Proposal for the (Full Day) Workshop on

Fuel Cell Power System Modeling and Control

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Fuel cell based power systems present a wide range of challenging problems for control and system integration. Complicated system configurations and interactive subsystems, coupled with the demanding requirement of mobile operations, lead to intricate transient dynamics and difficult control tasks. Recent development in system modeling, control analysis and system optimization has offered new insights and design tools for system performance improvement and robustness enhancement.

The goal of this workshop is to expose the audience to the issues and technical development associated fuel cell power systems. The presentation will be focused on the modeling and control aspects of the fuel cell systems, while other challenges such as those related to cell design and material research will be highlighted. A wide range of topics, including the modeling and control design of the fuel cell stack and fuel processing systems, the optimization of fuel cell vehicles and fuel cell based combined heat and power systems, and the control and dynamics of fuel cell enabled distributed power systems, will be covered. Future technical needs and research requirements will also be addressed.

The speakers for the workshop will include both industrial technical leaders and academic researchers. The topics will be organized into six (6) coherent modules. Detailed information on the topics, as well as the abstract and the name of the presenter for each module, is given as follows:

1. **Industry Perspective and Needs (Subbarao Varigonda, United Technology Research Center)**
   Abstract: We present the system and control design challenges for PEMFC systems in stationary and transportation applications. The impact of typical customer requirements on the system architecture and control design is discussed. The development and use of system level dynamic models using modern equation oriented modeling tools such as Dymola and gPROMS and their use at UTC for analyzing transient performance trade-offs and for model based control design and verification is described. The need for good diagnostics and fault tolerance at the power plant level and at the stack level is emphasized. Future directions for control to improve the system design and reliability and reduce the barriers for commercialization are discussed.

2. **Fuel Cell Stack System (Anna Stefanopoulou, University of Michigan)**
   Abstract: We first introduce the critical control, estimation, and diagnostics problems in Polymer Electrolyte Fuel Cell Systems. We then present system-level dynamic models that are important for integrated Fuel Cell Stack control design and analysis. The model consists of four interacting sub-models, namely, stack voltage, cathode flow, anode flow, and membrane hydration models. The physics-based component models use flow characteristics, point-mass inertia dynamics, lumped-

volume manifold filling dynamics, time-evolving spatially homogeneous reactant pressure or concentration, and simple diffusion, transport, and heat equations. Identification techniques and calibration of the lumped parameter models will be discussed. Model-based control methodologies will be highlighted.

3. **Optimization and Control of Fuel Cell Vehicle (Lino Guzzella, ETH Zurich)**
   Abstract: Fuel cells are one option for future clean and efficient propulsion systems for passenger vehicles. In this module first the advantages and drawbacks of such an approach are discussed on a broader perspective. Then the main components of the system to be analyzed are introduced and appropriate mathematical descriptions are presented ("backwards" or "quasi static" formulations). The main goal is to correctly predict the fuel consumption and system efficiency for test cycles and realistic driving patterns. Once these models are available, the main approaches for system optimization are discussed. Several problem areas are mentioned (structural optimization, system parameter optimization, supervisory control algorithms). Several case studies show how these tools are applied to optimize the performance of real vehicles.

4. **Dynamics and Control of Distributed Power Systems (Ian Hiskens, University of Wisconsin)**
   Abstract: Connection of fuel cells to AC power systems requires conversion of voltages and currents from DC to AC. This conversion process is achieved using power electronic based devices called inverters. Averaging techniques underlie the development of inverter models that are suited to exploring the dynamics of distributed power systems. The presentation will review these modeling concepts. Inverter controls typically regulate the real power delivered to the AC system, and the AC bus voltage. Various control philosophies will be presented. It will be shown that interactions between adjacent inverters can lead to poorly damped oscillations, or even instability. Coordination of multiple energy sources will therefore be discussed.

5. **Fuel Processing for Hydrogen Generation (Anna Stefanopoulou, University of Michigan)**
   Abstract: The components and processes of fuel processors for hydrogen generation are explained. Then the control challenges associated with the partial oxidation based natural gas fuel processor are highlighted, with case studies in reactor temperature and composition regulation during transient load changes.

6. **Fuel Cell Based Combined Heat Power Systems (Jing Sun, University of Michigan)**
   Abstract: Combining fuel cell systems with conventional power and heat plants, such as gas turbine generator sets and catalytic burners, will have a strong synergetic effect on boosting system efficiency. The so-called fuel cell based CHP (combined heat power) systems exploit the complementary features of different technologies to provide very efficient and environmentally friendly power solutions for both stationary and mobile applications. In this presentation, we will discuss the modeling and control integration issues associated with the fuel cell based CHP systems. Models for key subsystems, such as the catalytic burner and heat exchanger, will be briefly reviewed. Recent results on system optimization and dynamic interaction management will be discussed for a system consisting of a PEM fuel cell stack, a fuel processing system, and a catalytic burner, and heat exchangers. General challenges as well opportunities in modeling, analysis and control of fuel cell based CHP systems, including the solid oxide fuel cell (SOFC) based CHP systems, will be highlighted for mobile applications.