Abstract

Power electronic converters have experienced a surge in popularity due to their ability to meet the expanding demands of industrial applications. Power electronics applications require either a DC supply or an AC supply for operation. Among the power electronics converters, DC-DC converters occupy a significant portion of the power handling scale. The current focus is on enhancing energy efficiency and integration of renewable energy sources with step-up converters. Broadly, DC-DC converters with high voltage gain act as front-end converters for driving various loads. High-intensity discharge lamps (HID) for automobiles, network servers, data centers, and fuel cell electric vehicles are a few of the applications of high-voltage gain converters.

This thesis proposes high-voltage gain converters to meet the requirements of DC loads. Two categories of power converters are demonstrated in this thesis based on the duty cycle operation. This thesis enhances the performance of high-gain DC-DC converters by integrating voltage-boosting techniques with unique structural arrangements at the input side. The first contribution of the thesis is achieving a high voltage conversion ratio through low-duty cycle operation while minimizing voltage stress on both the switches and diodes. Initially, the thesis demonstrates the high-gain DC-DC converters based on impedance source networks to power DC loads. Within this category, a quasi-impedance source-based converter is presented, which can also supply both DC and AC loads as a hybrid converter. These converters offer higher voltage gains compared to contemporary alternatives. The low-duty operation of these converters reduces the conduction losses caused by switches, diodes, and the internal resistance of passive components. Performance improvements include reduced voltage stress, reduced costs, and improved efficiency.

The second contribution of this thesis involves arranging converters in a manner that allows for achieving a high voltage conversion ratio with low current stress

through the inductors. Additionally, wide-duty operation-based converters are proposed. However, impedance source converters require larger-rated inductors to achieve the same output power, resulting in bulkier sizes. In this type of network, only active switches participate in charging the inductor without the need for an additional switch. The input current is equally divided into ASL networks, and inductors carry an equal amount of current for the entire duty cycle range ($0 < D < 1$). The key features of the ASL network are low switch current and low voltage across it (one-fourth of output voltage). Furthermore, an interleaved converter is proposed with a similar gain to achieve soft switched-based zero voltage switching (ZVS) without using additional components. The third contribution of this thesis introduces a modified ASL network with the shared ground to minimize low electromagnetic interference (EMI) and achieve flexible higher gain through a combination of two duty cycles.

Finally, a closed-loop PI controller controls the proposed converters for voltage regulation. Analyzing the operation of these converters involved detailed and comprehensive analytical derivations and simulation studies. Moreover, the performance of the proposed converters was evaluated against that of previously reported converters. Experimental validation of the converters' operation was conducted using laboratory prototypes. These proposed converters present a promising alternative to existing converter options in residential and industrial applications requiring higher DC voltages.