STUDY AND ANALYSIS OF CONVENTIONAL AND MODIFIED INTERLEAVED BUCK CONVERTER

Krishna P S [Mtech student] EEE, Jubin Eldho Paul [Associate Professor] EEE, Hari Kumar R [Associate Professor] EEE

krishnaps6@gmail.com, jubineldho@gmail.com

Abstract— This paper proposes an Interleaved Buck Converter (IBC) with continuous input current, extremely low output current ripple, low switching losses and improved step-down conversion ratio. Unlike the conventional IBC, the proposed converter has continuous input current and its output current ripple is extremely low. The proposed converter has lower voltage stress in comparison to the conventional IBC and also can provide a high step-down ratio which makes it a proper choice for high power applications where non-isolated step-down converter with low output current ripple and continuous input current is required. The proposed IBC shows that the voltage stress across all the active switches is half of the input voltage before turn-on or after turnoff when the operating duty is below 50%. Also the proposed converter can provide current-sharing between two interleaved modules without using additional current-sharing control method. All these benefits are obtained without any additional stress on the circuit components. The simulation is done by using MATLAB 7.12.0(R2014a).

Keywords— buck converter, interleaved, low switching loss,

INTRODUCTION

A basic buck converter is a voltage step down and current step up converter. It is mainly used in applications such as dc motor speed control and regulated dc supplies. It is also useful for tasks such as converting the main voltage in a computer down to the voltage needed by the processor. It has high efficiency due to no energy conversion. It has low switch current than load current. It has a disadvantage of ripples and during turn off current decays to zero.

In places where non isolation, step down conversion ratio and high output current with low ripple interleaved buck converter is used. It has a simple structure. Interleaving adds additional benefits such as reduced ripple currents in both the input and output circuits. In interleaved buck converter, all semi-converter 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. Higher efficiency is realized by splitting the output current into two paths, substantially reducing losses. To achieve high power density and better dynamics, it is required that the converter operates at higher switching frequency. But high switching frequency increase the switching losses. Therefore the efficiency is deteriorated.

BASIC BUCK CONVERTER

A buck converter [2] is a voltage step down and current step up converter. It has main application in regulated dc supplies and dc motor speed control. It is also useful for tasks such as converting the main voltage in a computer down to the voltage needed by the processor. When switch S is turned ON, the diode become reverse biased and the input provides energy to the load as well as to the inductor.

$$V_L = V_i - V_0 \quad (1)$$

When switch is OFF, the inductor current flows through the diode, transferring some of its stored energy to the load.

$$V_L = -V_0 \quad (2)$$

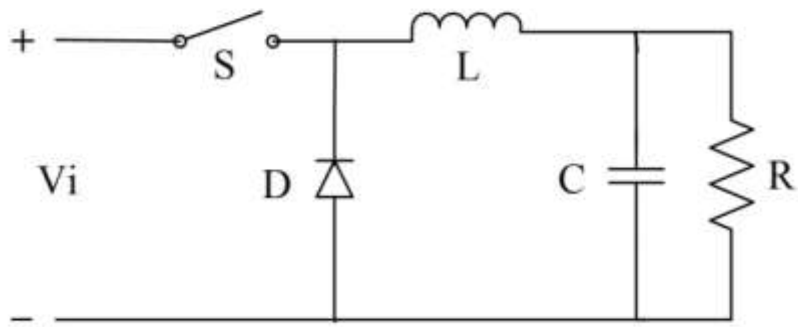

Fig.1 buck converter

According to volt-sec balance we will get,

$$\frac{V_0}{V_i} = D \quad (3)$$

$$L = \frac{V_i \times D \times (1-D)}{I_L \times F_S} \quad (4)$$

$$C = \frac{\Delta i_L}{8 \times V_0 \times F_S} \quad (5)$$

The buck converter has an advantage of high efficiency due to no energy conversion and also have low switch current than load current. But it have a disadvantage of high ripple and during T_{OFF}, current decays to zero.

INTERLEAVED BUCK CONVERTER

Interleaving technique connects dc-dc converter in parallel to share the power flow between two or more conversion chains. It implies a reduction in the size, weight and volume of the inductors and capacitors. Also a proper control of the parallel converters increases the ripple frequency and reduces the ripple waveforms at the input and output of the power conversion system, which leads to a significant reduction of current and voltage ripples.

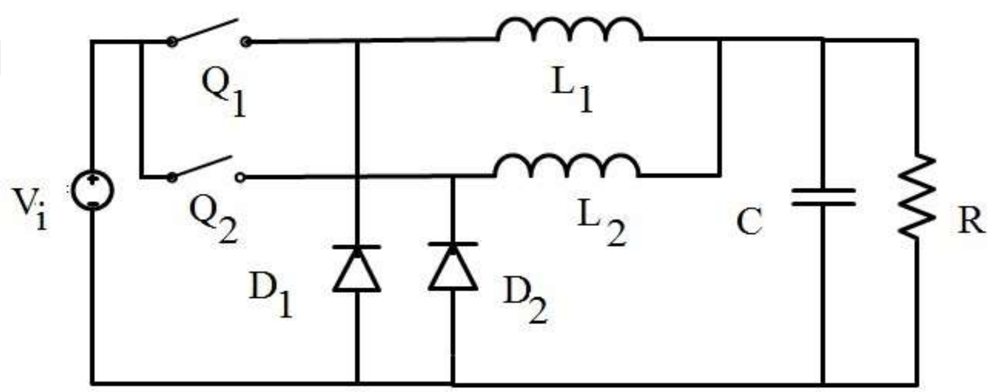

Fig.2 Interleaved buck converter

Due to the simple structure and low control complexity of interleaved buck converter, it is used in applications where non isolation, step down conversion ratio, high output current with low ripple is required.

When switch Q_1 turns ON and Q_2 turns OFF inductor L_1 charges and L_2 dicharges and freewheels through the diode D_2. The inductor current flows through the diode, transferring some of its stored energy to the load.

$$V_{L1} = V_i - V_0 \quad (6)$$

$$V_{L2} = - V_0 \quad (7)$$

When both Q_1 and Q_2 turns OFF, the both inductors L_1 and L_2 discharges and freewheels through D_1 and D_2 .The equations are,

$$V_{L1} = V_{L2} = -V_0 \quad (8)$$

When Q_2 turns ON, the inductor L_2 charges and L_1 discharges and freewheels through the diode D_1.

$$V_{L1} = V_i - V_0 \quad (9)$$

$$V_{L2} = - V_0 \quad (10)$$

According to volt sec balance we get,

$$\frac{V_0}{V_i} = \mathrm{D} \quad (11)$$

$$L_1 = L_2 = \frac{(V_i - V_0)\times D}{\Delta i_L \times F_s} \quad (12)$$

In IBC [3]-[8], the active switches suffer from the input source voltage due to its parallel connection with the source. So high voltage devices should be used. But high voltage rated devices is characterized with high forward voltage drop, high cost, intense reverse recovery, high on resistance. Due to the hard switching condition, the operating efficiency is very poor. For getting good dynamics and higher power density converter requires to operate at higher switching frequency. But at higher switching frequency switching losses is increased and thus, efficiency is further reduced.

MODIFIED INTERLEAVED BUCK CONVERTER

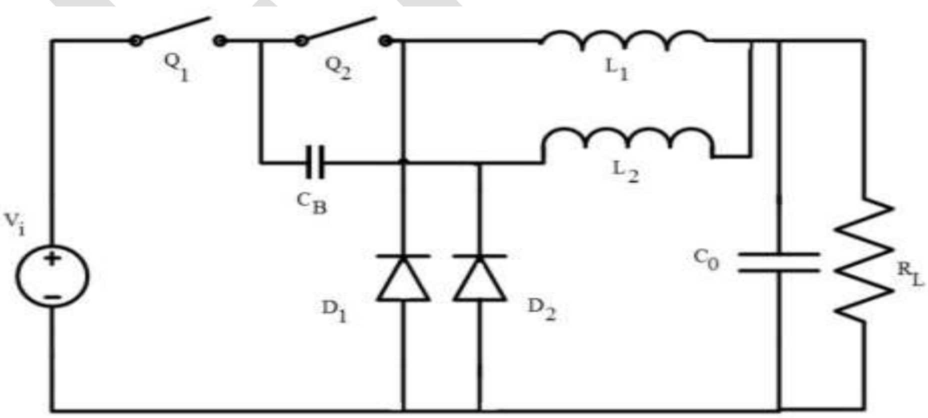

Fig.3 Modified interleaved buck converter

In the proposed IBC [1] two switches are connected in series and there is a coupling capacitor in the power path. The two switches Q1 and Q2 are activated with a phase shift angle of 180º.The output voltage can be regulated by adjusting the duty cycle at fixed switching frequency. The new IBC is operates at continuous conduction mode .So its current stress is low. The voltage stress of active switches is half of the input voltage before turn on and after turn off under steady state. So the capacitive discharging and switching losses reduces considerably. The voltage stress of freewheeling diode is also considerably reduced. So the reverse recovery and conduction losses on the freewheeling diode improve by using schottky diode which have generally low break down voltage. A good conversion ratio and low output current ripple can be obtained with proposed topology. The new IBC is suitable for applications where the input voltage is high and duty cycle is less than 50%. The proposed system is analysed when D <0.5.

When Q_1 turns ON the inductor L_2 charges through the capacitor and the inductor L_1 discharges and freewheels through the diode D_2.

$$V_{L1} = V_i - V_{CB} - V_0 \quad (13)$$

$$V_{L2} = -V_0 \quad (14)$$

When both Q_1 and Q_2 turns OFF both the inductors L_1 and L_2 discharges and freewheels through the diodes D_1 and D_2.

$$V_{L1} = -V_0 \quad (15)$$

$$V_{L2} = -V_0 \quad (16)$$

When Q_2 turns ON the inductor L_1 charges and L_2 discharges and freewheels through the diode D_2.

$$V_{L1} = -V_0 \quad (17)$$

$$V_{L2} = V_{CB} - V_0 \quad (18)$$

According to volt-sec balance,

$$(\mathrm{V_i} - \mathrm{V_{CB}} - \mathrm{V_0}) \times \mathrm{D} \times \mathrm{T_s} = \mathrm{V_0} \times (1 - \mathrm{D}) \times \mathrm{T_s} \quad (19)$$

$$(\mathrm{V_{CB}} - \mathrm{V_0}) \times \mathrm{D} \times \mathrm{T_s} = \mathrm{V_0} \times (1 - \mathrm{D}) \times \mathrm{T_s} \quad (20)$$

$$\frac{V_o}{V_i} = \frac{D}{2} \quad (21)$$

SIMULATION RESULTS

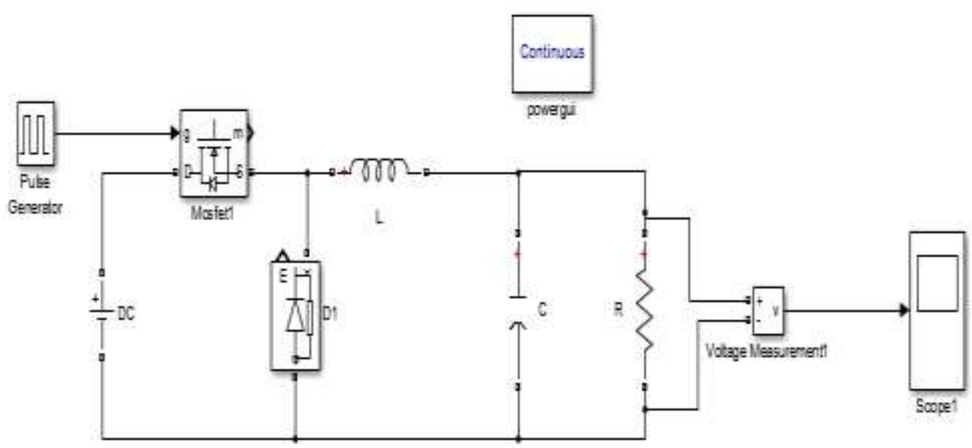

Fig.4 Simulation of buck converter

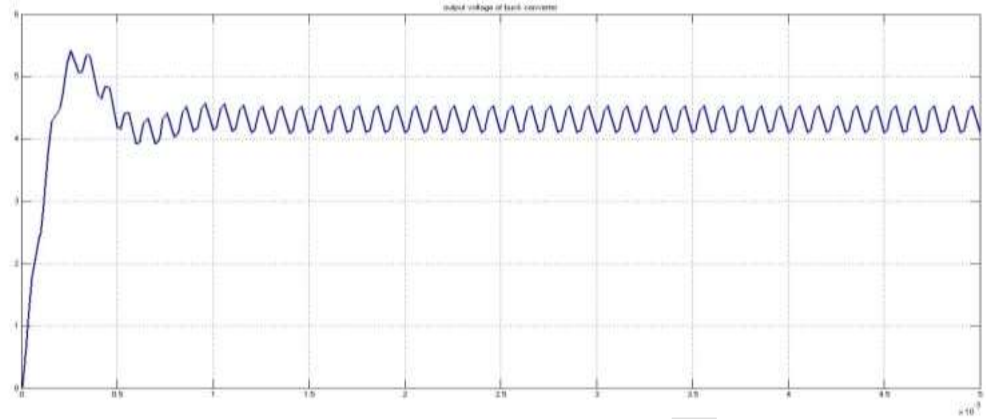

Fig.5 Output voltage of buck converter

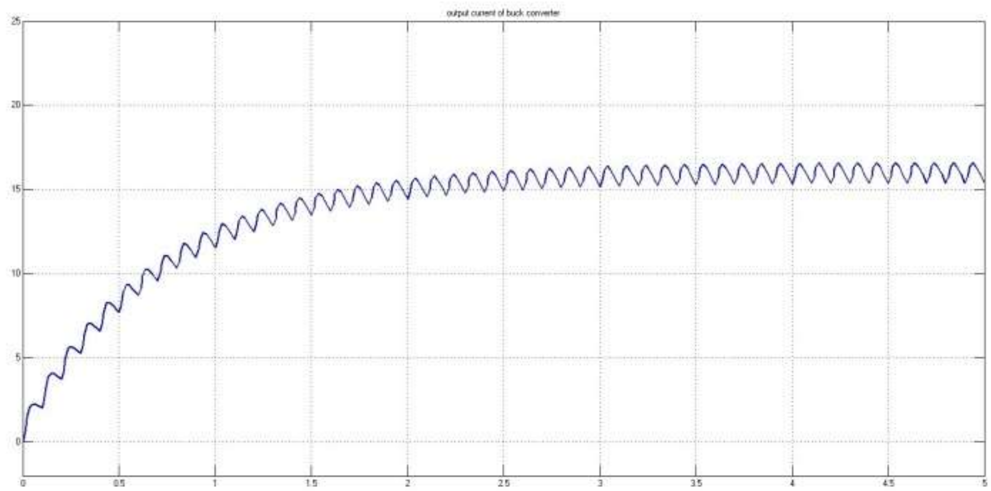

Fig.6 Output current of buck converter

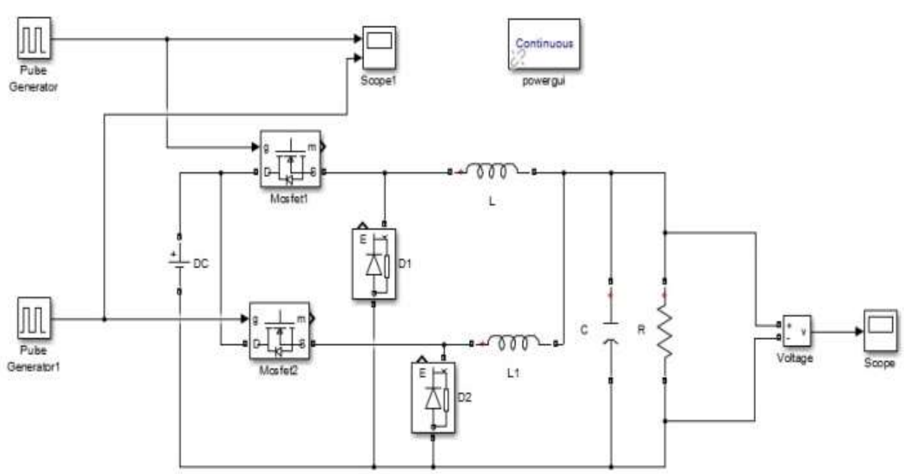

Fig. 7 Simulation of Interleaved buck converter

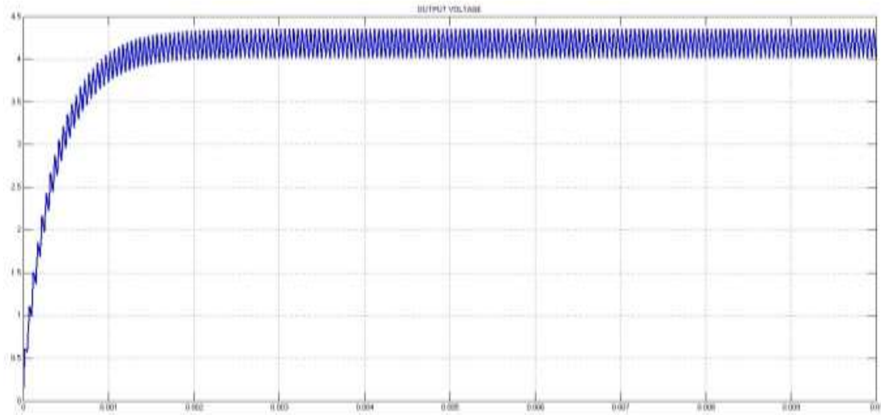

Fig.8 Output voltage of Interleaved buck converter

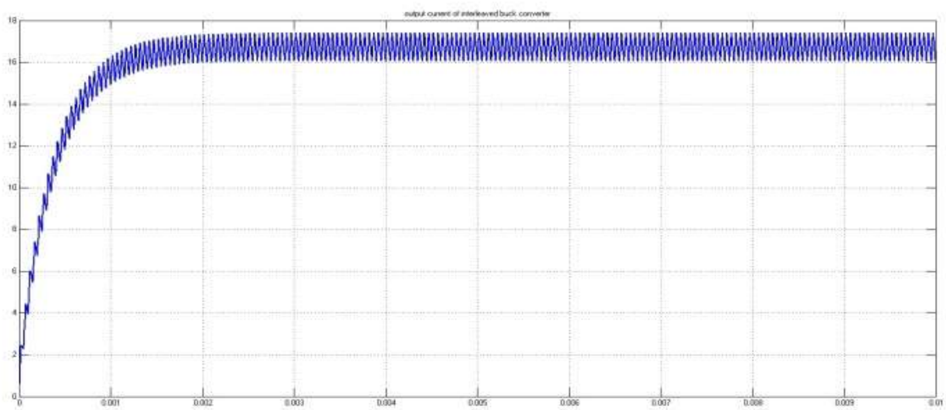

Fig. 9 Output current of Interleaved buck converter

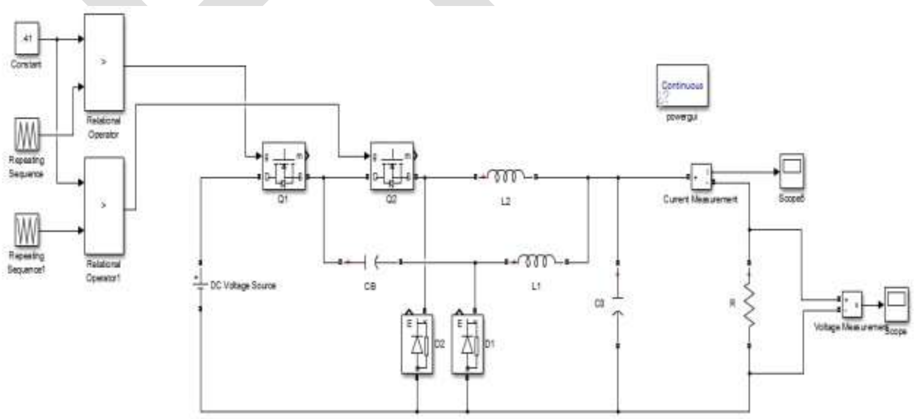

Fig.10 Simulation of Modified Interleaved buck converter

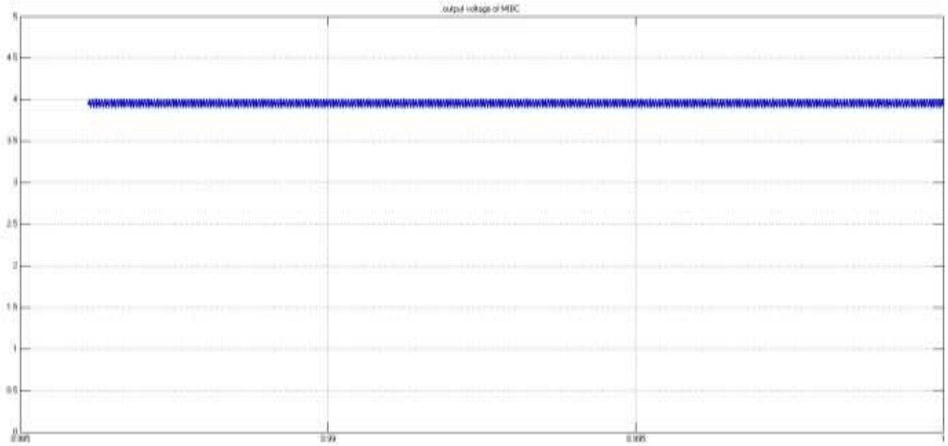

Fig. 11 Output voltage of Modified Interleaved buck converter

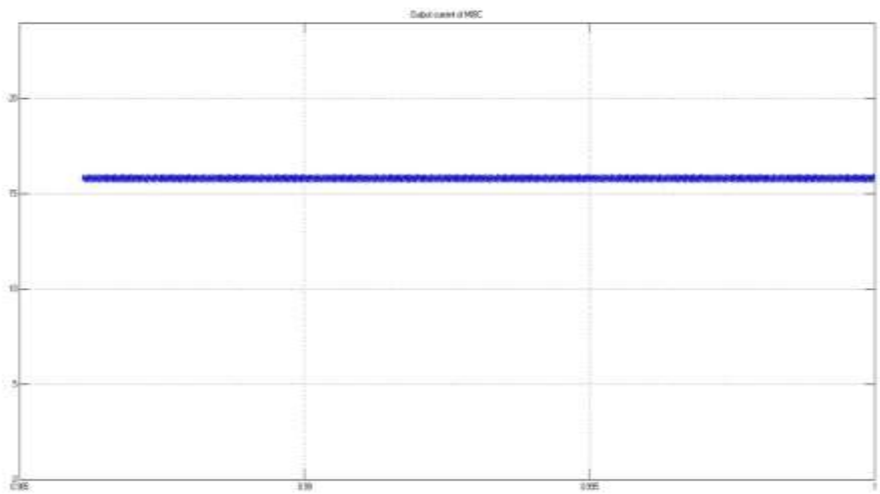

Fig. 12 Output current of Modified Interleaved buck converter

In this paper the simulation of buck converter, interleaved buck converter and modified interleaved buck converter is done and their output voltage and current waveforms are shown above. The analysis is done only for duty ratio less than 0.5. Their analysis of output voltage and ripple contents are shown in table below.

CONVERTER	BUCK	IBC	MIBC
DUTY RATIO	D	D	0.5D for D<0.5 D^2 for D>0.5
INPUT VOLTAGE	24	24	24
OUTPUT VOLTAGE	>4	>4	>4
VOLTAGE RIPPLE	0.43	0.344	0.1065
CURRENT RIPPLE	0.0496	0.0397	0.352

ACKNOWLEDGMENT

I would like to thank to almighty, my teachers, parents and friends for successfully completing this paper work.

CONCLUSION

In this paper, from the analysis of buck, interleaved buck and modified interleaved buck converter we can conclude that the current ripple and the voltage ripple is very low for interleaved buck converter. Modified interleaved buck converter is used for high input voltage, high step down and non-isolation applications. They have low switching loss and improved step down conversion ratio.

REFERENCES:

[1] Il-Oun Lee; Shin-Young Cho; Gun-Woo Moon, "Interleaved buck converter having low switching losses and improved step-down conversion ratio," *IEEE Trans. Power Electron*, vol.27, no.8, pp.3664,3675, Aug. 2012.

[2] Mohan Undeland Riobbins, "Power Electronics converters Applications, and Design"

[3] R. L. Lin, C. C. Hsu, and S. K. Changchien, "Interleaved four-phase buck-based current source with isolated energy recovery scheme

for electrical discharge machine," *IEEE Trans. Power Electron.*, vol. 24, no. 7, pp. 2249–2258, Jul. 2009.

[4] C. Garcia, P. Zumel, A. D. Castro, and J. A. Cobos,"Automotive DC–DC bidirectional converter made with many interleaved buck stages," *IEEE Trans. Power Electron.*, vol. 21, no. 21, pp. 578–586, May 2006.

[5] J. H. Lee, H. S. Bae, and B. H. Cho, "Resistive control for a photovoltaic battery charging system using a microcontroller," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2767–2775, Jul. 2008.

[6] Y. C. Chuang, "High-efficiency ZCS buck converter for rechargeable batteries," *IEEE Trans. Ind. Electron.*, vol. 57, no. 7, pp. 2463–2472, Jul. 2010.

[7] C. S.Moo, Y. J. Chen, H. L. Cheng, and Y. C. Hsieh, "Twin-buck converter with zero-voltage-transition,"*IEEE Trans. Ind. Electron.*,

vol. 58, no. 6, pp. 2366– 2371, Jun. 2011.

[8] X. Du and H. M. Tai, "Double-frequency buck converter," *IEEE Trans. Ind. Electron.*, vol. 56, no. 54, pp. 1690–1698, May 2009.