VII.G.5 Smart Energy Management and Control for Fuel Cell Based Micro-Grid Connected Neighborhoods*

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**Congressionally directed project*

Objectives

- To demonstrate that smart energy management of a fuel cell based micro-grid connected neighborhood can be efficient and cost-effective
- To define the most economical micro-grid configuration
- To determine how residential micro-grid connected fuel cell(s) can contribute to America's hydrogen energy future

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- B. Cost
- D. Thermal, Air and Water Management
- F. Fuel Cell Power System Integration
- J. Startup Time/Transient Operation

Approach

- The University of South Alabama together with its industry partner, Radiance Technology, Inc., will evaluate, develop and simulate fuel cell powered micro-grid connected neighborhoods over a 12-month project period.

- As an important part of this research, the team will migrate and expand on the Local Energy Management System (LEMSYS) and the Micro-grid Energy Management System (MEMSYS) developed in Phase II to the micro-grid connected neighborhoods (Phase III). In addition a Smart Energy Management at the Appliance Level will be developed.
- This research will accelerate the development of fuel cell applications for residential energy customers, will ensure load smoothing during peak demand periods, and will support the development of hydrogen use for energy supply systems.
- An economic analysis will be conducted to determine the feasibility of the proposed micro-grid connected neighborhood in terms of the optimal strategy to manage the electric, thermal, and hydrogen energy.

Accomplishments

- Developed the micro-grid simulation using SEMaC client software

Future Directions

- Integrate the simulation application into the LEMSYS software to allow faster simulation and to simplify the software. Develop a Smart Energy Management at the Appliance Level.

Introduction

Fuel cell power generation promises to be an efficient, pollution-free, reliable power source in both large scale and small scale, remote applications. With their inherently high, 60-70% conversion efficiencies, significantly reduced carbon dioxide emissions, and negligible emissions of other pollutants, fuel cells will be the obvious choice for a broad variety of commercial and residential applications when their cost effectiveness is improved.

Approach

In a research project funded by the Department of Energy, the research team has been investigating smart fuel cell operated residential micro-grid communities. This research has focused on using smart control systems in conjunction with fuel cell power plants, with the goal to reduce energy consumption, reduce demand peaks and still meet the energy requirements of any household in a micro-grid community environment. In Phases I and II, a micro-grid simulation using SEMaC client software was developed and extended to a micro-grid community. In addition, an optimal configuration was determined for a single fuel cell power plant supplying power to a micro-grid community of ten homes. In Phase III, the plan is to expand this work to fuel cell based micro-grid connected neighborhoods (mini-grid). The economic implications of hydrogen cogeneration will be investigated.

A major challenge facing the routine implementation and use of a fuel cell based mini-grid is the varying electrical demand of the individual micro-grids, and, therefore, analyzing these issues is vital. Efforts are needed to determine the most appropriate means of implementing micro-grids and the costs and processes involved with their extended operation.

With the development and availability of fuel cell based stand-alone power plants, an electrical mini-grid, encompassing several connected residential neighborhoods, has become a viable concept. A primary objective of this project is to define the parameters of an economically efficient fuel cell based mini-grid. Since pure hydrogen is not economically available in sufficient quantities at the present time, the use of reforming technology to produce and store excess hydrogen will also be investigated.

From a broader perspective, the factors that bear upon the feasibility of fuel cell based micro-grid connected neighborhoods are similar to those pertaining to the electrification of a small town with a localized power generating station containing several conventional generating units. In the conventional case, the town or locality would also be connected to the larger grid system of the utility company. Therefore, in the case of the fuel cell based micro-grid connected neighborhoods, this option should also be available.

Results

In Year III, the University of South Alabama and Radiance implemented historical analysis algorithms to further enhance the management capabilities of the GIFCO LEMSYS software. Using the SEMaC client software developed in Year I, and the micro-grid simulation developed in Year II of the project as a starting point, we have written a database interface to allow the storage of appliance level load data. This database resides on each LEMSYS computer and stores the date and time, appliance ID, and power usage of the appliance at 15 second intervals. In Year II, the micro-grid home simulation software was external to LEMSYS. In Year III, it was decided to integrate the simulation application into the LEMSYS software to allow faster simulation and to simplify the software.

Results to-date indicate that managing the micro-grid of ten loads has almost the same average power delivered as the unmanaged scenario, but the managed case produces a smoother load profile than the unmanaged case. Due to peak load shedding a potential saving in the order of 50% in installed capacity is possible.

Future Directions

The algorithm development task is still in a design phase, and it has not been decided which specific algorithms will provide the best mix of performance and accuracy. A Back Propagation Neural Network and Fuzzy Logic Rule based approach are both candidates, as is a simple statistical data mining approach. Once the simulation integration is complete, we will begin implementing these for comparison and evaluation against each other.

Summary

The installation of the current system is very costly and the utility of some of its functions is questionable. If the primary purpose of MEMSYS is power management, the commercial product could simply manage the larger loads in the house like the washer, dryer, water heater and stove. If electric companies can manage the usage of these specific items during their peak usage periods, they will be managing the majority of a home's load. The system could pay for itself in a smaller time period and will be less intrusive.

FY 2005 Publications

1. M. Y. El-Sharkh, M. Tanrioven, A. Rahman and M. S. Alam, "Impact of Hydrogen Production on Optimal Economical Operation of a Grid-parallel PEM Fuel Cell Power Plant," accepted for publication, *Journal of Power Sources*, Vol. 139, 2005.
2. M. Y. El-Sharkh, A. Rahman and M. S. Alam, "Evolutionary Programming Based Methodology for Economical Output Power from PEM Fuel Cell for Micro-Grid Application," *Journal of Power Sources*, Vol. 139, p. 165-169, 2005.
3. M. Tanrioven and M. S. Alam, "Reliability Modeling and Analysis of Stand Alone PEM Fuel Cell Power Plants," accepted for publication, *International Journal of Renewable Energy*, 2005.
4. M. Tanrioven and M. S. Alam, "Reliability Modeling and Evaluation of Grid-connected PEM Fuel Cell Power Plants Based on Markov Models," *Journal of Power Sources*, Vol. 142, p. 264-278, 2005.
5. M. Y. El-Sharkh, A. Rahman, M. S. Alam, P. C. Byrne, A. A. Sakla, T. Thomas, "A dynamic model for a stand-alone PEM fuel cell power plant for residential applications," Journal of Power Sources, 138 (2004) 199-204.
6. M. Y. El-Sharkh. A. Rahman, M. S. Alam, A. A. Sakla, P. C. Byrne and T. Thomas, "Analysis of Active and Reactive Power Control of a Stand-Alone PEM Fuel Cell Power Plant," *IEEE Transactions on Power Systems*, vol. 19, no. 4, pp. 2022-2028, November 2004.
7. M. Y. El-Sharkh, A. Rahman and M. S. Alam, "Neural Networks Based Control of Active and Reactive Power of a Stand-alone PEM Fuel Cell Power Plant," *Journal of Power Sources*, Vol. 135, p. 88-94, 2004.
8. P. Byrne, T. Thomas, M. Alam, A. Rahman, M. El-Shark, A. Sakla, "Proton Exchange Membrane Fuel Cell Steady-State Model for Residential Use," (under review)