ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 251- 254 (2013)
Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai

Comparison of Simulation and Experimental Results of Phase-Shifted Full-Bridge Series-Resonant DC-DC Converters for Wide Load Variations

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Abstract— **This paper presents simulation and experimentation of a phase-shifted full-bridge series resonant converter (PS-FB SRC). It is operated in series resonant mode at normal loads. The switching frequency is varied to regulate the output voltage. The fixed-frequency phase-shifted pulse width modulation, on the other hand, is used to adjust the effective duty cycle and regulate the output voltage at light loads. The proposed converter exhibits high conversion efficiency for wide-range load conditions. The relationships among the voltage gain, the switching frequency, and the effective duty cycle are discussed and analyzed.Experiments are conducted to verify the simulation results.**

Index Terms— **Conversion efficiency, phase-shifted full-bridge converter, series resonant converter (SRC).**

I. INTRODUCTION

Higher conversion efficiency and power density are urgent targets for power electronics industries. To satisfy these demands, many topologies and control methods are proposed. Among them, dc-to-dc series resonant converters (SRCs) with zero-voltage-switching (ZVS) features are getting more attention [1]–[3]. For an SRC, the output voltage is regulated by changing the switching frequency. However, it is impractical to raise the switching frequency at lighter loads due to the limitation of a semiconductor switch device. Several schemes are proposed to solve this problem such as burst mode control, turn-off time modulation, etc. [4], [5]. The penalty is that the ZVS feature is no longer kept. In this paper, the phase-shifted duty cycle control [6]–[17] with ZVS at a fixed highest switching frequency is proposed to regulate the output voltage at light loads. Although the phase-shifted modulation features the constant switching frequency and ZVS function over wide input voltage and output load ranges, its efficiency at heavy load is lower than that of an SRC due to the high duty cycle loss. Therefore, the proposed control scheme adopts the frequency modulation with high heavy-load efficiency and the phase-shifted modulation with a better output voltage regulation and ZVS function at light loads. High conversion efficiency is fulfilled for wide-range load variations.

II. CIRCUIT ANALYSIS

Figure 1 shows the schematic of a full-bridge SRC. The primary side contains four active switches, Q_A , Q_D , with their output parasitic capacitors $C_{oss,A} \sim C_{oss,D}$, the resonant capacitor C_r , and the resonant inductor L_r . The turns ratio of a center-tapped transformer is $n : 1 : 1$. The secondary side includes rectifier diodes D_1, D_2, a filter capacitor C_O , and a load R_L. The duty cycle of the primary-side active

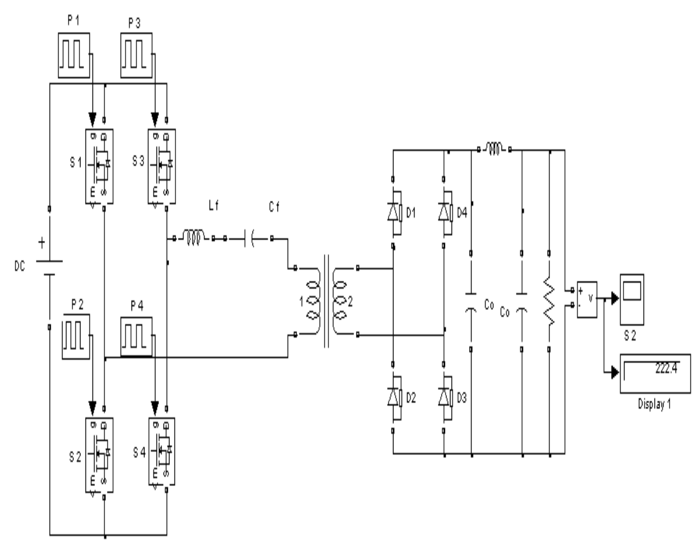

Figure. 1. Circuit diagram

III.SIMULATION RESULTS

The simulations are done using MATLAB software. The simulation results are presented in this section. The input voltage is shown in figure2. The switching pulses for four switches are shown in figure3. The gate voltage and drain to source voltage across the switches is shown in figure4. The transformer primary and secondary output voltage are shown in figures 5 and 6 respectively. The output voltage output voltage is shown in figure7. The output current is shown in figure 8.

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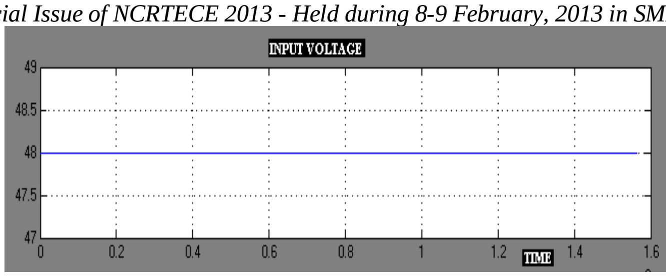

Figure2. Input voltage T(s)

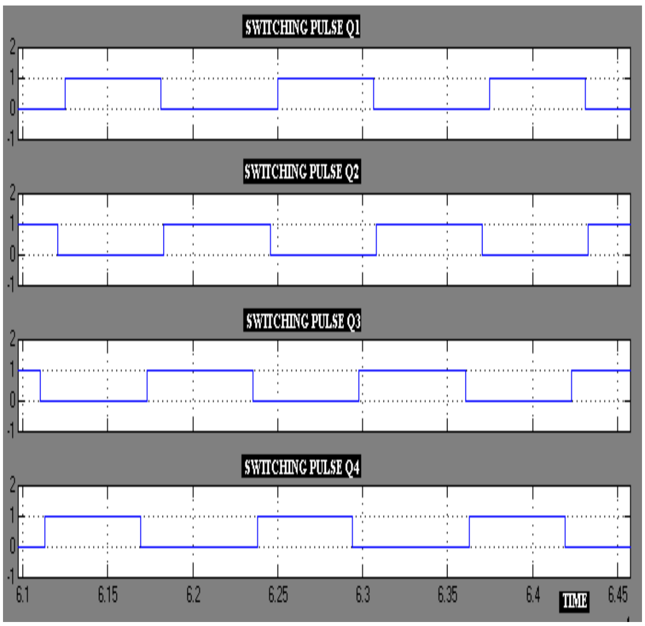

Figure3. Switching pulses T(s)

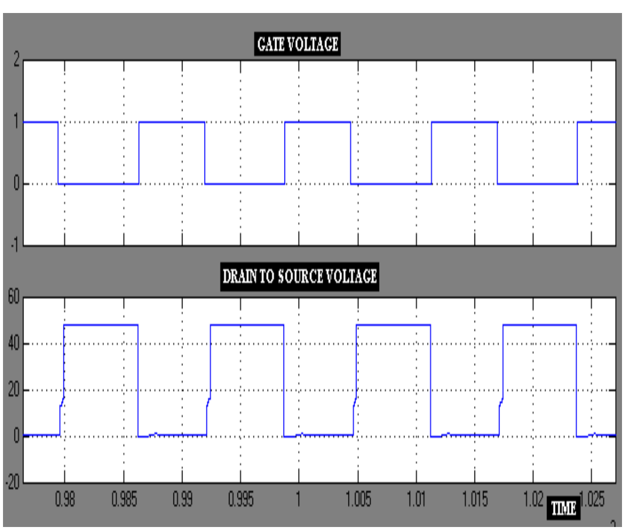

Figure4. Gate voltage and Drain to Source voltage T(s)

Volts

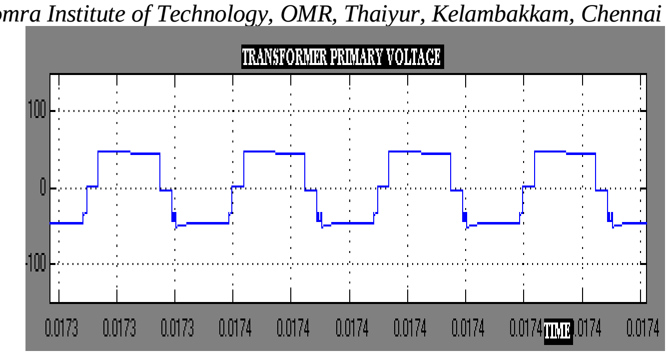

Figure5. Transformer Primary Voltage

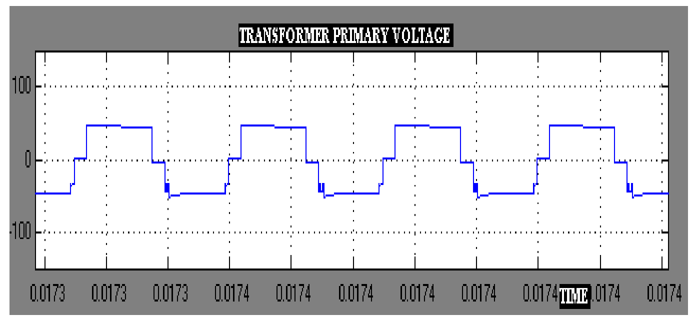

Figure6. Transformer Secondary Voltage T(s)

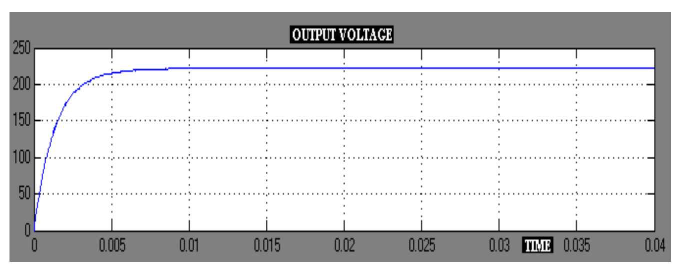

Figure7. Output Voltage T(s)

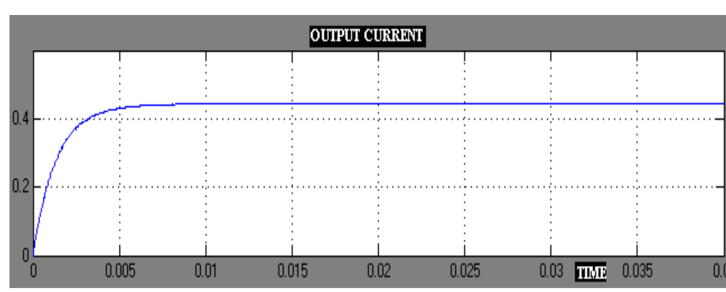

Figure8. Output current T(s)

V.EXPERIMENTAL RESULTS

The experimental setup is shown in figure9. The input voltage to the converter is shown in figure 10.The gate pulses applied to the switches M1 and M2 are shown in figure11 and 12 respectively. The transformer primary and

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secondary voltages are shown in figures 13 and 14 respectively. The output voltage is shown in figure15.

Figure9. Experimental setup

Volts

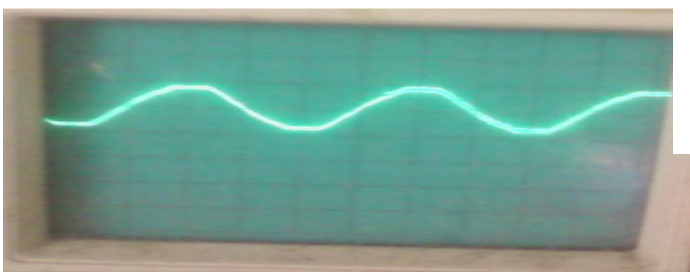

Figure 10Input Volatge T(s)

Volts

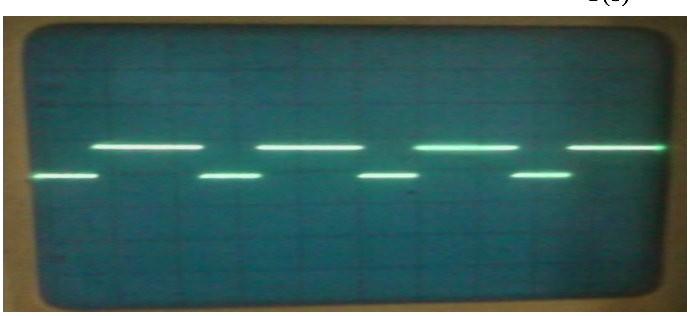

Figure11. Gate pulses for M1 T(s)

Volts

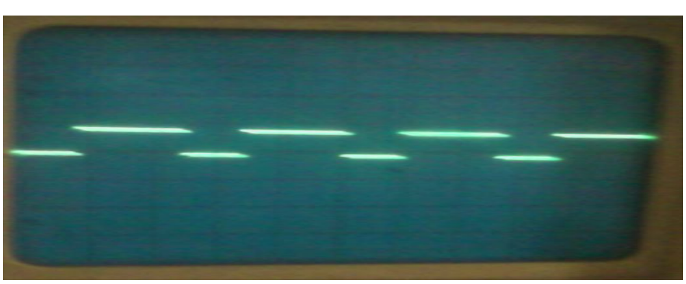

Figure12. Gate pulses for M3 T(s)

Volts

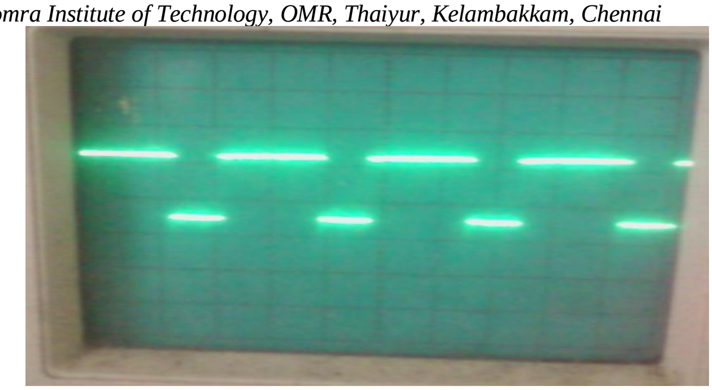

Figure13. Transformer primary voltage T(s)

Volts

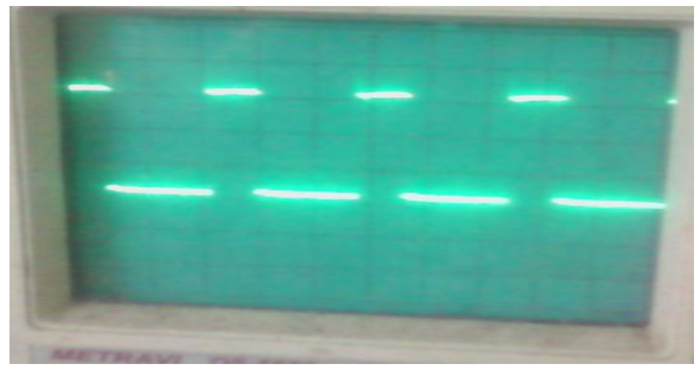

Figure14. Transformer secondary voltage T(s)

Volts

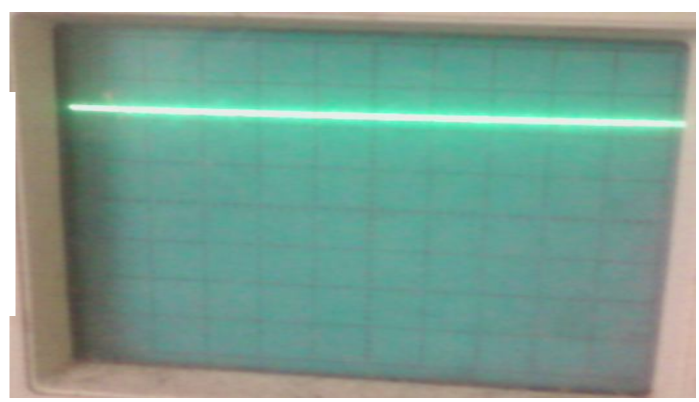

Figure 15.Output Voltage T(s)

V.CONCLUSION

To cope with the poor output voltage regulation and low conversion efficiency at light loads for the full-bridge SRC, a two-mode control strategy is presented in this paper. The FB SRC is operated under switching frequency modulation for most of the load range to achieve ZVS and low switching noises. For the lighter loads, the FB SRC is operated under phase-shifted duty cycle modulation to regulate the output voltage and maintain the ZVS feature. It

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is observed that the experimental results are similar to simulation results.The proposed two-mode control scheme for a FB SRC is especially suitable for applications with wide input voltage and load variations.

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