ANALYSIS AND SIMULATION OF DC TO DC CONVERTER WITH MINIMISED CURRENT RIPPLE

Madhusudhanan.R[1], Rama Reddy.S[2]
[1]Research scholar, Sathyabama university, Chennai, India.
[2]Jerusalem college of engineering, Chennai, India.
Email: [1]madhujeppiaar@india.com

Abstract

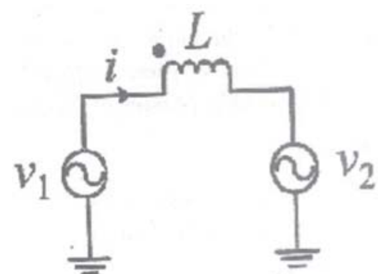
This paper deals with digital simulation of resonant DC to DC converter with reduced current ripple. DC to DC converter is realized using a push pull inverter and a full wave rectifier. The ripple in the output current is reduced by using high frequency inverter and filter inductor. Conventional and modified resonant DC to DC converters are simulated and the results are depicted. This converter has advantages like high power density, reduced losses and low EMI.

Keywords: Simulation, DC to DC Converter, Ripple

I. INTRODUCTION

Compared to a pulsewidth modulation (PWM) converter, a resonant converter has the ability of natural zero voltage switching or zero current switching, which is very desirable for high frequency operation as a result of low switching losses. However, this advantage comes at a price that its conduction losses are typically higher than its PWM counterpart due to the higher current ripple. It is this reason that motivated the search for reduced or even zero current ripple for resonant converters.

The idea of a switching converter with zero current ripple proposed and demonstrated by [1], was thoroughly studied by numerous authors, [2]-[8].Under certain conditions, named zero ripple conditions (ZRC), current ripple of magnetic devices in all but one particular winding may be cancelled. ZRC could be achieved by means of proper magnetic coupling between the inductive elements in the circuit. Zero current ripple converters relay on a basic physical principle of magnetic induction and may be readily understood. The basic circuit shown in Fig.1 illustrates a loop around an inductive element L. Here V1 is an independent voltage source and V2 is the e.m.f., induced by some other windings. With V2 been equal to V1, no voltage difference is present across the inductor resulting in (di/dt) = 0 and consequently, zero current ripple. Magnetic design for zero ripple may dramatically improve the input or output current characteristics of a switching converter. Another benefit of this approach is the possibility of incorporating several magnetic elements, which otherwise would require separate cores, in a single structure with multiple windings. Integrating Magnetic structure may potentially lower the power stage volume, weight and cost. The penalty is the increasingly complicated converter behavior and intricate magnetic component design. ZRC requires that a proper V2 voltage. One difficulty is finding or creating voltages in the converter circuit, similar in form, magnitude and phase. Another complexity is the management of the winding leakage is an unknown parameter of the core and winding geometry and it may require empirical fine-tuning. Variations in leakage parameter may alter the flux relationships, impair ZRC and degrade the performance. Fig.1 shows the inductor loop under ZRC.



$$v_1 = v_2 \Rightarrow \frac{di}{dt} = 0$$

Fig.1. Inductor loop under ZRC.

In PWM circuits some of the voltages across the inductive elements are of similar rectangular shape and timed at the same precise moment, making the realization of ZRC possible. Several methods for realizing ZRC in hard-switched topologies where proposed in literature demonstrating some real ingenuity. It is much more difficult, however, to achieve ZRC in resonant converters due to their complex behavior. Voltages of these converters are of irregular shapes, some sinusoidal, some rectangular other quasi-sinusoidal with some linear portions. Also there are inherent phase differences that are load and frequency dependent. Due to these facts, ZRC for resonant converters is hardly achievable and such attempts seem as not been reported widely, reference [8] being one of few.

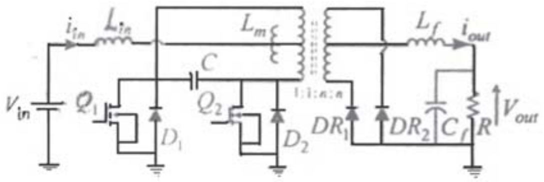


Fig.2.Topology of the resonant DC –DC Converter

This paper presents a resonant converter topology capable of providing ZRC by properly coupling of magnetic elements in Fig. 2. The basic properties of the topology are discussed then the ZRC is verified by simulation results. The remarkable symmetry and the proportional voltages of the circuit allow it to maintain zero output current ripple, independent of the load and switching frequency. Furthermore, the zero ripple output current makes it possible for the rectifiers to operate in the continuous conduction mode avoiding peaking of the output voltage at light load [9]. [10].

II. REVIEW OF THE UNDERLAY RESONANT DC-DC CONVERTER TOPOLOGY

The topology of the resonant DC-DC converter of Fig.2 was analyzed in detail in [11]. Here only some essential qualitative and approximate qualitative discussion will be conducted to facilitate the approach to the idea of ZRC in the given circuit.

The circuit is comprised of a current –fed push-pull parallel resonant inverter followed by a full-wave rectifier with LC output filter. The resonant tank of the inverter is formed by the magnetizing inductance of the transformer, Lm, and the parallel capacitance placed across the primary winding. Switch parasitic capacitances may be also considered as part of the resonant capacitance. The input and output filter inductance and therefore are modeled as DC current sources. The main switches are gated by a square wave drive voltage of a constant frequency, below the resonance.

The switching action of the switches steers the input current into the resonant tank in an alternating fashion creating two symmetrical half cycles. A switching half-cycle starts with the resonant Mode M1. The equivalent circuit of this mode is shown in Fig.3 (a). During this interval a quasi-sinusoidal voltage develops across the resonant cycle, $(To/2) = \prod \sqrt{LmC}$. The clamp mode M2 starts when the resonant capacitor voltage returns to zero and the anti-parallel diode of the complimentary switch free-wheels the resonant inductor current, as shown in fig.3(b),clamping the voltage across the resonant tank till the next half cycle.

Note the MOSFET turn-off occurs with its parallel capacitance still at zero voltage (ZVS turn off). The complimentary switch turns-on while its anti-parallel diode still conducts clamping its voltage to zero (ZVS turn on). Since the secondary voltage follows the voltage across the mail switches, the rectifiers' commutation is naturally synchronized to the appropriate mail switch. Hence, all of the switching elements of the power stage benefit from the zero voltage switching conditions.

III. SIMULATION RESULTS

Resonant DC to DC converter is simulated using matlab. Conventional circuit of DC to DC converter is shown in Fig. 3., Driving pulses are shown in Fig.4. voltage across the switches S1 and S2 is shown in Fig. 5. secondary voltage of the transformer is shown in Fig. 6. output current is shown in Fig. 7, output voltage is shown in Fig. 8. Modified resonant DC to DC converter is shown in Fig. 9. secondary voltage of transformer is shown in Fig 10. DC output voltage is shown in Fig.11. comparison of current ripple is shown in Fig 12. comparison of output voltage ripple is shown in Fig 13. It can be seen that the modified circuit has less ripple than the conventional circuit.

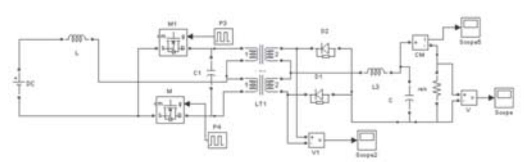


Fig. 3.Conventional Circuit

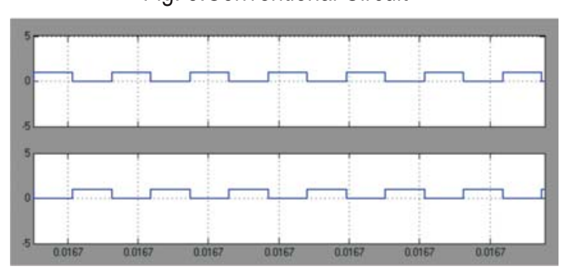


Fig. 4. Driving pulses

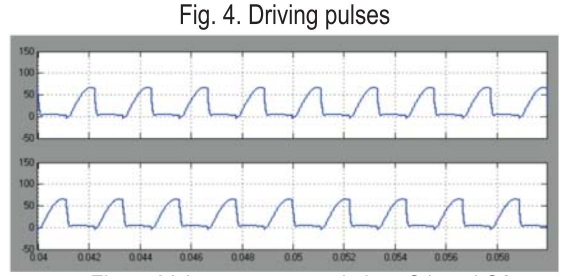


Fig. 5. Voltage across switches S1 and S2

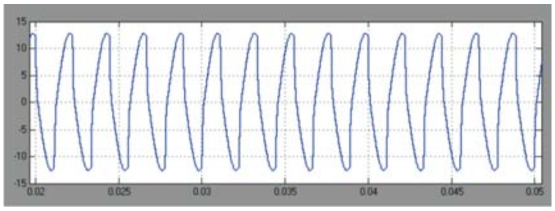


Fig. 6.Transformer output

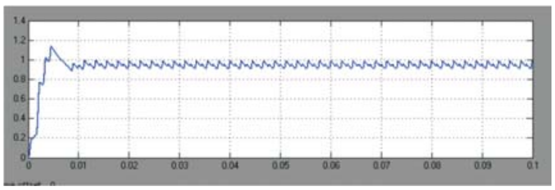


Fig. 7. Output current

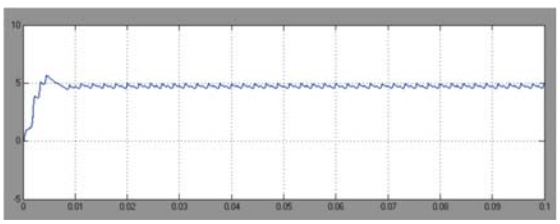


Fig. 8. Output voltage

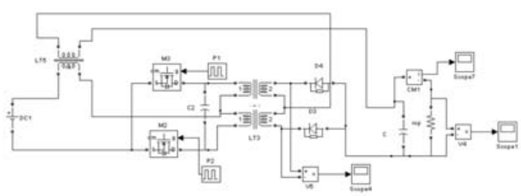


Fig. 9. Modified DC to DC converter circuit

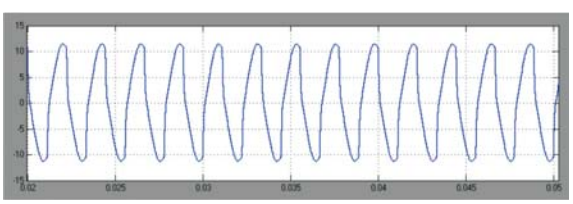


Fig. 10. Transformer output

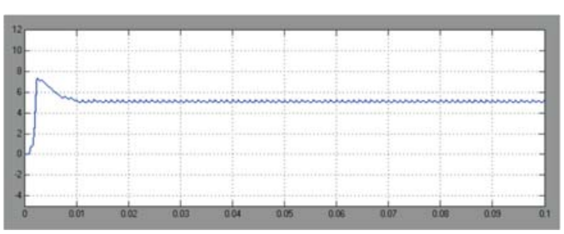


Fig. 11. Output voltage

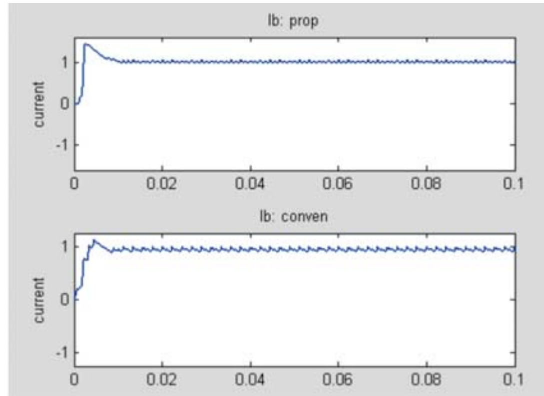


Fig.12. Comparison of current ripple

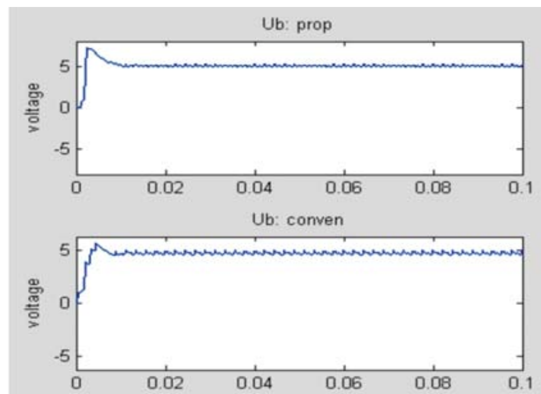


Fig. 12. Comparison of output voltage ripple

IV. CONCLUSION

This paper has presented DC to DC converter with reduced ripple. Resonant technique reduces switching losses and switching stresses. EMI is also reduced by using soft switching. Digital simulation is done by using MATLAB and the results of conventional and modified converter are compared. The ripple is reduced by using coupled inductance between input and output. The simulation results agree with the analytical predictions.

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Madhusudhanan.R obtained his graduated from from Visveswariah Technological University and post graduated in Sathyabama University. He has 4 years of teaching experience. His research area is on DC-DC converters.