Time & Location: March 29, 2012 at 8:00 AM in HEC 356
Title: Analysis and Design Optimization of Resonant DC-DC Converters

The development in power conversion technology is in constant demand of high power efficiency and high power density. The DC-DC power conversion is an indispensable stage for numerous power supplies and energy related applications. Particularly, in PV micro-inverters and front-end converter of power supplies, great challenges are imposed on the power performances of the DC-DC converter stage, which not only require high efficiency and density but also the capability to regulate a wide variation range of input voltage and load conditions. The resonant DC-DC converters are good candidates to meet these challenges with the advantages of achieving soft switching and low EMI. Among the resonant converters, the LLC converter is very attractive for its high gain range and providing ZVS from full load to zero load condition.

The operation of the LLC converter is complicated due to its multiple resonant stage mechanism. In this dissertation, a literature review of different analysis methods are presented, and it shows that the study on the LLC is still incomplete. Therefore, an operation mode analysis method is proposed, which divides the operation into six major modes based on the occurrence of resonant stages. The resonant currents, voltages and the DC gain characteristics for each mode is investigated. To get a thorough view of the converter behavior, the boundaries of every mode are studied, and the mode distribution is discussed. An experimental prototype is built and tested to demonstrate its accuracy in operation waveforms and gain prediction.

Since most of the LLC modes have no closed-form solutions, simplification is necessary in order to utilize this mode model in practical design. As the peak gain is an important design parameters indicating the LLC’s operating limit of input voltage and switching frequency, a numerical peak gain approximation method is developed, which provide a direct way to calculate the peak gain and its corresponding load and frequency condition. In addition, as PO mode is the most favorable operation mode of the LLC, its operation region is investigated and an approximation approach is developed to determine its boundary.

The design optimization of the LLC has always been a difficult problem as there are many parameters affecting the design and it lacks clear design guidance in selecting the optimal resonant tank parameters. Based on the operation mode model, three optimization methods are proposed according to the design scenarios. These methods focus on minimize the conduction loss of resonant tank while maintaining the required voltage gain level, and the approximations of peak gains and mode boundary can be applied here to facilitate the design. A design example is presented following one of the optimization procedure. As a comparison, the L-C component values are reselected and tested while the design specifications are the same. The experiments show that the optimal design has better efficiency performance.

Finally, a generalized approach for resonant converter analysis is developed. It can be implemented by computer programs or numerical analysis tools to derive the operation waveforms and DC characteristics of resonant converters.

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Approved for distribution by John Shen, Committee Chair, on March 9, 2012.

The public is welcome to attend.