EMI Modeling and Reduction of Conducted Noise in Switching Power Converters

張, 柏華

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氏　　名　：張　柏華

論 文 名　：EMI Modeling and Reduction of Conducted Noise in Switching Power Converters
（スイッチング電源の EMI モデリングと伝導ノイズ低減に関する研究）

区　　分　：甲

論　文　内　容　の　要　旨

With the development of the power electronics techniques, the switching power converters tend to become more and more compact and efficient. However, associated with the continuously improved switching frequency and switching speed, electromagnetic interference (EMI) and electromagnetic compatibility (EMC) issues have become more and more important for the application of the switching power converters.

This thesis studies the modeling and reduction method of conducted EMI emissions in power converters by applying the Fourier series expansion as a tool of noise spectra analysis, especially the EMI modeling of DC-DC converters and the zero-crossing spike current noise reduction in totem-pole bridgeless PFC converter.

In Chapter one, an introduction to EMI and EMC, and the EMI emission measurement and regulations are presented, the importance of the EMI control of the switching power converters and the thesis outlines are introduced as well.

In Chapter two, the Fourier series expansion is applied as a useful method for analyzing EMI problems in switching power converters. The basic of Fourier series expansion and the calculation of the Fourier coefficients of different typical waveforms in switching power converters are reviewed; the calculation of the Fourier coefficients of some specific waveforms is also discussed.

In Chapter three, an accurate noise source model for the simple frequency domain EMI modeling method is proposed. The classical frequency domain EMI modeling method is relatively simple and convenient, however suffers from the inaccuracy of the high-frequency noise modeling. On the basis of the analysis of generation mechanism of the noise source waveforms, an accurate noise source model composed by an S-shape waveform and exponential sinusoidal waveforms is proposed to improve the accuracy of high-frequency noise modeling. Also, the accuracy of the proposed noise source model is evaluated by transforming the expressions from frequency domain to time domain and comparing with the experimentally measured waveforms. Finally, the accuracy of the classical frequency domain EMI modeling method with the proposed noise source model is evaluated on a DC-DC buck converter and a DC-DC boost converter, by comparing the calculated and experimentally measured noise spectra. Furthermore, the noise spectra calculated using the conventional noise source model and the proposed noise source model are compared to verify the improvement of EMI noise modeling brought by the proposed noise source model.

In Chapter four, EMI prediction and reduction of zero-crossing spike current issue in totem-pole bridgeless power factor correction (PFC) converter are presented. Totem-pole bridgeless PFC converter is one of the bridgeless PFC converter family that proposed to improve the efficiency of the converter by removing the diode bridge to eliminate its conduction loss. However, a spike current occurs at every input voltage zero-crossing due to its specific topology, and becomes a severe noise source thus rendering the application of this highly efficient PFC converter. The generation mechanism of the zero-crossing spike current is presented to investigate the EMI problem caused by this issue. The noise spectrum due to this issue is predicted by a theoretical analysis based on the Fourier coefficient of an approximated spike current waveform. Finally, on the basis of the analysis, a noise reduction method is proposed and then improved to efficiently reduce the spike current, and verified by experimental measurements implemented on a GaN-based totem-pole bridgeless PFC converter, the noise peak caused by zero-crossing spike current in the high-frequency range of the noise spectrum can be approximately reduced by 8 dB. Furthermore, the noise spectra measured without and with the reduced zero-crossing spike current are compared to validate the analysis of the noise spectrum caused by the zero-crossing issue.

In Chapter five, the contributions of this thesis are summarized, and the expected future work is presented.