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Effect of Coupled Inductor in Boost Converter

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ABSTRACT:This paper does the comparative analysis of effect of coupled inductor in soft switched boost converters using SIMULINK. The comparison of the converter with or without coupled inductor have been done to identify which one is highly efficient in terms of performance, voltage stress, complexity etc. Simulation of the two topologies under the same condition are included in this paper. This paper should act as a reference for future work in the field of soft switched boost converter for high power application.

KEYWORDS: Boost converter, Coupled inductor, Soft switched

I.INTRODUCTION

There is an increasing demand for boost converters with power conditioning due to high and sudden variations in load such as DC drives. When switched at high frequency to obtain dynamic & steady state specifications, the losses increases in the converter. Turn on at zero current and turn off at zero voltage is one of the possible solution to reduce the switching losses. In order to achieve improved performance snubber circuits are introduced with boost converter.

At turn on instant a series inductor named as snubber inductor is included to limit the rate of rise of current through the switch. At turn off condition a shunt capacitor named as snubber capacitor is included to limit the rate of rise of voltage across the switch. At the time of snubbing energy is stored in the electric/magnetic field of these components. In order to ensure repetitive snubbing action, stored energy must be removed after every switching transition. The easy way is to discharge the stored energy into a resistor, which leads to dissipative snubber.

For high power application large snubber is required, which leads to huge amount of stored energy in the snubber element & simultaneously leads to more energy loss in snubber. Nowadays all electrical systems are focused towards high efficiency, in order to increase the performance, the use of energy recovery or non-dissipative snubber is introduced. This snubber have the capacity to recover a part of the stored energy by feeding it back to the supply or load. In this paper, the effect of dissipative and non-dissipative snubber is analysed at the same conditions. Performance evaluations are also presented with the help of MATLAB/SIMULINK

II. LITERATURE SURVEY

Several soft switching boost converters with an auxiliary switch and passive components have been proposed [1], [2].In [1] an active snubber is used to reduce the reverse recovery related losses, the voltage and current stresses of the components in this active snubber boost converter are similar to those in its conventional hard-switched counterpart.Proposed active snubber is effective in extending the power range of boost converter, but the overall efficiency is reduced.The snubber cell in [2] is implemented by using only one quasi resonant circuit, which will lead to complicated design method.Only passive components are used in[3],[4].In [3] the proposed solution requires one additional winding of the boost inductor and one additional rectifier to reduce the reverse recovery related losses,but the reverse recovery current still present in the added rectifier.In [4] instead of using snubber inductor only, a saturable inductor connected in series with the snubber inductor is used to delay the rise of the switch current.Since the circuit contains more components,increases complexity.In [5] the two switches are operated with asymmetrical complimentary to regulate the output voltage.Here the auxiliary switch require a floating gate drive. In [6] the auxiliary circuit consists of several components which will lead to increased complexity.In [7] converter reduces the reverse recovery loss of the diode by adding a coupled inductor diode branch parallel with the output diode.But for high power application turns ratio of the coupled inductor has to be increased to meet the ZCS turnoff of the main diode.

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III.STUDY OF DIFFERENT TOPOLOGIES

The 2 different topologies that are analysed in this paper are
1) Boost converter without coupled inductor
2) Boost converter with coupled inductor

1)*Boost Converter without Coupled Inductor*

The proposed converter shown in Fig.1 is a simple boost topology with a snubber consisting of a resonant inductor (Lr), resonant capacitor (Cr), a reset resistor (Rr) and 2 diodes (D1 & D2). The boost inductor is denoted as L, Q is the switch, D0 is the output diode, C0 is the output capacitor, and R0 is the load.

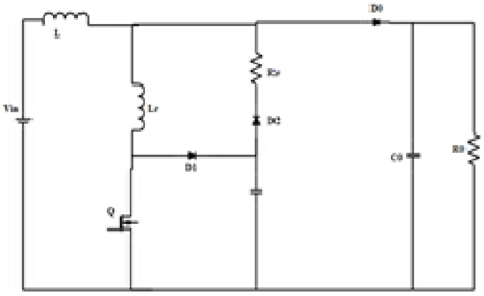

Fig. 1Boost converter without coupling inductor

Operation:

This circuit is analyzed based on the conduction intervals of switches in different modes of operation. There are 8 modes of operation in this circuit.

Mode 1: The switch Q is off.

Mode 2: The switch Q is turned on under ZCS, D1 is reverse biased. At the end of this mode D0 is turned off and D2 is forward biased.

Mode 3: Resonance occurs between Lr and Cr. Complete discharging of Cr occurs at the end of this mode.

Mode 4: Diodes D1 and D2 are forward biased. In this mode energy stored in Lr is dissipated in Rr. Recovery of snubber occur during this mode.

Mode 5: Power from the source is transferred to the boost inductor Lr.

Mode 6: The switch Q is turned off. D1 is forward biased. At the end of this mode Cr is charged towards the output voltageV0.

Mode 7: Similar to mode 4. Rr resets Lr.

Mode 8: In this mode, D is forward biased and the power is transferred from the boost inductor to the load.

2)*Boost Converter with Coupled Inductor*

The proposed converter is shown in Fig 2. It consists of a MOSFET switch Q, Boost inductor L1, Coupled inductors L2 and L3 with turns ratio N1, two resonant capacitors are denoted by C1 and C2, snubber circuit diodes are denoted as D1 and D2, output capacitor is C0, output diode is D0. The input voltage is denoted by Vin and the output resistance is represented by R0.

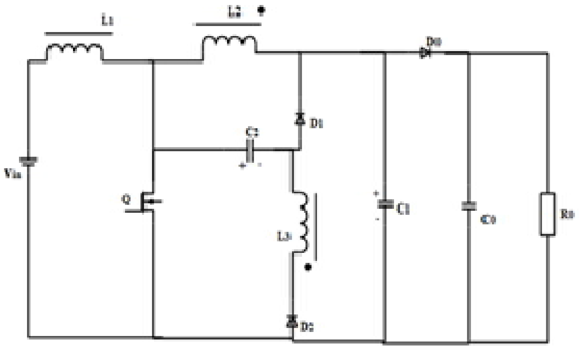

Fig. 2Boost converter with coupling inductor

Operation:

This circuit is analyzed based on the conduction intervals of switches in different modes of operation. There are seven modes of operation in this circuit.

Mode 1 (before t0): The switch Q is off, D1 and D2 are blocked, converter is in freewheeling stage.

Mode 2 (t0 - t1): At t0, Q is on under ZCS. D1 and D2 are still blocked.

Mode 3 (t1 - t2):At t1, VC1 = V0, D0 is off under ZVS. D1 and D2 are still blocked. C1 and L2 begin to resonate.

Mode 4 (t2 - t3):As VL3 = VC2 at t2 i.e., VC2= Vb = N1 VC1(t2) then D2 forward biased and stored energy in C2 is transferred to L3.

Mode 5 (t3 - t4): At t3, VC1 = VC2 = 0 then D1 conducts. The stored energy in C1 and C2 is transferred to L2 and L3 completely.

Mode 6 (t4 - t5): At t4, switch Q turns off under ZVS. Double resonance occur between L2, L3 and C1, C2$. The stored energy in L2, L3 transferred to C1, C2.

Mode 7 (t5-t6):At t5,   VC1 = V0, then D0 conducts

III.SIMULATION RESULTS AND DISCUSSIONS

The 2 topologies are simulated in MATLAB/SIMULINK, with the following common parameters

Table -1: Simulation Parameters

Parameter	Values
Supply voltage	55 V
Duty ratio (D)	0.5
Switching frequency (fsw)	30 kHz
Coupling inductor (Lr1)	20 µH
Load (R0)	25 Ω
Output capacitor (C0)	470 µF

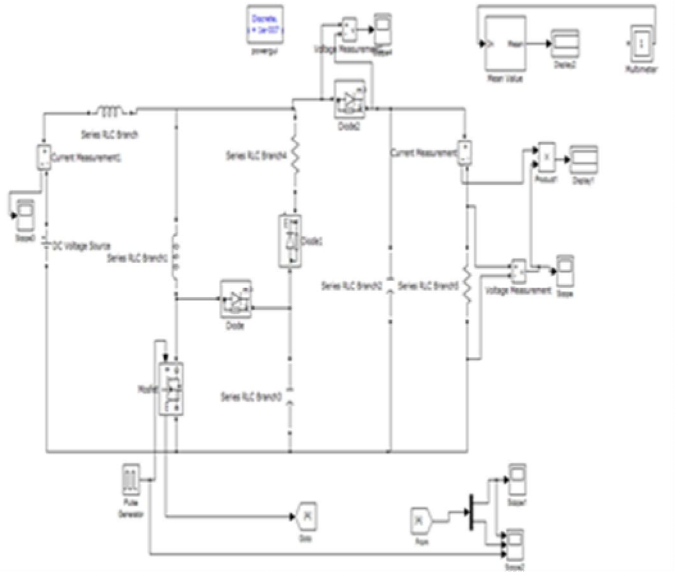

Fig. 3Simulation diagram of boost converter without coupled inductor

The output voltage of the waveform is greater than 100 V. So that gain of the converter is approximately equal to 2. The simulation diagram of the proposed converter is shown in fig 3, output waveform is shown in Fig.4 and the switching waveforms are in Fig.5.

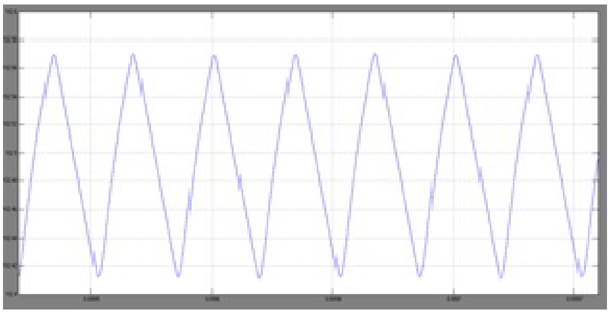

Fig .4 Output waveform of boost converter without coupled inductor

The switch stress is greater than 143 V and peak switch current is larger than 14A.From the switching waveforms it is very clear that the switch is turned on at ZCS and turned off at ZVS, hence switching losses are reduced.

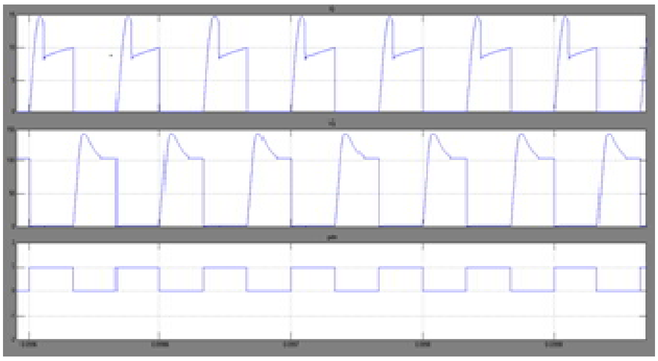

Fig .5 Waveforms of VQ, IQ and gate of boost converter without coupled inductor

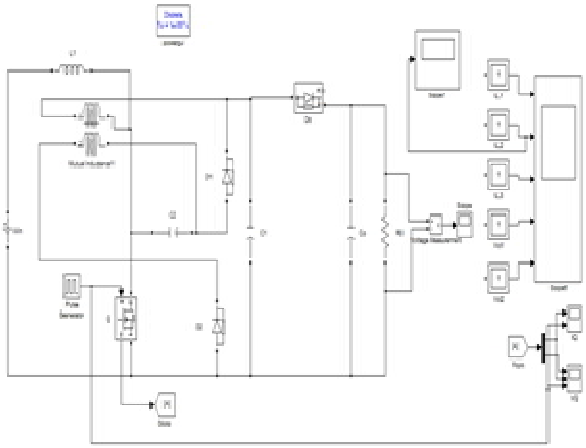

Fig .6 Simulation diagram of boost converter with coupled inductor

The output voltage of the waveform is lower than 100 V. So that gain of the converter is lesser than that of converter [1]. The simulation diagram of the proposed converter is shown in fig 6, output waveform is shown in Fig.7 and the switching waveforms are in Fig.8.

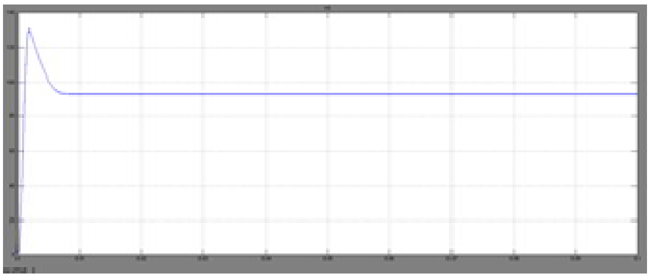

Fig .7 Output waveform of boost converter with coupled inductor

The switch stress is lesser than 143 V and peak switch current is larger than 14A.From the switching waveforms it is very clear that the switch is turned on at ZCS and turned off at ZVS, hence switching losses are reduced.The efficiency of the converter is found to be greater than 90%.

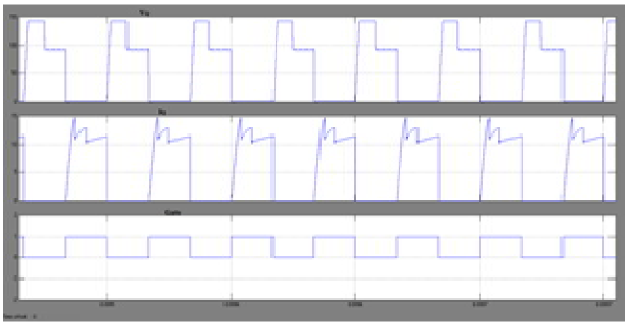

Fig .8 Waveforms of VQ, IQ and gate of boost converter with coupled inductor

The detailed comparison of the 2 topologies are summarized in Table.2.

Table -2:Comparison between the 2 Topologies Based on the Various Parameters

Parameters	**Converter of [1]**	**Converter of [2]**
Output voltage (V)	102.57	93.3
Voltage gain	1.864	1.6963
Output power (W)	420.8	348.2
Efficiency (%)	85.40	93.08
Voltage stress on the switch (V)	143.757	142
Peak switch current (A)	14.75	14.615
Voltage stress on output diode (V)	0.812	0.823
Number of extra components	5	6

Inference:

A comparison of 2 different soft switched topologies are shown in Table I. The simulation is performed by MATLAB/SIMULINK using the same parameters. The results shows that converter of [2] has higher efficiency, less voltage stress, reduced peak switch current. The number of components used in converter of [2] is less compared to converter of [1] but the performance is poor in terms of efficiency.

VI.CONCLUSION

This paper presents analysis of soft-switched boost converter topologies with the effect of coupled inductor. The converter of [1] act analogous to conventional hard switched converter & soft-switched converter with auxiliary switches. In addition to efficiency a wide soft switching range is provided by non-dissipative snubber but the system become complex. The comparison table should serve as a reference in selecting the right converter topology for various applications related to renewable energy. The simulation results of 2 topologies for an input voltage of 55V and load of 25Ω are presented.

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