Multi-objective Design Optimization and Selection of Bidirectional DC-DC Converters for Solid Oxide Fuel Cell

A multi-objective optimization approach is introduced in this paper to design and select the best candidate dc-dc interface for a 16 kW, bidirectional solid oxide fuel cell (SOFC). The optimization framework considers both charging (electrolysis) and discharging (fuel cell) phases of the fuel cells as illustrated in Fig.1. In electrolysis mode, the SOFCs are fed with a low-frequency (2 kHz) pulsed square-wave current that alternates between 0A and 50A. Conversely, the SOFCs consistently discharge at a current of 20 A in fuel cell-mode.

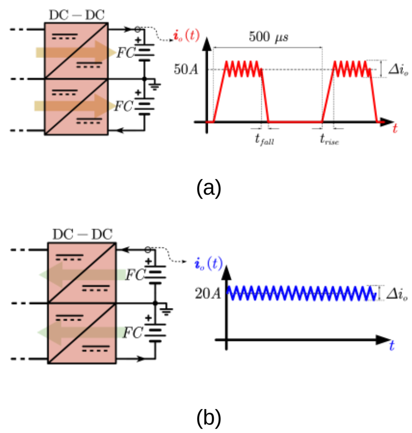

Fig. 1. SOFCs operating modes: (a) Electrolysis mode (b) Fuel cell mode

Three different candidate topologies, namely a four switches buck-boost converter (FSBB) and two-and three-channel interleaved buck converters, were assessed based on their achieved efficiency and weight. Loss and weight models were formulated for each physical component utilized in constructing candidate converters, encompassing semiconductor devices, magnetic components, and capacitors. MATLAB software was used to automate the multi-objective optimization strategy, leveraging prebuilt libraires containing a variety of semiconductor devices and passive components. The three considered topologies were compared based on two performance metrics: efficiency and weight.

As illustrated in Fig. 2, the optimization strategy adopted to compare candidate topologies is demonstrated in detail. Initially, system specification and design constraints are defined. Secondly, the converter level design is carried out, where the converter design variables are populated with upper and lower bounds for the sweeping purpose. Subsequently, all design variables are swept in an iterative manner to cover all design space specified for each candidate topology. In every iterative step, passive components values are obtained considering the bidirectional requirements of SOFCs. Once computed, component design level is performed, where dc bus capacitor is selected, along with weight and loss estimation. On the other hand, semiconductor devices, inductor cores, and materials are swept in a nested manner.

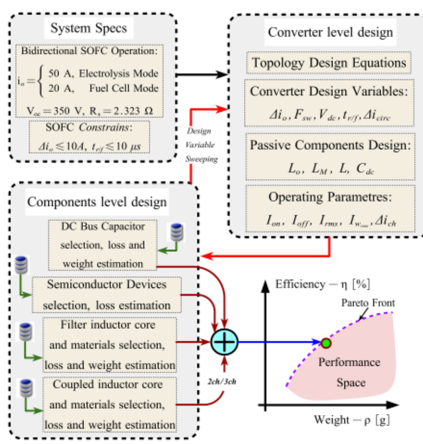

Fig. 2: Optimization strategy flow diagram

The performance plots generated by the optimization strategies clearly demonstrate the superior performance of interleaved converters in comparison to the FSBB topology. The weight of the filter inductor in the FSBB acts as a significant barrier to achieving improved designs in the performance space. While the three-channel buck converter demonstrated slightly better performance compared to its two-channel counterpart, the latter was chosen as the final selection due to its reduced complexity when implementing the coupled inductor.