Explicit/Multi-Parametric Model Predictive Control of a Solid Oxide Fuel Cell

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Fuel Cell power systems have important potential for many applications, both stationary and mobile, due to their outstanding energy efficiency and environmental characteristics [2]. In particular, Solid Oxide Fuel Cell (SOFC) systems emerge as one of the most commercially widespread technologies, together with Proton Exchange Membrane fuel cells (PEMFC), offering high energy efficiency and robust performance. Their operation is based on an exothermic electrochemical reaction which takes place at elevated temperatures. The SOFC value has already been demonstrated in residential and military installations [4]. SOFC systems are suitable for many power generation applications due to their fuel versatility, high electric efficiency, allowing higher power-to-heat ratios in CHP applications, and minimal environmental impact. However, the complex physical, chemical and electrical operation of SOFCs gives rise to important modelling and control challenges. The efficient and stable operation of fuel cells depends on the efficient control of the generated voltage/power and the prevention of voltage surges in the presence of varying operating conditions and disturbances, as well as the efficient heat management of the system [1,2,3,4,5]. The disturbances and varying operating conditions are mainly associated with the fluctuations of the electric load which corresponds mainly to demand fluctuations or failures in the network [2,4]. Recent work on the control of voltage and temperature of PEMFC [1] and voltage regulation of SOFC [3,4] has shown that modern online model-based control methods such as linear quadratic regulation [4], Model Predictive Control (MPC) and Explicit MPC [3,6] are promising control methods for ensuring that the above control objectives are met in the presence of varying conditions/disturbances while satisfying the system constraints.

In this work a unified framework for the multi-parametric programming and explicit/multi-parametric MPC [7] of fuel cells is presented and illustrated on a SOFC system case study. The framework consists of four main steps: a) A detailed mathematical model for the SOFC is formulated which includes the mass, energy and electric charge balances of the fuel cell, and is used to perform dynamic simulation studies for the evaluation of the SOFC performance under varying operating conditions. b) A set of reduced order (approximating) models are obtained suitable for designing modern model-based controllers. c) An explicit/multi-parametric MPC controller is obtained to ensure voltage regulation in the presence of disturbances and varying operating conditions. d) The performance of the explicit MPC controller is evaluated and tested by directly applying it to the original detailed dynamic model of the SOFC. This is achieved by performing a set of open-loop simulation results of the SOFC and comparing the approximating model with the original detailed SOFC model and the simulation results of the closed-loop implementation of the explicit MPC controller. The potential reduction of Carbon Footprint will be also assessed using the methodology published elsewhere [8,9].

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References:


