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DESIGN AND IMPLEMENTATION OF RESONANT CIRCUIT BASED ON HALF-BRIDGE BOOST RECTIFIER WITH OUTPUT VOLTAGE BALANCE CONTROL

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Abstract- This paper proposes a resonant circuit based on half-bridge rectifier with auxiliary resonant circuit. The zero current switching can greatly reduce the switching losses and electromagnetic noises. Significant reductions in conduction losses and current stress are realized because circulating current for the soft switching flows only through the auxiliary circuit. Balance output voltage can be obtained using the auxiliary resonant circuit. In this paper the principle of the zero current switching operation, design of the resonant circuits and the control sequence are described from theoretical and practical point of view.

Keywords :auxiliary resonant circuit, balance control technique,(ZCS)zero current switching,(ZVS)zero voltage switching

1.INTRODUCTION

In industrial applications such as ac/dc converters, one of the favorite topology is the half-bridge rectifier. For high-efficiency and low electromagnetic interference (EMI) applications, various soft-switching solutions are provided numerously wherein auxiliary resonant circuits are utilized to not only support the required resonant operations but also to reduce the switch stress compared to conventional resonant power converters. In general, the soft-switching methods include zero-current-switching (ZCS) and zero voltage-switching (ZVS) depending on the characteristics of the used switches. One of the advantages of using ZCS techniques is the current tail phenomenon in insulated gate bipolar transistor can be eliminated while transited to be off, resulting in less power loss at the transition. Which benefits comprise lower current stress and ZCS on both switches compared to traditional resonant circuits applied to power converters has two resonant frequencies in operation and is more complicated than the other circuit which has only one resonant frequency.

Based on the advantages of soft-switching, this paper provides a novel ZCS-pulse width modulation (PWM) half-bridge boost to increase the efficiency and restrain EMI. Although the half-bridge rectifier can provide double dc output voltages on the two split capacitors, it is an important issue that the two dc output may cause imbalance problem, but they are only suitable for the specific PWM controllers and associated control strategies, that is, modifications and variations must be made for the used controller.

2. CIRCUIT DIAGRAM FOR PROPOSED SYSTEM

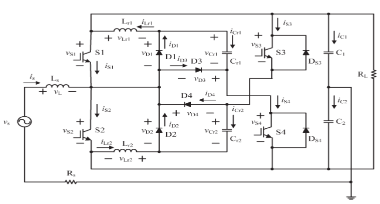

Fig 2.1 ZCS-PWM Half-Bridge Boost Topology.

Before analysis, some assumptions are made:

a) All elements are considered as ideal, with no parasitic components.

b) Voltages across the output capacitors are equal, $V_{o1} = V_{o2} = E$ and $V_{o1} + V_{o2} = 2E = V_o$ due to balance control.

c) Input current is considered as a constant within one switching period, $i_s = I_s$; and

d) Resonant capacitor voltages are zero, $v_{Cr} = 0$, and resonant inductor currents are equal to input current, $i_{Lr} = I_s$, when $t \le t_0$. During $t \le t_0$, the primary switch S2 keeps the off state and the input current I_s flow through the diode D1, the resonant inductor L_{r1}, and the output capacitor C_1 so that C_1 is charged and L_{r1} is demagnetized. The operation analysis for positive half-cycle consists of seven periods.

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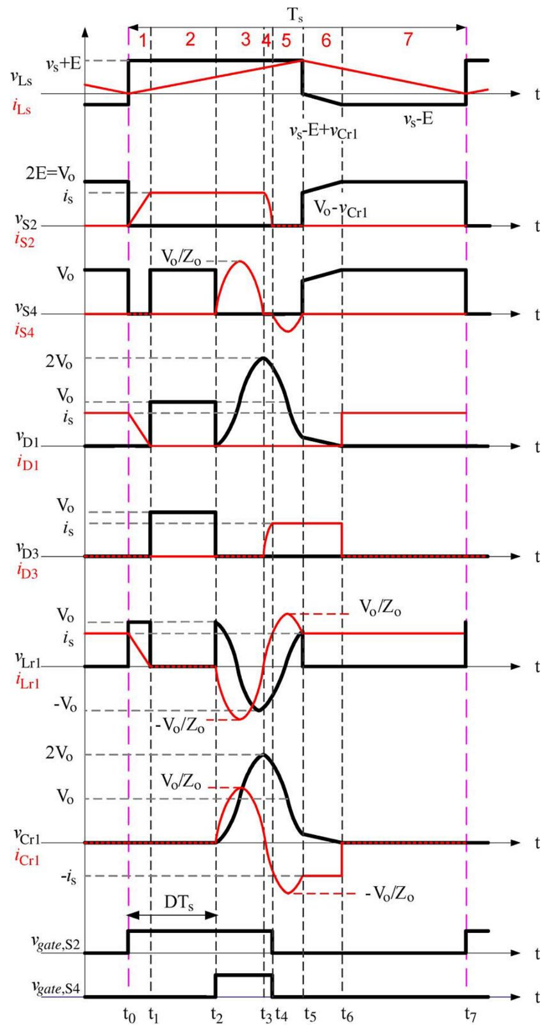

Fig .2.1 Waveforms for positive half-cycle operations.

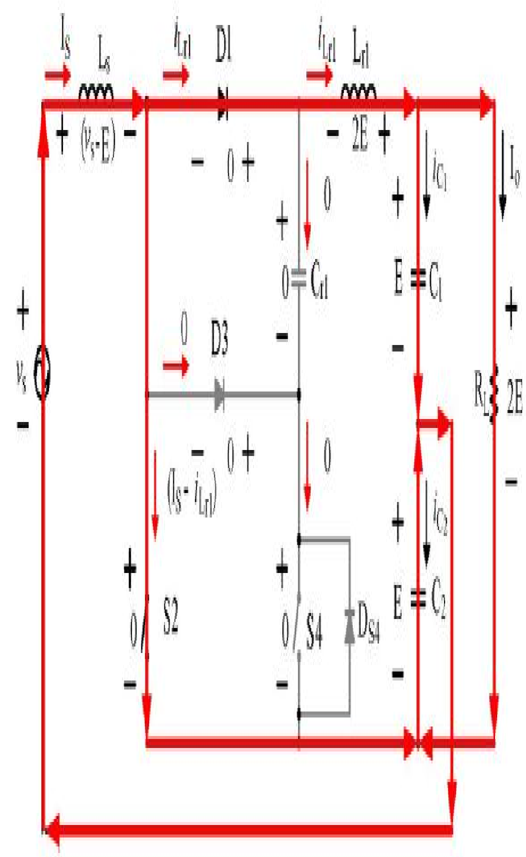

Fig 3.1 Equivalent circuit during first period, $t0 \le t \le t1$

3. MODES OF OPERATION:

First Period, [$t0 \le t \le t1$]: In this duration primary active switch S2 is turned on, and the input current *i*s passes through S2, while *t* = *t*0. The resonant inductor current goes to zero, *i*Lr1 = 0, so that the free-wheeling diode D1 is turned off with ZCS, while *t* = *t*

$$iLr1 = Is - Vo/ Lr1 (t - t1)$$

$$vCr1 = 0$$

and the time interval during the first period, *t*1 − *t*0, can be computed as

$$\Delta t1 = IsLr1/Vo$$

Second Period, [$t1 \le t \le t2$]: The primary switch S2 is still on, and other elements all are off while *t* = *t*1. During this time interval, the input inductor *L*s is magnetized by the input voltage *v*s and the voltage across *C*2, the input current *I*s passes through S2 and discharges *C*2, the equivalent circuit Based on the analysis as above, the equations related to the voltage across *L*s and the resonant tank can be derived as

$$vLs(t) = vs + E$$

$$iLr1(t) = 0$$

$$vCr1(t) = 0$$

the time interval during the second period, *t*2 − *t*1, can be computed as

$$\Delta t2 = DTs - \Delta t1$$

Where *D* is duty cycle and *T*s is switching period.

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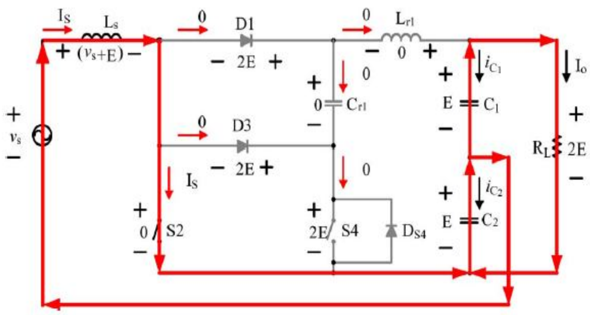

Fig 3.2 Equivalent circuit during second period, $t1 \le t \le t2$.

Third Period, [t2 ≤ t ≤ t3]: The auxiliary switch S2 is turned on while $t = t2$, two output voltages across capacitors $C1$ and $C2$ and the resonant elements $Lr1$ and $Cr1$ form the resonant path, the input inductor Ls is kept to be magnetized, the input current Is passes through S2 and discharges $C2$ with the resonant current $iLr1$, the equivalent circuit Based on the analysis as above, the equations related to the resonant tank can be derived as

$$iLr1(t) = -Vo/Zo\sin \omega r(t-t2)$$
$$vCr1(t) = Vo - Vo \cos\omega r(t-t2)$$
$$Zo=\sqrt{Lr1/Cr1}$$
$$\omega r=1 \sqrt{Lr1Cr1}$$

Wherein Zo is the characteristic impedance and ωr is the resonant radius frequency,

$$\omega r= 2\pi fr$$

The time interval during the third period, $t3 - t2$, can be Computed as

$$\Delta t3 = \pi/\omega\ r$$

This duration ends at $t = t3$, and the voltage across the Resonant capacitor $Cr1$ is

$$vCr1, peak= vCr1(t3) = 2Vo.$$

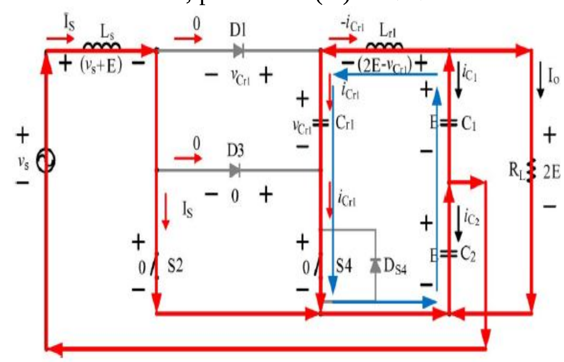

Fig 3.3 Equivalent circuit during third period, $t2 \le t \le t3$

Fourth Period, [t3 ≤ t ≤ t4]: The resonant capacitor $Cr1$ is discharged to provide energy for the resonant tank while $t = t3$. The current $iCr1$ passes through the output capacitor $C1$ and $C2$, the resonant tank elements $Lr1$ and $Cr1$, the primary switch S2, and the diode D3 so that the auxiliary at this time and the current passes through S2 is

that $iS2 = Is - iLr1$. Also, the primary switch S2 is turned off with ZCS while $iLr1 = Is$. The equivalent circuit is shown in Fig. 9, and based on the analysis as above, the equations related to the voltage across Ls and the resonant tank can be derived as

$$iLr1(t) = Vo/Zo\sin \omega r(t-t3)$$
$$vCr1(t) = Vo + Vo\cos\omega r(t-t3)$$

and the time interval during fourth period, $t4 - t3$, can be computed as

$$\Delta t4 = 1/\omega r\sin-1(IsZo/Vo).$$

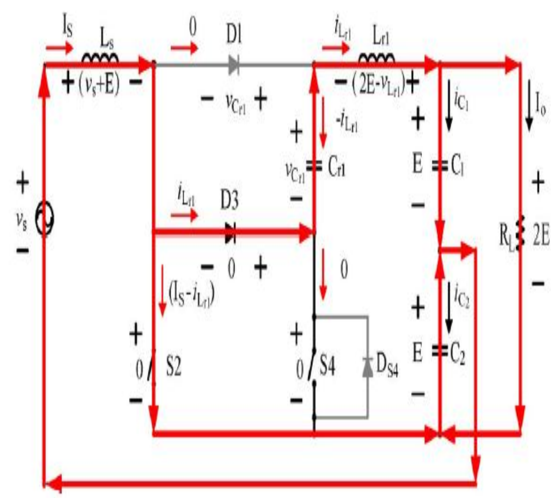

Fig3.4 Equivalent circuit during fourth period, $t3 \le t \le t4$

Fifth Period, [t4 ≤ t ≤ t5]: Because the resonant current will be larger than the input current $iLr1 \ge Is$ while $t = t4$, the current passing through $DS4$ is $iLr1 - Is$. The equivalent circuit is shown, and the related equations are the same as those during fourth period

$$iLr1(t) = Vo/Zo\sin \omega r(t-t4)$$
$$vCr1(t) = Vo + Vo\cos\omega r(t-t4)$$

and the time interval during fifth period, $t5 - t4$, can be computed as

$$\Delta t5= \pi/\omega r - 2\Delta t4$$

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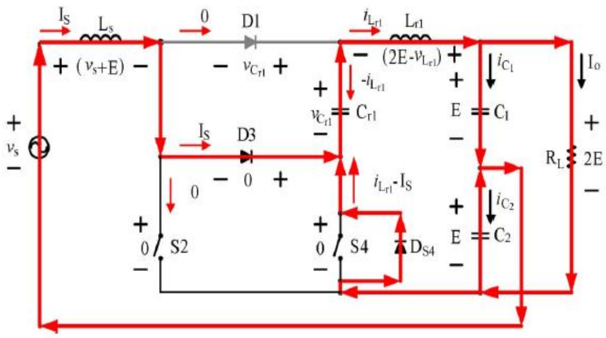


Fig 3.5 Equivalent circuit during fifth period, $t4 \leq t \leq t5$

Sixth Period, [t5 ≤ t ≤ t6]: The resonant capacitor *C*r1 is discharged by the input current *I*s and the input inductor *L*s is demagnetized while *i*Lr1 = *I*s. Based on the analysis as above, the equations related to the voltage across *L*s and the resonant tank can be derived as

$$vLs = vs - E + vCr1$$
$$vCr1 = vCr1(t5) - Is/Cr1(t - t5)$$
$$vLr1(t) = 0$$
$$iCr1(t) = -Is$$

and the time interval during sixth period, $t6 - t5$, can be computed as

$$\Delta t6 = 2VoCr1/Is\cos[\omega r(\Delta t4 + \Delta t5)]$$

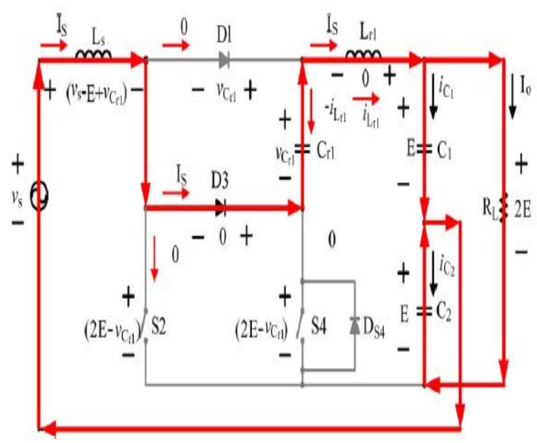


Fig 3.6 Equivalent circuit during sixth period, $t5 \leq t \leq t6$

Seventh Period, [t6 ≤ t ≤ t7]: The free-wheeling diode D1 is turned on with ZVS because *v*cr1 (*t*6) = *v*D1(*t*6) = 0 while *t* = *t*6. The input inductor *L*s continues to be demagnetized and the equivalent circuit. Based on the analysis as above, the equations related to the voltage across *L*s and the resonant tank can be derived as

$$vLs = vs - E$$
$$iLr1 = Is$$
$$vCr1 = 0$$

and the time interval during seventh period, $t7 - t6$, can be computed as, $\Delta t7 = Ts - DTs - 2\pi/\omega r + \Delta t4 - \Delta t6$

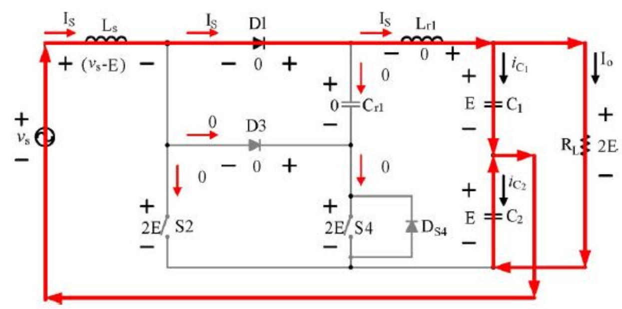


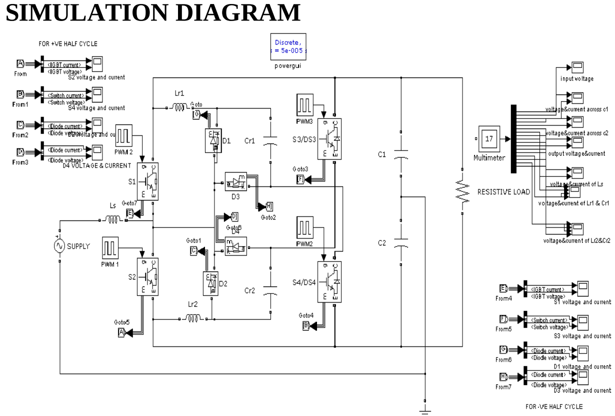
Fig 3.7 Equivalent circuit during seventh period, $t6 \leq t \leq t7$

In order to achieve ZCS on the primary switch and the auxiliary switch based on the analysis as above, the condition can be derived as

$$Vo/Zo \geq Is,peak$$

Where Is, peak is the peak value of the input current.

SIMULATION DIAGRAM



WAVEFORMS:

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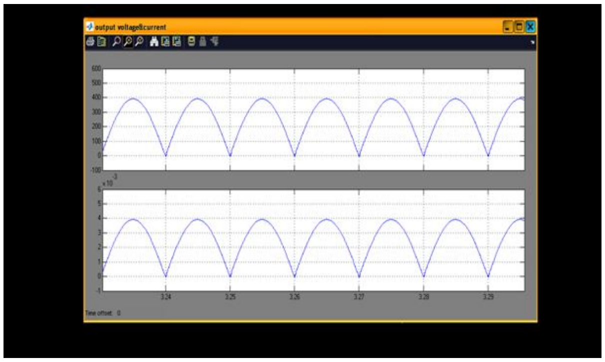
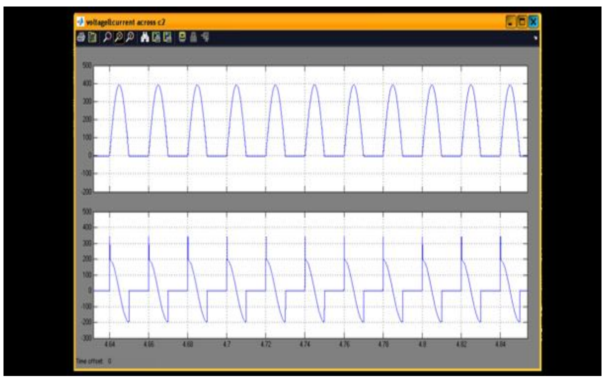
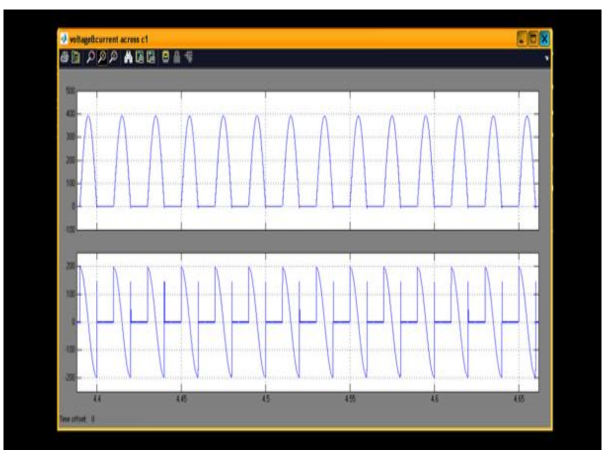
Input inductor current and voltage Output waveforms:



Balanced output:
Capacitor c1:

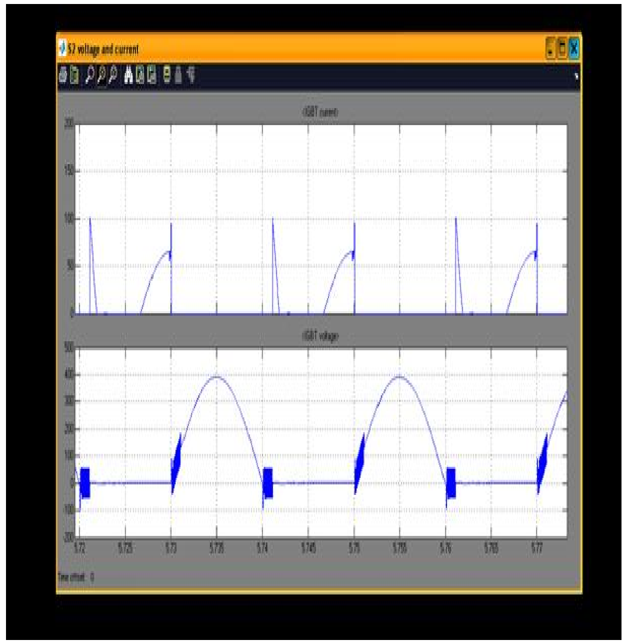


Capacitor c2:

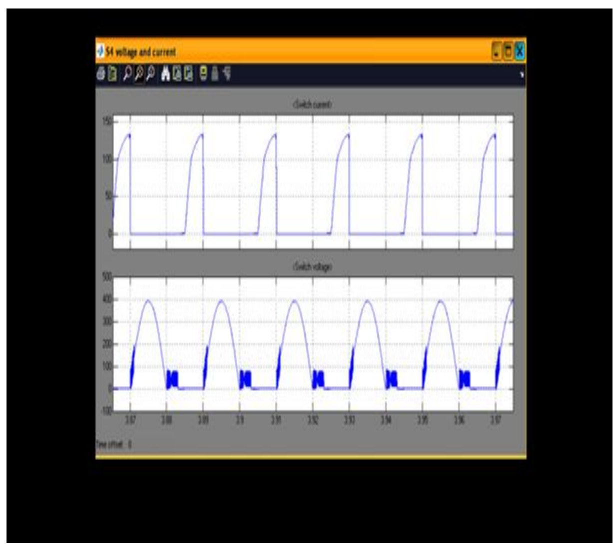


ZCS&ZVS during positive half cycle:

Voltage and current across IGBT switch 2:



Voltage and current across IGBT switch 4:



Voltage and current across diode D2:

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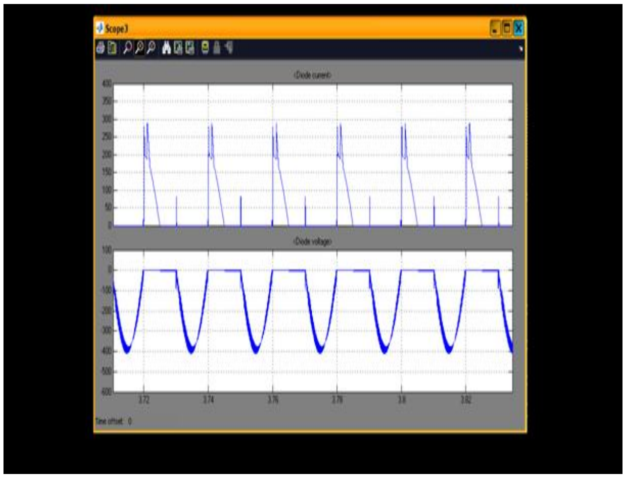
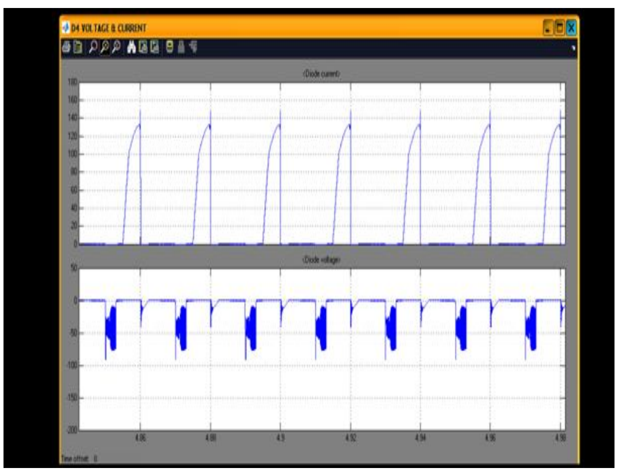
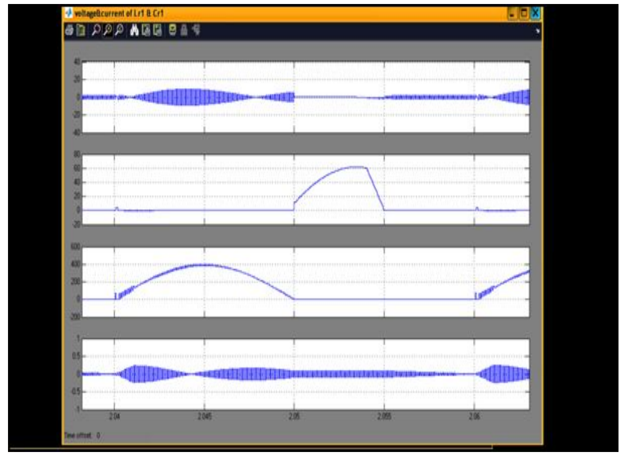


Voltage and current across diode D4:



Voltage and current across resonant circuit Lr1&Cr1:



ZCS&ZVS during negative half cycle:
Voltage and current across IGBT switch S1

Voltage and current across IGBT switch S3:

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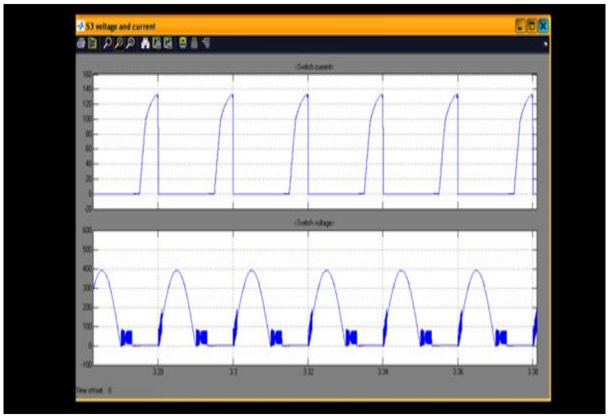
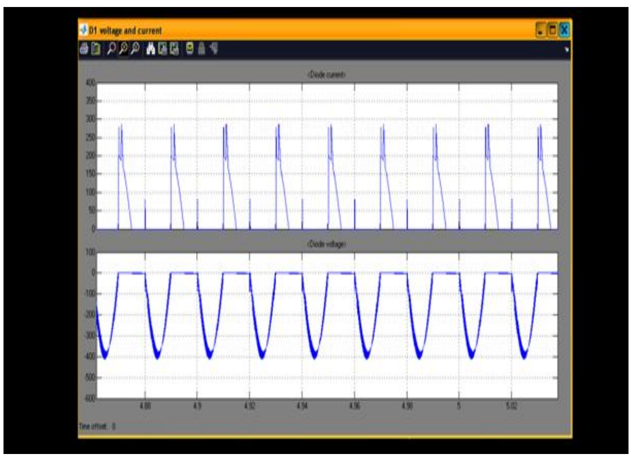
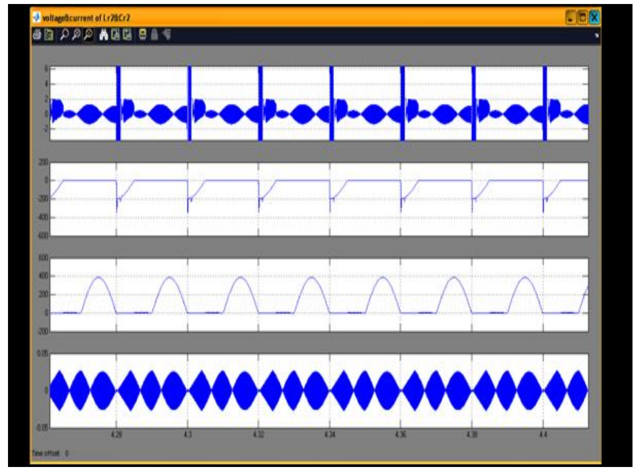


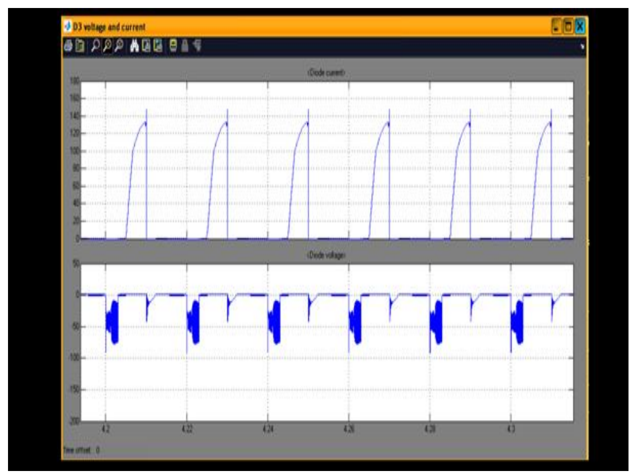
Voltage and current across diode D1:



Voltage and current across diodeD3:



Voltage and current across resonant circuit Lr1&Cr1:



CONCLUSION

This paper proposes and implements a novel ZCS-PWM half-bridge boost with two output voltage balance control. Steady-state analyses including seven periods for positive half cycle was performed in detail. The small-signal analysis was discussed, and design of the corresponding current and voltage error amplifiers was realized. The balance control scheme for two output capacitor voltage was designed and implemented to eliminate the inherent imbalance phenomenon. Compared to conventional half-ridge rectifier, benefits of the proposed novel ZCS-PWM half-bridge boost include:

1) soft-switching comprising ZCS and ZVS without extra stress;

2) high efficiency because of ZCS in active switches and ZVS in passive switches;

3) two output voltage balance without influencing power factor; and

4) easy and simple design and implementation because of using off-self PWM IC.

Design and implementation of an exemplary novel ZCS-PWM half-bridge boost with output voltage balance control have verified the system performance.

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