A two-dimensional multi-physics approach of transient PEMFC modeling in a virtual fuel cell car

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During the past few years there has been a surge in the development of polymer electrolyte membrane fuel cell (PEMFC) powered automobiles [1]. Although a lot of research has been carried out on the transient loading of fuel cells with respect to cell aging and degradation [2], most of the studies focus on the cell performance at nominal fuel cell operating conditions or simulated time-periodic loads. However, in the real life fuel cell based transport applications, the power demand can be highly non-periodic. So, in order to predict the real life cell degradation and aging, the fuel cell model must be loaded under such a highly transient power demand.

In this study, we model the operating behaviour of a PEMFC under transient loading conditions via a virtual PEMFC car running on the New European Driving Cycle (NEDC). In this approach, the velocity demand from the driving cycle is converted into a power demand by fixing the physical characteristics of the car. The car model is based on a force balance and Newton's laws of motion. The engine controller includes anti-windup formalism. The resulting power demand is fed to a virtual fuel cell stack. The fuel cell itself is modeled by using a 2D multi-physics approach [3]. The model includes a coupled multi-component transport of fuel, air and water in the gas channels, diffusion layers and the polymer membrane with the help of computational fluid dynamics over the 2D cell geometry. The electrochemical kinetics of oxygen reduction in the catalyst layer is derived from elementary reaction steps and is implemented in a modified Butler-Volmer formalism.

We demonstrate multi-scale software coupling of the car model (implemented in SIMULINK) and the fuel cell model (implemented in COMSOL). The fuel cell performance over the transient loading is analysed in terms of dynamic current and voltage behaviour as well as water management. Different flow rates and flow modes of fuel and oxidiser are compared.

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