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Resonance Analysis and Soft Switching Design of Isolated Boost Converter

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Abstract: ***The resonance analysis and soft switching design of boost converter with coupled inductors is studied here. The resonance participated by voltage doubler capacitor, clamping capacitor and leakage inductance of coupled inductors ,the problem of reverse recovery of secondary diode has been restrained within range of whole operation. By selecting suitable magnetic inductance of coupled inductors, ZVS on of main MOSFET's has been obtained in the same working condition, without the help of any device in addition. For achieving soft switching and an optimal operational point, the duty ratio range has been enlarged with minimum ripple current input, when duty ratio is approaching 0.5. Then for achieving power density, there are two types of resonances which are analyzed and also the optimized resonance has been used. The prototype is implemented for the vehicle inverter requiring 150w output power, input voltage range varying from 10.8 to 16v, and 360v output voltage.***

Keywords: Resonance analysis, Boost converter, Soft switching

1. Introduction

The vehicle inverter has become very important now a days. Earlier inverters were comprised of two stages, i.e. DC-DC converters and the DC-AC inverter. For achieving a 220V RMS sinusoidal wave, an input of 360V DC is required for the DC-AC inverter with a high level of efficiency.

The batteries in the vehicles show a low voltage of about 10.8 to 16V but usually we consider it to be 12V. Hence, the conversion ratio of DC-AC inverter should have the voltage as high as possible at beginning of the DC-DC converter stage. The efficient vehicle inverter involves following points: The life span of a battery, the space where it is mounted with a natural cooling, for a DC-DC converter the current ripple at input should be low, the efficiency of operation has to be high. In DC-DC stage the push-pull topology has been in wide use, when compared to other topology.

In case of voltage-fed topology of push-pull converters, the current ripple is found to be high as the primary current is discontinuous. Therefore, for minimizing the current ripple an LC low pass filter can be used at the input. The introduction of low pass filter may increase the volume of system for high current at the input for minimizing the current ripple. But the conversion ratio of the voltage at converter will be estimated by turn's ratio of the transformer leakage inductance which will degrade the power density and performance of the circuit.

We can choose the current-fed push-pull topology for lesser input voltage and more input current as it contains inductor at input. The fuel cell system uses many topologies; the application where a battery is used as source, for achieving clamping along with resonance has become popular where we can implement 0V switching ON of the MOSFETs or to resolve the problem of reverse-recovery posed by the rectifying diodes at the secondary.

Soft-Switching characteristic and high operational frequency is used to achieve high power density and high efficiency. The active clamping in case of current-fed topology of the push pull converter is considered for better performance of vehicle inverter. The optimized resonance can be designed in order to minimize the volume of the capacitors and to improve the power density. From the previous research of study, resonance converters can be classified in two classes based on characteristic of soft switching which is to obtain zero voltage switching ON of MOSFETs and to obtain turn off softy of secondary diodes.

This paper presents the design of soft switching isolated step up converter and its analysis. Comparison is done between previous proposed converter, ZCS of a secondary diodes and switching at zero voltage of main MOSFETs at similar working conditions. Here the duty cycle, D is enlarged in order to design and also to obtain optimal point of operation, when D reaches 0.5, input current ripple approaches to zero. By using small size transformers and capacitors the converter volume can be decreased. To carry out verification of design implementation of dc-dc converter for application like vehicle inverter is done.

2. Proposed Topology

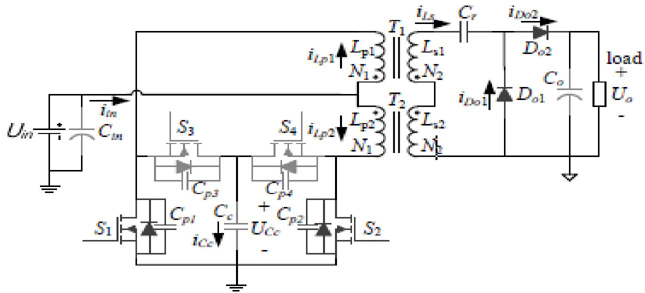


Fig.1. Schematic of the converter.

The above scheme shows the resonance analysis and soft switching of a isolated boost converter with coupled inductor. The soft switching method is used to reduce the losses present in the scheme.Fig.1 shows the implementation of schematic diagram of converter which is obtained by comparing with the former proposed converter, the switching ON of a MOSFETs at zero voltage and switching OFF at zero current of secondary diodes is obtained in same conditions of working without including additional devices. The duty ratio is enlarged in the design and D approaches 0.5.The converter volume is decreased by using small transformers and small capacitors. The implementation of

DC to DC converter is done for a application of vehicle inverter in order to verify design.

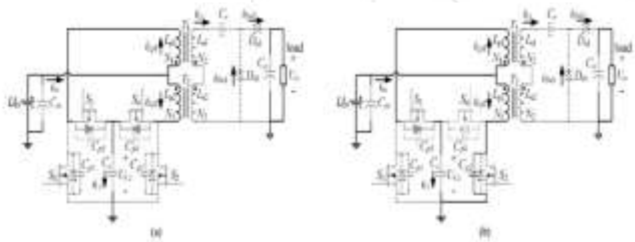
3. Operational Principle

Controlling the switches S1 and S2, the frequency il is twice of that of switching frequency which results in reduction in ripple of input current and when D approaches 0.5 ,the ripple in the input is approximately 0.The principle operation is as shown below:

1.Principle of operation for D<0.5
If the value D is less than 0.5 , operation of resonance takes place in non-overlapping interval.

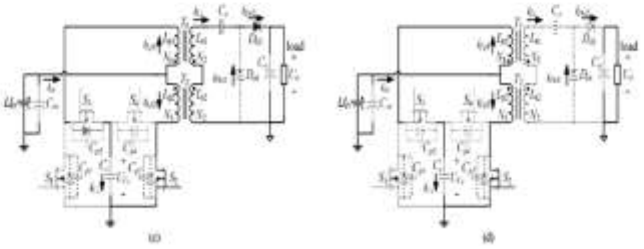
a) Mode 1:(t0,t1)
The switch S1 is switched off and S2 is already in off state at t0. The inductor Lp1 and Lp2 are discharging and di/dt equals (Uin - UCc) / Lp. At t1 iLp2 is under zero, due to small inductance of Lp1 and Lp2.The reverse current flows through the clamping capacitor Cc, auxiliary MOSFET S4 to inductor Lp2. The energy is not transformed to secondary side.The fig a shows the equivalent circuit of converter for mode 1.

b) Mode 2: (t1,t2)
The switch S4 is switched off at t1 and iLp2 is in reverse state. Cp2 of S2 is discharged due to inductor Lp2 for freewheeling. If Lp2 reverse current is very large then that energy is used to discharge UDS2 to zero value at t2.The fig b shows the equivalent circuit of converter for mode 2.



C) Mode 3: (t2, t3)
The switch S2 is turned on at t2 when UDS2 reaches zero.ZVS on of S2 is achieved.S1 is still off. The inductor Lp1 is discharging and di/dt equals (Uin-UCc) /Lp. Inductor Lp2 is charging and di/dt equals Uin/Lp. The secondary circuit stars conducting. Transformer T1 works as flyback converter and transformer T2 works as forward converter. When the leakage inductor of transformer ,clamping capacitor Cc and voltage doubler capacitor Cr start to resonate ,both iLp1 and iLp2 contain magnetizing current and resonant current. The fig c shows the equivalent circuit of converter for mode 3.

D) Mode 4: (t3, t4)
At t3 secondary current iLs decreases to zero and resonant circuit is cut off by diode Do2. Hence, the secondary diode is turned off softly and reverse –recovery problem is removed. Inductor Lp1 is still discharging with rate determined by (Uin-UCc)/Lp1. Inductor Lp2 is still charging with rate determined by Uin/Lp. The fig d shows the equivalent circuit of converter for mode 4.



3.1 Simulation Results

The simulation is being done in MATLAB/SIMULINK version 7.11.0.584(R2010b) for the proposed converter using 4 MOSFET'S and DC source with Vdc 12V shown in fig. The converter results with the output of 360V.

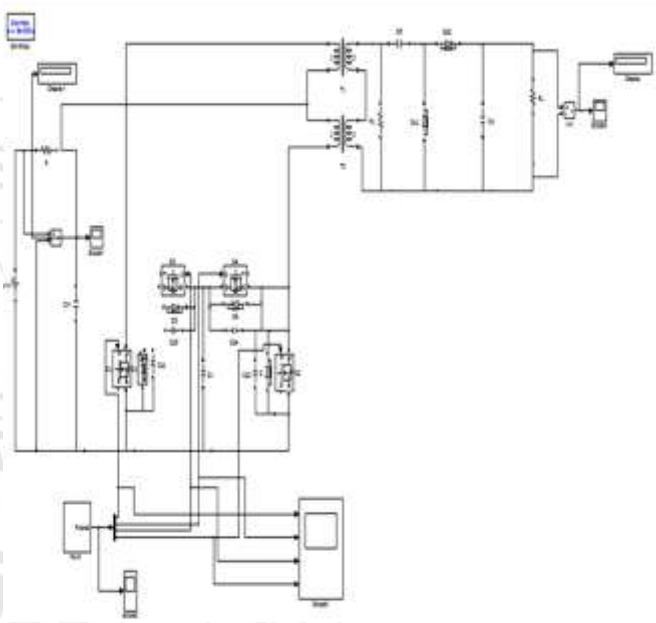


Figure 2: MATLAB/SIMULINK model of proposed converter

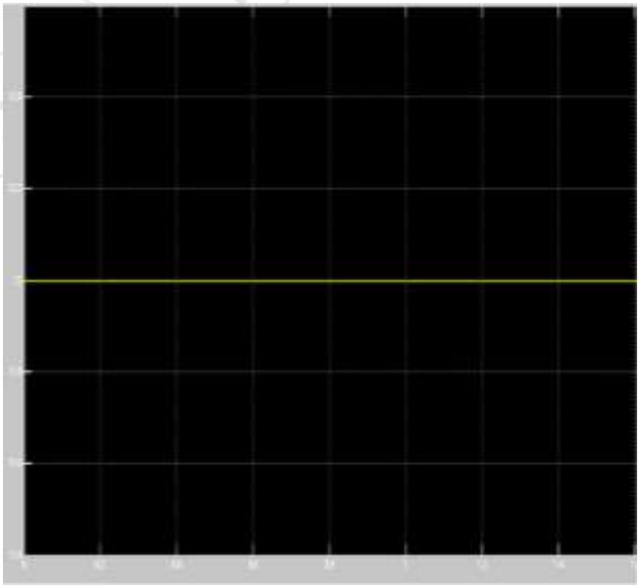


Figure 3: Waveform of input voltage

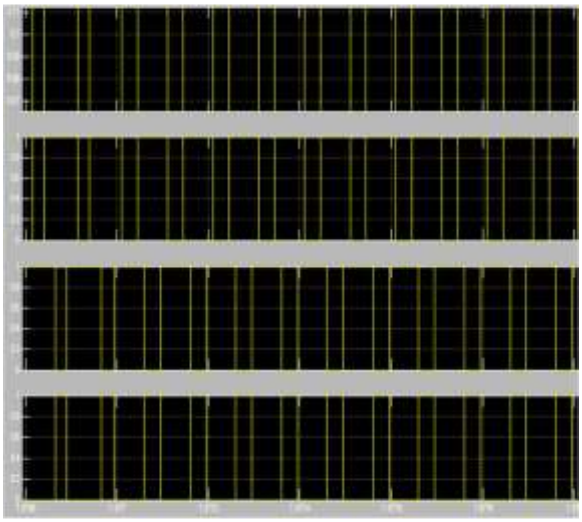


Figure 4: Waveform of S1,S2,S3,S4 for D<0.5

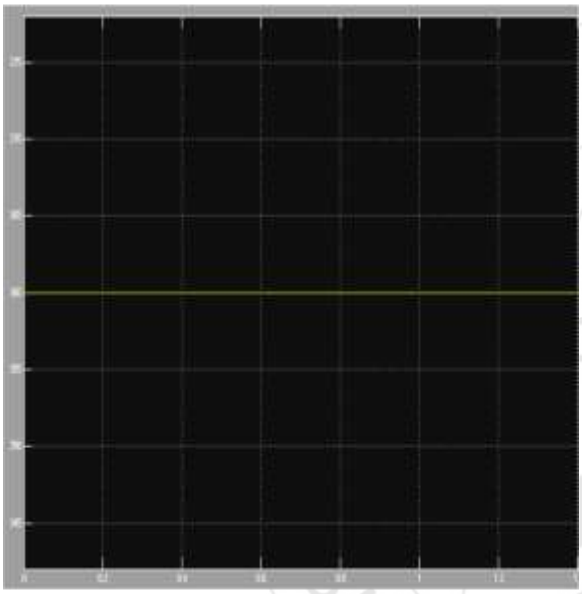


Figure 5: Waveform of output voltage

3.1 Experimental Setup:

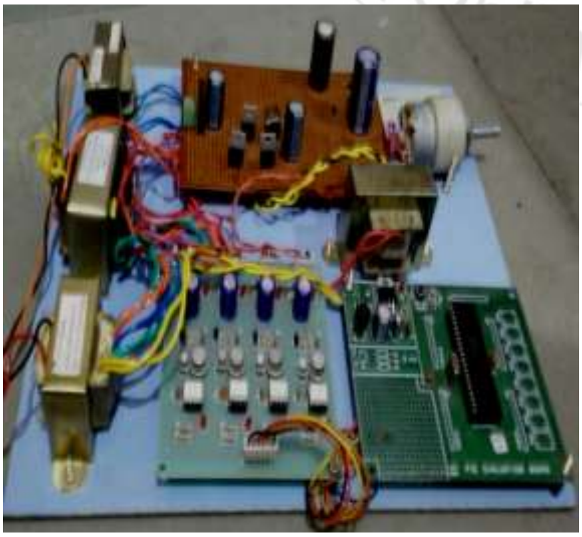


Figure 6: Proposed system prototype

Table 1: Hardware result

Input Voltage	Output Voltage
12V	360V

The fig.6 Shows the experimental setup of the proposed system.The proposed converter is experimentally validated with 4 MOSFET'S and a DC source.The microcontroller used is PIC 16F877A.The microcontroller is used to implement the control algorithm by generating the gating pulses for switching devices. The driver circuit is to switch a power semiconductor device from off state to on state and vice versa. Driver circuits mainly used to amplify the signals from controllers in order to control power switches in converter devices. The input given to the proposed system is 12V to obtain 360V output.

4. Conclusion

In this paper, resonance analysis and soft-switching design of an isolated boost converter with coupled inductor is presented. Two kinds of resonance are analyzed to obtain ZVS on of main switches or ZCS off of secondary rectifying diodes. Relationship between the resonances is sketched and an optimized resonance between the two kinds of resonances is used to increase power density and lower converter cost. ZVS ON of the main MOSFETs and ZCS OFF of the secondary diodes can be achieved collectively at the same working conditions without any additional devices ,by choosing appropriate magnetic inductance of coupled inductors. Additionally the restricted range of duty ratio is removed and an optimal operation point with zero input ripple current is gained. Finally a 12V-360V high efficiency prototype converter is built to verify the analysis.

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