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BLIL PFC Boost Converter for Plug in Hybrid Electric Vehicle Battery Charger

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Abstract: ***AC-DC Converters are the key component in the battery chargers of PHEV (Plug-in Hybrid Electric Vehicles). Most commonly used AC-DC PFC (Power Factor Correction) topologies in PEHV battery chargers are conventional PFC boost converter, bridgeless PFC boost converter and interleaved PFC boost converter. To overcome the disadvantages of the above mentioned topologies bridgeless interleaved (BLIL) PFC boost converter was developed. The conventional PFC boost converter and bridgeless interleaved PFC Boost topology were designed and simulated using MATLAB/SIMULINK. Conventional PFC Boost Converter was designed for interval D=0.6 and bridgeless interleaved topology were designed for two duty intervals D>0.5 and D<0.5.The input performance parameters such as THD (Total Harmonic Distortion) and power factor for the two topologies were obtained and comparison were made between the two topologies. The input supply voltage used for both the converters are 230V.***

Keywords: AC-DC Converter, Power Factor Correction, Bridgeless PFC Converter, Interleaved PFC converter.

1. Introduction

A plug-in hybrid electric vehicle utilizes rechargeable batteries, or another energy storage device, that can be restored to full charge by connecting a plug to an external electric power source [2]. The most common charger architecture includes an AC input filter, AC-DC PFC topology [3] and DC output filter as shown in Fig.1. Proper selection of AC-DC PFC topologies is essential to meet the regulatory requirement for input current harmonics and implementation of power factor correction at the input.

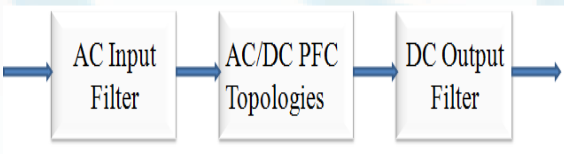

Figure 1: PHEV Charger Architecture

In Section II a review of common AC–DC PFC topologies used in PFC battery chargers are done. Novel bridgeless interleaved (BLIL) boost topology is described in Section III. Design and simulation result of conventional PFC boost converter and BLIL PFC is given in section IV. In section V simulation results of two converters are given.

2. Common AC-DC PFC Topologies

The conventional PFC boost converter, bridgeless PFC boost converter and interleaved PFC boost converter are the common AC-DC PFC topologies used in PHEV battery chargers. The review of the above mentioned three topologies are provided in the following sections.

2.1 Conventional PFC Boost Converter

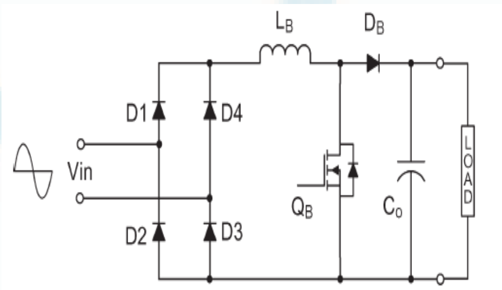

Figure 2: Conventional PFC boost converter

It has a diode bridge rectifier at the input which is used to rectify the input AC voltage into DC voltage. This rectified voltage is given to the PFC boost converter where the input voltage gets stepped up. It has two modes of operations. During the first mode, the switch will be closed. During this time the inductor will get charged to its peak value of voltage (V_L) [4]. During this time the capacitor will maintain the output voltage.

$$V_L = L\frac{di}{dt} \quad (1)$$

When the switch is open, inductor will discharge to the load. With this topology, the output capacitor ripple current is very high [8] and is the difference between diode current and the dc output current. Furthermore, as the power level increases, the diode bridge losses significantly degrade the efficiency.

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2.2 Bridgeless PFC Boost Converter

During the positive half cycle, Q_1 and Q_2 are turned on, the inductors will get charged through the path: Supply-L_1-Q_1-Q_2 (body diode)-L_2 -Supply. When the switches are turned off, the inductors discharge through the path: Supply-L_1-D_1-Load-Q_2 (body diode)-L_2-Supply.During the negative half cycle the voltage across the inductor L_2 and L_1 will rises as the current flows through the path: Supply-L_2-Q_2- Q_1 (body diode) L_1-supply. When the switches are turned off, the inductors L_2 and L_1 will discharge through the path: L_2-D_2-Load-L_1-supply.The disadvantages of this topology are it introduces increased EMI and floating input line with respect to the PFC stage ground [5].

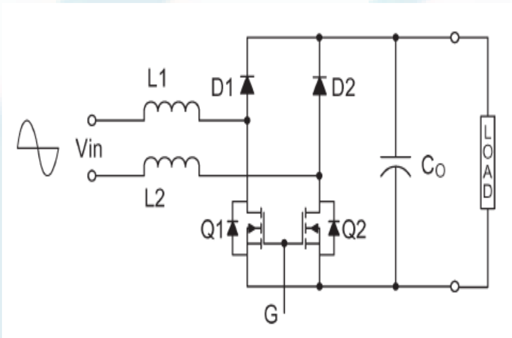

Figure 3: Bridgeless PFC boost converter

2.3 Interleaved PFC Boost Converter

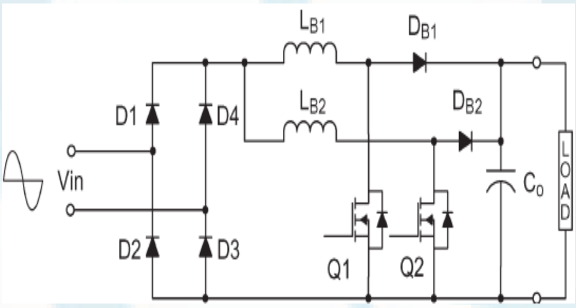

Figure 4: Interleaved PFC boost converter

The interleaved boost converter, illustrated in Fig. 3, consists of two boost converters in parallel, operating 180^0 out of phase [7].Since the two converters are connected out of phase with each other the ripples will cancel each other and the ripple content will get reduced. So the size of filter can be reduced. The input current is the sum of the current through the two inductors. It has two switches Q_1 and Q_2.During the first half cycle the switch Q_1 will be on, the inductor L_{B1} will get charged. When the switch Q_1 is off the inductor will start to discharge through the diode D_{B1}.During the negative half cycle the same operation will happen but the switch Q_2, L_{B2} and D_{B2} will operate. One significant drawback of the interleaved boost PFC converter is that similar to the boost PFC converter, loss will be high due to the input diode bridge.

3. Bridgeless Interleaved PFC Boost Converter

It has the same device count as the interleaved boost converter. BLIL boost converter uses 4 fast diodes and 4 MOSFETs in which losses will be less and efficiency will be high[1]. The circuit diagram of the BLIL boost converter is shown Fig.5. The circuit operation can be divided into positive half cycle and negative half cycle operation. The operations of the converter mainly depend upon turn on/turn off of the switches. So the circuit operation depends on the duty cycle (D) of the converter. The detailed circuit operation for the positive half cycle and negative half cycle (D<0.5 & D>0.5) operation is given in the following sections.

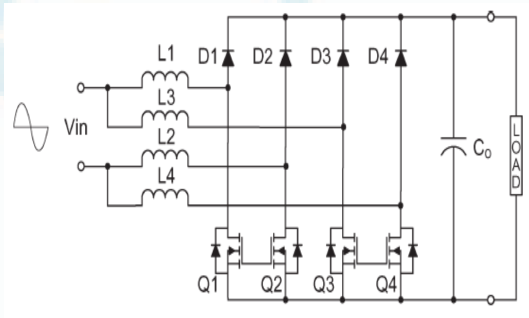

Figure 5: BLIL PFC boost converter

3.1. Positive Half Cycle Operation

During the positive half cycle, the switch Q_1 and Q_2 turn on, inductors L_1 and L_2 get charged (energy stored) through the path: L_1-Q_1- Q_2 (body diode)-L_2 and back to supply. When the switch Q_1 and Q_2 turn off, inductors L_1 and L_2 discharges (energy released) through the path: L_1-D_1-Load-Q_2 (body diode)-L_2 and back to supply. The supply voltage along with the voltage across the inductor will appear across the load which will produce a boosted voltage across the load.

With interleaving, the same mode happens for the switch Q_3 and Q_4, but with 180^0 phase delay. When the switch Q_3 and Q_4 on, the inductor L_3 and L_4 will get charged (energy stored) through the path: supply-L_3-Q_3-Q_4 (body diode)-L_4 back to the supply. When the switch Q_3 and Q_4 turn off, inductors L_3 and L_4 will discharge (energy released) through the path: L_3-D_3-Load-Q_4 (body diode)-back supply. Since the ripple current in two inductors L1 and L3 are in anti phase with each other, the high frequency ripple will cancel each other. This will reduce the ripple content caused due to boost switching.

3.2. Negative Half Cycle Operation

During the negative half cycle, switch Q_1 and Q_2 turn on the inductor L_2 and L_1 get charged (energy stored) through the path: L_2-Q_2-Q_1 (body diode)-L_1 back to supply. When the switches Q_1 and Q_2 turn off, inductors L_1 and L_2 will discharge (energy released) through the path:Supply-L_2-D_2-Load-Q_1(body diode)-L_1-Supply.

With interleaving, the same mode happens for the switch Q_3 and Q_4, but with 180^0 phase delay. When the switch Q_3 and Q_4 are on, the inductor L_3 and L_4 will get charged (energy stored) through the path: Supply-L_4-Q_4-Q_3 (body diode)-L_3-Supply. When the switch Q_3 and Q_4 turn off, inductors L_3 and L_4 will discharge (energy released) through the path: Supply-L_4-D_4-Load-Q_3 (body diode)-L_3-Supply.

4. Design and Simulations

4.1. Conventional PFC Boost Converter

The duty ratio is given by [4], [6]:

$$D = \frac{V_{out} - V_{in}}{V_{out}} \quad (2)$$

The value of capacitor and the inductor can be obtained from the relation below:

$$C = \frac{V_{out} \times D}{f \times \Delta V \times R} \quad (3)$$

ΔV-Ripple voltage (0-10% of output voltage)
f- Frequency
R- Load resistance
C- Capacitance

$$L = \frac{V_{in} \times D}{\Delta I \times f} \quad (4)$$

ΔI-Ripple current (0-20% of the load current)

Table 1: Parameters of Conventional PFC Boost Converter

Input Voltage	*230V*
Output Voltage	575V
Inductance	$1.89*10^{-3}$H
Capacitance	$3.44*10^{-5}$F
Resistor	52.27Ω
Switching Frequency	66.666KHz
Duty ratio	0.6

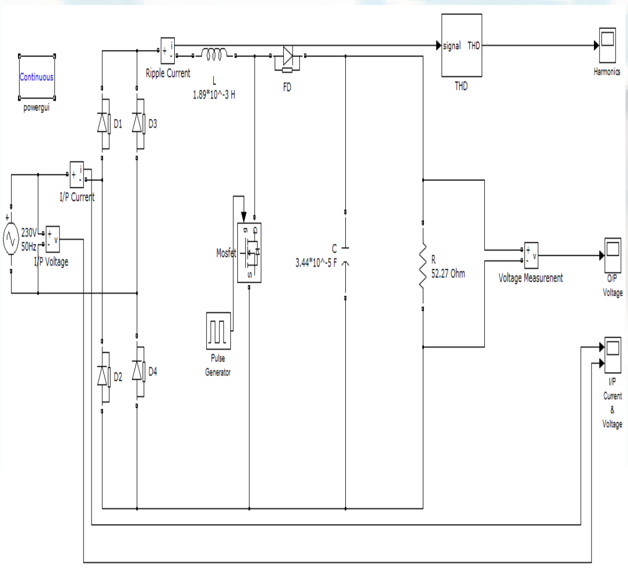

Figure 6: Simulation of conventional PFC boost converter

4.2. BLIL PFC Boost Converter

The duty ratio is given by:

$$D = \frac{V_{out} - V_{in}}{V_{out}} \quad (5)$$

The value of capacitor and the inductor can be obtained from the relation below:

$$C = \frac{V_{out} \times D}{f \times \Delta V \times R} \quad (6)$$

ΔV-Ripple voltage (0-10% of output voltage)
f- Frequency
R- Load resistance
C- Capacitance

$$L = \frac{V_{in} \times D}{\Delta I \times f} \quad (7)$$

ΔI-Ripple current (0-20% of the load current)

The converter is designed for the switching frequency of 66.666 KHz and duty ratio of 0.6.The parameter values are tabulated as shown below.

Table 2: Parameters of BLIL PFC Boost Converter (D>0.5)

Input Voltage	230V
Output Voltage	575V
Inductance	$1.89*10^{-3}$H
Capacitance	$3.44*10^{-5}$F
Resistor	52.27Ω
Switching Frequency	66.666KHz
Duty Ratio	0.6

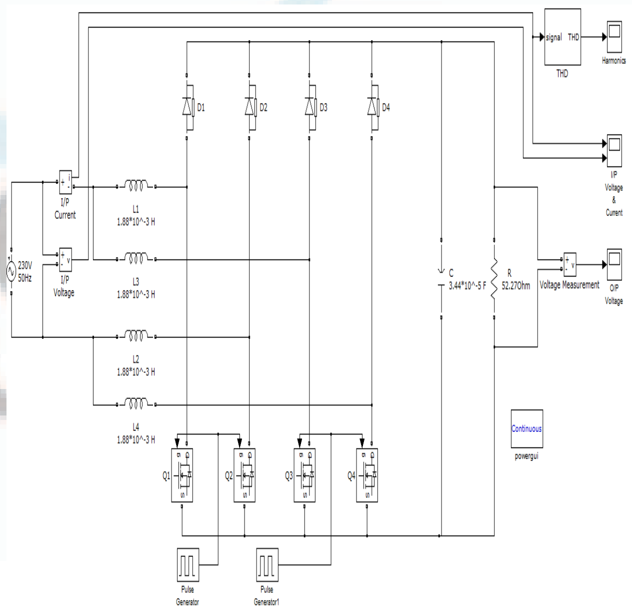

Figure 7: Simulation of BLIL PFC boost converter (D>0.5)

Table 3: Parameters of BLIL PFC Boost Converter (D<0.5)

Input Voltage	230V
Output Voltage	383.33V
Inductance	$1.25*10^{-3}$H
Capacitance	$3.44*10^{-5}$F
Resistor	34.84Ω
Switching Frequency	66.666KHz
Duty Ratio	0.4

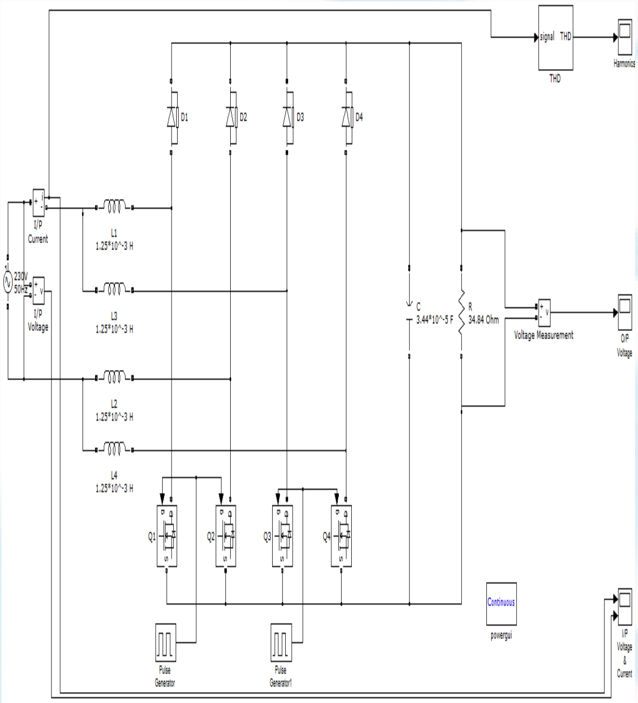

Figure 8: Simulation of BLIL PFC boost converter (D<0.5)

5. Simulation Results

The conventional PFC Boost Converter and BLIL PFC boost converter were simulated using MATLAB/SIMULINK and the resulting waveforms are as shown below.

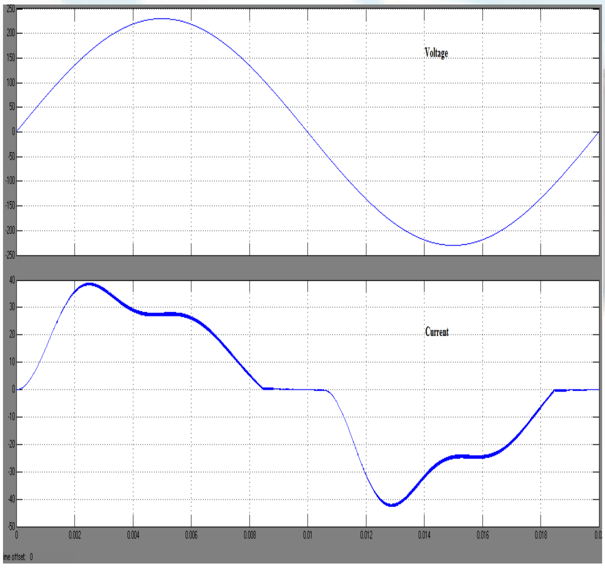

Figure 9: Input current and voltage waveform of conventional PFC boost converter

Analysis:
1. The total harmonic distortion was calculated to be 0.7882.
2. The power factor was obtained as 0.778.

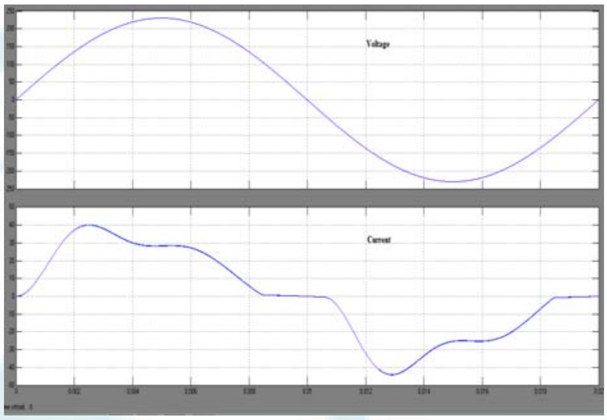

Figure 10: Input current and voltage waveform of BLIL PFC boost converter (D>0.5)

Analysis:
1. The total harmonic distortion was calculated to be 0.059
2. The power factor was obtained as 0.9982.

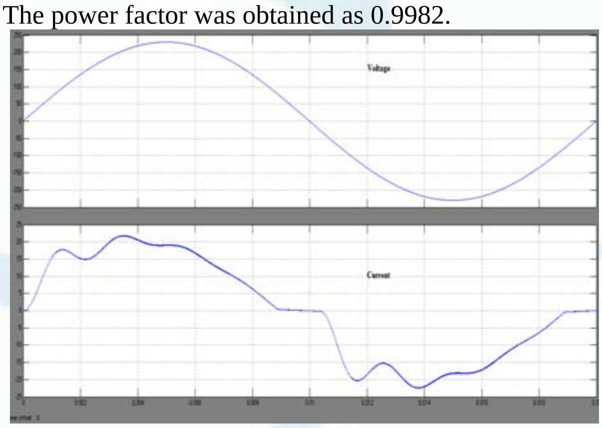

Figure 11: Input current and voltage waveform of BLIL PFC boost converter (D>0.5)

Analysis:
1. The total harmonic distortion was calculated to be 0.078
2. The power factor was obtained as 0.996.

Table 4: Comparison of Input Performance Parameters

Converter	*THD*	*PF*
Conventional Boost	0.7882	0.7853
BLIL(D>0.5)	0.059	0.9982
BLIL(D<0.5)	0.078	0.9962

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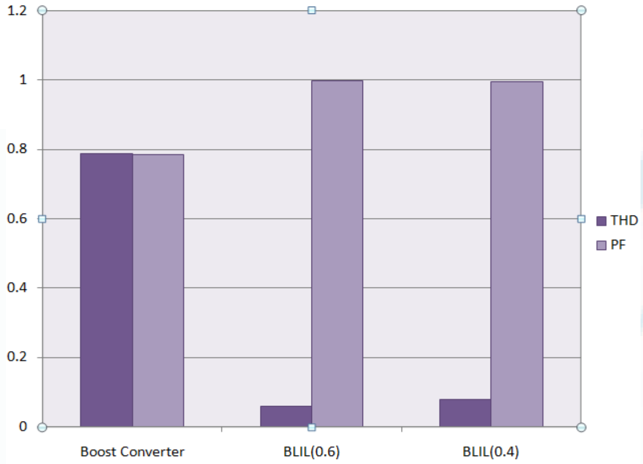

Figure 12: Comparison of THD and power factor of two converters

6. Conclusions

The conventional PFC boost converter and BLIL PFC boost converter were simulated using MATLAB/SIMULINK. The comparisons between the input performance parameters were made. It was found the total harmonic distortion was lower for the BLIL PFC boost converter and power factor is greater than the conventional boost converter. Form this it is clear that the BLIL PFC boost converter is a better topology compared to the conventional boost converter.

References

[1] F. Musavi, W.Eberle and W.G.Dunford "A high performance single- phase bridgeless interleaved PFC converter for plug-in hybrid electric vehicle battery chargers," IEEE Trans. Industry Applications., Vol. 47,pp. 1833–1843, Jul. 2011.
[2] K. Morrow, D. Karner, and J. Francfort, "Plug-in hybrid electric vehicle charging infrastructure review," U.S. Dept. Energy—Vehicle Technologies Program, Washington, DC, INL-EXT-08-15058, 2008.
[3] Singh, B. N. Singh, A. Chandra, K. Al-Haddad, A. Pandey, and D. P. Kothari, "A review of single-phase improved power quality AC–DC converters," IEEE Trans. Ind. Electron., vol. 50, no. 5, pp. 962–981,Oct. 2003.
[4] M.H.Rashid "Power Electronics," third edition pp-190
[5] L. Huber, Y. Jang, and M. M. Jovanovic, "Performance evaluation of bridgeless PFC boost rectifiers," IEEE Trans. Power Electron., vol. 23,no. 3, pp. 1381–1390, May 2008.
[6] B.M Hasaneen, and A.Elbaset Mohammed, "Design and simulation of DC/DC boost converter," IEEE Trans.ind.Electron, pp-335-340
[7] L. Balogh and R. Redl, "Power-factor correction with interleaved boost converters in continuous-inductor-current mode," in Proc. IEEE Appl.Power Electron. Conf. Expo., 1993, pp. 168–174.
[8] D. Xu, J. Zhang, W. Chen, J. Lin, and F. C. Lee, "Evaluation of output filter capacitor current ripples in single phase PFC converters," in Proc.PCC, Osaka, Japan, 2002, vol. 3, pp. 1226–1231.

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