Control Theory Based Models for the Dynamic Operation of SOFCs

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This paper presents the development of a control theory based model for the dynamic operation of SOFCs. The objective for building this model is to find a general framework for simulating the startup and dynamic operation for different types of single cells, which provides guidelines for achieving minimum startup time, maximum stack performance and maximum durability.

In order to optimize single cells with regard to maximum electrical efficiency and life expectancy, the relationships between material properties and working conditions of single cells and their electrical performance ought to be well understood.

The formation of the cathode/electrolyte interface, i.e. microstructural and compositional changes during the first electrical loading of the cell, is crucial to achieve maximum cell performance. Fig. 1 shows the temporal course of the cell voltage and the corresponding anodic and cathodic polarizations. With increasing electrical load j, the cell voltage first decreases according to the internal resistance of the cell. Afterwards a significant increase of the cell voltage at a constant current density takes place, which can be attributed to a decreased polarization resistance of the cathode.

A dynamic physical model of the cathode including electrochemical reactions as well as changes in chemical composition and microstructure is not feasible because of the complexity of the interface reactions. The elementary processes running at the interface during SOFC operation and leading to the cathodic polarization losses are not completely understood.

Though there is a great deal of expert knowledge about the reactions at the interface, conventional modeling techniques of materials science cannot utilize this knowledge, because it is not given by mathematical equations but by linguistic rules containing qualitative and uncertain premises and conclusions.

Therefore a qualitative modeling approach to build a dynamic model of the formation of the cathode/electrolyte interface during the first electric loading of SOFC single cells. Computational intelligence techniques are applied to build a qualitative model from expert knowledge, physical relations, and experimental results.

The paper first introduces the investigated SOFC materials and their startup behaviour. General requirements of building a model are considered from a control and systems theoretic point of view. The system and control theory and their model structures for different applications will be presented.

Starting from qualitative expert knowledge, a nonlinear dynamic model of the microstructural changes during startup is developed (2,3). For that purpose, the expert knowledge is transferred into simplified if-then-rules.

The resulting model allows to predict the cell behaviour qualitatively (Fig. 1). First simulation results for different cathode compositions of $(La_{0.8-x}Sr_{0.2})MnO_3$ are presented and a first application for stack simulation is shown.

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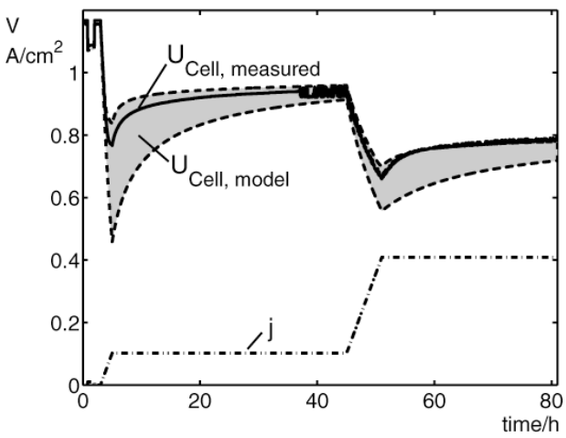

Fig 1: Qualitative simulation of the cell voltages and comparison to measured data.