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Performance Study of LCC and LLC Resonant Converter for High Voltage Applications

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Abstract: ***The aim of this work is to analyse and study the difference between LCC and LLC DC-DC resonant converter for high voltage applications, the two types of resonant converter are discussed, tested using MATLAB and the performance are compared. Simulation studies are carried out using MATLAB / SIMULINK model. The output voltage, output current and voltage gain of both type of comarators are calculated and studied. After the analysis of LCC and LLC resonant converters, it is found that the LLC converter can give more gain characteristics compared to LCC converter and also with more output voltage. Thus the characteristics of two resonant converters are studied and compared.***

Keywords: Resonant Converter, LCC, LLC, SIMULINK

1. Introduction

Resonant converter topologies are being widely used in power processing systems because of their soft-switching characteristics at high frequencies [1, 2]. The advantages of this topology are high-frequency operation including smaller size and lighter weight for the passive components. There are two converters proposed and compared in this paper [3]. The LLC and LCC resonant converters improve the efficiency and reduce the switching losses through Zero voltage switching. The operation can be achieved even at narrow frequency variation over wide load range [4, 5]. The generalized circuit diagram of resonant converter is shown in Figure 1.1. This can be converted into different topology of resonant converter.

LCC type topology of resonant converter in which additional capacitor is placed in series with the resonant inductor. In LLC type topology of resonant converter an additional inductor is connected in parallel with the resonant capacitor in the series resonant converter. This type of converter is also known as multiple energy storage element resonant power converters. The high frequency causes low efficiency because of high switching losses. Since the resonant converter has ZVS or ZCS function for reducing switching losses, the resonant converter has been widely used in Power industry [6, 7].

To do the comparative study between LLC and LCC DC-DC resonant converter for high voltage applications, the two most promising topologies of this converter class are presented and compared in this paper. LCC and LLC resonant converters can achieve both high efficiency and wide input voltage range capability because of its voltage gain characteristics and small switching loss but the LLC showed the high gain compared to the LCC. The proposed circuit of the bridge LLC and LCC resonant converter was constructed in MATLAB Simulink to verify the performance of the resonant tank.

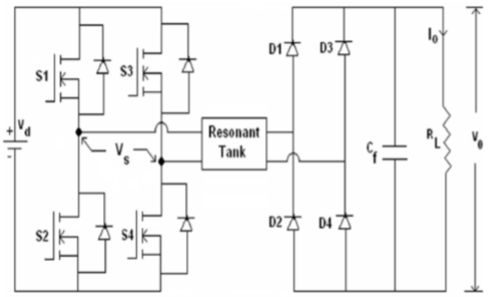

Figure 1.1: Generalized Resonant Converter

2. Simulation of LCC Resonant Converter

Simulation studies for LCC converter is carried out using MATLAB/SIMULINK and the simulation circuit is shown in Figure 2.1. Simulation results of LCC Resonant DC-DC converter for an input of 48 V are presented. The driving pulses for the MOSFETs 1 & 2 are shown in Figure 2.2. The output voltage & current of this converter are shown in Figures 2.3 & 2.4. It is observed that the output voltage and current for this converter are around 8.7 Volts & 3 Amperes.

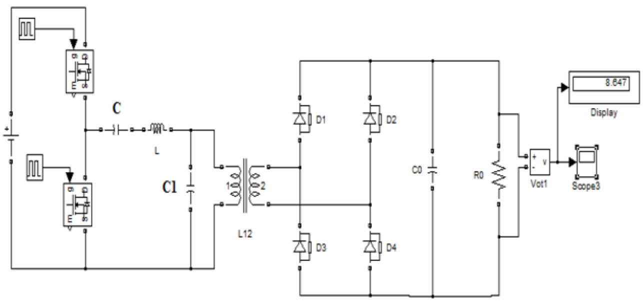

Figure 2.1: Simulation Circuit Diagram for LCC Resonant Converter

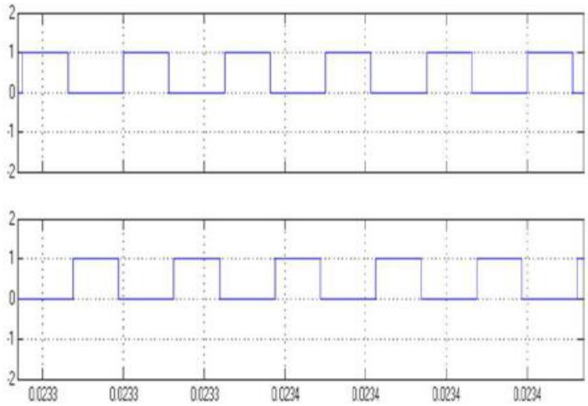

Figure 2.2: Driving Pulses for the MOSFETs 1&2

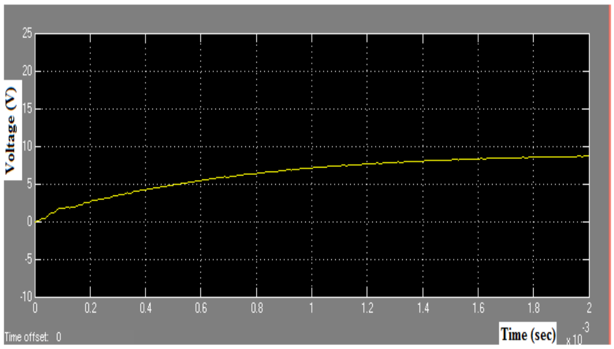

Figure 2.3: Output Voltage

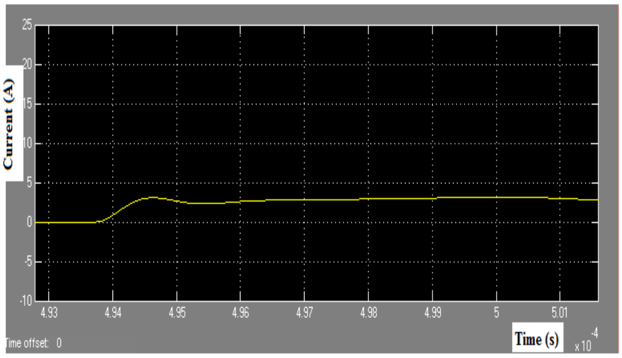

Figure 2.4: Output Current

3. Simulation of LLC Resonant Converter

LLC resonant converter gains attention high value because of its ability to operate at higher frequencies with low switching losses. It consists of two inductors and one capacitor and the converter can regulate the output voltage against the line and load variations over a wide range. Soft switching can be achieved over the entire operating range compared with LCC resonant converter. The resonant tank of LLC resonant converter is shown in Figure 3.1. The performance parameters such as output voltage ripple, output voltage and output current are computed by using MATLAB / Simulink and shown in Figure 3.2 to Figure 3.5.

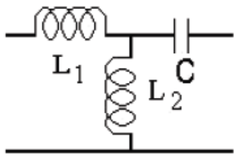

Figure 3.1: Equivalent Circuit of LLC Resonant Converter

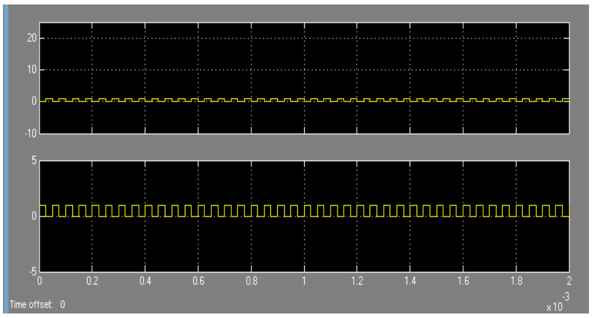

Figure 3.2: Driving Pulses for the MOSFETs 1&2

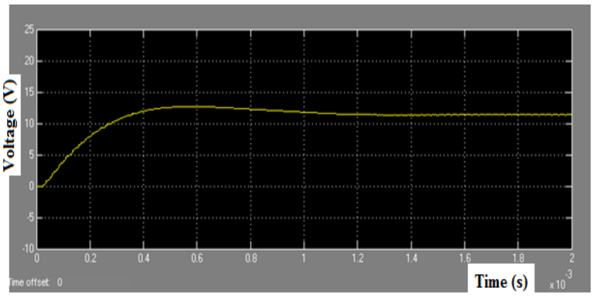

Figure 3.3: Output Voltage

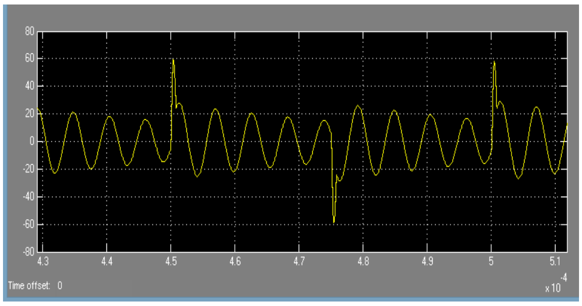

Figure 3.4: Current Through L_r

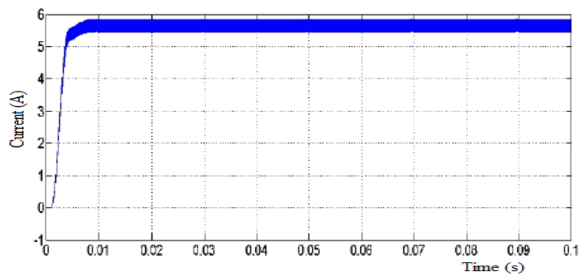

Figure 3.5: Output Current

4. Comparison of LLC & LCC Resonant Converters

The performance of LLC & LCC resonant converter is investigated by calculating the voltage gain and losses [8]. The voltage gain of two converters was compared and it is shown in Table 4.1. The switching loss and voltage ripple of two resonant DC-DC converters are calculated using equations (4.1) to (4.3). Power loss includes conduction and switching losses and it is calculated as follows:

Conduction losses are given by

$$P_{cond} = I^2_{on} R_{ds\ on} \tag{4.1}$$

where I_{on} is the drain current when the MOSFET is on and $R_{ds,\ on}$ is the drain source resistance when the MOSFET is on.

The switching loss is given by

$$P_{sw}= (C_{oss}+ C_p)V^2 f_{sw} \tag{4.2}$$

where C_{oss} is the output capacitance of MOSFET, C_p is the parasitic winding capacitance of MOSFET, V is the input voltage of the MOSFET, f_{sw} is the switching frequency of resonant converter. The values of $R_{ds,on}$, C_{oss} , C_p are taken from data sheet values. The total power losses are given by the sum of conduction losses and switching losses.

The output voltage ripple is calculated as

$$V_{ripple} = V_{max} - V_{min} / V_{avg} \tag{4.3}$$

where V_{avg} is the average value of maximum and minimum voltage from voltage ripple waveform. To improve the performance of the DC-DC converter for the wide voltage range applications a novel resonant converter with the combination LLC resonant converter is proposed. When it was compared with the single topology LCC resonant converter the voltage gain and the output current were high and it was tabulated in Table 4.1. From the Table 4.1, it is clear that the output voltage and gain is higher in the case of LLC converter. The increase in output voltage is due to the presence of full wave rectifier and capacitor at the output.

Table 4.1: Comparison of Voltage, Current& Voltage Gain

Parameters	LLC Resonant Converter	LCC Resonant converter
Output Voltage (V)	12	8.7
Output current (A)	5.5	3
Voltage Gain	0.733	0.1733

5. Conclusion

The resonant topologies were investigated for front end DC \ DC application. The target is to find topology, which could be optimized at high input voltage with low switching loss. The traditional resonant topology such as series resonant converter, parallel resonant converter and series parallel resonant converter suffered from wide input range problem and could not optimized for high input voltage. LCC resonant topology was introduced by observing the tank. Characteristics of series parallel resonant converter are studied, the performance at high input voltage could be optimized and the converter still could cover wide input voltage range. Test results show that with LLC resonant converter, the efficiency could be improved more. Also from the analysis and test, LLC resonant converter is proved to be able to improve the performance of DC/DC converter significantly.

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Author Profile

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