MODELING AND SIMULATION OF CLOSED LOOP CONTROLLED INTERLEAVED THREE SWITCH BUCK CONVERTER FED DC DRIVE

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Abstract- This paper deals with modeling and simulation of interleaved buck converter fed DC drive. A new interleaved buck converter with three switches is proposed. Three pulses with a phase shift of 1200 are applied to reduce the ripple in the output. This reduces the ripple in the armature current. Therefore the torque ripple is also reduced. Open loop and closed loop controlled drive systems are modeled using the blocks of Simulink and the results are presented.

Index terms- Buck Converter, interleaved, low switching losses and switching stresses.

I. INTRODUCTION

In applications where non isolation, step-down conversion ratio, and high output current with low ripple are required, an interleaved buck converter (IBC) has received a lot of attention due to its simple structure and low control complexity [1]–[6]. However, in the conventional IBC shown in Fig. 1, all semiconductor devices suffer from the input voltage, and hence, high-voltage devices rated above the input voltage should be used. High-voltage-rated devices have generally poor characteristics such as high cost, high on-resistance, high forward voltage drop, severe reverse recovery, etc. In addition, the converter operates under hard switching condition. Thus, the cost becomes high and the efficiency becomes poor. And, for higher power density and better dynamics, it is required that the converter operates at higher switching frequencies. However, higher switching frequencies increase the switching losses associated with turn-on, turn-off, and reverse recovery. Consequently, the efficiency is further deteriorated. Also, it experiences an extremely short duty cycle in the case of high-input and low-output voltage applications.

In [8]–[10], three-level buck converters are introduced. The voltage stress is half of the input voltage in the converters. However, so many components are required for the use of IBC. In [11], an IBC with a single-capacitor turnoff snubber is introduced. Its advantages are that the switching loss associated with turn-off transition can be reduced, and single coupled inductor implements the converter as two output inductors. However, since it operates at discontinuous conduction mode (DCM), all elements suffer from high-current stress, resulting in high conduction and core losses. In addition, the voltages across all semiconductor devices are still the input voltage. In [12], an IBC with active-clamp circuits is introduced. In the converter, all active switches are turned ON with zero-voltage switching (ZVS). In addition, a high step-down conversion ratio can be obtained and the voltage stress across the freewheeling diodes can be reduced. However, in order to obtain the mentioned advantages, it requires additional passive elements and active switches, which increases the cost significantly at low or middle levels of power applications. In [13], an IBC with zero-current transition (ZCT) is introduced to reduce diode reverse recovery losses. The ZCT is implemented by only adding an inductor into the conventional IBC.

However, in spite of these advantages, the converter suffers from high current stress, because the output current flows through each module in a complementary way. And it still has the drawbacks of the conventional IBC. An IBC with two winding coupled inductors is introduced in [14] and [15]. The converter has the following advantages. Since it operates at continuous conduction mode (CCM), the current stress is lower than that of DCM IBC. The voltages across all semiconductor devices can be reduced by adjusting the turn ratio of the coupled inductors, which allows that although it operates with hard switching, the switching losses can be reduced. Additionally, a high step-down conversion ratio can also be obtained.

To overcome the aforementioned drawbacks of the conventional IBC, some pieces of research for reducing the voltage stress of a buck converter and several kinds of IBCs have been presented until now.

![Fig. 1. Conventional IBC](image-url)
In the Fig 2, a two stage IBC, which is suitable for the applications where the input voltage is high and the operating duty is below 50%, is proposed. It is similar to the conventional IBC, but two active switches are connected in series and a coupling capacitor is employed in the power path. The two active switches are driven with the phase shift angle of 180° and the output voltage is regulated by adjusting the duty cycle at a fixed switching frequency. The features of the proposed IBC are similar to those of the IBC in [14]. Since the proposed IBC also operates at CCM, the current stress is low. During the steady state, the voltage stress across all active switches before turn-on or after turn-off is half of the input voltage [16] – [19]. Thus, the capacitive discharging and switching losses can be reduced considerably. The voltage stress of the freewheeling diodes is also lower than that of the conventional IBC so that the reverse-recovery and conduction losses on the freewheeling diodes can be improved by employing schottky diodes that have generally low breakdown voltages, typically below 200V. The conversion ratio and output current ripple are lower than those of the conventional IBC.

The proposed IBC is described in Section II in detail. The relevant analysis results are presented in Section III. The performance of the proposed IBC is confirmed by the simulation results of prototype converters with 150–200V input, 33 V/17A output in Section III. The conclusion is made in Section IV.

The above literature does not deal with three switch IBC. This work proposes three switches for the control of output voltage. The Simulink models are open and closed loop controlled IBC fed DC drives are also not present in the literature. This work develops Simulink models for open and closed loop controlled three switch IBC systems.

II. INTERLEAVED BOOST CONVERTER

Interleaved boost converter structure is similar to a conventional IBC except three active switches in series and a coupling capacitor employed in the power path. The pulses given to the switches are displaced by 1200. Three switch interleaved buck converter system is shown in Fig.3.

III. SIMULATION RESULTS

DC input voltage is shown in Fig. 3a. The switching pulses for M1, M2 and M3 are shown in Fig. 3b. They are shifted by 1200. The switching pulse for M1 and output voltage are shown in Fig 3c. The switching pulse for M2 and output voltage are shown in Fig 3d. The voltage across the capacitor CB is shown in Fig. 3e. The waveforms of output voltage and current in switch2 are shown in Fig. 3f. The waveforms of iL1 and iL2 are shown in Fig. 3g. DC output current and voltage are shown in Figs 3h and 3i respectively. The DC output voltage is 33V and the output current is 17 Amps.
Three switch interleaved buck converter fed DC servo drive is shown in Fig. 4a. The separately excited DC motor is used as the load. Scopes are connected to display the speed and torque. DC input voltage is shown in Fig. 4b. The input voltage is 150 Volts. Speed response is shown in Fig. 4c. The speed increases and settles at 330 rpm. The torque decreases and settles at 2 N-M.
CONCLUSION

Three switch interleaved buck converter fed DC servo drive is successfully modeled and simulated using Matlab simulink. The circuit models for open loop and closed loop systems are developed and they are used for simulation. The switching losses and stresses are reduced by soft switching. The closed loop system is able to regulate the speed. The torque ripple is minimized by using the proposed three switch interleaved buck converter system. The interleaved three switch buck converter system is a viable alternative to the exiting converters since it has reduced ripple and improved speed regulation.

REFERENCES


Modeling And Simulation of Closed Loop Controlled Interleaved Three Switch Buck Converter FED DC Drive


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