# A Non-Isolated Boost Charger for the Li-Ion Battery Suitable for the Fuel Cell Powered Laptop Computer

Nguyen Van Sang and Woojin Choi

Department of Electrical Engineering, Soongsil University,

***Abstract* – In spite of its compactness and lightness, conventioan boost converter is not preferred for the charge applications. In this paper, a non-isolated boost converter topology for the Li-Ion battery suitable for fuel cell powered laptop computer is proposed and analyzed. The proposed converter has an additional inductor at the output to reduce the output ripple current and voltage. This feature makes it suitable for the charger application by eliminating the disadvantages of the conventional non-isolated boost converter mentioned above.**

***Index Terms*–Non-isolated Boost Converter, BatteryCharger, Laptop Computer, Output Inductor, Ripple Current**

## I. INTRODUCTION

In these days, the portable electronics are more fully-featured than ever before and the users are increasingly dependent on these mobile devices and are spending ever-longer-periods of time without access to ac sources. The fuel cells are good candidates to replace batteries as power sources for the next generation portable electronics such as laptop computer owing to its high energy density guaranteeing the longer operation time. However, in order to use the fuel cell in parallel with the Li-ion battery as new power source, the conventional power architecture needs to be modified. In this paper a direct boost charger is introduced to charge the Li-Ion battery of the laptop computer from fuel cell source [1].

The conventional boost converter is a well-known and simple topology which is widely used in many applications in spite of its limitation on continuous conduction mode (CCM) such as poor dynamic response and discontinuous output current. However, it is unsuitable for battery charging application due to its high ripple current at the output. The ripple current can cause the undesirable effects to the battery such as appreciable heating thereby reducing the battery life. This also decreases the efficiency of the battery, resulting in less net current available to be drawn from the battery.

## II. PROPOSED POWER DISTRIBUTION ARCHITECTURE OF THE FUEL CELL POWERED LAPTOP COMPUTER

Fig. 1 shows the proposed power distribution architecture of the fuel cell powered laptop computer. A fuel cell system is located externally to supply the power to the laptop when the ac source is not available. The fuel cell voltage is stepped up through the boost converter and directly charges the battery pack. The voltage regulator modules, battery pack, power monitor, power path controller are inside laptop. When ac input is available, the switch Q1 is on, connecting the ac-dc converter to the VRM through the buck converter. When the ac input is lost, switch Q2 connect the fuel cell system and boost charger to the battery pack to charge the battery through switch Q3 and the energy from the battery is used for the laptop operation.

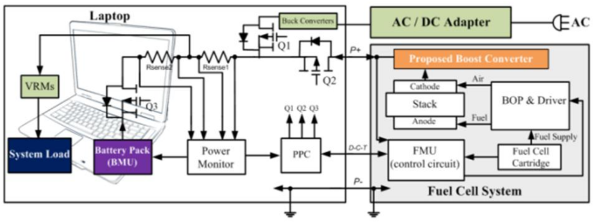

Fig. 1.Proposed power distribution architecture of the fuel cell powered laptop computer

## III. MODEL DEVELOPMENT OF THE PROPOSED BOOST CONVERTER TOPOLOGY

Fig.2 shows the proposed boost converter topology for the battery charger. The additional inductor (Lo) produces the continuous current and makes the output current ripple smaller. The battery is modeled with an R-C series circuit, where R and C represent the equivalent series resistance and the equivalent capacitance of the battery respectively [2].

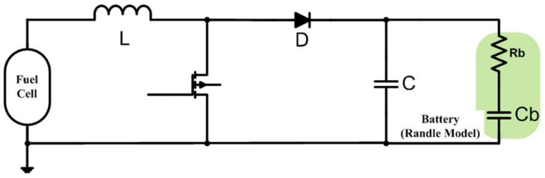

Fig. 2.Proposed boost converter topology suitable for the charge application

PWM converters can be modeled with a circuit averaging technique. The switch is modeled as a current-dependent current-source in CCM operations, where the total duty cycle is $\bar{d} = D + \tilde{d}$ , and the input inductor current is $\bar{i}_L = I_L + \tilde{i}_L$ .The resulting model becomes $\bar{i}_S = \bar{d} \times \bar{i}_L$ and $\bar{v}_D = \bar{d} \times \bar{v}_C$. The small-signal model of the proposed converter can be redrawn as Fig. 3

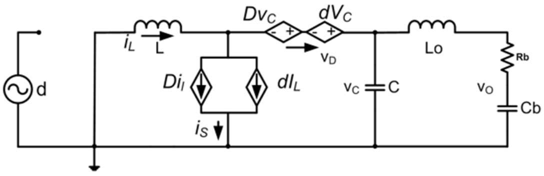

Fig. 3.Small-signal model of the proposed boost converter with battery load

By using KVL and KCL, the control-to-output voltage transfer function and the control-to-input current transfer function can be derived as (1) and (2), respectively.

$$Gvd\big|_{\tilde{v}_{in}=0} = \frac{V_o}{1-D}\,\frac{1+s\left(C_bR_b - L(1-\frac{V_b}{V_o})\frac{1}{R_b(1-D)^2}\right) - s^2C_bR_bL(1-\frac{V_b}{V_o})\frac{1}{R_b(1-D)^2}}{1+sC_bR_b+s^2\left(C_bL_0+\frac{C_bL}{(1-D)^2}\right)+s^3\frac{LCC_bR_b}{(1-D)^2}+s^4\frac{LL_0CC_b}{(1-D)^2}} \quad (1)$$

$$Gid\big|_{\tilde{v}_{in}=0} = \frac{\frac{I_0}{1-D} + s\left(C_b + \frac{I_0 R_b C_b}{1-D}\right) + s^2\left(\frac{I_0 L_o C_b}{1-D} + V_{in} R_b C_b C\right) + s^3 V_{in} L_0 C_b C}{1 + sR_b C_b + s^2\left(\frac{LC_b}{1-D} + L_0 C_b\right) + s^3 \frac{LR_b C_b C}{1-D} + s^4 \frac{LL_0 C_b C}{1-D}} \qquad (2)$$

## IV. DESIGN OF THE CHARGE CONTROLLER

In this section, the control algorithm of the proposed boost converter is discussed. Fig.4 is the block diagram of battery charge control algorithm using a double control loop. It consists of an outer control loop, regulating the converter output voltage (CV Mode) and an inner control loop, serving for current control (CC Mode).

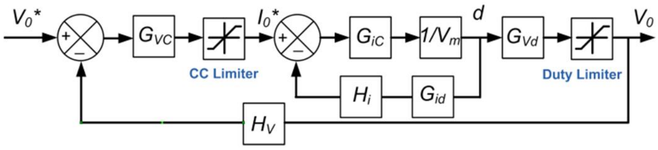

Fig. 4. Block diagram of the battery charge control algorithm

In the control output voltage ($V_0$) is detected and compared with reference voltage ($V_0$*). Then the error signal is generated and amplified to generate the current reference ($I_L$*). Since the charge control starts with constant current (CC Mode) at the beginning, the current reference should be limited at the appropriate value of the inductor current. The current reference ($I_L$*) is then compared with the measured input current and generates the error signal, which is transmitted to the current controller. The output of the current controller is then compared with the triangular wave to generate the PWM signal for the switch.

## V. SIMULATION

The system parameters for the simulation can be found in the Table 1.

TABLE I. SYSTEM PARAMETERS FOR THE PSIM SIMULATION

| | | |
|---|---|---|
| Input voltage/ Output voltage | $V_{in}/V_{out}$ | 6 ~ 10/12.6 V |
| Output power/ Frequency | $P_O$/f | 45 W/60kHz |
| Input inductor/ Additional inductor | L/ $L_O$ | 32 µH/6 µH |
| Capacitor | C | 1000 µF |
| Equivalent capacitance of the battery | $C_b$ | 9660 F |
| Equivalent series resistance of the battery | $R_b$ | 0.3 Ω |

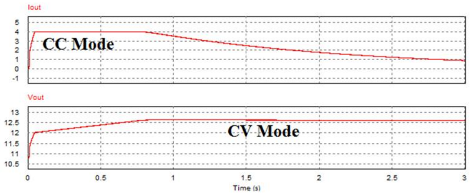

Fig. 5. PSIM simulation results of the proposed boost charger

From the result in Fig.5, it can be seen that the battery charge current is regulated at the reference value of 4[A] during the CC mode. The voltage of laptop battery gradually increase until it reaches to the upper limit of the charge voltage and then the battery charger automatically shifts to CV mode. In the CV mode, the battery voltage is kept constant at 12.6[V] and the charge current decreases exponentially.

## VI. EXPERIMENTAL RESULTS

To implement the CC/CV mode control algorithm mentioned in the previous section, the digital signal processor (DSP) "TMS 20F28335" from TI was used for full digital control of the proposedboost charger and its charge algorithm.

Fig. 6 shows the output ripple current of the conventional boost converter and the proposed boost converter. As can be seen in the Fig.6, the output ripple current was reduced to 0.102[A] due to an output inductor of which value is 6[µH].

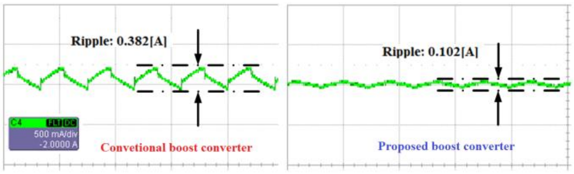

Fig. 6.Output ripple current of the converters

Fig.7 shows the output ripple voltage of the conventional boost converter and the proposed boost converter.

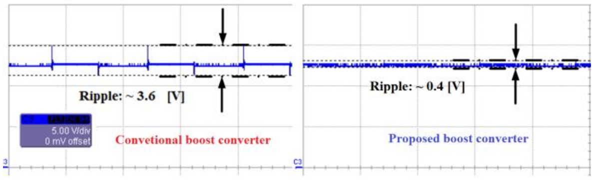

Fig. 7.Output ripple voltage of the converters

To maximize performance, the voltage regulation tolerance on the voltage applied to the cell should be better than ±1% [3].As can be seen in the figures, ripple voltage of the proposed boost charger was reduced from 3.6[V] to 0.4[V] and it satisfies the requirement of the voltage ripple for the battery.

## VII. CONCLUSION

In this paper, a non-isolated boost converter topology for the Li-Ion battery suitable for fuel cell powered laptop computer was proposed and implemented. The proposed converter has an additional inductor at the output to significantly reduce output ripple values of the voltage and current, making it suitable for boost charge application

## VIII. REFERENCES

[1] Yalcinoz, T.; Alam, M.S.;"The Dynamic Performance of PEM Fuel Cells under Various Operating Conditions of a Laptop Computer" EUROCON, 2007. The International Conference on "Computer as a Tool"

[2] Bryant, B.; Kazimierczuk, M.K.;"Small-signal duty-cycle to inductor current transfer function for boost PWM DC-DC converter in continuous conduction mode" Circuits and Systems, 2004. ISCAS '04. Proceedings of the 2004 International Symposium on

[3] Scott Dearborn.; "Charging Li-ion Batteries for Maximum Run Times" Power Electronics Technology Magazine, April 2005.