DC/DC converter based on SiC semiconductors combined with online EIS detection functionality for Fuel Cell Electrical Vehicles

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Proton Exchange Membrane Fuel Cell (PEMFC), which is treated as one of the most attractive green power source, features different characteristics such as zero pollution, low operating temperature, fast start-up, long cell and stack life [1]. So far, general lifespan of PEMFC cannot reach the expectation of commercial application. For example, a typical life expectancy of the PEMFC under actual transportation constraints is around 3000 h, whereas transportation applications require at least 5000 h [2]. Hence, the operating conditions of PEMFC are essential to be monitored and controlled for the purpose of expending lifespan of power source. Electrochemical impedance spectroscopy (EIS) is established as a powerful characterization tool to detect different failure mechanisms occurring in a fuel cell. As a high-current low-voltage power source, PEMFC system's output voltage must be increased to approximately a few hundred volts to be suitable with vehicle powertrains. EIS detection based on fuel cell connected converter is an attractive method which is possible to realize on-line detection without any additional equipment.

In light of these mentioned previously, a 6-Phase Interleaved Boost Converter (IBC) is selected as the power conversion interface of PEMFC for FCEV application. Silicon Carbide (SiC) semiconductors are selected for the purpose to operate at high switching frequency and good thermal performance. Inverse coupled inductors are introduced to achieve a more compact system, which is an important point for automotive applications, and meanwhile, the core losses can be decreased compared with uncoupled inductor. Furthermore, Sliding Mode Control (SMC) is utilized to satisfy the strict control requirements of the coupled inductor currents. Meanwhile, DC bus voltage can be well controlled either under nominal condition or diagnosis condition. Small sinusoidal perturbation is superposed with the current reference signal and in this way AC perturbation can be added to fuel cell voltage and current. The detected AC components of fuel cell voltage and current are analyzed by Discrete Fourier Transform (DFT) and the impedance spectrums are obtained. Therefore, EIS has been achieved by the proposed DC/DC converter without additional hardware, cost and volume. The proposed process allows real time using of EIS results for embedded diagnosis of PEMFC.

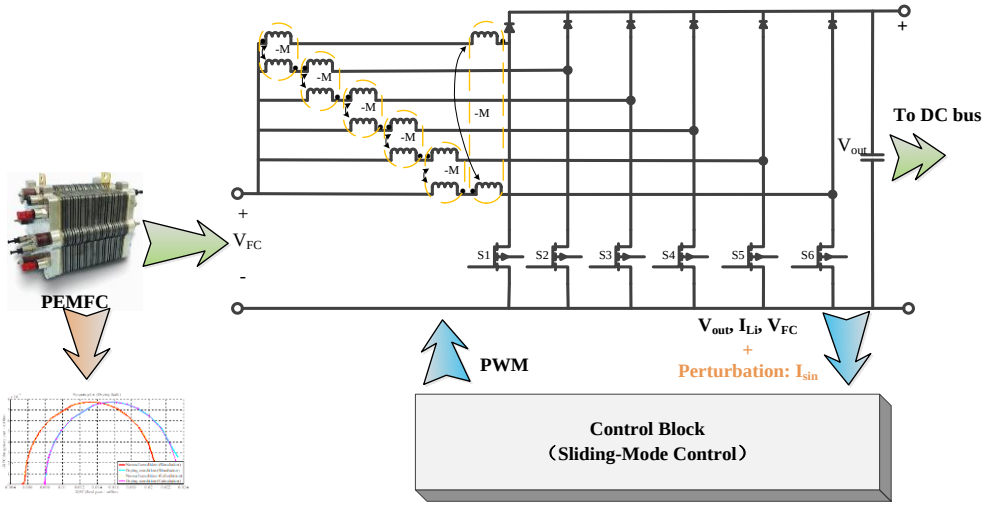

Fig.1 The simple flowchart of proposed strategy for EIS on-line detection based on PEMFC connected DC/DC Boost converter without any additional equipment

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[2] Sutharssan T, Montalvao D, Chen Y K, et al. A review on prognostics and health monitoring of proton exchange membrane fuel cell[J]. Renewable and Sustainable Energy Reviews, 2017, 75: 440-450.