Isolated Soft Switching Current Fed Series LC Resonant DC-DC Convertor for Electrical Vehicle Application

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Article History: Received: 10 November 2020; Revised 12 January 2021 Accepted: 27 January 2021; Published online: 5 April 2021

Abstract: The current fed series resonant converter for electrical vehicle application is offered in this paper. The converter is able to achieve ZVS for primary side semiconductor switches. In the overlap time of voltage and current at zero crossing series resonant tank circuit is gives short interval of resonant pulse. This resonant pulse provide natural voltage decrease for semiconductor switches and voltage pulse is zero earlier compare to current across switches and ZVS achieve for semiconductor switches. All devices turn off softly so dependency on snubber is decreased to clamp the voltage across the switches. Presented converter reduce the circulating current so switching losses is decreased and converter efficiency will improvise. The proposed converter is simulated in MATLAB Simulink environment to investigate and analyses the proposed converter.

Keywords: electrical vehicles, State of charge, DC-DC Convertor, Buck-Boost Convertor, Zero Voltage Switching

1. Introduction

These days' solution for the environmental pollution and CO_2 emission through the conventional energy resources are major problem for the world is providing by the EV's and HEV's. Now day's scientists, government and industries pay more attention on renewable energy resources and electrical vehicles to reduce CO_2 emission and reduce the uses of fossil fuels uses [1]. Generally the battery uses in electrical vehicle are more half kW rating and isolated dc/dc convertor for power conversion is used [2].

Conventional dc-dc converters realize the main necessity of assimilating alternative energy sources into dc microgrids. The adaptable power supply voltage makes it difficult for semiconductor devices to switch in a considerable operating range, which greatly reduces the converter efficiency. If we can limits convertor process at high frequency subsequent

In larger magnetics and immense system. The main key task is to be attain soft-switching for semiconductor devices when source voltage and load has wide dissimilarity. While achieving the soft switching has highly reliable, and volume, and cost is low of the converter [3].

In the works, assessment of soft switched voltage served convertor and current served convertor is presented. The current fed convertor has various advantages such as small input current wave and inherent short circuit current protection, high voltage gain, higher efficiency, wide soft switching range these advantages makes current-fed topology more popular for HV gain and low voltage high current use. With the current fed converter high voltage spikes through the semiconductor devices through turn-off is the main task with the current-fed converter, inactive sunbber take stress-free solution to defeat the device turn-off voltage point but with this convertor efficiency is compromise. Instead of use active clamping achieves and passive sunbber, ZVS of the semiconductor switches and result is enhanced effectiveness but its ads to the peak currents, and reduce boost capacity [4].

Various techniques and innovative topologies permitting soft-switching and removing the essential of outmoded snubber circuit has been stated in literature. The idea of sunbberless natural commutation and voltage clamping of semiconductor switches by applying secondary regulation in many current fed methods. Current operated resonant converter utilizing high frequency transformer and resonant tank and circuit parasitic to achieve soft switching for switches [5].

This paper investigate the zero voltage switching for front end switches for Converter. The battery side converter designated as a current fed full bridge boost converter to attain double voltage gain from primary to secondary transformer. Converter action and regulator is explained in section II. Detailed steady state investigation is explained in section III. Design steps exist presented in section IV. Simulation effects are explain in section V to validate the investigation. Conclusion are strained in section VI.

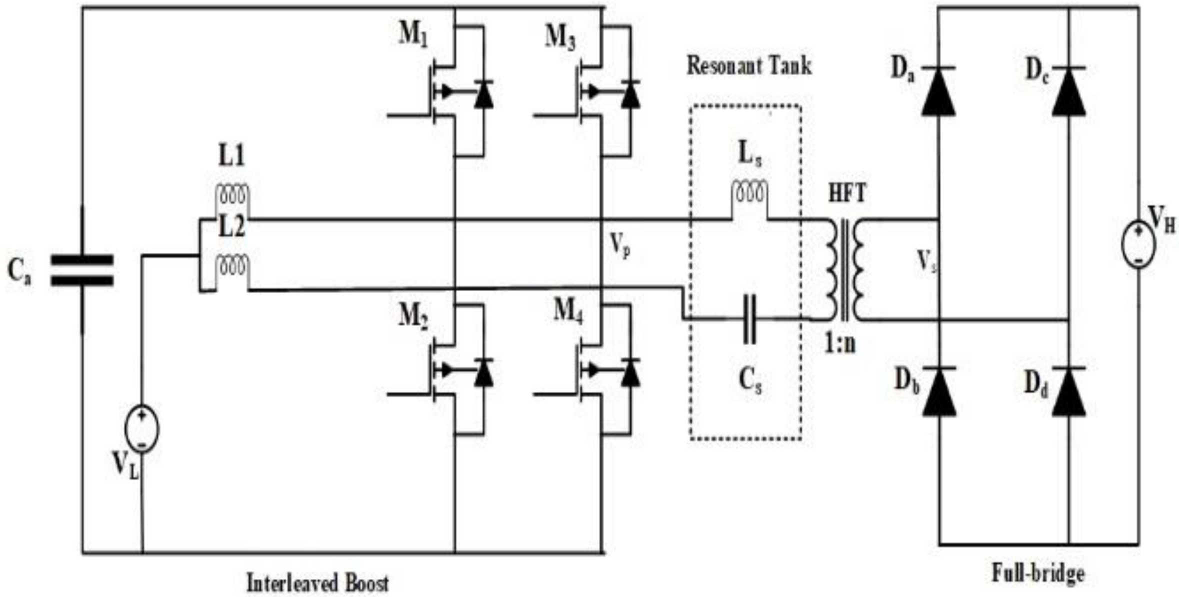


Fig. 1. Offered Isolated Soft Switching Current Fed Series LC Resonant DC-DC Converter

2. Proposed Convertor Technique And Operation Principles

A. Proposed converter

The recommended series resonant converter is presented in fig. 1, presented converter has capability to offer high voltage output due to its interleaved boost connected to the primary of the HF transformer, and secondary side of the HF transformer connected with diode bridge rectifier. The resonant tank circuit is used to provide smooth sine wave at both secondary and primary verges of the high frequency transformer, which allows low conduction losses of switching devices. A resonant indictor L_s and capacitor C_s used as to realize ZVS for primary side of the switches. If the voltages of V_H and V_L are constant by DC source, the current be able to be controlled by current control loop, then voltages of V_L or V_H can be straight delimited by voltage control loop [6].

B. Modulation and Operating Principles

An easy PWM control technique is adopt to control the series resonant DC-DC converter. The SF of the convertor is static at the series resonant tank. The semiconductor switches are connected in the similar pare are operated opposite The 2 switching leg on the primary side function in an interleaving mode. The subsequent examination will designate that the voltage gain charterstics of the planned series resonant dc/dc is very like to the PWM converters, those voltage gain also controlled through the duty cycle of the switches, thus the moved power and the way of power movement can be controlled simply through modest PWM regulator.

3. Stady State Analysis

This part of the article describe about the steady state process and examination of the series resonant dc/dc current fed converter. Designed for abridging the convertor investigation, the subsequent assumption are complete

a) A higher significance of the boost inductor is selected to transfer a inflexible dc current.

b) Completely semiconductor switches are idyllic and loss free.

c) The output filter capacitor value is sufficient to provide the continuous output voltage.

d) Capacitor C_s and inductor L_s of the high frequency transformer constitute for resonant tank parameter.

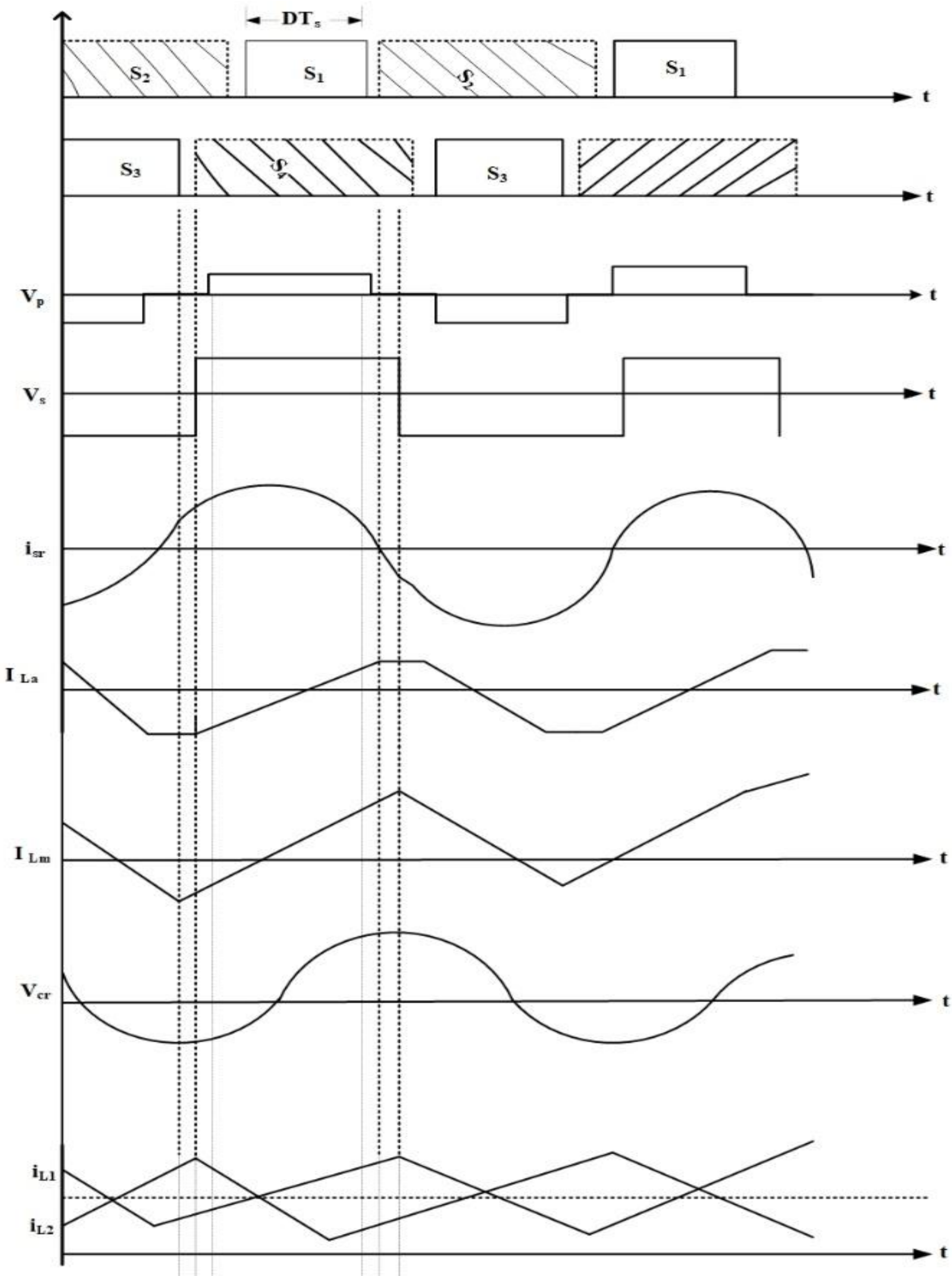
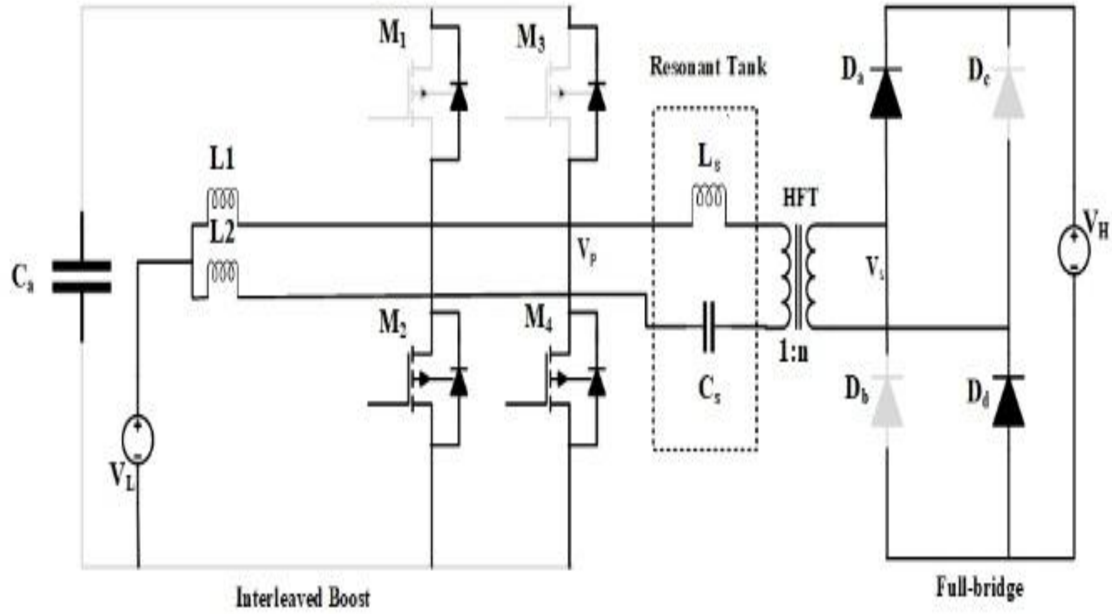


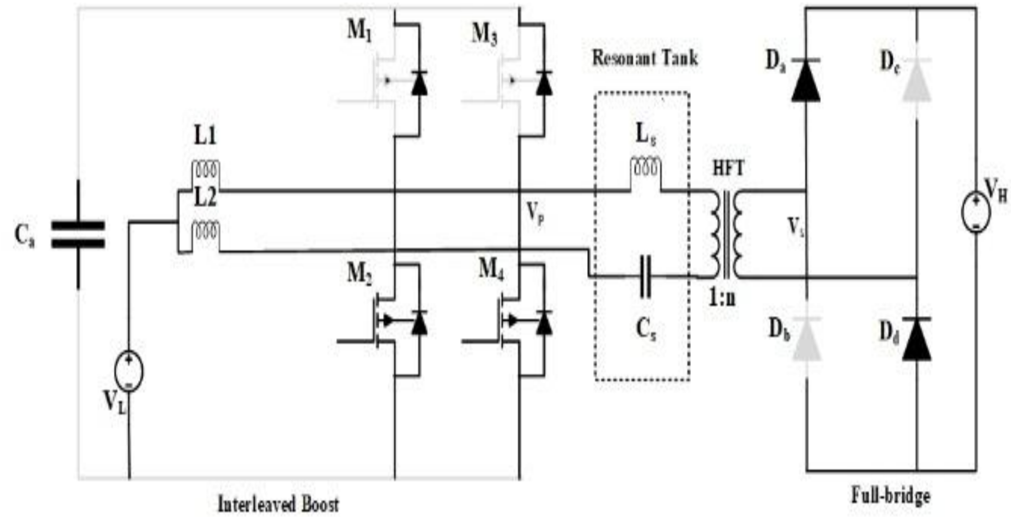
Fig.2 Series resonant converter steady state waveform on forward mode of conduction

Mode I [t_0-t_1] [Fig. 3(a)] earlier t_0, M_2 and M_4 are closed to 0 at the center voltage V_p of the primary side bridge, while the center voltage V_s of the secondary side is $-V_H$ at t_0, and then the diodes D_a, D_d are converted to V_H.

Mode II [t_1-t_2] [Fig 3(b)] at t_1 the diode D_a and D_d in forward conduction.


M1
M3
Resonant Tank
Da
Dc
L1
Ls
HFT
L2
Ca
Vp
Vs
VH
M2
M4
1:n
Cs
Db
Dd
VL
Interleaved Boost
Full-bridge

(a)


M1
M3
Resonant Tank
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Ls
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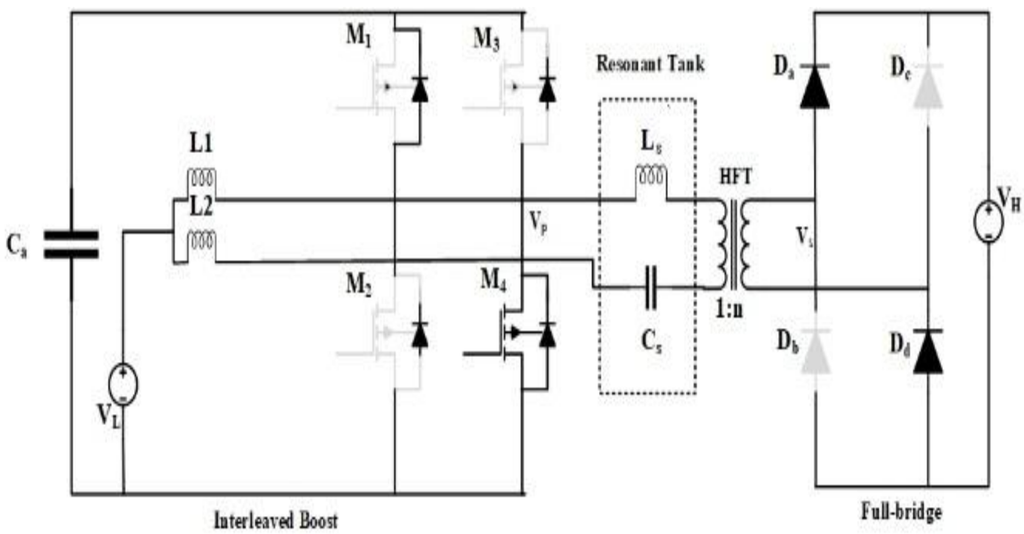
Full-bridge

(b)


M1
M3
Resonant Tank
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Dc
L1
Ls
HFT
L2
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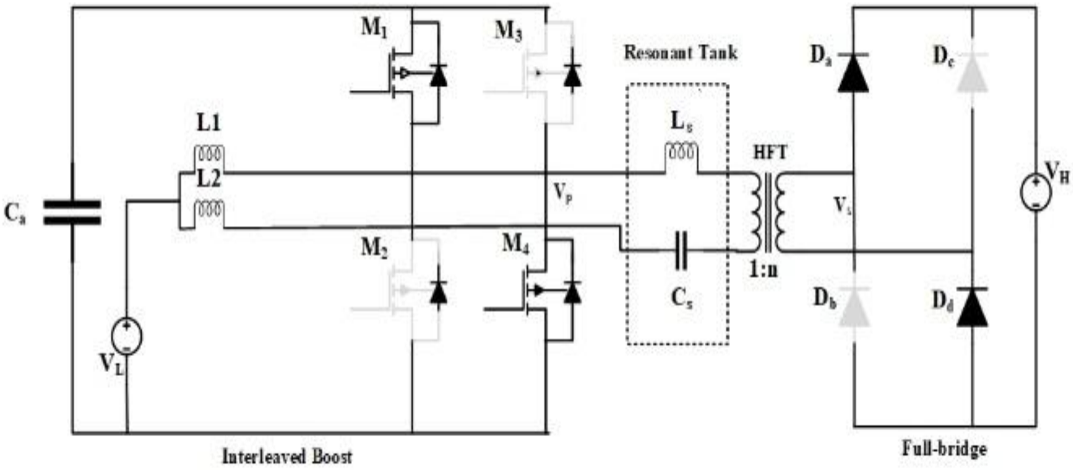
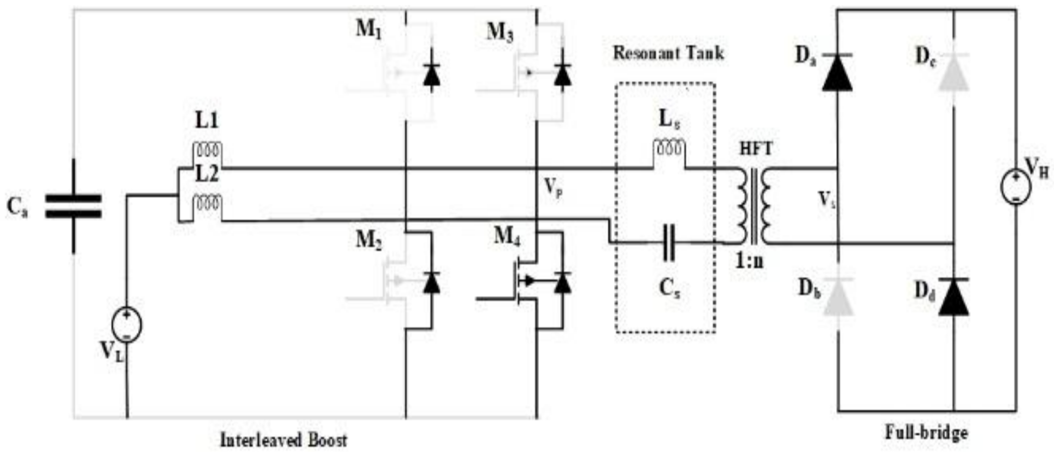
Full-bridge

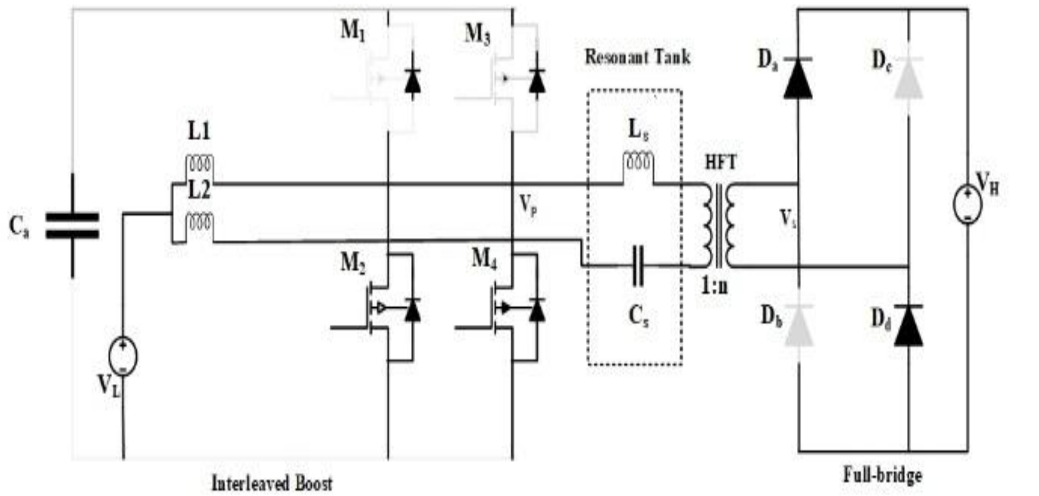
(c)



(d)



(e)



(f)

Fig.3. Proposed converter for different Switching modes

During the mode first as well as second, V_p =0 and V_s= V_H.

$$\frac{di_L}{dt} = \frac{V_H}{L_m} \qquad (1)$$

When both M_2 and M_4 are ON, the current of inductor L_1 and L_2 are changed by V_L.

$$\frac{di_{L1}}{dt} = \frac{di_{L2}}{dt} = \frac{V_L}{L} \qquad (2)$$

Here $L_1$and L_2=L. in addition, L_s and C_s and in the resonant tank stores energy is served to the HV side. The subsequent equation is obtained.

$$C_s \frac{dv_{Cr}(t)}{dt} = i_{Ls}(t) \qquad (3)$$

$$L_s \frac{di_{Ls}}{dt} + V_{cs}(t) = -\frac{V_H}{n} \qquad (4)$$

The current of Ls and voltage on Cs at t0 and V0, respectively, the solutions if i_{Ls}(t) and V_{cs}(t) can be stated as follows:

$$i_{Ls}(t) = I_0 \cos w_s(t) - \frac{(nV_0 + V_{H)}}{nZ_r} \sin w_s(t) \qquad (5)$$

$$V_{cs}(t) = -\frac{V_H}{n} + I_o Z_s \sin W_s(t) + \left(V_0 + {}^{V_H}/_{n}\right) \cos w_r t \qquad (6)$$

Mode III [t_2-t_3] [Fig. 4 (c)]: On t_2 the devise M_2 is turned-off and the body diode of M_1 commences to behavior since of the positive current of i_{L1}. The voltage V_p commutes to V_a, temporarily the inductor L_1 is discharged and i_{L1}, reductions:

$$\frac{di_{L1}}{dt} = \frac{V_L - V_a}{L} \qquad (7)$$

Mode IV [t_3-t_4] [Fig. 4 (d)]: M_1 opens. The voltage is zero at t_3. The end of this phase, until M_1 is closed at t_4

Mode V [t_4-t_5] [Fig. 4 (e)]: At t_4, M_1 is closed. Due to the positive current of i_{Ls}, the body diode of M_2 twitches to comportment. Therefore, the voltage V_p transitions to 0, and the inductor L_1 starts to be charged by V_L yet again.

Mode VI [t_5-t_6] [Fig. 4 (f)]: at t_5, M_1 is turned ON with zero voltage.

After t_6 a same process the whole thing in the next cycle of the switching period.

4. Convertor Design

A 1000 W converter design to operate at 110 kHz switching frequency is taken to identify the main parameter design. The parameters are follow V_L =100V- 180V, V_H = 250 V resonant frequency f_r= 90 kHz.

A. Turns Ratio of the Transformer

The turn's proportion of the transformer would be intended to mark indisputable that the power and voltage can be controlled with in the complete range of low to high voltage. This can be identified effortlessly since the regularized the voltage improvement of the converter can be widely controlled. In the case of a larger duty cycle D, a lower voltage strain can be obtained on the primary side switch. With the new point of view for the resonant period, the main duty cycle of the resonant energy stored in the resonant tank is not affected by the smallest value of D and 1-D. with respect to increase the capacity of resonant tank circuit, the duty cycle should be taken 0.45. Taking these factors into account, it is suggested to select the transformer's turn's ratio. When setting duty cycle is 0.45 the voltage at center of the complete voltage range [7].

Established on these consideration, the turns ratio of the transformer is calculated at n=1 so that duty cycle D=0.5 after the battery voltage is at center 140V.

B. Resonant Tank

The main concern for the specification of the resonant tank (that is, L_r and C_r) is to make the resonant frequency equivalent to the SF of the converter. In edict to decrease the current stress and conduction loss linked to circulating current, the worth of the resonance tank must be larger. But, the peak voltage on the resonant capacitor is equivalent to the impedance Z_r. However, a larger resonant inductance will damage the capacity and power thickness of the converter. The value of Z_r is recommended to be in the range of 15 to 30.

For the scheme example, seeing that the actual worth of C_r is 50nf, select C_r. Then, given the resonant frequency, the resonant inductor L_r is 44.54uH.

C. Filter Inductors L1 and L2

The Boost converter on the primary side function in the interleaved method. For the assumed duty cycle L_1=L_2=L, the current ripple and the total current wave ΔI_L on the battery side can be designed as:

$$\Delta I_L = \frac{V_L\,(1-D)T_s}{L} \quad (8)$$

Considering the current ripple and the soft switching performance of the primary side switch, L_1 and L_2 are designed to be 250uH.

D. Clamping Capacitor Ca

Ca is designed based on the wave on the capacitor, which is the similar as the scheme of filter capacitors in maximum power converters. In a scheme example, a 10uF capacitor is used for Ca.

5 Simulation Results

The Isolated Soft Switching Current Fed Series LC Resonant DC-DC Converter is simulated by using MATLAB SIMULINK to authenticate the theoretic notions of DC-DC convertor.

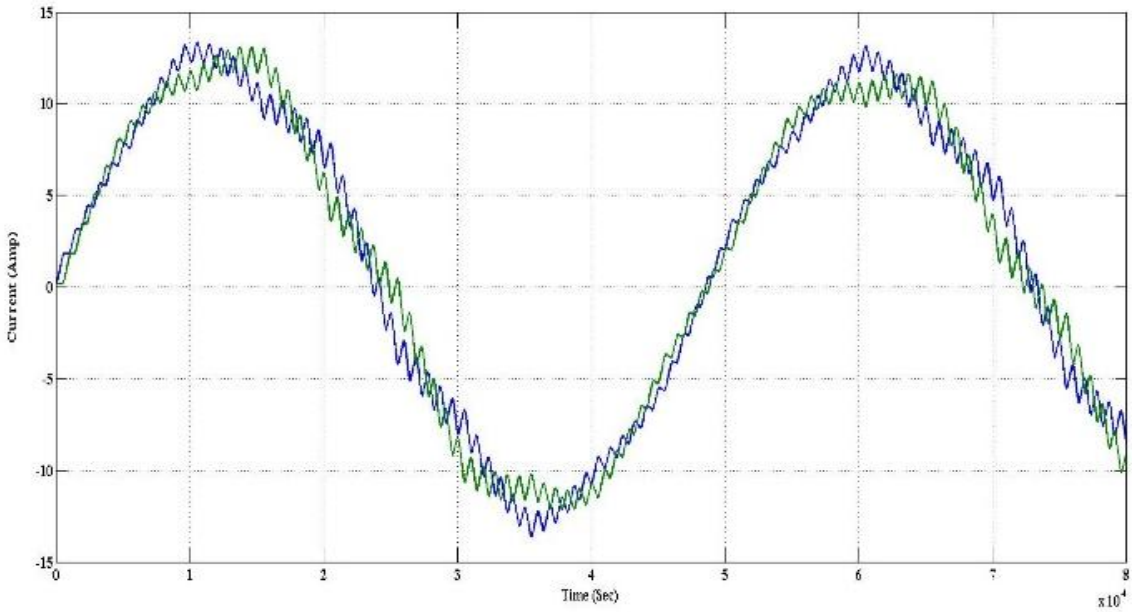


Fig.4 Waveform of the primary side boost converter

In Fig.4 shows an input side interleaved inductor current waveforms. It is vibrant that the simulated waveforms contest with the theoretic examination.

In Fig.5 displays that zero voltage switching at key switches M_1 to M_4. Where it is seen soft switching attained for all switches.

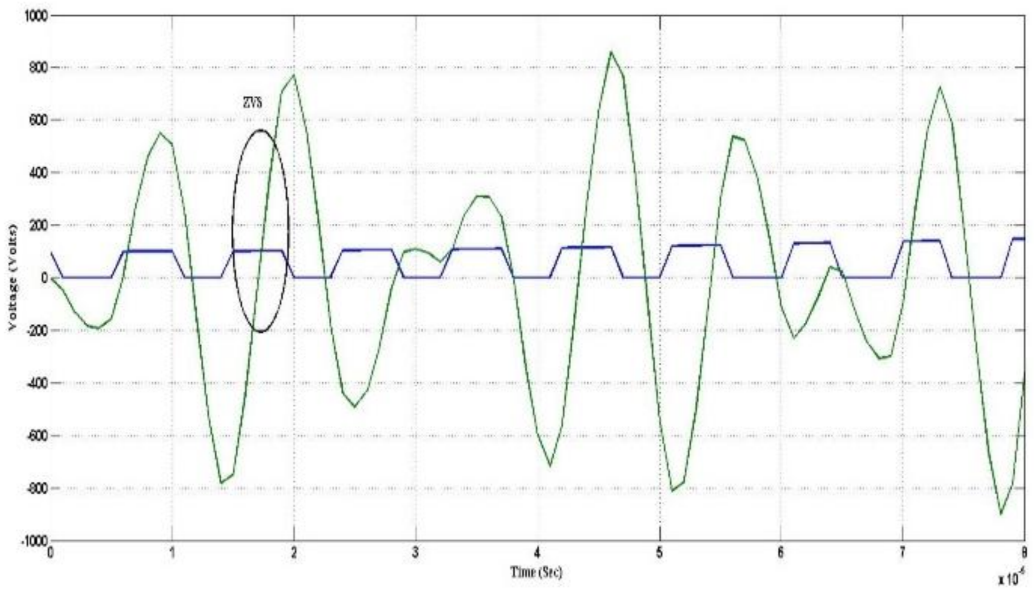


Fig.5 Zero voltage switching waveforms primary side switches in the advancing mode

The waveform of the resonant tank voltage at primary cross of the transformer presented in fig. 6 100 V input voltage achieved at primary cross of the high HFT. Where it is seen simulated waveform counterpart with the theoretical analysis.

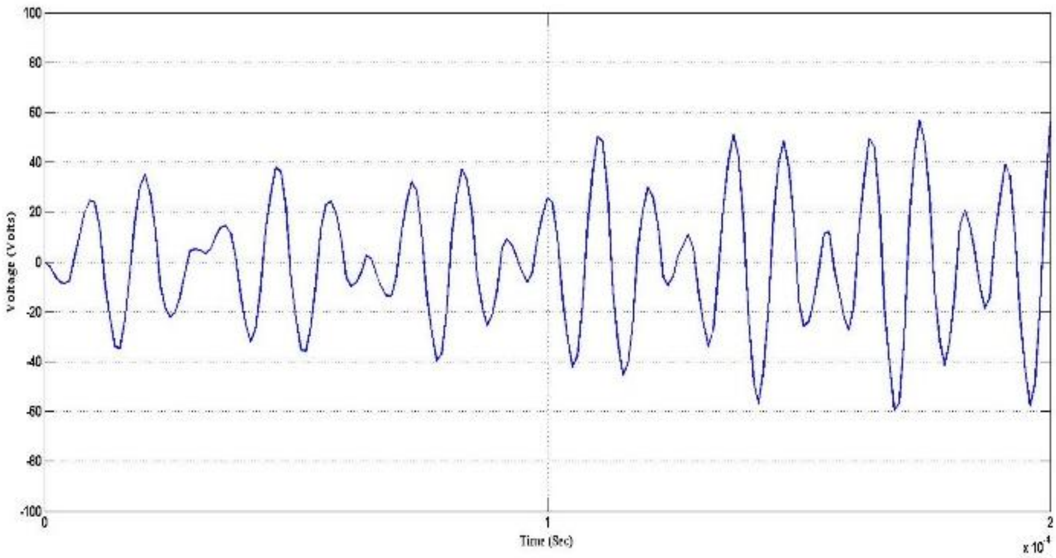


Fig.6 Waveform of the resonant tank in forward mode.

6 Conclusion

Isolated Current Fed Series LC Resonant DC-DC Converter takes occurred offered and substantiated in this article. Theoretic examination of simulated confirmation specifies that zero voltage switching achieved for primary side of semiconductor switches and conduction losses in minimized and efficiency of the converter improvised. The investigation and simulated verification designate that offered convertor is suitable for electrical vehicle charging. It can be used in maintainable energy power system uninterruptable power supplies, micro grids etc.

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