A COMPACT DC/AC INVERTER FOR AUTOMOTIVE APPLICATION

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ABSTRACT

A compact dc/ac inverter for automotive is presented and experimented. The proposed inverter consists of full bridge inverter and a new ZVCS quasi-resonant push pull dc/dc converter. The new dc/dc converter converts input 12 V (from battery) to high voltage (about) 200V at very high conversion efficiency without regulation. The high voltage will be converted to ac at the desired voltage and frequency by the full bridge inverter. The experimental results show the new unregulated push-pull dc/dc converter can be applied for the automotive inverter to reduce the size and increase the conversion efficiency.

1. INTRODUCTION

To powering the consumer electrical or electronics equipments from 12V battery, the dc/ac inverter is needed to invert the direct current to alternative current. Most of battery powered dc/ac inverter use 2-stage conversion technique shown in fig.1. The step-up dc/dc converter is used for step the battery voltage (12V or 24V) up to high dc voltage, which higher than the output peak voltage, and the bridge inverter is used for invert the high dc voltage to the desired ac voltage and frequency. Generally, push-pull, forward or flyback dc/dc converters are used for step-up but theirs conversion efficiencies are low. A quasi-resonant dc/dc converter topologies suitable for unregulated low-voltage to high-voltage conversion are presented by [1]-[2], The low output ripple voltage resonant push-pull dc/dc converter [2] is applied in this paper for step the battery voltage up to the desired voltage for use by a subsequent full bridge inverter. The converter acts as a dc-transformer in system where power from low-voltage source and the input currents can exceed input voltage by an order of magnitude with high conversion efficiency. All switches and rectifier diodes operate under zero-voltage and zero-current switching conditions.

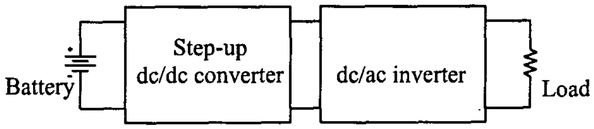

Figure 1. Two-stage conversions dc/ac inverter block diagram.

In this paper, we present the application of a new ZVCS resonant push-pull dc/dc converter in the title "A compact dc/ac inverter for automotive application "

2. CIRCUIT DESCRIPTION

Figure 2 shows the proposed dc/ac inverter, it consists of the ZVCS quasi-resonant push-pull dc/dc converter and full-bridge dc/ac inverter. The converter is based on push-pull dc/dc converter, it consists of MOSFET primary switches (S_1,S_2), series resonant circuit (L_r-C_r), output rectifier (D_1-D_4), output capacitor (C_B) and use the inherent drain-source capacitance of S_1,S_2 as the switch shunt capacitors. The series inductor (L_r) is the leakage-inductance of the secondary side of the high-frequency transformer. The resonant circuit (L_r-C_r) resonates at the switching frequency of S_1 and S_2. The full-bridge inverter consists of switches S_3-S_6, low frequency output filer (L_O-C_O) and output load.

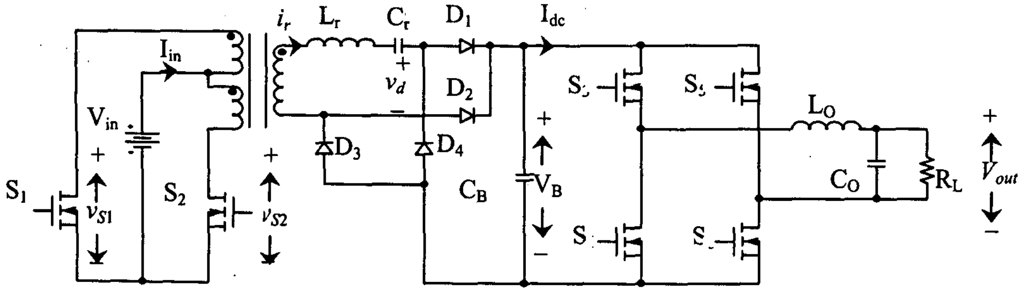

Figure 2. Proposed dc/ac inverter

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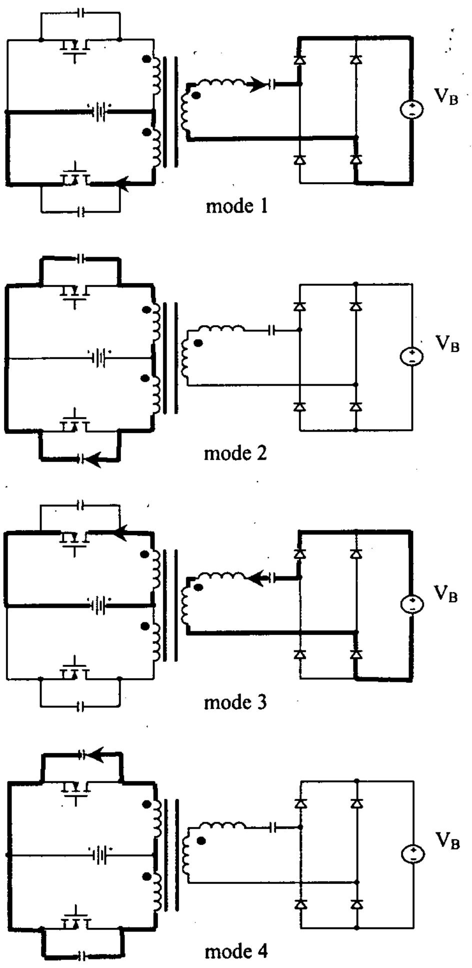


Figure 3. ZVCS quasi-resonant push-pull dc/dc converter operations

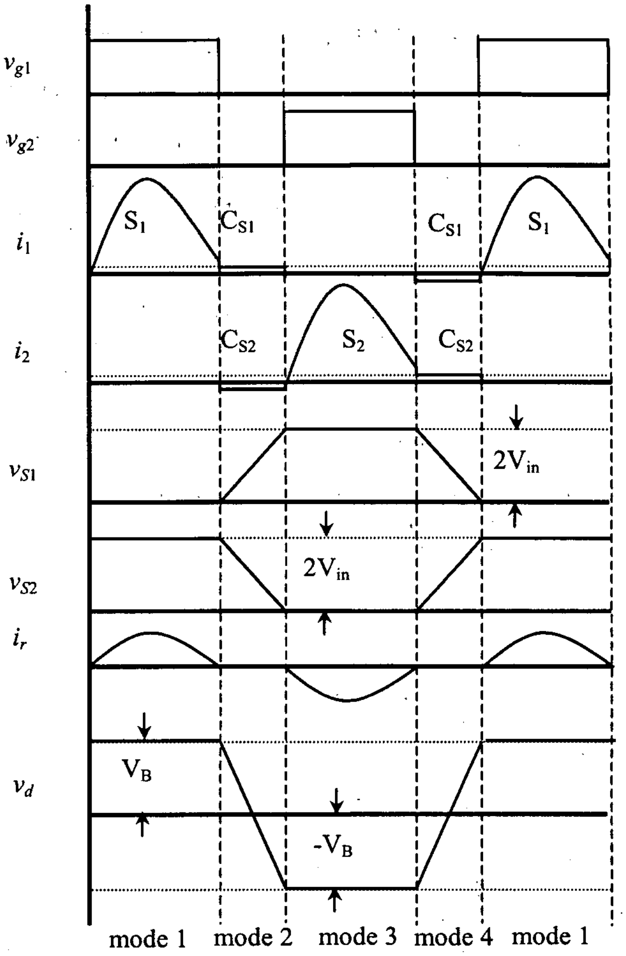


Figure 4. Idealized operating waveforms

3. CIRCUIT OPERATION

The primary switches (S_1,S_2) are driven by a fixed switching frequency at duty ratio below than 50%; out of phase. The circuit operation modes are shown in fig.3 and the idealized operating waveforms are shown in fig.4. The quality factor (Q) of the resonant circuit (L_r-C_r) have to low enough to keep the resonant current (i_r) is discontinuous.

Mode 1: S_1 is driven by v_{g1} to conduct the transformer primary current i_1 at the zero-voltage condition, and S_1 is turned-off at zero current due by the resonant circuit (L_r-C_r).

Mode 2: Both switches are turned-off and the inherent drain-source capacitance of S_1 (C_{S1}) will be charged until its voltage reached to $2V_{in}$ by the remain transformer magnetizing current, in the same time inherent drain-source capacitance of S_2 (C_{S2}) will be discharged from $2V_{in}$ to zero volt.

Mode 3: S_2 is driven by v_{g2} to conduct the transformer primary current i_2 at the zero-voltage condition, and S_2 is turned-off at zero current due by the resonant circuit (L_r-C_r).

Mode 4: Both switches are turned-off and C_{S2} will be charged until its voltage reached to $2V_{in}$ by the remain transformer magnetizing current, in the same time C_{S1} will be discharged from $2V_{in}$ to zero volt. In mode 1 and 3, the rectifier diodes are also turned on and off at zero current switching. The time duration of mode 2 and 4 are depended on the inherent drain-source capacitances of the switches and the transformer magnetizing current of the transformer.

4. EXPERIMENTAL RESULTS

In experimentation, a 12V input 130W prototype converter was built and tested. The ferrite core TDK PQ3220-PC44 with primary windings Np1=Np2=2 turns (0.6mm*3 lines) and secondary winding Ns=36 turns (0.6mm*2 lines) was used as the transformer, the secondary lumped model is shown in fig. 5.

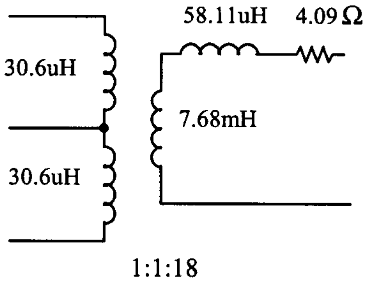
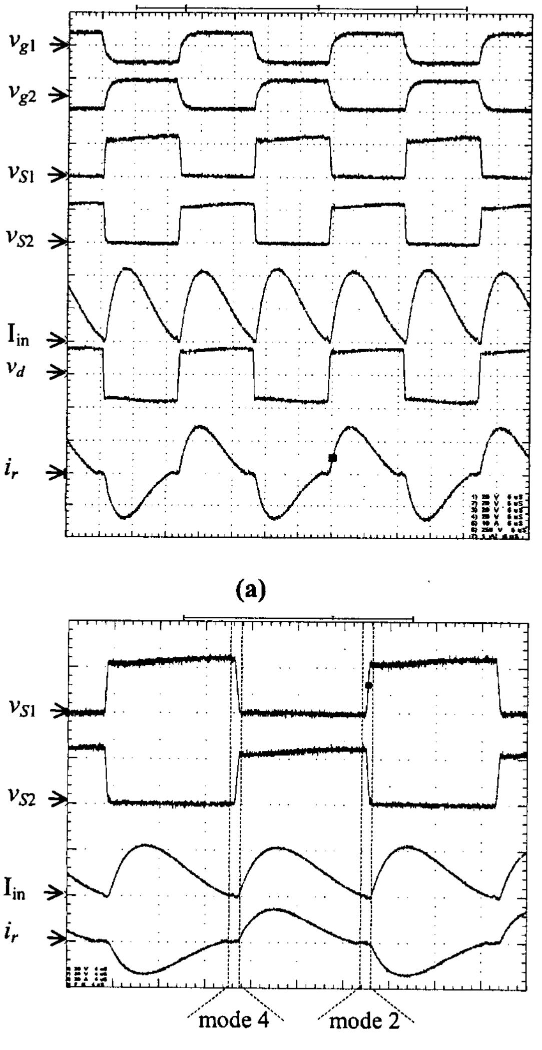


Figure 5. Transformer lumped secondary model



(b)

(vertical v_{g1},v_{g2}, v_{S1},v_{S2}: 20V/div; I_{in}: 20A/div; v_d: 250V/div; i_r:1A/div, horizontal 5uS/div)

Figure 6. Experimental converter voltages and currents waveforms at full load (P_{out}=138.5W, V_{in}=12V, V_{out}=188.3V and f_S=44kHz)

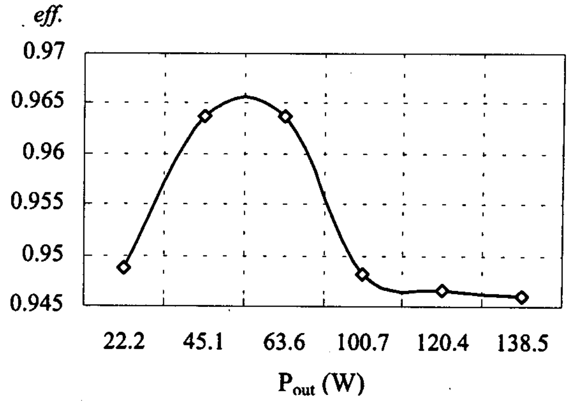


Figure 7. Conversion efficiency versus output power

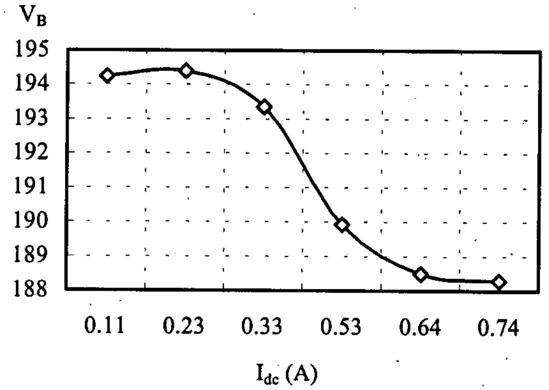


Figure 8. Output voltage versus output current

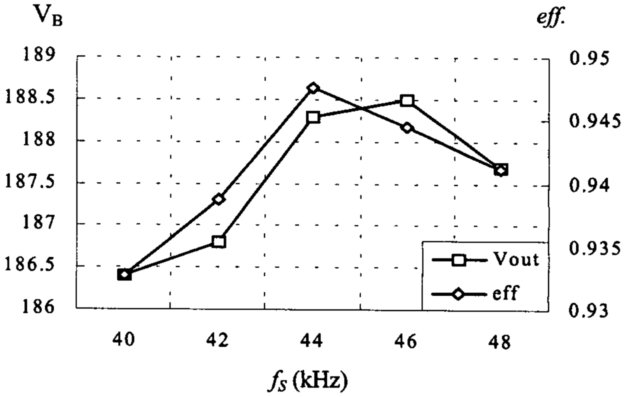


Figure 9. Output voltage versus output current

We use the MOSFET IRL2505S (R_{ds} on=0.008 Ω) as the primary switches, rectifier diodes RPG10B*4 as the output rectifier, 221.67nF as the resonant capacitor (C) and 3.3uF as the output capacitor. The converter switching frequency was calculated from the resonant frequency of L-C circuit. From fig.5, the measured secondary leakage inductance of the transformer L=58.11uH, so the resonant frequency is equal 44.34kHz. Figure 6 shows the experimental converter voltages and current waveforms when loaded by 250 Ω resistor at V_B=188.3V. The switching frequency (f_S) was fixed at 44kHz and both of v_{g1} and

v_{g2} duty ratios are equal to 48.5%. Figure 6(b) shows the zero-voltage-zero-current (ZVCS) turn-on and turn-off switching of the primary switches, and shows the time durations of mode2 and 4. Figure 7 shows the conversion efficiency versus output power. The conversion efficiency can be maintained over 94.5% when supply load 22.2 to 138.5 watt. Figure 8 shows the output voltage loading effect when the output current is increased from 0.11A to 0.74A. Figure 9 shows the relation of output voltage and the conversion efficiency when the switching frequency was varied and output load was fixed at 250 Ω.

5. CONCLUSIONS

A new ZVCS quasi-resonant dc/dc converter topology can operates at high-conversion efficiency and very low switching noise with simple operation and low cost. It is ideally suited for unregulated dc/dc conversion from low-voltage high-current source for use by a subsequent bridge inverter. Since it uses the secondary leakage inductance as the resonant element and the converter needs no high Q resonant circuit, so the discrete resonant inductor is not required. Moreover, it easily to control the output ripple voltage because most of resonant current flow through the output capacitor.

6. REFERENCES

[1] M.J. Ryan, W.E. Brumsickle, D.M. Divan and R.D. Lorenz, "A new ZVS LCL-resonant push-pull dc-dc converter topology," *IEEE Trans. Industry Application.*, Vol. 34, No. 5, pp.1164-1174, Sep/Oct 1998.

[2] Itsda Boonyaroonate and Shinsaku Mori, "A new ZVCS resonant push-pull dc/dc converter topology," Power electronics specialist conference 2002.