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論 文 名　：Modeling and Suppression Techniques of Common Mode Conducted EMI Noise in Power Electronic Converters
（電力変換器のコモンモード伝導 EMI ノイズのモデリングおよび低減技術に関する研究）

区　　分　：甲

論　文　内　容　の　要　旨

Electromagnetic interference (EMI) issues in power electronic converters are associated with the high-speed operation of semiconductor switches. On one hand, the emergence of wide-gap semiconductor (like Silicon Carbide and Gallium Nitride) with high power and high switching frequency made the EMI emission more prominent. While on the other hand, the modern power converter is developing towards miniaturization and lightweight, which impose harsh requirement on the volume of EMI filters. For these reasons, an accurate EMI noise model is essential to study the EMI generation mechanism, evaluate the EMI problems and predict the effectiveness of the noise filter.

This thesis studies the modeling and mitigation technology of common mode (CM) conducted EMI noise in power converters. The research objects include DC-DC non-isolation converter, DC-DC isolation converter and DC-AC inverter. Due to the characteristics and application scenario of different converters, behavioral modeling method and analytical modeling method are investigated. About the noise mitigation research, a noise filter design based on behavioral model and the impedance balancing technology optimization based on analytical model are investigated in this study.

In chapter one, the research background, basic knowledge about EMI measurement and standards, state of art review of noise modeling and suppression technologies in power electronic converters are introduced.

In chapter two, an improved CM noise modeling method based on terminal port theory is introduced. Compared with previous behavioral modeling methods, the proposed method has a clear inner structure and better accuracy. Specifically, the clear structure of two-port terminal can help strengthen the connection of noise model and the physical circuit. In addition, the proposed interpolation algorithm can improve model accuracy by reducing impedance error. This method is utilized in both boost converter and the single-phase inverter. Using the proposed noise model, not only the EMI noise filter at input side, but also the harmonic filter at the output side are evaluated as well.

In chapter three, a novel analytical modeling method is developed to analyze the CM noise in flyback converter. The noise generation mechanism is investigated at first and the simplified noise model is proposed accordingly. Compared with the former work, the accuracy of this proposed noise model is improved in two aspects: 1. The ringing voltages generated with turn

on and off of the switch are been considered in the noise source model; 2. The leakage inductance of the flyback transformer is taken into account when analyzing the noise current propagation. The former one could improve the accuracy of noise source, especially the high frequency segments. The latter one firstly discussed the leakage inductance, which was ignored by the previous studies but plays a certain role in the noise current transmission path. The experimental spectrum could successfully demonstrate the feasibility and effectiveness of the proposed noise model.

In chapter four, the CM noise mitigation technology with balanced impedance is analyzed and modified. The analytical noise modeling method, which proposed in the third chapter, is utilized to analyze the balanced boost converter, which helps to make clear the EMI noise generation mechanism and investigate the noise current propagation. In this chapter, the noise source attenuation degree is evaluated by combining the noise spectra and the impedance information. Therefore, the effectiveness of the balance technology could be directly evaluated. In addition, two optimized schemes were proposed to deal with the noise peak, which is a major drawback of the previous work. Experimental results show that the noise peak has been attenuated at the conducted frequency band with proposed schemes, and the noise suppression effect is even better than the normal choke filter.

In chapter five, the entire thesis is summarized and some ideas and proposals are presented for future work.