductor Field Effect Transistors (MOSFETs) was set to $8\text{M}\Omega$. The forward voltage of the diodes was set to 0.7V . The turn ratio of the high-frequency transformer was 2.5. The magnetic inductance measured from the primary side was set to 1.4MH . The leakage inductance was set to $11\mu\text{H}$. The switching frequency was 10kHz and the output voltage was 400V [6]. The dead time between S1 and S2 is $2\mu\text{s}$. The switching pulse for the switch S1 of the converter is shown in figure 10.

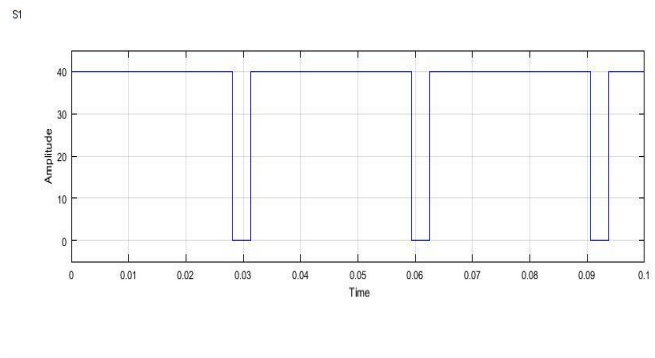


Fig.10. Switching pulse waveform for Switch S1

The switching pulse for the switch S2 of the converter is shown in figure 11.

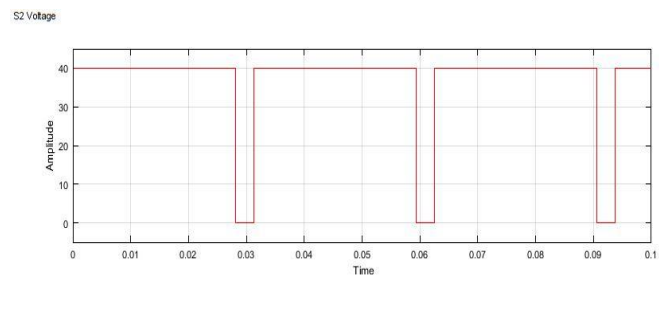


Fig.11. Switching pulse waveform for Switch S2

The switching pulse for the switch S3 of the converter is shown figure 12.

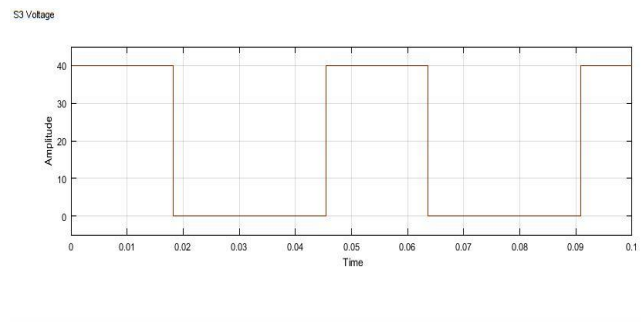


Fig.12. Switching pulse waveform for Switch S3

The proposed three switch dc dc converter follows the dynamic change in the duty cycle and has a better transient response during the step change in the load with voltage regulation. The boosted output voltage the proposed converter has been observed as 400V and it is shown in figure 13.

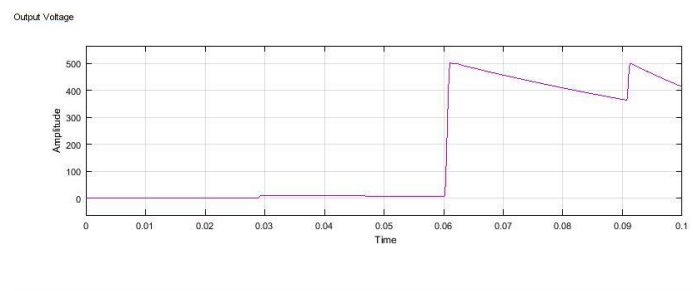


Fig.13. Output Voltage of the converter

These simulation study results and the performance of the proposed converter have been successfully validated with the help of MATLAB simulation results.

V. CONCLUSION

The proposed converter has the following characteristics: continuous input current reduced one active switch, unchanged primary and secondary voltage waveforms of the transformer, and no snubber circuit. The operating principles, analysis, parameter design guidelines, and simulation results are presented.

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