Switched LC based High Voltage Gain Power Electronic Interfaces for Low Voltage DC Sources

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by

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6.1 Conclusion

This thesis presents a high voltage gain DC-DC converter using voltage boosting techniques. Two classes of high gain converters are discussed based on the duty cycle operations, called a low and wide range of duty operation. In the first category, low-duty operations of the impedance source converters are discussed. In these converters, the maximum duty cycle is limited to 50%. The voltage stress of these converters are lesser than the output voltage. Furthermore, an improved version of the Z-source converter is proposed to achieve high gain at a lower range of duty cycle. This converter addresses the limitation of a traditional Z-source converter. Its salient features include higher voltage conversion as compared to other Z-source converters for lower shoot-through duration but at the cost of more components. In the Z-source high-voltage gain converters, the input inductor is always in series with the source voltage. To achieve a voltage conversion ratio, more current is drawn from the source side, which eventually increases the size and rating of inductors for the same load power.

Another category of high voltage gain DC-DC converters is referred to as wide-duty operation converters. These converters use an ASL network at the low voltage side, while a passive capacitor network is integrated on the load side. The arrangement of inductors and switches in these converters are strategically used to minimize the voltage and current stress. These ASL-based converters achieve high gain at low-duty cycle with lower component count. Furthermore, an ASL converter can achieve ZVS-based soft switching for discontinuous input current. This drawback of the ASL network is resolved by using, an interleaving structure to accomplish ZVS operation with a continuous input current and improved efficiency.

Moreover, an improved version of the ASL network with three switches is developed to achieve higher voltage gain. In this converter, flexible gain is achieved by the combination of two duty cycles. The main switch can be operated at a low duty range to reduce the conduction losses of ASL network switches and thereby enhance converter efficiency. All the proposed converters are validated experimentally at a certain duty cycle, which is in good accordance with the theoretical analysis. Magnetic components, namely inductors, are involved in voltage boosting techniques, and to reduce the converter size, the ASL network provides better solutions. In high-gain converters, small variations in the duty can significantly enhance the voltage gain. To control the load voltage, a PI controller is used and experimentally validated for voltage regulation.

Overall, the five converters proposed in this thesis are mainly for high-gain DC-DC conversion, where each converter has its own merits. From the proposed converters, quasi Z-source converters achieve high voltage gain for a low range of duty cycle, which reduces the conduction loss of the semiconductor devices. On the other hand, ASL-derived converters require a low component count, low voltage stress across semiconductor devices, and low current stress through inductors to achieve a voltage conversion ratio. Due to topological advantage, these proposed solutions are potential candidates for household/industrial applications.

6.2 Future work

A small change in the duty cycle leads to a large change in the gain of the converters. In order to precisely control the gain, controller requirement is the key challenge for high-gain converters. Numerous methods for designing controllers to regulate DC-DC power converters have been presented. Among these approaches, utilizing the single-input, single-output capabilities of MATLAB provides a more straightforward method for designing voltage-mode controllers. Nonetheless, these designs do not inherently ensure the proper closed-loop performance and cannot be guaranteed across diverse operating scenarios. Moreover, high gain converters have the problem of right half zero. Therefore, it becomes difficult to track the reference quantity. Conventionally, PI controllers are fulfilling the purpose at the cost of limited dynamic performance (in terms of precise control on gain, tracking, and transient performance). Although, customized controllers could be used for non-minimum-phase systems. Other strategies can be investigate to mitigate the impact of the right-half plane zero. Furthermore, inductor placement at the load side with SC multiplier can mitigate the issue of RHZ at the cost of discontinuous input current. In order to address these challenges, the researchers can investiagte other control ideas which could meet the demand of the high gain converter. Based on the above discussion, it is apparent that forthcoming efforts might concentrate on improving non-isolated high-gain converters.

1. The high gain boost converter has a right-hand zero in the s-plane, making the system response sluggish; there would be a need for a fast controller for voltage regulations.

2. Thermal management, efficiency, and reliability are some concerns of these front-end high-gain converters, and they could be the future scope of these converters.

3. A compact structure, unique gate driver design, and utilization of better SiC devices would result in low electromagnetic noise.

4. Achieving a high conversion ratio with low device stress, minimum EMI with common ground features, and low component count are the trade-offs for high-gain converters. To fulfill all these features in a single topology is a challenge.

5. Integrating renewable sources to extract maximum power and maintain voltage regulation at the load side during standalone or single-stage mode can be the future work for these front-end converters.

Finally, achieving a compact power converter structure has become a necessity. A compact printed circuit board (PCB) and the substitution of conventional silicon devices with wide-bandgap power devices may be potential solutions. Key attributes such as minimal resistance and reduced switching losses are crucial in determining overall efficiency. This would reduce the size and improve the efficiency of high-gain DC-DC converters, which could be advantageous for residential applications.