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A HIGH EFFICIENT BOOST CHOPPER COUPLED WITH AN INTERLEAVED INDUCTOR FOR HYBRID ELECTRICAL VEHICLES

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ABSTRACT
The proposed work illustrates an improved efficiency of a dc-dc boost chopper with a clamp network. The coupled-inductor boost choppers are interleaved in this system. A d boost chopper is used to clamp the voltage stresses of all the switches in the interleaved choppers, caused by the leakage inductances present in the practical coupled inductors, to a low voltage level. The High efficiency is achieved by recycling of leaked energies, voltage stress of the switches are reduced mitigation of the output diode is reverse recovery problem, and interleaving of the choppers. The leakage energy of the inter- leaved dc-dc choppers are fed to a clamp capacitor and recycled to the output by the clamp boost chopper. In many applications, high- efficiency, high-voltage step-up dc–dc choppers are required as an interface between the available low voltage sources and the output loads, which are operated at much higher voltages. The proposed work is carried out for as such application in Electric Vehicles(EV). Different distributed energy storage components such as batteries, fuel cells, and ultra capacitors are used in the power trains of hybrid electric vehicles (HEV), electric vehicles (EV), and fuel cell vehicles (FCV).The proposed chopper topology can be used in this applications.

Keywords:
Active Clamping, Interleaved Choppers, Boost Choppers, Electrical Vehicles (EV) and Hybrid Electric Vehicles (HEV)

INTRODUCTION
In a conventional boost chopper, the duty ratio increases as the output to input voltage ratio increases. However, the some applications require high-voltage step-up (step-up ratio 6 or more) and high-efficiency power conversion [1]. Hence, the conventional boost choppers require extreme duty ratio's to meet the high- step-up voltage requirements. In such environment, it is a significant challenge to operate the boost choppers effectively. For the reason that, with the high-output voltage, the switch used in boost chopper has to block a large voltage and hence the ON-state resistance, *RDS*- ON, which proportionally varies with the square of blocking voltage, will be very high.[5] Furthermore, the low-level input voltages cause large input currents to flow through the switches. The extreme duty-cycle operation drives short-pulsed currents with high amplitude to flow through the output diodes and the capacitors; which cause severe diode reverse recovery problem and increases in the conduction losses [7]. Moreover, the parasitic ringing, present in the practical circuits, induces additional voltage stresses and necessitates the use of switches with higher blocking voltage ratings, which will lead to more losses. The high *RDS*-ON of the switches, the increased conduction losses, and the severe reverse-recovery problem will degrade the efficiency and limit the power level of the conventional boost choppers.

The turns ratio of the primary inductor ($L1$) to the secondary inductor ($L2$) of the coupled inductor can be effectively used to reduce the duty ratio and the voltage stress of the switch. Hence, the coupled-inductor boost chopper can be a good solution to the previously discussed problems of the conventional boost chopper [16]. But, for high power applications, large input currents handling from the low-input voltage sources remain a

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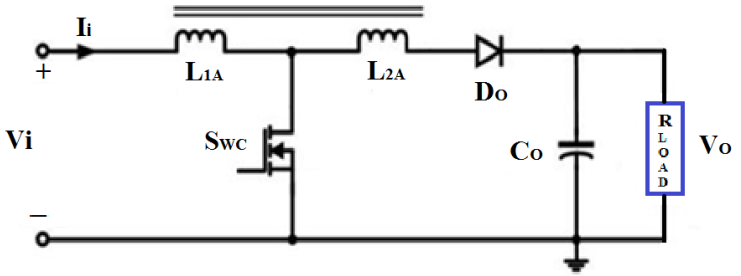
practical concern. Various chopper topologies using magnetically coupled inductors are reported in the literature to reduce to the extreme duty ratio operation for non isolated high step-up applications. But they are not suitable for high current and high power applications, and moreover, the circuits are complex to design and model. For high-input current, it can be proposed to interleave the coupled-inductor boost choppers to process high power, and to achieve high efficiency.

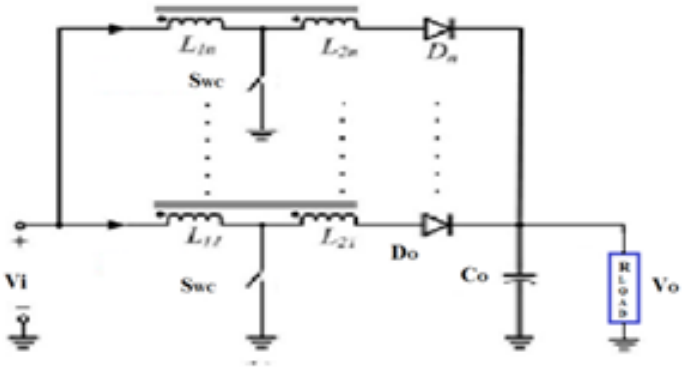
High polluting nature, reduced efficiency with respect to fuel consumption is the significant concerns for Internal Combustion engines(IC). Different energy storage components that are distributed like batteries, fuel cells, etc are effectively used in HEV and EV to provide the demanded DC voltage source for achieving good efficiency. The voltage rating of the energy storage elements are normally low whereas the motors are driven at much higher voltages. So, high power and high voltage step-up dc-dc converter is necessary for providing the interface between the energy storage components and high voltage dc-link bus of the inverter. Hence the proposed converter achieves the requirements of the hybrid vehicles.

PROPOSED CHOPPER

Boost Chopper Coupled with an Interleaved Inductor



(Fig 2.1)(a) Coupled-inductor boost converter



(Fig. 2.1.) (b) Interleaved coupled inductor boostconverter.

Assume that the ideal coupled- inductor boost chopper is operating in continuous conduction mode. .The dynamic equation of the input current is given in Eqn.1

$$\frac{di_{l1}}{dt} = \begin{cases} \frac{v_{in}}{L_1} \\ \frac{v_{in}-v_o}{L1}\frac{1}{N+1} \end{cases}, \begin{matrix} t \in [0, dT] \\ t \in [dT, T] \end{matrix} \quad \text{----------Eq.1}$$

where *vin* is the input voltage, *vo* is the output voltage, *d* is duty ratio of the chopper, *T* is the switching time period, and *N* is the secondary inductor turns to primary inductor turns ratio[18].

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The steady- state operating points of the chopper can be defined as:

$Vin = vin$, $Vo = vo$, and $D = d$.

Under steady state, the output voltage to input voltage ratio can be obtained by applying the volt-second balance condition to the primary inductor $L1$ [20] .

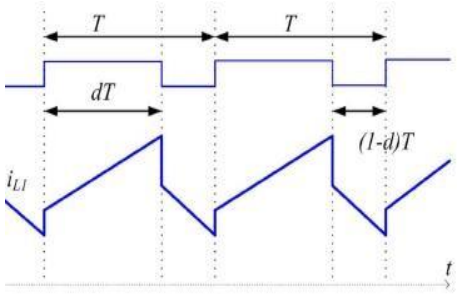

Fig 2.2 Gate pulses and primary inductor current of an ideal coupled inductor boost chopper

It is seen that, for the voltage gain, the duty cycle can be reduced by increasing turn ratio. Considering, the coupling between the primary and secondary inductors are ideal, the voltage stress *Vst* on the switch is given in Eqn.2

$$Vst = \frac{NV_{in}+V_o}{N+1} \text{----------Eq.2}$$

The ON-state switch resistance R_{DS}-ON is varying proportionally with the square of the voltage rating of the switch. Therefore, the conduction loss in the coupled-inductor boost chopper switch is a function of the turn ratio and the step-up ratio of the voltage[2]. The switch conduction losses of a boost chopper (*Wsb*) and a coupled inductor boost chopper (*Wsc*) are compared. The ratio of these two losses for various turns ratio (*N*) and step-up ratio (*Vo*/*Vi*) are plotted in the figure 2. It can be seen that with suitable choice of the number of turns, the switch conduction losses in the coupled- inductor boost chopper can be significantly reduced.

MODE OF OPERATION

The leakage inductances will be present in the practical coupled inductors, due to the non ideal coupling between the primary and the secondary windings [5]. When the switch is turned off, this leakage inductance will cause high-voltage spikes. Hence the result is a high-voltage stress across the switches and in circulating losses. A parallel diode is proposed to clamp the switch voltage to the output voltage. The energy stored in the leakage inductor is discharged directly to the output by the parallel diode, and the switch voltage is clamped to the output voltage in this clamp circuit. It is seen that the chopper avoids the disadvantage of series conduction loss of the total power, but the switch voltage stress is equal to the voltage at the output.

Hence this configuration does not take entire advantages of the coupled- inductor topology. So, it is unsuitable for high-step-up application where the high output voltage level is present. In the proposed methodology active clamp circuit, in each phase, a clamp-diode (*Do*1,*Do*2, . . .*Don*) is connected to the primary inductor, the secondary inductor in its common mode and the switch of boost chopper. The cathode terminals of the clamp diodes are connected to a clamp capacitor *C*. The energies stored in the leakage inductors of the are discharged through the clamp diodes and gathered in the clamp capacitor *Cc*.

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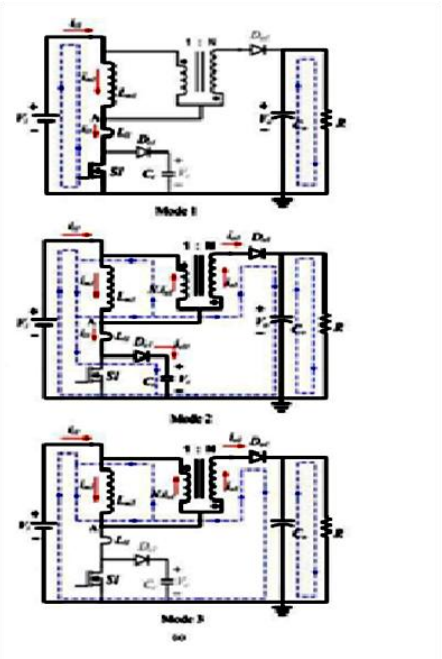

Fig. 3.1 (a) Operation modes (Mode 1: $t \in [t0, t1]$, Mode 2: $t \in [t1, t2]$, Mode 3: t [$t2$ -$t3$])

The boost chopper is transfers the stored energy in the capacitor to the output of the boost choppers coupled with inductors, the voltage level of the clamp capacitor is maintained to a lower level. The voltage stress in the switches (*S*1, *S*2, .. . *Sn*) is determined by the clamp-capacitor voltage. The other chopper technologies are also suggested for similar boost operation while maintaining the voltage of the clamp capacitor [20].

RESULTS AND DISCUSSION

Input Pulse for Coupled Inductor Boost Chopper

The input gate pulses applied to switches of the interleaved coupled inductor boost choppers is shown in the Fig 4.1.

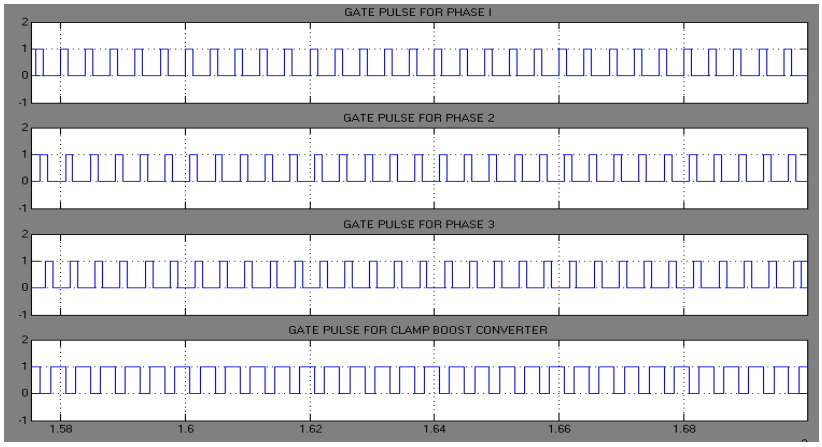

Figure 4.1 Input pulse waveform of interleaved coupled inductor boost chopper

Generation of the Output Voltage

The simulation output voltage waveform for interleaved coupled inductor boost chopper is achieved.

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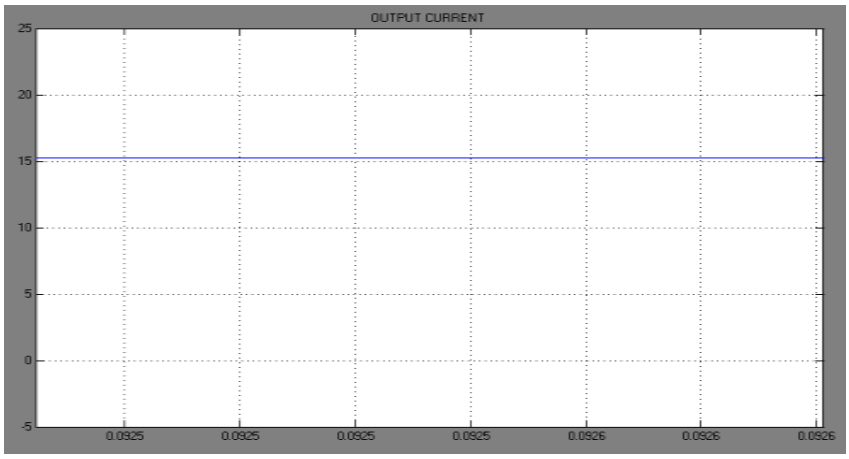

Figure 4.2 Output voltage

Matlab Model

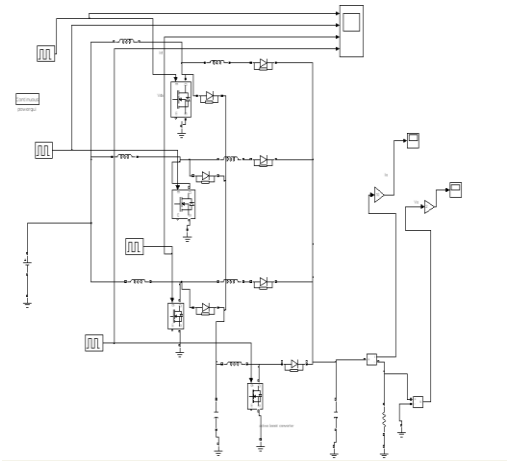

Figure 4.3 MATLAB Model for the Coupled Boost Chopper

The output voltage is boosted to around 16v based the clamping and boosting operations performed in the interleaved boost chopper. The efficiency is improved by using the proposed chopper circuit. The MatLab model and simulated waveforms are described in the above Figures

CONCLUSION

Coupled-inductor boost choppers is proposed to interleave for obtaining high-step-up power conversion without extreme duty ratio operation while the high- input current is handled in an efficient manner. In a practical coupled-inductor boost chopper, the switch is with a high voltage stress due to the leakage inductance present in the non-ideal coupled inductor. The proposed clamp circuit, based on a single boost chopper, successfully reduces the voltage stress of the MOSFET switches close to the low-level voltage stress in an ideal coupled-inductor boost chopper. The leakage energies of all the coupled-inductor boost choppers are collected by The common clamp capacitor of this active-clamp circuit and the chopper recycles the leakage energies to the output circuit. The analysis of the operation and the performance of the proposed chopper were presented in a detailed manner. The switches of lower voltage rating, the recovered leakage energy, and the other benefits of an ideal coupled-inductor boost chopper and interleaving, the chopper can achieve high efficiency for high step-up power conversion is found.Due to this properties these converters can be used in hybrid electrical vehicles for efficient utilization of the energies stored in the battery banks or online energy supply.

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