International Conference on Interdisciplinary Research in Electronics and Instrumentation Engineering 2015 [ICIREIE 2015]

ISBN	978-81-929866-3-0
Website	www.icireie.org
Received	10 - July - 2015
Article ID	ICIREIE008

VOL	01
eMail	icireie@asdf.res.in
Accepted	31- July - 2015
eAID	ICIREIE.2015.008

A New Passive Snubber for Improvement of Efficiency in Soft Switched Boost PFC Converter for Battery Charging Systems

S. Aiswariya[1], R.Dhanasekaran[2]
[1]Assistant Professor, [2]Director - Research
Department of Electrical and Electronics Engineering
Syed Ammal Engineering College, Ramanathapuram, Tamilnadu, India

Abstract: *This paper proposes a new passive snubber for enhancing the power conversion efficiency on a single phase ac-dc power factor correction (PFC) converter based on boost topology for battery charging systems. Soft switching can be achieved in the proposed converter with the proposed auxillary passive snubber circuit which is added to the conventional boost PFC converter. The converter switch is provided with zero current switching turn ON. The converter is analysed in the continuous conduction mode. The proposed converter achieves high input power factor, low line input current harmonics, simple control and soft switching at turn ON. Contrasted with the conventional boost converter, the proposed PFC boost converter has lower switching stresses and higher voltage gain. The new prototype of 100 W / 20 kHz, 40* V_{dc} *output with 24* V_{ac} *input is verified experimentally with an efficiency of 96% with near unity power factor.*

Keywords: Battery charging systems, Boost converter, Current stress, Passive snubber, Soft switching, PFC, Voltage stress, ZCS, ZVS.

I. INTRODUCTION

Hybrid Electric vehicles are being made by manufacturers to reduce the carbon dioxide releases and to lessen the traditional fuel energy utilization. As of late, vehicle manufacturers are developing plug-in hybrid electric vehicles (PHEV) which decreases the environmental contamination. These vehicles have an AC/DC converter that provides power from a commercial power supply to an on-board charger along with a DC/DC converter to provide energy to its accessories. In light of the constraint in the charging time and restricted space, the AC/DC converters should have to be designed efficiently [1-5]. Battery chargers are another key sections required for the development and acceptance of PHEVs. For PHEV applications, the recognized system incorporates utilizing an as a part of vehicle charger [6]. The common charger that is utilized as a part of PHEV incorporates an AC-DC converter with power factor correction (PFC) followed by an isolated DC-DC converter with input and output EMI filters. The front-end ac–dc converter is a key part of the charger system. Proper choice of this topology is fundamental to meet the regulatory requirements for input current harmonics, output voltage regulation and implementation of power factor correction. The boost converter is one of the straightforward and most broadly utilized topology for the battery charger/discharger converter when isolation is not required. In high power applications, the voltage and current stress can easily go beyond the range that one power device can handle. The main sources

Cite this article as: S. Aiswariya, R. Dhanasekaran. "A New Passive Snubber for Improvement of Efficiency in Soft Switched Boost PFC Converter for Battery Charging Systems." *International Conference on Interdisciplinary Research in Electronics and Instrumentation Engineering (2015)*: 44-48. Print.

of switching losses in boost PFC converters are hard turn -ON of the MOSFET and the reverse recovery of the boost diode during its turn-OFF. Selecting the ideal topology and accessing power losses in power semiconductors are vital ventures in the design and advancement of these battery chargers [8].

The incorporated EV battery chargers into the electrical drive system have been accounted in the literature. Reference [9] presented the integrated battery chargers utilizing the inductor of induction motor during charging time to constitute a dc/dc boost PFC converter with the three-phase VSI. The battery voltage of this system should be more than maximum line-to-line peak voltage to ensure unity power factor operation. In [10], a single-phase integrated charger for an electrical scooter with an interior permanent magnet motor traction drive was shown. The battery system operated as a dc/dc boost PFC converter where the motor works as a coupled inductor, which utilised the three phase VSI as a switch in the charging mode. Different soft-switched boost converters with active or passive snubber circuits have been proposed. Power semiconductor devices commutate under two possible circumstances: hard and soft. With hard switching, the devices will change the states (ON or OFF) when both current and voltage are not zero. High switching stresses are because of overlap between voltage and current, and results in high switching losses.

Soft switching is intended to scale back the mentioned overlap between voltage and current at the commutation periods and can be classified in either active or passive methods. Snubber for a given application by and large varies.. Active methods will decrease the switching losses by using auxiliary switches. umfortunately, an auxiliary switch rises the complexity of both power and control circuits. The control strategy will be intense because of the issues connected with the proper understanding between control signals of the switches during Switching periods. Circuit cost is increased due to this and reliability is similarly affected by using active snubbers [11-14].Passive snubber circuits can achieve soft switching and lessen the reverse recovery current of a rectifier diode by using only passive components for example inductors, capacitors, and diodes without auxiliary switches. Compared with active snubber circuits, passive snubber circuits are by and large easier to design and have fewer components; therefore, they are less expensive, more reliable, and smaller [15]–[22].

A passive lossless snubber will effectively prohibit switching losses and EMI noise using no active elements and no power dissipative elements. No extra control is required and no circulating energy is produced. Circuit structure is as simple as RCD snubbers while circuit efficiency is as high as active snubbers and resonant converters. Less cost, good performance, and high reliability are the distinct benefits of a passive lossless snubber. The association of the paper is as follows: Section 2 gives the circuit of the proposed converter. Section 3 exhibits the experimental results. Comparison between the proposed topology and the conventional boost is given in Section 4. Section 5 concludes the paper.

II. THE PROPOSED PFC CONVERTER: PRINCIPLE OF OPERATION AND ANALYSIS

The circuit with the conventional boost converter incorporates boost inductor L_m, boost switch S, boost diode D_f and output capacitor C_o. Moreover, the proposed boost converter comprises of a passive snubber cell comprising of two inductors L_{S1}, L_{S2}, capacitor C_s and diode D_s. The proposed novel passive boost PFC converter comprises of five modes for one switching cycle. The equivalent circuit diagrams of the operation modes are given in fig. 2(a)–(e) respectively. The key waveforms related to the operation modes are shown in Fig. 1.

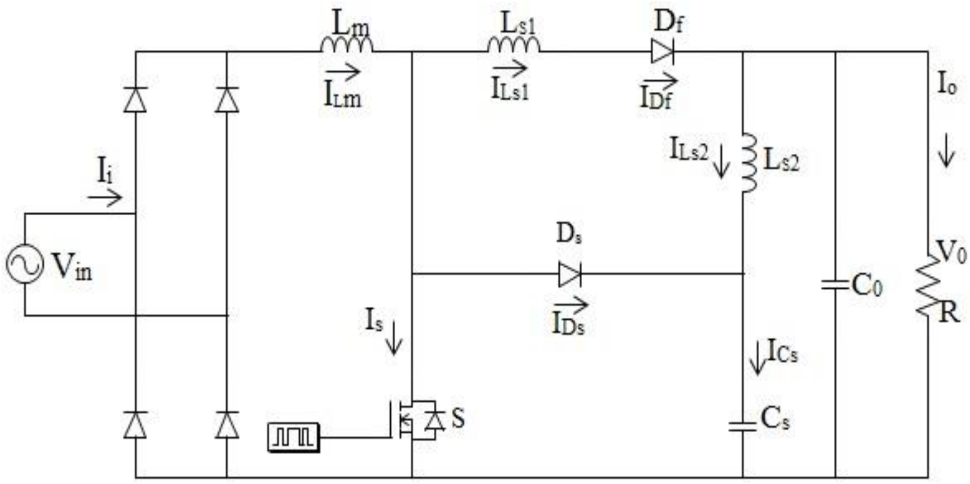


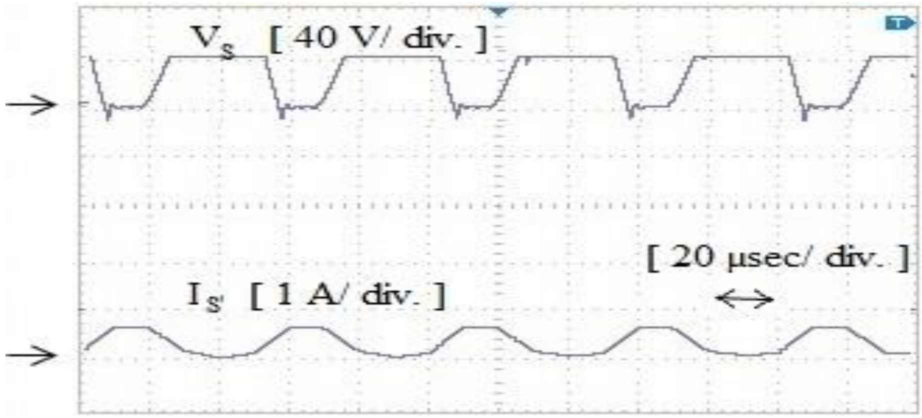
Figure. 1. Proposed Boost PFC Converter.

III. EXPERIMENTAL VERIFICATION

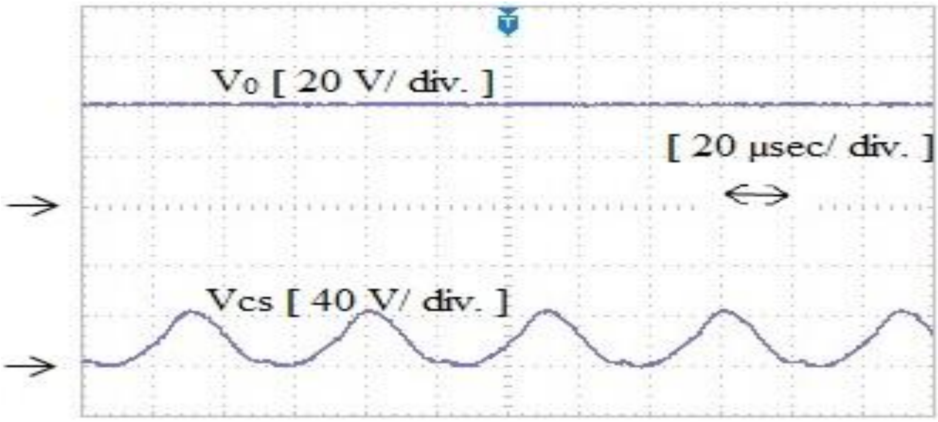
The performance of the proposed converter is verified by the experimental results based on a laboratory prototype. with rated specification and design.

Fig. 2 (a) demonstrates the waveforms of voltage and current of the switch S. As believed, the output voltage is seemed to be clamped across switch. It thus proved switch S is turned ON with ZCS.

Cite this article as: S. Aiswariya, R. Dhanasekaran. "A New Passive Snubber for Improvement of Efficiency in Soft Switched Boost PFC Converter for Battery Charging Systems." *International Conference on Interdisciplinary Research in Electronics and Instrumentation Engineering (2015)*: 44-48. Print.



(a)



(b)

Figure. 2. Measured waveforms for the proposed converter (a) main switch voltage V_S and main switch current I_S; (b) output voltage V_0 and voltage across snubber capacitance V_{CS}.

The voltage and current waveforms for the main switch S shows no overlap between them. Fig. 2 (b) shows the output voltage waveform and voltage across the energy transfer capacitor respectively. Based on the measured input/output current and voltage waveforms shown in Fig. 2, the measured efficiency is about 96%. The measured waveforms are in a good agreement with the key waveforms.

IV CONVENTIONAL BOOST PFC VERSUS THE PROPOSED BOOST PFC RECTIFIER

The conventional boost topology used for PFC applications uses a diode bridge to convert input AC voltage to DC voltage. The diode bridge is then followed by a boost converter. The boost converter has circuit components like a boost inductor, switch, diode and an output capacitor connected to the output side load. The boost converter is a type of DC-DC converter that helps in increasing the DC output voltage more than the input DC voltage.

Table 1. Performance comparison of the proposed PFC converter and the conventional PFC converters

Circuit Type	Switching Features	Components Count	Power Factor	Efficiency (%)
Conventional Boost PFC	Hard Switching	No extra Component	0.9641	91.18
Proposed passive Boost PFC	S – ZCS Turn ON and turn OFF	2 inductor 1 capacitor 1 Diode	0.9897	95.3

The problem associated with the boost PFC circuit is that, at higher power levels, the losses across the circuit increase; thereby the efficiency is reduced. The output capacitor current has more ripples. Due to these drawbacks, more heat is dissipated for a smaller area. The output voltage is not in a regulated manner and the input current is not perfectly sinusoidal. The voltage stresses on the switch S_1 and the diode D_3 of the proposed converter is less than that for the conventional boost converter. Therefore, these reduced voltage stresses can make the proposed converter to use a power MOSFET with low RDS-ON and Schottky diodes to reduce the reverse recovery problem of diodes. The following table presents a comparative performance of the proposed PFC and conventional PFC converters. The circuit parameters for the conventional PFC boost converter are the same as those used for the proposed

Cite this article as: S. Aiswariya, R. Dhanasekaran. "A New Passive Snubber for Improvement of Efficiency in Soft Switched Boost PFC Converter for Battery Charging Systems." *International Conference on Interdisciplinary Research in Electronics and Instrumentation Engineering (2015)*: 44-48. Print.

converter. An efficiency and power factor comparison between the conventional and the proposed boost rectifiers is performed based on simulation results. In this comparison, both rectifiers are assumed to operate in CCM with the same operating conditions and parameters. According to the simulation results, the simulated efficiency for the conventional boost is about 92 % while it is 96 % for the proposed boost rectifier with near unity power factor. It is clear that the efficiency of the proposed ZC-ZVS boost PFC converter is about 4 % higher than the conventional PFC boost converter at the full-load condition. The benefit obtained is the enhancement of overall circuit efficiency. The proposed converter achieves a near unity power factor at all output load levels and is comparatively higher than the conventional converters.

V. CONCLUSION

In this paper a passive snubber has been designed and developed for boost PFC rectifier in battery charging systems. The analysis was carried out in CCM mode. The converter switch is turned ON at zero current. The proposed draws perfect sinusoidal currents from the utility and has distinct good benefits like high power factor, low switching stresses and improved efficiency than that of the conventional PFC converters. The proposed converter is tested experimentally with a 100 W/20 kHz prototype. The converter efficiency is improved more than 4 % at full load. The proposed topology in this paper presents a simple and reliable technique for battery charging systems which is currently being researched and will be reported in the near future.

References

[1] Masayoshi Hirota, TakeshiBaba, Xiaoguang Zheng, Kazuhiko NII, Shingo Ohashi, Takeshi Ariyoshi and Hiroyuki Fujikawa, “Development of New AC/DC Converter for PHEVs and EVs,” Sei Technical Review , no. 73 , Oct. 2011.

[2] Juan de Santiago, Hans Bernhoff, Boel Ekergård, Sandra Eriksson, Senad Ferhatovic, Rafael Waters, and Mats Leijon, “Electrical Motor Drivelines in Commercial All Electric Vehicles: a Review,” *IEEE Transactions on Vehicular Technology*,2012.

[3] S. M. Lukic, J. Cao, R. C. Bansal, F. Rodriguez, and A. Emadi, “Energy storage systems for automotive applications,” *IEEE Trans. Ind. Electron*., vol. 55, no. 6, pp. 2258–2267, Jun. 2008.

[4] Y.-J. Lee, A. Khaligh, and A. Emadi, “Advanced integrated bidirectional AC/DC and DC/DC converter for plug-in hybrid electric vehicles,” *IEEE Trans. Veh. Technol*., vol. 58, no. 8,pp. 3970–3980, Oct. 2009.

[5] Fariborz Musavi, Wilson Eberle and William G. Dunford , “A High-ance Single-Phase Bridgeless Interleaved PFC Converter for Plug-in Hybrid Electric Vehicle Battery Chargers,” *IEEE Transactions on Industry Applications*, vol. 47, No. 4, July/August 2011.

[6] Lisheng Shi; Meintz, A.; Ferdowsi, M., "Single-Phase Bidirectional ACDC Converters for Plug-in Hybrid Electric Vehicle Applications," *IEEE Vehicle Power and Propulsion Conference, VPPC*, pp. 1 – 5, 2008.

[7] Singh, B.; Singh, B.N.; Chandra, A.; Al-Haddad, K.; Pandey, A.; Kothari, D.P., "A Review of Single-Phase Improved Power Quality ACDC Converters," *IEEE Transactions on Industrial Electronics*, vol. 50, pp. 962 - 981, 2003.

[8] Jinjun Liu; Weiyun Chen; Jindong Zhang; Dehong Xu; Lee, F.C., "Evaluation of power losses in different CCM mode single-phase boost PFC converters via a simulation tool " *in IEEE Industry Applications Conference*. vol. 4, 2001, pp. 2455 - 2459.

[9] Jung-Hyo Lee, Jung-Song Moon, Yong-Seok Lee, Young-Real Kim and Chung-Yuen Won, “Fast Charging Technique for EV Battery Charger Using Three-Phase AC-DC Boost Converter,” *IECON 2011-37th Annual Conference on IEEE Industrial Electronics Society., Melbourne, VIC*., pp. 4577-4582 , 7-10 Nov. 2011.

[10] Pellegrino, G., Armando, E. and Guglielmi, P., “An Integral Battery Charger With Power Factor Correction for Electric Scooter,” *Power Electronics, IEEE Transactions onpower Electron*., vol. 25, Issue: 3 , pp. 751–759, March 2010.

[11] Aiswariya. S, and Dhanasekaran. R, “Power Factor Correction Converter with an Active Snubber,” in *Proc. ICMTSET*, pp. 71-74, 2013.

[12] Aiswariya. S, and Dhanasekaran. R, “Simulation of a New Active Snubber for Power Factor Correction Converter Applications – A Performance Evaluation,” in *International Journal of Applied Engineering Research*, vol. 10, no. 6, pp. 5600-5605, 2015.

[13] Aiswariya. S, and Dhanasekaran. R, “A New Soft Switched Boost PFC Converter With An Active Snubber,” in *International Journal of Applied Engineering Research*, vol. 10, no. 5, pp. 4325-4330, 2015.

[14] Aiswariya. S, and Dhanasekaran. R, “An AC/DC PFC Converter with Active Soft Switching Technique,” in *International Journal of Energy Optimization and Engineering*, pp. 101-121, 2014.

[15] M. R. Amini and H. Farzanehfard, “Novel family of PWM soft-single switched dc–dc converters with coupled inductors,” *IEEE Trans. Ind. Electron*., vol. 56, no. 6, pp. 2108–2114, Jun. 2009.

[16] J. M. Kwon, W. Y. Choi, and B. H. Kwon, “Cost-effective boost converter with reverse-recovery reduction and power factor correction,” *IEEE Trans. Ind. Electron*., vol. 55, no. 1, pp. 471–473, Jan. 2008.

[17] R. H. Li, H. S. H. Chung, and A. T. Sung, “Passive lossless snubber for boost PFC with minimum voltage and current stress,” *IEEE Trans. Power Electron*., vol. 25, no. 3, pp. 602–613, Mar. 2010.

[18] R. J.Wai, C. Y. Lin, R. Y. Daun, and Y. R. Chang, “High-efficiency dc–dc converter with high voltage gain and reduced switch stress,” *IEEE Trans. Ind. Electron*., vol. 54, no. 1, pp. 354–364, Feb. 2007.

[19] C. A. Callo, F. L. Tofoli, and J. A. C. Pinto, “A passive lossless snubber applied to the ac–dc interleaved boost converter,” *IEEE Trans. Power Electron*., vol. 25, no. 3, pp. 775–785, Mar. 2010.

[20] R. J.Wai and R. Y. Daun, “High step-up converter with coupled-inductor,” *IEEE Trans. Power Electron*., vol. 20, no. 5, pp. 1025–1035, Sep. 2005.

Cite this article as: S. Aiswariya, R. Dhanasekaran. “A New Passive Snubber for Improvement of Efficiency in Soft Switched Boost PFC Converter for Battery Charging Systems.” *International Conference on Interdisciplinary Research in Electronics and Instrumentation Engineering (2015)*: 44-48. Print.

[21] R. H. Li and H. S. Chung, "A passive lossless snubber cell with minimum stress and wide soft-switching range," *IEEE Trans. Power Electron.*, vol. 25, no. 7, pp. 1725–1738, Jul. 2010.
[22] S. Aiswariya, and R. Dhanasekaran, "Simulation and Analysis of a Single Phase AC-DC Boost PFC Converter with a Passive Snubber for Power Quality Improvement," in *Proc. ICACCCT*, pp. 421-425, 2014.

Cite this article as: S. Aiswariya, R. Dhanasekaran. "A New Passive Snubber for Improvement of Efficiency in Soft Switched Boost PFC Converter for Battery Charging Systems." *International Conference on Interdisciplinary Research in Electronics and Instrumentation Engineering (2015)*: 44-48. Print.