New Active Snubber Boost PFC Converter for Efficiency Improvement in Home Appliances Applications

In Wha Jeong, Mingyu Park, Kee-Ju Um, Chang Jae Heo, JunHo Lee, Kwangsoo Kim, Bum-Seok Suh, Yong-Wook Kim*, and Rae-Young Kim*

FP Lab, Samsung Electro-Mechanics Co., Ltd.
Energy Electronics Control System Lab, Hanyang University*

Abstract - **This paper proposes a new active snubber boost PFC converter to provide a zero-voltage-switching (ZVS) turn-on condition and reduce electromagnetic interference (EMI) noise in home appliances and renewable energy applications, including solar or fuel cell electric systems. The proposed active snubber circuit enables a main boost switch of the boost-type PFC or grid converter to turn on under a ZVS condition and reduce the switching losses of the main boost switch. Moreover, for the purpose of a specialized intelligent power module (IPM) fabrication, the proposed boost circuit is designed to satisfy some design aspects such as space saving, low cost, and easy fabrication. Simulation and experimental results of a 2kW IPM boost-type PFC converter are provided to verify the effectiveness of the proposed active snubber boost circuit.**

1. INTRODUCTION

Renewable energies have enormous potential to become the most dominant energy source in the future. Especially, solar or photovoltaic (PV) cells are the main source for capturing the sun's energy and experiencing the highest growth rate of any energy producing technology. With today's advanced technologies, PV power systems improve the flexibility and security of the power transmission network through a modular and distributed power generation approach.

Intelligent power modules (IPMs) are used in a variety of applications, including renewable energy, motor control, traction systems, home appliances, and other industrial applications. For a PV system, the PV modules convert solar energy into DC current and the IPM-based grid converters invert the DC into high quality AC source to transfer the generated solar energy to the utility grid. These IPM-based boost converters offer a high overall efficiency, large power density, long reliability, and low converter cost.

Various power converter techniques and topologies have been proposed and used in order to improve the boost converter performances for home appliances and renewable energy applications. One of the widely used techniques is a soft switching, which generates zero-voltage-switching (ZVS) and/or zero-current-switching (ZCS). Several benefits of this technique include improved efficiency, reduced stresses and electromagnetic interference (EMI) noises.

In this paper, a new active snubber boost circuit is proposed to provide a ZVS turn-on switching and reduced EMI noise level for the conventional boost circuit of the boost power factor correction (PFC) or grid converters. The operating principle, theoretical analysis, and design procedure of the proposed boost circuit are explained. Simulation and experimental verification are also provided by a 2kW IPM-based boost converter with the active snubber in a boost PFC application.

2. PROPOSED BOOST CIRCUIT PRINCIPLE

Fig. 1 shows the circuit scheme of the proposed boost converter with an active snubber. This boost circuit differs from the conventional PWM boost converter, which consists of an auxiliary inductor L_r and an active snubber switch S_2. Generally, the active snubber switch S_2 has lower power rating than the main boost switch S_1. The following assumptions are given to make the steady state analysis during one switching cycle.

a) Input voltage V_{in} is constant.
b) Output capacitor C_o is large enough.
c) Main boost inductor L_f is large enough.
d) Main inductor L_f is much larger than the auxiliary inductor L_r.

For one switching cycle, the proposed circuit operations can be divided into eight stages. Each stage waveforms and equivalent circuits are shown in Fig. 2.

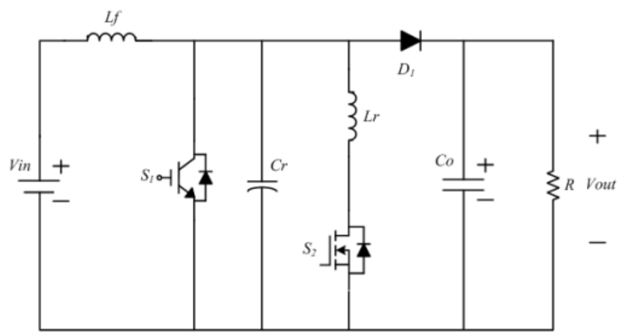

Fig. 1. Proposed Active Snubber Boost Converter Topology

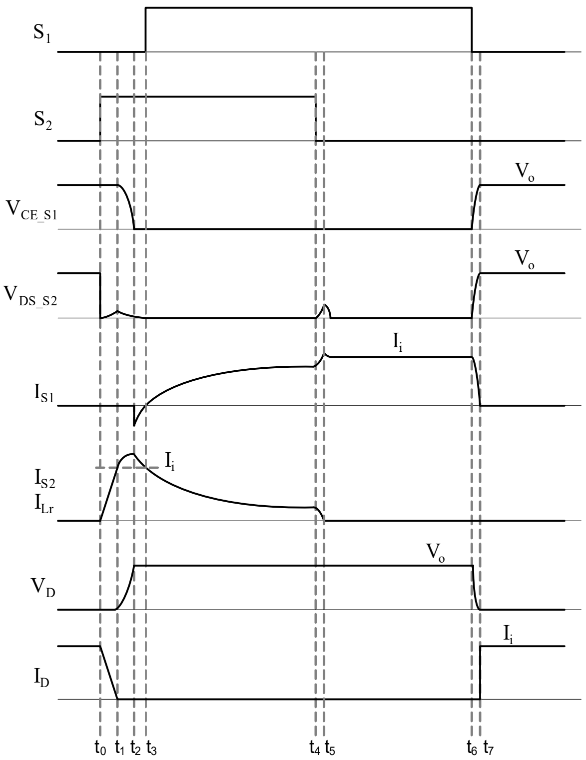

Fig. 2. Waveforms of Proposed Active Snubber Boost Converter

3. EXPERIMENTAL RESULTS

Two different kinds of 2kW active snubber boost converter prototypes in Fig. 3 and Fig. 5 have been built to verify the effectiveness of the proposed active snubber boost circuit.

The current and voltage waveforms of the main boost IGBT and active snubber IGBT are shown in Fig. 4 and Fig. 6. It can be seen that the main boost IGBT turns on with ZVS condition, which provides low switching losses and reduced EMI noise level for the boost PFC converter. The efficiency of the proposed active snubber boost PFC converter is about 97.4%.

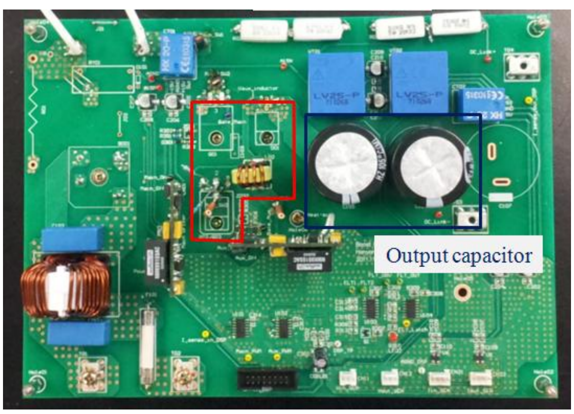

Fig. 3. 2kW Discrete-Level Boost PFC Converter with Active Snubber

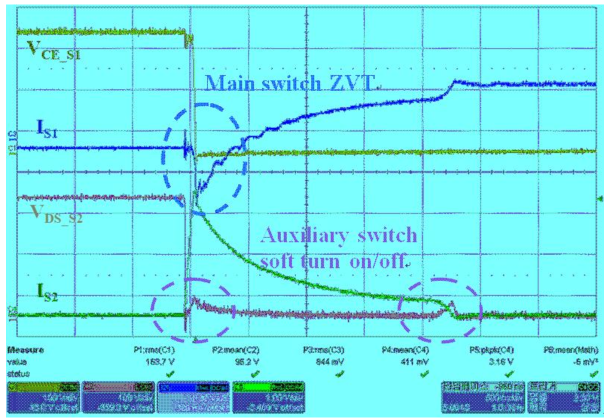

Fig. 4. Boost IGBT and Active Snubber IGBT Turn-On Waveforms of Proposed Discrete-Level Boost PFC Converter

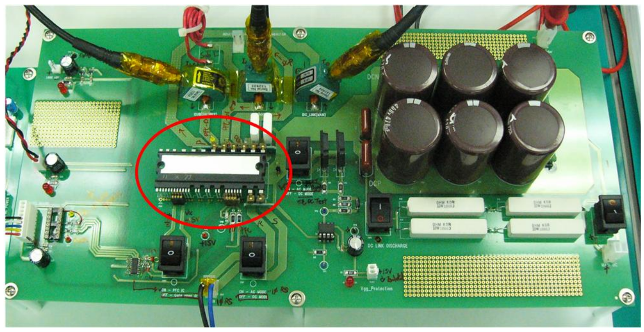

Fig. 5. 2kW IPM-Level Boost PFC Converter with Active Snubber

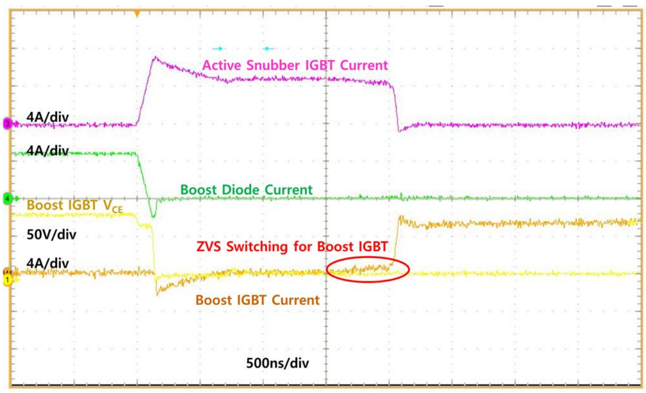

Fig. 6. Boost IGBT ZVS Turn-On Waveforms of Proposed IPM-Level Boost PFC Converter

4. CONCLUSION

This paper presents a new active snubber boost circuit for the boost PFC or grid converters in home appliances and renewable energy applications. As shown in experimental results, the proposed method improves the efficiency by ZVS operation of the main boost IGBT, and reduces current and voltage stresses of the main boost and active snubber IGBTs. Finally, this research shows that IPM-based boost PFC converters can be the best cost-effective platform to improve the overall efficiency of home appliances and renewable power systems.