Novel Family of PWM Soft-Single-Switched DC–DC Converters With Coupled Inductors

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***Abstract*—In this paper, a novel family of pulsewidth-modulation soft-single-switched dc–dc converters without high voltage and current stresses is described. These converters do not require any extra switch to achieve soft switching, which considerably simplifies the control circuit. In all converter family members, the switch is turned on under zero-current condition and is turned off at almost zero-voltage condition. From the proposed converter family, the boost topology is analyzed, and its operating modes are explained. The presented experimental results of a prototype boost converter confirm the theoretical analysis.**

***Index Terms*—Pulsewidth modulation (PWM), soft-single switched (SSS), zero-current switching (ZCS), zero-voltage switching (ZVS).**

I. INTRODUCTION

IN ORDER to reduce the size and weight of switching converters and increase power density, a high switching frequency is required. However, in hard-switching converters, as the switching frequency increases, switching losses and electromagnetic interference increase. To solve this problem, soft-switching converters are indispensable.

In recent years, great amount of research is done to develop soft-switching techniques in dc–dc converters. In these converters, it is desirable to control the output voltage by pulsewidth modulation (PWM) because of its simplicity and constant frequency. A low number of components, particularly active components, is also desirable. Quasi-resonant converters do not have any extra switch to provide soft-switching conditions; however, they must be controlled by the variation of switching frequency [1]. Furthermore, zero-voltage transition, zero-current transition, and active clamped converters are PWM controlled but require at least two switches, which increases the complexity of power and control circuits [2]–[9].

PWM soft-single-switched (SSS) converters [10]–[14] and lossless passive snubbers [15], [16] enjoy all the mentioned advantages, usually at the cost of additional current and voltage stresses. However, they usually have a large number of passive elements, which makes the converter implementation difficult [10]–[14], [16]. The lossless passive snubber circuit introduced in [15] is simple and easy to implement. However, in this converter, a soft-switching condition is not achieved for the switch turnoff instant. Furthermore, in [16], an additional diode is added in the main power path, which would further increase the converter conduction losses.

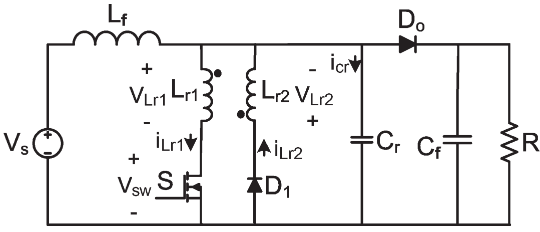

Fig. 1. Proposed PWM SSS boost converter.

In this paper, a family of PWM SSS converters without any substantial increase in voltage and current stresses is presented. Furthermore, in this converter family, the number of additional components is not high. The switch in all proposed converters is turned on under zero-current-switching (ZCS) condition and is turned off at almost zero-voltage-switching (ZVS) condition. The converter main diode turns on under ZVS condition and turns off under zero-voltage zero-current switching (ZVZCS) conditions. Furthermore, an auxiliary diode turns on under ZVS condition and turns off under ZCS condition. The proposed method can be easily applied to single-switch converters such as buck, boost, buck–boost, Cuk, SEPIC, and Zeta. Furthermore, it can be applied to isolated single-switch converters such as forward, flyback, isolated Cuk, isolated SEPIC, and isolated Zeta.

In this paper, from the proposed PWM SSS converters, the boost converter is analyzed, and its operating modes are described in Section II. General design considerations and experimental results from a 120-W 100-kHz prototype boost converter are presented in Sections III and IV, respectively. The topology variation of the proposed converter is illustrated in Section V.

II. CIRCUIT DESCRIPTION AND OPERATION

The circuit configuration of the proposed boost converter is shown in Fig. 1. The circuit components including L_{r1}, L_{r2}, D_1, and C_r are added to the conventional boost converter. It is assumed that L_f and C_f are large enough so that they can be replaced by a current source (I_{in}) and a voltage source (V_o), respectively.

To further simplify the converter analysis, it is assumed that all circuit components are ideal. The nonideal effects of circuit components, particularly the leakage inductance of the coupled inductors, are discussed in Section IV. It is assumed

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