Model-based Design and Control of DC-DC Power Converters with Fuel cell/Converter Fault-Tolerant Capability for Hybrid Fuel Cell Systems

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Research Topic

- Robust control and reliability analysis for DC-DC converters using model-based approach
- Fault tolerant control for DC-DC converter with online diagnosis of fuel cell system
- Energy management and fault tolerant control for hybrid fuel cell powertrain

Research Content

1) **DC-DC converter topologies analysis, comparison and design:**
   This part analyzes and compares the existed DC-DC converter topologies for fuel cell applications. The main principles are: high voltage gain, low current ripple, high reliability (works under degraded mode of fuel cells) and can be used for high power applications, such as FCEV. The main objective is to design a novel DC-DC converter with both fuel cell and converter fault tolerant capacity for high power fuel cell applications.

2) **Robust controller design for DC-DC converter:**
   This part is dedicated to design an advanced nonlinear controller for the presented converter. The DC-DC converter is a non-linear time-varying uncertain system. The uncertainties could be the operating point (input voltage and output load demand) variations or fuel cell performance degradations. Therefore, it is necessary to design a nonlinear robust controller for the DC-DC converter by considering also the fuel cell operation performance. Specially, in order to protect the fuel cell stack, the soft-start-up of the DC-DC converter is also very important.

3) **Fault tolerant control design for DC-DC converter:**
   A well-designed robust controller can ensure the performance of DC-DC converter and fuel cell in healthy mode. However, what if the switch or fuel cell failure? It has been reported in the literature that the power switch, capacitor and fuel cell stack are the most fragile components. Therefore, this part tries to analyze and calculate the reliability of the fuel cell and DC-DC power converters based on Markov Model. After that, the fault tolerant control is designed to improve the reliability and durability of the fuel cell powered system.

4) **Energy management and fault tolerant control for hybrid fuel cell systems:**
   Constructing a more complicate fuel cell/ultra-capacitor hybrid system, as shown in Fig.1, will be considered for transport applications. The dynamical response of fuel cell stack is relatively slow, therefore, an auxiliary power source is often added to improve the performance during acceleration and regenerative braking. The inverter and the following wheel motor can be
simulated by a DC electronic load. The load current profile can be generated by using some typical driving cycle, such as UDDS (Urban Dynanometer Driving Schedule). The fuel cell can be emulated by a programmable voltage source with the help of dSpace. Introducing such an ultra-capacitor and bidirectional dc-dc converter will create much more possibilities for energy management.

The hierarchical strategy will be adopted for this hybrid system. The upper level (energy management) is not the emphasis. One simple strategy is dividing the output load current demand as high frequency part and low frequency part. Then the faster current demand is sent to the ultra-capacitor, and the low frequency part is sent to the fuel cell stack. The lower level is the emphasis of the PhD project. That is, design a robust control for the fuel cell converter and ultra-capacitor converter, to achieve the goals of tight bus voltage regulation and reference current tracking even under fuel cell or converter fault conditions.

Fig. 1 Power circuit of a typical hybrid vehicle

References