High Efficiency Reversible Fuel Cell Power Converter

The large scale integration of renewable energy sources requires suitable energy storage systems to balance energy production and demand in the electrical grid. Bidirectional fuel cells are an attractive technology for energy storage systems due to the high energy density of fuel. Compared to traditional unidirectional fuel cell, bidirectional fuel cells have increased operating voltage and current ranges. These characteristics increase the stresses on dc-dc and dc-ac converters in the electrical system, which require proper design and advanced optimization. This work is part of the PhD project entitled "High Efficiency Reversible Fuel Cell Power Converter" and it presents the design of a high efficiency dc-dc converter developed and optimized for bidirectional fuel cell applications. First, a brief overview of fuel cell and energy storage technologies is presented. Different system topologies as well as different dc-ac and dc-dc converter topologies are presented and analyzed. A new ac-dc topology for high efficiency data center applications is proposed and an efficiency characterization based on the fuel cell stack I-V characteristic curve is presented. The second part discusses the main converter components. Wide bandgap power semiconductors are introduced due to their superior performance in comparison to traditional silicon power devices. The analysis presents a study based on switching loss measurements performed on Si IGBTs, SiC JFETs, SiC MOSFETs and their respective gate drivers. Magnetic components are a fundamental part in most power converters and have a significant impact on power converters performance and cost. After basic introduction on magnetic components, planar magnetics are evaluated for fuel cell (high current) applications as a possible candidate for reducing the cost of magnetic components especially for large production volumes. At last, the complete converter design is presented in detailed and characterized in efficiency terms. Both benefits, provided by SiC power devices and by a redesign of the converter layout increased the converter power density up to 2.2 kW/l, achieving efficiency above 98%. A flyback derived topology designed for low power high voltage applications is also presented as a side task in connection to the PhD project.