System/Component Modeling/Optimization for Fuel Cell System Design and Control

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Objective
The focus of this project is to develop an enabling design-for-the-environment tool for use in the development and control of PEMFC technologies. The major tasks envisioned are as follows:

- Develop a fully transient nonlinear, general model of PEMFC stacks and a variety of BOPSS (balance-of-plant subsystem) components.
- Develop realistic load profile scenarios for various types of stationary and non-stationary applications for use in generating optimal control strategies for PEMFC systems.
- Implement bottom-up & top-down approaches for the development of optimal control strategies.

Desirable FCS Characteristics

Reactivity
- Capability of long continuous periods of operation
- Cell materials such as the electrolyte and catalysts with long-term endurance
- Capability of effectively interfacing with conventional utility grids
- Capability of handling significant and frequent transients

Reliability
- System efficiency based on LHV vs. Cost: PEMFC Total Energy System

Cost: PEMFC Total Energy System (TES)

Optimization

The single-level optimization techniques can be employed to solve non-linear and mixed integer nonlinear optimization problems which are not too complex. For highly complex and dynamic problems, decomposition techniques (e.g., conceptual, time, physical, and disciplinary) can be employed to break the problem into a set of nearly equivalent smaller problems in order to facilitate the solution of the larger problem and overcome both the mathematical and cultural (e.g., geographical and design team boundary) difficulties.

Battery Management & Control

The master controller will calculate the ideal current ($I_{ideal}$) to be supplied by the battery, depending on the additional load requirement and the BOPSS output. The master controller will calculate the current to be fed by the battery depending on the state-of-charge of the battery (SOC) and the error. The active filter which is a power converter injects the required amount of current into the circuit.

Optimal BOPSS Transient Responses

The optimal FPS efficiency is higher than one at times due to the fact that no additional energy during those times is required to generate steam and the efficiency is plotted as an "instantaneous efficiency". Furthermore, the instantaneous FPP efficiency is higher at low load regimes because the residence time in the reformer increases for low loads, improving the conversion. In a similar manner, the instantaneous SS efficiency tends to be higher on average at the lower loads.

Dynamic System Control

The diagram below shows a proposed control scheme for the FPS and WRAS (work recovery and air-supply sub-system) integrated with the PES (power electronics sub-system). A special control approach is used in order to help improve time response and reliability. An NN based predictive model of the PEMFC is used to predict the output of the stack. Depending on the predicted output, the master controller will adjust the PES control, which includes the control of the battery system, and the BOPSS control in order to optimize the system.

PES Optimization

This top-down optimization study is focused on developing an optimum PES topology and optimal control strategy which will fulfill the following objectives:

- Optimize the size of the battery
- Maximize the efficiency of the PEMFC system

Battery

Performance & Efficiency

- Minimize the total system degradation and maintenance required
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