PhD Public Defence

Title: An Optimized Dual Active Bridge Converter for EV On-board Charger

Location: Online (find stream link on et.aau.dk) - PON 101 1.001

Time: Monday 23 November 2020 at 13.00

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Opponents: Assistant Professor Daniel-Ioan Stroe, Dept. of Energy Technology, Aalborg University (Chairman)
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All are welcome. The defence will be streamed live in English.

Abstract:

With the global interests and efforts to popularize electric vehicles (EVs) due to their zero carbon emission, the EV sales are increasing fast in recent years. As key part, the on-board charger (OBC) considerably facilitates the development of the EV industry by providing the freedom to fueling the vehicle anywhere electricity is available, especially in the metropolitan areas. However, due to the space and weight limitation in an EV, the OBC requires a high power density DC-DC converter transferring the power from a rectified DC-link to the battery pack in the vehicle.

The dual active bridge (DAB) converter has drawn worldwide attention as a promising candidate for the OBC application. Much research has been done to improve the DAB performance regarding different aspects such as efficiency and reliability. Nonetheless, there are still challenges ahead, which should be addressed to advance the on-board charging. Firstly, an accurate modeling of the DAB converter is needed to investigate the effect of the control variable on the power transfer. Due to the high-frequency ac current of the transformer, it is challenging to build an accurate DAB model because the commonly used moving average model is no longer suitable. Besides, the model is expected to incorporate the power dissipation on the active and passive components so that it can offer an easy way to evaluate the whole OBC performance and alleviate the controller design.

Secondly, one key advantage of the DAB converter is the zero-voltage-switching (ZVS) achievement for all power semiconductor devices. However, the ZVS is easy to lose in light load and can not be guaranteed in a wide battery voltage range. The soft-switching failure could lead to greatly increased switching losses due to the high switching frequency, and even further destroy the power device caused by excessive changing rate of the drain-source voltage during the switching transients. Therefore, accurate ZVS range calculation is demanded for the DAB design. Thirdly, the DAB converter has larger conduction losses compared to other topology counterparts. Many optimization methods have been proposed in literature to suppress the conduction losses. However, the close-loop control procedure would become more complex if employing the improved method. Hence a simple and easy optimization scheme is needed in respect to an easy real-time control. Fourthly, the ambient temperature could be very high under the vehicle hood.

This will challenge the reliable operation of the DAB converter by overheating the pivotal components such as the power semiconductor device. Therefore, during the usage phase of the OBC, an active thermal management method is needed to achieve higher system reliability. Aiming to tackle these challenges, this Ph.D project investigates the corresponding solutions. The high frequency ac current in the DAB converter is modeled by considering individual harmonic components. The modeling procedure and mathematical derivation are analyzed in detail. It turns out that different harmonic components dominate the modeling accuracy depending on the loading situations.
Then the soft-switching conditions are derived based on the practical switching transition. The key point is to include the non-linear output capacitance of the power device into the ZVS calculation. In order to validate the soft-switching conditions, a comprehensive comparison with the prior-art calculation methods are implemented. Next, a linear control strategy is presented to reduce the conduction losses without sacrificing the other converter performances. The DAB converter is operated with two modulation schemes for different power loading. The operating principle behind this hybrid modulation is explained from the original loss distribution to the final linear control derivation. Finally, the conventional driving signal with a fixed 50\% duty cycle is modified to regulate the loss distribution. As a result, the thermal stress of the power devices can be controlled and redistributed. Operating the DAB converter in various loading situations, the measured case temperatures in the experiments are able to demonstrate the effectiveness of the modified modulation scheme.