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Design and Simulation of an Efficient Interleaved Soft Switching Boost Converter Fed Single Phase DC Drive

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Abstract

The power converters can be very beneficial for high performance in electrical equipment applications. Reduction in size and electromagnetic emission along with an increase in efficiency, transient response, and reliability are among the many advantages to using such converters. This topology is used to raise the efficiency of the AC/DC converter, and it minimizes switching losses by adopting a resonant soft switching method.In this paper, design of an inductor and capacitor for interleaved soft switching boost converter fed DC drive is simulated for reducing the switching loss and switching using MATLAB/SIMULINK software.

Index Terms- interleaved boost converter (IBC), Zero-current switching (ZCS), Zero-voltage switching (ZVS), ripple, and resonant converter

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Introduction

Recently, switch-mode power supplies have become smaller and lighter due to higher switching frequency. In low power converters, the main effort is devoted to increase the switching frequency to reduce the size of reactive components and consequently the whole converter. As the switching losses are directly proportional to switching frequency, soft switching techniques are generally used in high frequency converters both at low power and at high power[4].

At higher power levels, the interest is still on increasing the switching frequency but due to having higher switching losses raising the switching frequency is practically limited. In high power applications, the stress on the power switches and the rectifiers can be so high that it is impossible to obtain the required power using a single converter. Hence, parallel operation of converters is necessary. [2]The main advantage comes from the fact that sharing the input current among paralleled converters improves important aspects such as maintenance, repairing, loss-heat dissipation, reliability and fault tolerance.

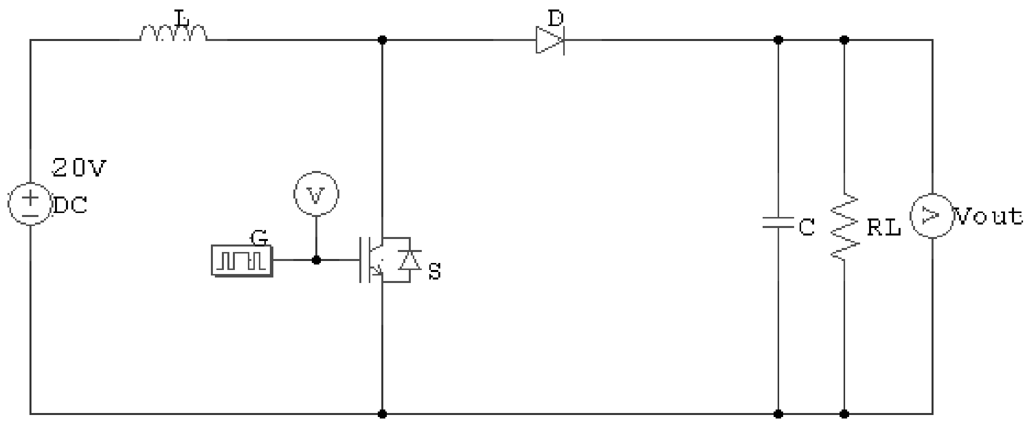

Fig. 1 Basic diagram of Boost topology

Resonant switching techniques reduce the switching losses to practically zero; the switching frequency then may be increased to hundreds of kHz to achieve higher power densities. Such converters in general are classified as `Soft switching converters' [6]. In these converters, the switching transitions occur with zero loss. Exploitation of resonant transitions in power conversion is not new. The use of such Resonant circuit technique is diminished with the introduction of fully controlled switches such as BJTs, MOSFETS and IGBTs. With the demand for higher power density and lower switching loss, there is a renewed interest in the resonant switching techniques.

The switching techniques in the resonant converter employ zero voltage switching and/or zero current switching. Soft switching is also referred to as Zero current switching (ZCS) or Zero voltage switching (ZVS) in the literature [6]. In zero current switching, the device turns-on with zero current and turns-off after the current drops to zero. In zero voltage switching, the switch turns-off at zero voltage and turns-on after the device voltage drops to zero.

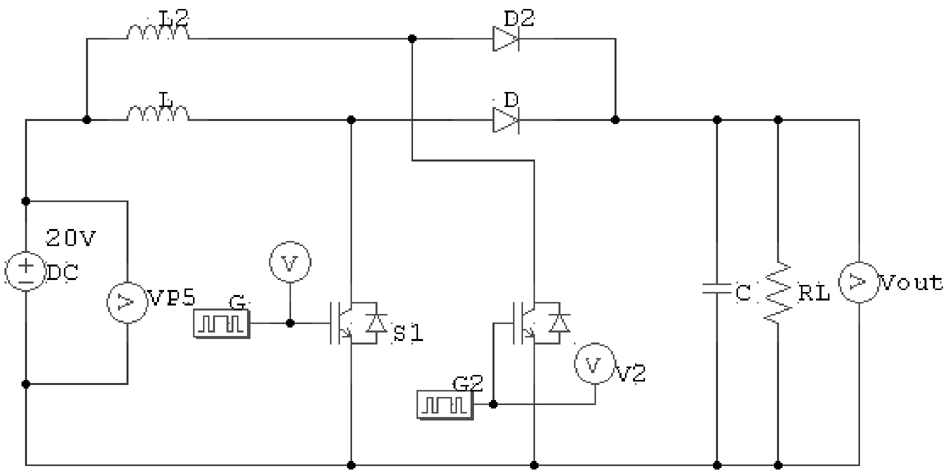

Fig. 2 Circuit Diagram of IBC

A new soft-switching boost converter with an auxiliary switch and resonant circuit is proposed in this paper.

Proposed single-switch type soft-switching boost converter minimizes switching loss by adopting a resonant soft-switching method. And, no additional switches are needed for soft switching. Also, the proposed model reduces the input current ripple, output voltage ripple, and size of the passive components.

The proposed soft-switching interleaved boost converter not only exploits the interleaved converter but also reduce switching losses through the soft-switching technique. Therefore, the output power can be boosted with high efficiency. Compared with other soft-switching converters, the proposed converter improves the whole system's efficiency by reducing switching losses better than other converters at the same frequency.

II. THE PROPOSED SOFT SWITCHING BOOST CONVERTER FED DC DRIVE

A. Configuration

The interleaved soft switching boost converter is shown in fig.3. It consists of two single-phase boost converters connected in parallel and then to a single output capacitor. The two PWM signal difference is 180 degree and each switch is controlled in the interleaving method. Since each inductor current magnitude is decreased according to one per phase, the inductor size and Inductance can be reduced and also the input current ripple is decreased.

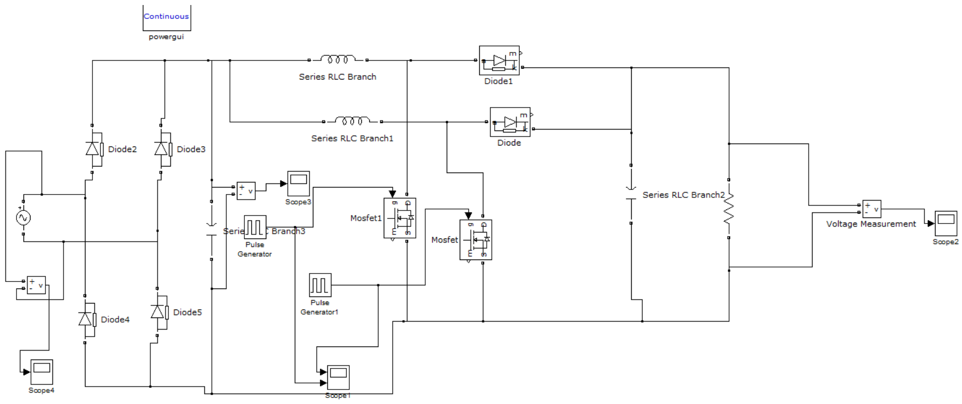

Fig. 3 Schematic of the interleaved soft-switching boost converter

B. Operational Analysis

Initially, the switch is in off state and the DC output of the diode rectifier is transmitted directly to the load through L_2 and D_6. In this mode, the main inductor voltage becomes – (V_O – V_{IN}). Thus, the main inductor current decreases linearly. If the switch is turned on under zero-current switching because of the resonant inductor L, as the output voltage is supplied to the resonant inductor L, the current increases linearly. When the resonant current becomes equal to the main inductor current, the current of the output side diode D_6 becomes zero.

The resonant inductor L and the resonant capacitor C resonate and the voltage of C decreases from the output voltage V_O to zero. The main inductor current i_L flows through L_1 and the switch. When the resonant capacitor voltage V_C becomes zero, the two auxiliary diodes D3 and D_4 are turned on and therefore the resonant inductor current now flows through main inductor L2 and through the two auxiliary diodes. The main inductor current increases linearly.

The switch turns off under the zero-voltage condition because of the auxiliary resonant capacitor C_2. The current divides it two paths. One is the L-C -V_{IN} loop for which the voltage of the resonant capacitor C increases linearly from zero to the output voltage Vo. The other is the L1–C–D5 loop for which the second resonance occurs. The energy stored in L is transferred to C.

The resonant current decreases linearly and the voltage across C reaches maximum. When the resonant capacitor voltage Vc is equal to the output voltage V_O, the energy flow from L3 to C is completed and the resonant current iL3 becomes zero. When the Vc becomes zero, the resonant current reverses its direction. When the voltage of C becomes zero, the anti parallel diode of the switch turns on. And now the current flows in two paths. The main inductor current i_{L2} transmits energy to the output through D_1 and decreases linearly. The resonant inductor current i_L also transmits energy to the load through D2 and flows through the anti parallel diode of the switch.

III. DESIGN PROCEDURE

The following design procedure is based on the soft-switching turn-ON and turn-OFF requirements of the main switch, the main diode, and the auxiliary switch. The duty ratio of the interleaved soft switching boost converter fed DC drive is calculated using the following formula.

a. Duty Ratio

$D = V_{out}/V_{in}$

b. Inductor (L) and Capacitor (C)

If the charging voltage of this capacitor is higher, the voltage stress of the switch is also higher. Consequently, this voltage must be lower than the output voltage. These conditions are satisfied by (2) and (3). Finally, (4) follows. Equation (5) is also satisfied.

$$Z_a I_{in,max} \leq V_o \tag{2}$$

$$\pi\sqrt{L_r}C_r \leq 0.1T_s \tag{3}$$

$$\omega_a \approx 942477.8, Z_a \leq 71.8 \tag{4}$$

$$L_r \leq \frac{Z_a}{\omega_a}, C_{r2} \geq \frac{1}{Z_{a\omega_a}} \tag{5}$$

IV. SIMULATION RESULTS

The simulation parameters are shown in Table I. This project simulated by MATLAB/simulink software. The simulation of interleaved soft switching boost converter fed DC drive was performed under a 100V of ac input voltage and 5HP single phase rectifier DC drive. The simulation model is shown in Fig. 4.

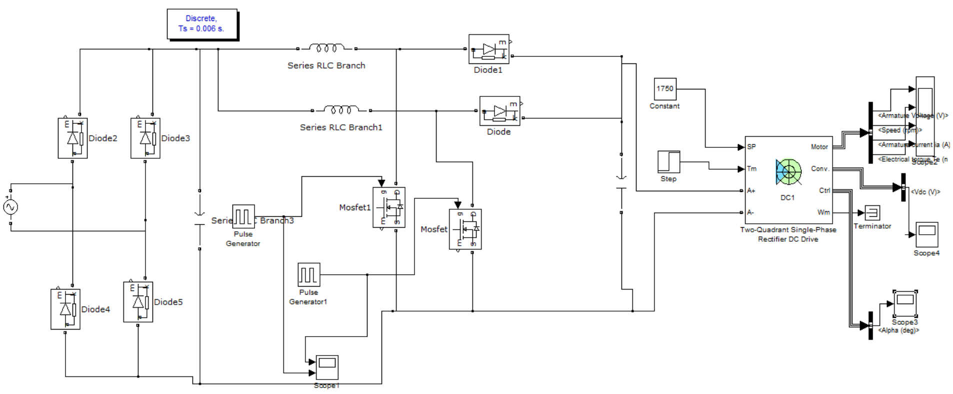

Fig. 4. Simulation model of the interleaved soft switching boost converter fed single phase DC drive

The figures 5 & 6 show the gating pulses of MOSFET switches M1 and M2 waveforms.

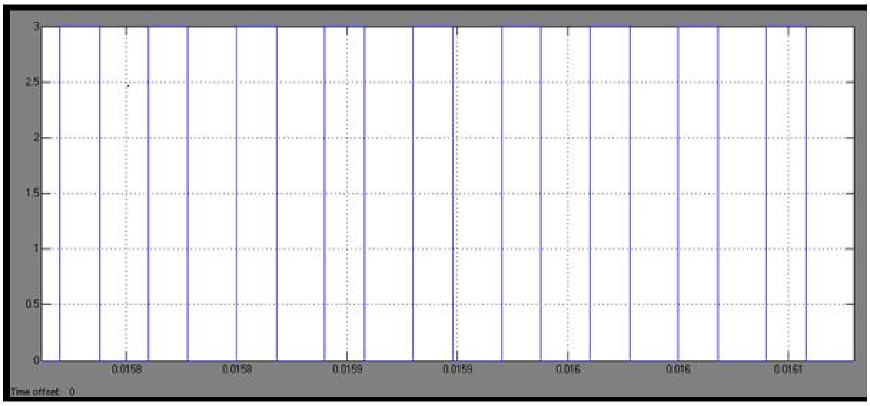

Fig. 5. Switching pulses for M1

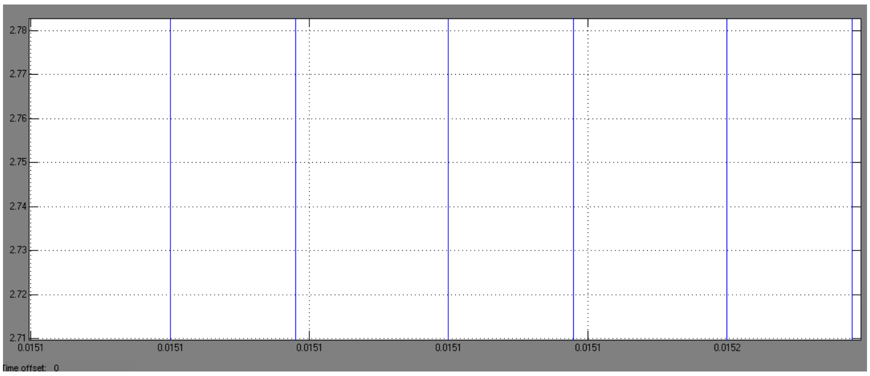

Fig. 6. Switching pulses for M2

The simulation waveforms of the AC input voltage.The peak value of AC input voltage is 100V have shown in Fig.7. Boosted Output Voltage is shown in Fig.8. The voltage is boosted to 170V and in Fig.9.The speed of 1700rpm is shown.

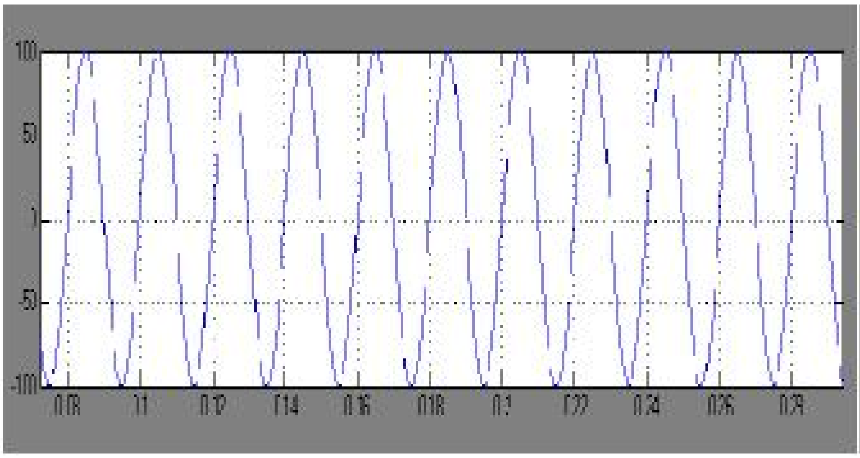

Fig. 7. AC input voltage waveform

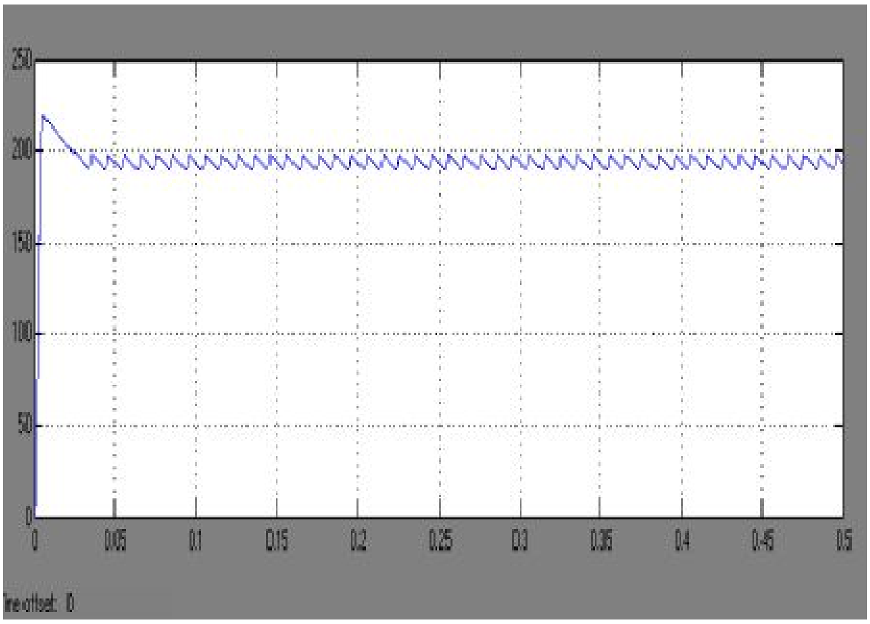

Fig. 8. Output voltage waveform

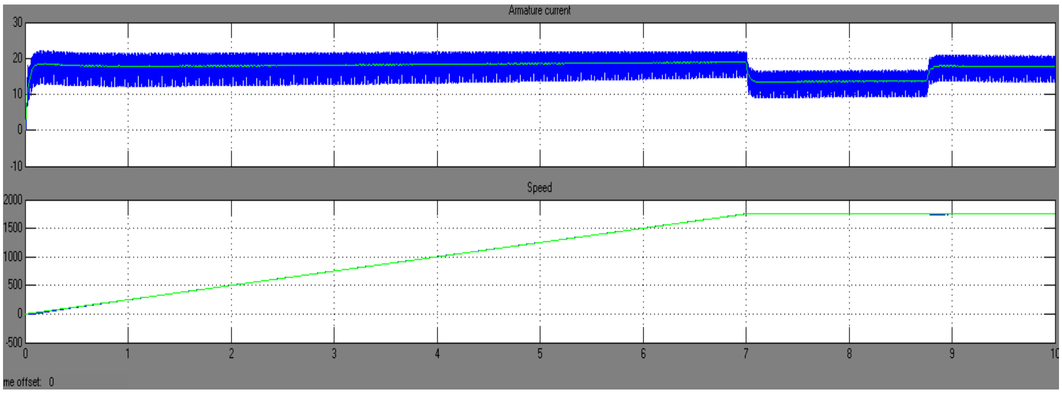

Fig. 9. Output current waveform

TABLE I: PARAMETERS OF THE INTERLEAVED SOFT-SWITCHING BOOST CONVERTER

S.no	Parameters	Values
1.	Input voltage(Vin)	100 V
2.	Output voltage (Vo) in R load	170 V
3.	Output current	17A
4.	Capacitor(C)	0.221mF
5.	Inductor(L)	0.015mH
6.	Speed	1700N-m
7.	Phase shift of Mosfet switch	180^{o} each

V. CONCLUSION

The simulation of an interleaved soft switching boost converter fed DC drive has been carried out in this paper using MATLAB/Simulink. The design equations for IBC have been presented. It is found that IBC effectively reduces the overall current ripple compared to that of conventional boost converter. The system has better efficient and is able to deliver the power to the load with stability operation.

The proposed converter has smaller output filter capacitor and lesser component count as compared to other topologies. And also compare to other boost topologies it has less THD value. The evaluation by using mathematical model has been analyzed and shown that the output voltage signal that can be controlled. The power factor can be corrected using closed loop control. The proposed converter is suitable for applications such as high-efficiency converters, photovoltaic dc/dc converters, a power-factor-correction circuit, and battery chargers.

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