Application of Verified Optimization Techniques to Parameter Identification for Solid Oxide Fuel Cells

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Abstract

Since the beginning of the 90's at the latest, design and development of solid oxide fuel cells (SOFC) have been in the focus of research in the area of decentralized energy supply. SOFCs convert chemical energy directly into electricity and are highly efficient owing to the fact that the produced heat can be reused. On the one hand, they are flexible with respect to the kind of fuel. On the other hand, SOFCs are difficult to manufacture and require advanced control strategies for instationary operating points. Besides, their system parameters are influenced by significant uncertainty due to either measurement or model imprecision. An objective of a current research project between the Universities of Rostock and Duisburg-Essen is to develop dynamic SOFC models accurately describing their instationary behavior while accounting for the uncertainty with the help of interval-based verified methods.

Interval methods guarantee the correctness of results obtained using a computer and allow us to represent bounded epistemic uncertainty in a natural way. Their main disadvantages are possible overestimation and comparative slowness, which makes their use in real-life scenarios challenging. In this presentation, we show how to apply a verified optimization algorithm based on [2] to identify parameters of a dynamic model for the thermal SOFC subsystem derived in [3]. The model takes into account preheated air and fuel gas supplied to the SOFC system as well as the corresponding reaction enthalpies. The parameters of interest describe the thermal resistances of the stack materials, the dependency of the heat capacities on the temperature, and the heat produced during the exothermic electrochemical reactions in each individual fuel cell. We consider different model dimensions resulting in different ODE systems and cost functions. Although the obtained results are not always entirely verified since optimality of candidates for system parameterizations cannot always be rigorously proved, they can be shown to be more accurate than the results of corresponding MATLAB simulations. The accuracy is an important issue in this case, because better parameterizations facilitate more precise control.

Since the structure of the cost function for parameter identification is complex, we use our own implementation of the optimization algorithm in the framework UniVerMec [1], which currently allows for the maximum degree of flexibility and adjustment to the problem. Besides, it parallelizes the process of parameter identification reducing the overall computing time. However, these times are still high. As an outlook, we show how the GPU can be used to decrease them further. This is not an easy task since there are no interval libraries for the GPU as of now. Another problem is that double precision computations on the GPU are significantly slower than single precision ones. In this presentation, we examine how single precision GPU computations influence the quadratic cost function for our optimization problem which is generally affected by cancelation. We conclude the talk by a summary of the main results and a perspective on our future research.

References

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