

Interleaved Boost Converter Fed DC Machine with Zero Voltage Switching and PWM Technique

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Abstract

In this paper an interleaved boost converter with Zero voltage Switching (ZVS) and Pulse Width modulation (PWM) techniques are proposed. The interleaved boost converters are preferred widely for the high power circuits since it has less input current ripple, reduced filter size, low cost and high efficiency. It regulates the DC output voltages by adjusting the duty cycle of the switches. In this proposed converter two boost DC-DC converters with interleaved operation is used to increase the output power and also it reduces the ripples in voltage and current. By incorporating ZVS and PWM technique the output voltage of 460V and 1450W is produced with 100V input supply. The simulation analysis by using MATLAB/simulink shows that the soft switching techniques will reduce the switching losses and it improves the overall efficiency (97%) of the proposed system when compared to the conventional interleaved boost converter.

Keywords: High power applications, Interleaved Boost Converter (IBC), MATLAB/Simulink, Pulse Width Modulation (PWM), Soft Switching

1. Introduction

The power converters are very important in renewable energy generation systems and power applications in order to achieve a good operation for supplying the load when main sources are not sufficient. Day by day the power supply devices need efficient conversion techniques to improve the performance in the field of electrical and control engineering (1–5). Generally the DC-DC converters are used to boost the input voltage level to required output voltage level and to get the high voltage gain. The circuit diagram of a simple boost converter circuit is shown in Figure 1. For getting high voltage gain the converter must operate with the duty cycle of less than 0.50. The conventional boost converter has the drawback of low voltage gain; to solve this problem an interleaved boost converter is used. The interleaved boost converter is used to reduce the current ripple in both input and output. In interleaved boost converter the number of phases is increased with the ripple content in input the complexity of the circuit is increased thereby the cost of implementation also increasing. Therefore to minimize the ripples, size, cost of input filter increasing

efficiency the two phase Interleaved boost converter is simulated. The circuit diagram of IBC is shown in Figure 2. The MOSFET switches are used for ZVS operation in order to get high efficiency by reducing the switching losses (7). The number of switching devices, number of inductors and diodes are same as the number of phases used in the circuit. The advanced technology of interleaved boost converter is soft switching method to reduce the stress across the switches. The interleaved ZVS-PWM boost converter not only employs the interleaved boosting operation and also decreases the switching losses by soft switching method. The soft switching method includes both zero voltage switching and zero current switching topologies. All these three converter operations are explained by both simulation and mathematical analysis.

2. Operational Analysis of ZVS-PWM IBC

The proposed ZVS-PWM interleaved boost converter is shown in Figure 3. The operation of proposed converter is alienated into two parts, first division consists

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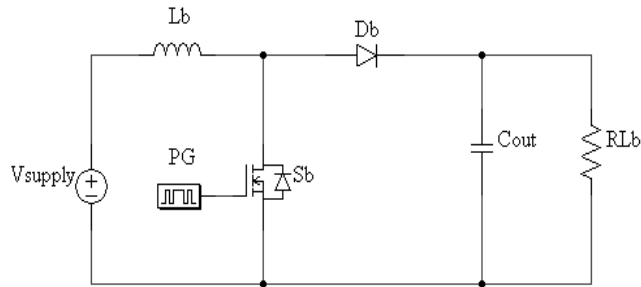


Figure 1. General boost converter.

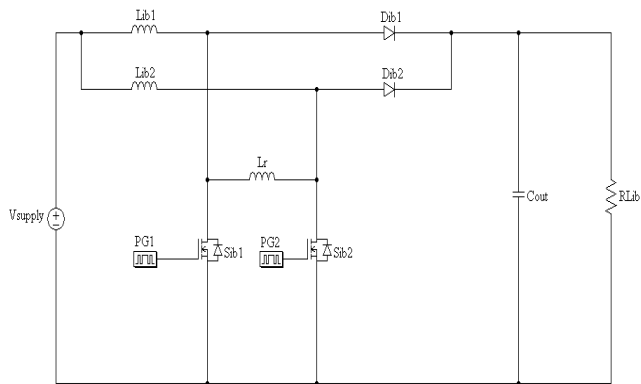


Figure 2. Interleaved boost converter.

of inductors L_{ib1} , L_{ib2} , switches S_{ib1} , S_{ib2} , diodes D_{ib1} , D_{ib2} and output capacitor C_{out} and this will performs the conventional interleaved boost converter operation. Second division consists of L_r , C_r , switch S_a , transformer T_a and auxiliary diodes D_{r1} and D_{r2} this will provide the ZVS on conventional converter. To simplify the operation the converter is assumed in a steady state condition and the modes of operations are explained using the following circuit diagram Figure 4.

2.1 STATE 1: (t_0-t_1)

At the time of starting ($t = 0$), the main switch S_1 and auxiliary switch S_a is in OFF condition and the main switch S_2 is in ON condition. Then the inductor current $I_{L_{ib1}}$ flows through the diode D_{ib1} and the output capacitor gets charging. When S_a turns ON, the inductor L_{ib2} is starts charging by the input DC voltage source (V_{input}). At $t = t_1$, the inductor current is reducing to zero (ZCS) and auxiliary inductor current i_{L_r} reaches $I_{L_{ib1}}$ then next state is started. At $t = t_1$ the diode D_{ib1} is turned OFF naturally.

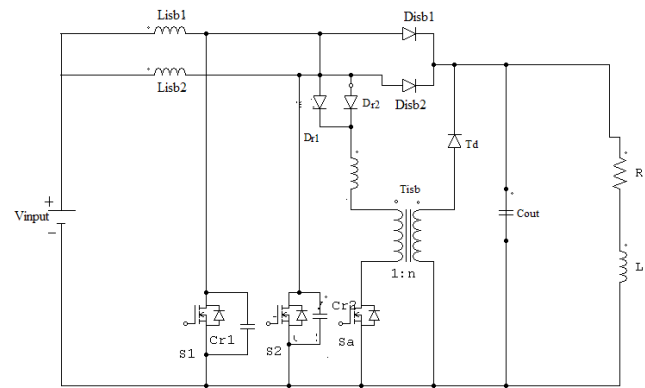


Figure 3. Simulation circuit of interleaved boost converter.

2.2 STATE 2: (t_1-t_2)

At this stage the resonant inductor current $i_{L_r}(t)$ is increases and the voltage of resonant capacitor $V_{Cr2}(t)$ is reducing due to the resonance operation of the circuit.

2.3 STATE 3: (t_2-t_3)

When the resonant capacitor voltage V_{Cr1} reaches zero then this state begins. During this time the main switch S_1 body diode is turned ON naturally with Zero Voltage Switching (ZVS) condition and the main switch S_1 also turned ON. The stored energy from the auxiliary inductor is delivering through $D_{r1} - T_{isb} - S_a$ and body diode of switch S_1 to the output. The auxiliary inductor current $i_{L_r}(t)$ is starts to decrease when the body diode of switch S_1 turns OFF and the energy is delivered through $D_{r1} - T_{isb} - S_a$ and main switch S_1 . When $i_{L_r}(t)$ reaches zero then this stage will end.

2.4 STATE 4: (t_3-t_4)

During this state, under Zero Current Switching (ZCS) the auxiliary switch S_a is turned ON and the converter main switches S_1 and S_2 also turned ON. When the main switch S_2 gets turns OFF then next state will begins.

2.5 STATE 5: (t_4-t_5)

When the main switch S_2 is turns OFF then the resonant capacitor C_{r2} gets charging by the input inductor current I_{L2} and the capacitor voltage V_{Cr2} starts increasing. When the capacitor voltage reaches the output voltage V_{out} then the next state will start.

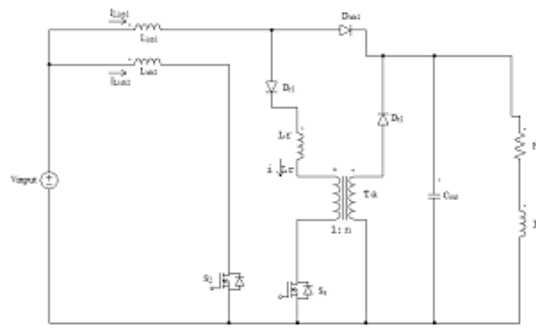


Fig .i

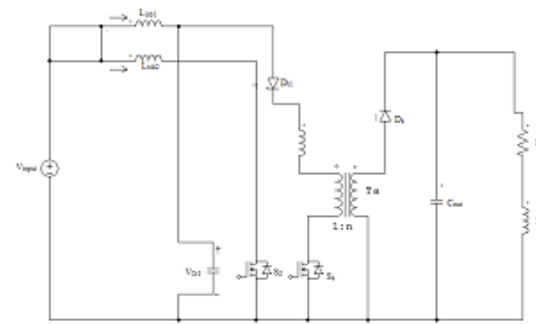


Fig .ii

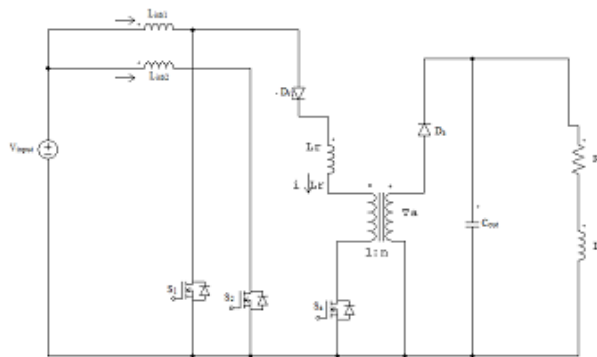


Fig .iii

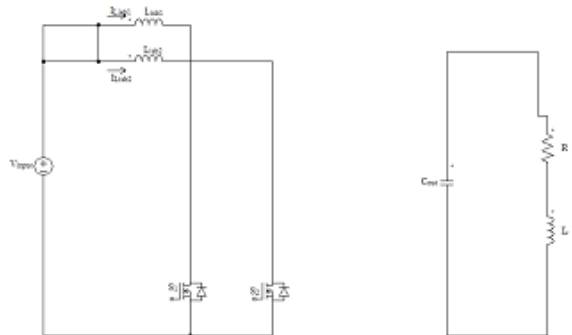


Fig .iv

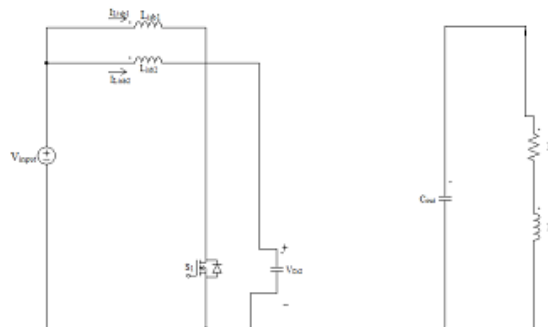


Fig .v

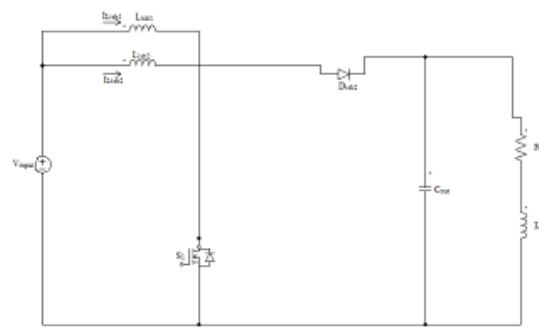


Fig .vi

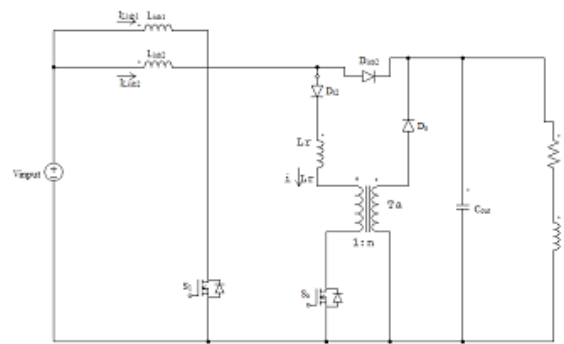


Fig .vii

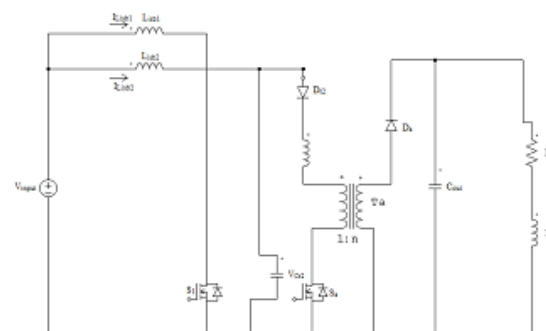


Fig .viii

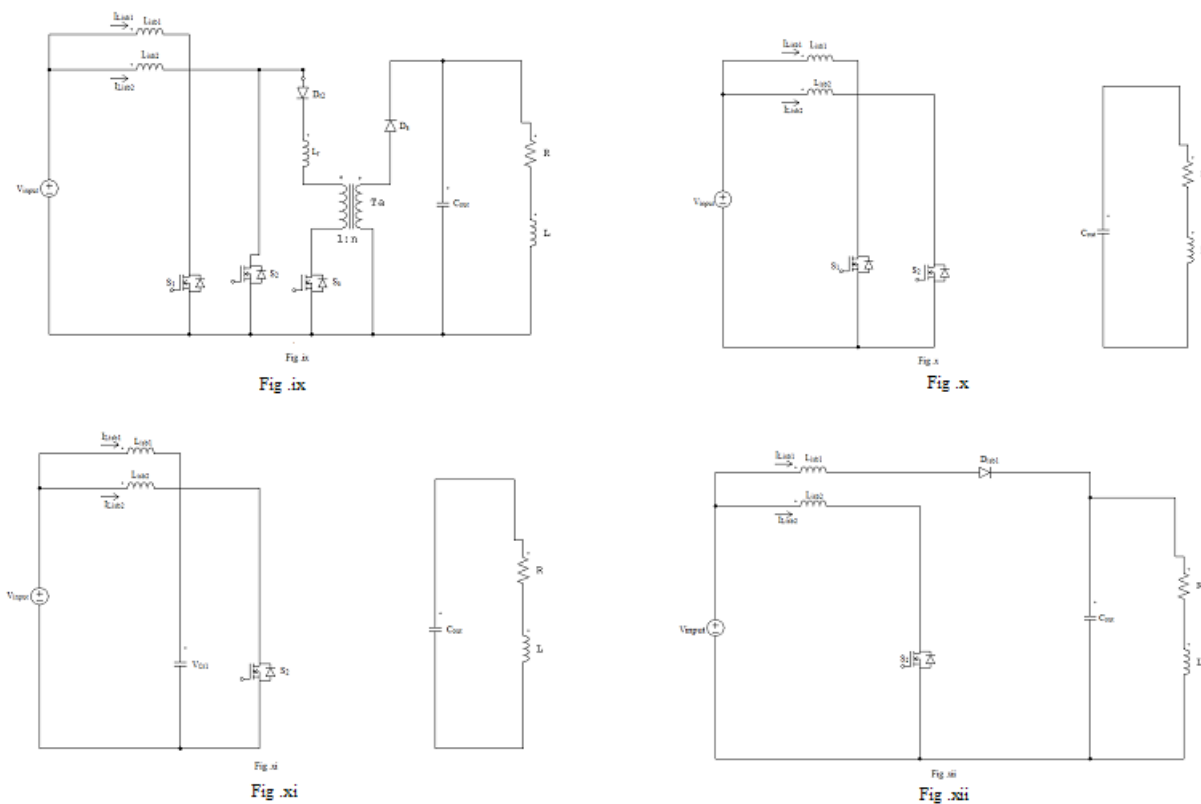


Figure 4. Modes of operation.

2.6 STATE 6: (t_5 - t_6)

When $V_{Cr2}(t) = V_{out}$ then this mode will started. During this time the input inductor current I_{Lisb1} flows through the diode D_{isb1} to the load. Using input DC voltage source the input resonant inductor L_{r2} is charged continuously. The operating principle of state 7 to state 12 are same that of state 1 to state 6. At this state,

$$V_{cr1} = V_{out} \quad (1)$$

$$V_{cr2} = 0 \quad (2)$$

$$I_{Lr} = 0 \quad (3)$$

$$V_{out} = \frac{V}{1 - (D_m + D_a)} \quad (4)$$

$$V_{Gain} = \frac{V_{out}}{V_{input}} \times 100 \quad (5)$$

Where, D_m is duty cycle of main switch and D_a is duty cycle of auxiliary switch or resonant switch.

3. Result Analysis and Discussion

The ZVS-PWM interleaved boost converter is simulated by MATLAB/Simulink software. This converter is simulated for 100V DC input voltage with 5HP DC machine and the MATLAB circuit is shown in Figure 5. The simulation parameters are specified in Table 1.

Figure 6 Shows the gating pulses of MOSFET main switches S1 and S2.

The input and output voltage waveforms are shown in Figures 7 and 8 with the input value of 100V DC and the boosted output voltage of 460.4V. The current ripple in the inductor is 0.089.

The output current ripple in inductor is less compare to input current ripple and it is showing in Figure 9 and 10. The speed can be varied with wide range for a proposed converter. The speed and electrical torque waveforms are shown in Figures 11 and 12. The speed increases and it resolved in 1650 rotation per minutes.

The main diodes are sensitively commutated by zero voltage switching technique and the main switches are operated under zero current switching. Therefore the switching

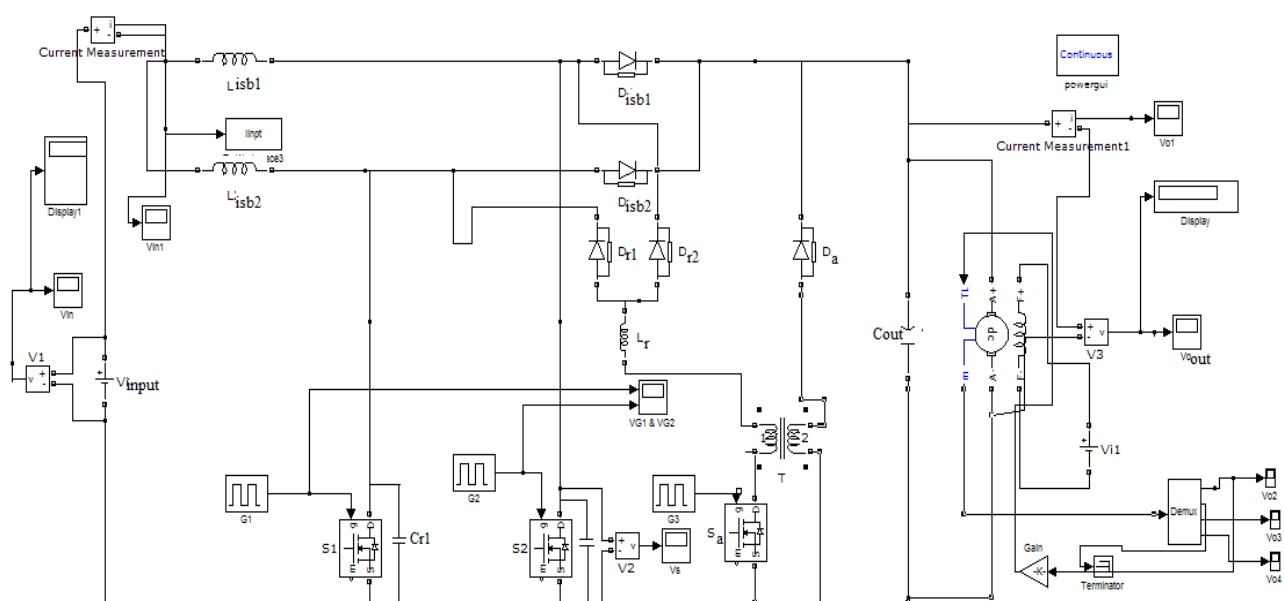


Figure 5. Simulation circuit for ZVS-PWM interleaved boost converter fed DC machine.

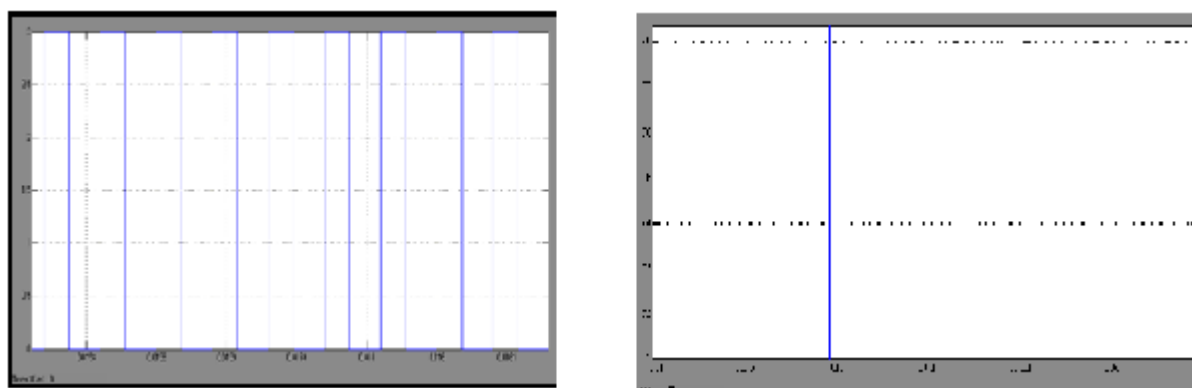


Figure 6. Pulses of main switches S1 and S2.

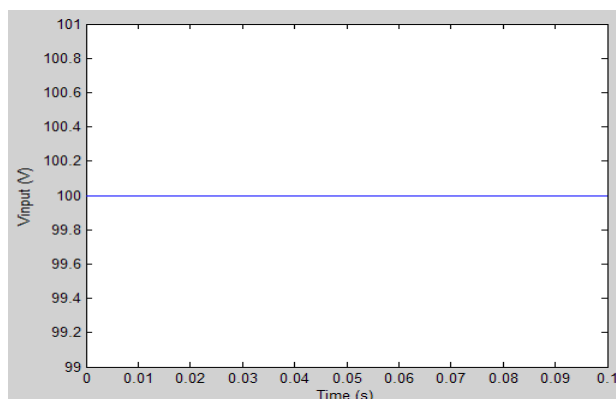


Figure 7. DC input Voltage V_{input} .

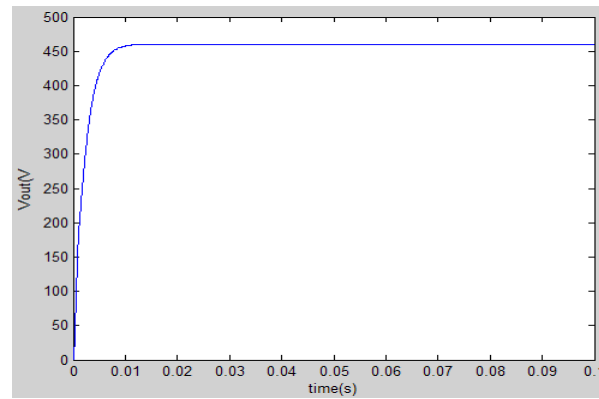


Figure 8. Output Voltage V_{out} .

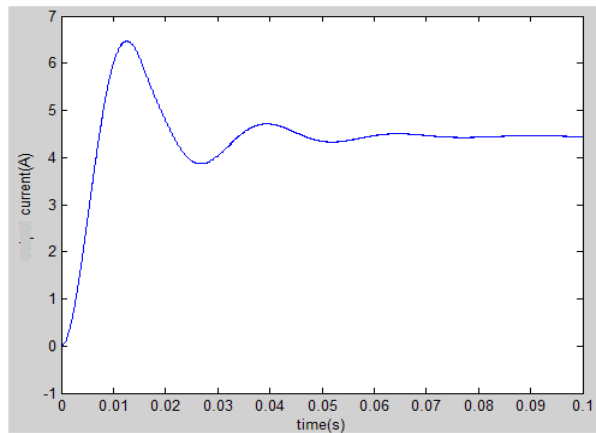


Figure 9. Input inductor current with ripple.

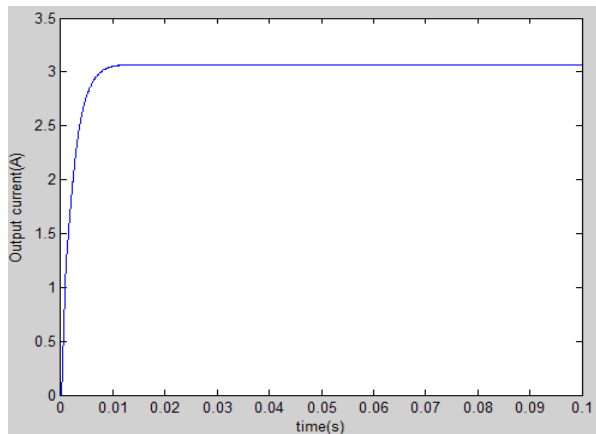


Figure 10. Output inductor current.

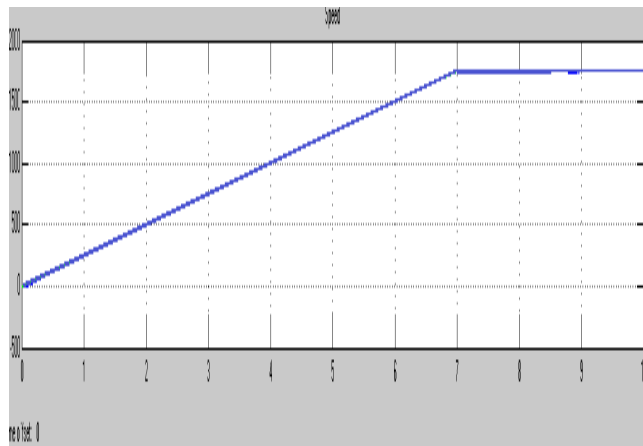


Figure 11. DC Machine speed (rad/s).

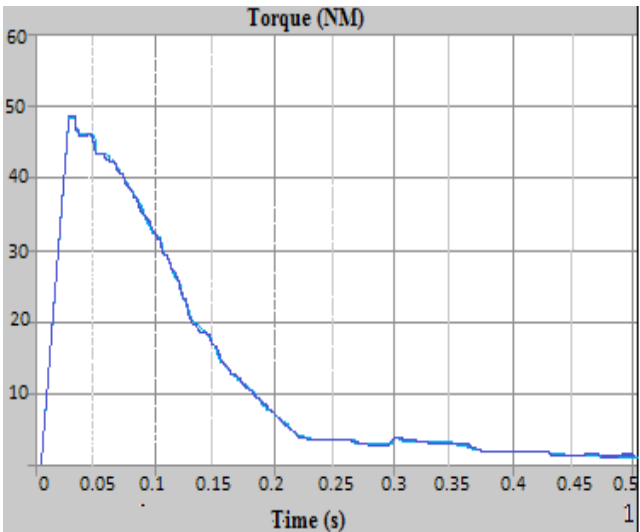


Figure 12. Electrical Torque (N-m).

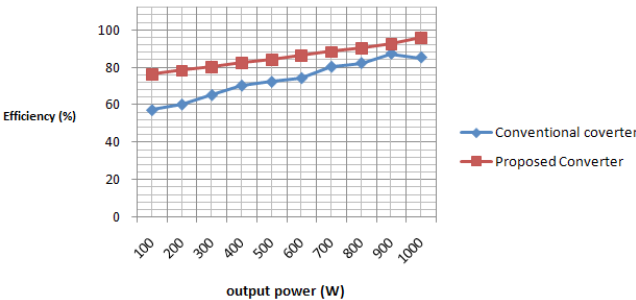


Figure 13. Comparison between Conventional and proposed Converter Efficiency with Output Power in watts.

Table 1. Simulation parameters of proposed converter

Sl.No	Parameter	Values
1.	Input Voltage (V)	100
2.	Output Voltage (V)	460
3.	Output Power (W)	1450
4.	Current Ripple	0.089
5.	Switching Frequency(KHz)	25
6.	Switch	MOSFET
7.	Inductor (H)	500e-6
8.	Capacitor (F)	9.7e-9
9.	Output Filter (F)	470e-6

losses of diodes and switches of proposed converter is less and approximately equal to zero and this will increase the overall efficiency of the converter. In Figure 13 the efficiency of conventional (86%) and proposed system (97%) is compared with output power in watts.

4. Conclusion

In this paper, PWM-ZVS based interleaved boost converter fed DC machine is analysed and the operating principle is explained using MATLAB simulation and mathematical equations.

The ZVS and ZCS techniques are used to reduce the stress in input and output voltages/currents, reducing the switching losses, reducing the size of filter capacitor and overall cost. When compared to conventional switching methods the proposed method is improving the overall performance as well as increasing the efficiency of the converter. Nowadays the PWM based interleaved boost converter is used in power electronics applications like Photovoltaic converters, fuel cell applications, hybrid systems and power factor correction circuits.

5. References

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