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A lossless switching technique for smart grid applications

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ABSTRACT

Smart grid is an upgrade of the existing electricity infrastructure in which integration of non conventional energy sources are an integral part. This leads to the introduction of harmonics and increased switching losses in the system. Thus there is a need of loss less switching techniques for smart grid applications. Switched mode power supplies (SMPSs) are being extensively used in most power processes [1]. Developments were carried out centered on hard switched converters, where switching frequency is limited to 10 s of kHz [2]. The uses of soft switching techniques, [3–6] zero voltage switching (ZVS) or zero current switching (ZCS), is an attempt to substantially reduce the switching losses and hence attain high efficiency at increased switching frequency. The soft-switching topologies belong to families namely resonant load converters [3], resonant switch converters [2,4], resonant transition converters [5,6], and most recently active clamped PWM converters [7–9]. The active clamp topology adds an active clamp network, consisting of a small auxiliary switch in series with a capacitance plus the associated drive circuitry to the traditional hard switch converters. The proposed paper basically deals with the design, modeling and simulation of a ZVS–PWM active clamp/reset forward converter having features like zero switching power losses, constant frequency and PWM operation, Soft-switching for all devices and Low voltage stresses on active devices due to clamping action.

1. Introduction

A smart grid is a digitally enabled electrical grid that accommodates attributes from suppliers as well as consumers. The smart grid can be viewed as a digital upgrade of the existing electricity infrastructure to allow for dynamic optimization of current operations as well as incorporate dynamic gateways for alternative sources of energy production. The telecommunication industry today is already using 'smart' technologies, some of which can be borrowed for smart operation of the electricity industry. The objectives of a smart grid are to minimize the cost of energy and reduce emissions.

A smart grid has certain basic functions for modernization of the grid:

- Have a self-healing capability.
- Be fault-tolerant by resisting attacks.
- Allow for integration of all energy generation and storage options including plug-in vehicles.
- Allow for dynamic optimization of grid operation and resources with full cyber-security.
- Allow for incorporation of demand-response, demand side and energy efficient resources.
- Allow electricity clients to actively participate in the grid operations by providing timely information and control options.
- Improve reliability, power quality, security and efficiency of the electricity infrastructure [16].

In order to carry out the functions mentioned above, switching at different level is required through power electronics converters.

One of these circuits, Fig. 1a, was employed in a flyback converter [15] to achieve soft switching too. The other circuit, Fig. 1b, with some modification was employed in forward converter to achieve soft switching too. Ref. [8] gives the steady state analysis of the active clamp/reset forward converter. The design consideration required for designing active clamp forward converter and flyback converter is also presented in [8].

Figs. 1a and 1b show the active clamp/reset forward converter. The main problems associated with this existing active clamp/reset forward converter is hard-switching of passive devices and parasitic ringing caused by the interaction of rectifier diode junction capacitance with resonant inductor L, induces high voltage stress on passive deices.

Under this condition voltage stress will be twice of the input voltage reflected to secondary side. Ideally, this parasitic ringing can be eliminated by inclusion of a clamping diode D_c [11], as shown in Fig. 2, limiting the voltage stress on the rectifier to the input voltage reflected to the secondary side.

Although the voltage stress on the rectifier has been eliminated, by the inclusion of clamping diode, all the diodes still present hard

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