V.I.5 Enlarging the Potential Market for Stationary Fuel Cells through System Design Optimization

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Project Start Date: January 1, 2011
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

Build an open-source tool (DG-BEAT[1]) that helps combined heat and power (CHP) fuel cell developers, end users, and other stakeholders to do the following for their systems, helping to drive economies of scale and cost reduction:

- Determine the appropriate sizing to reduce cost.
- Integrate to commercial building control and heating, ventilation and air conditioning systems to maximize durability.
- Compare performance relative to incumbent technologies.
- Determine optimum system configuration.
- Evaluate potential market penetration.

Fiscal Year (FY) 2014 Objectives

- Implement a control strategy which models fuel cell system response used for energy consumption calculations by accounting for system response lag.
- Implement a dispatch control for lowest greenhouse gas (GHG) emissions (CO_2) and criteria pollutants (ozone, SO_x, NO_x, PM10, CO), based on available regional electric grid emissions, and emissions profiles from stationary fuel cell systems.
- Identify and implement one additional set of commercial building energy usage profiles (16 types in 16 locations x 8,760 hours each, in 15-minute time steps).
- Deliver a compiled Windows executable of the model to the user's group, including 1,024 building energy load profiles.

Technical Barriers

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

(A) Durability

(B) Cost

(C) Performance

Technical Targets

This project is providing a tool to fuel cell manufacturers, end users, and other stakeholders to help them reduce the cost of fuel cell CHP installations by optimizing their sizing, combining them with hybridizing technologies such as thermal energy storage and batteries, dispatching them in cost-optimal ways, and investigating the fuel cell sizes and features to best address the national market. Relevant DOE targets (2020) are:

- Installed cost, natural gas: $1,500/kW
- Operating lifetime: 40,000-80,000 hours
- Electrical efficiency at rated power: >50%
- CHP energy efficiency: 90%

FY 2014 Accomplishments

- Implemented a non-predictive fuel cell load-following strategy that accounts for system lag. This will allow future improvements for optimization strategies.
- GHG and emissions reporting and minimization control strategies were implemented for CO_2, SO_2, and NO_x. The emissions reporting allows for a comparison of a stationary fuel cell integrated building system to a conventional building system. The GHG minimization control strategies sizes the fuel cell for emissions minimization of a specified pollutant.

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[1] Distributed Generation Build-out Economic Assessment Tool

- New building profiles were implemented which cover 16 regions, 16 building types, and three vintages for 768 new profiles. These are added to a previous set of 512 building profiles for 1,280 total. The profiles include electricity, heating, and cooling demands in 15-minute time step intervals for a year, which allow for energy storage modeling with a fuel cell.
- Improvements were made to the fuel cell performance profiles, including additions of molten carbonate fuel cells and polymer electrolyte membrane fuel cells. The model can now simulate four separate fuel cell types.
- Implemented improvements to feedstock costs and time-of-use electricity pricing in 16 regions, as well as several net-metering methods for electricity sell-back to grid.

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INTRODUCTION

This project aims to create an open-source software tool that allows fuel cell developers, their potential customers, and other stakeholders to evaluate the ability of fuel cell installations to save money relative to the grid/natural gas paradigm. The model includes 1,280 model building profiles covering the major American Society of Heating, Refrigerating and Air Conditioning Engineers climate zones in the United States.

The model can perform design optimizations on single fuel cells and building combinations or campuses of multiple buildings. In addition to fuel cells technologies that can be included in the buildings systems, the project scenario also includes chillers, energy storage technologies, and on-site renewables such as solar and wind.

APPROACH

The approach taken by the research team is to build a flexible, configurable model which allows users to create modules for the various components which make up a project scenario (fuel cells, energy storage, chillers, buildings and campuses). NREL has teamed with the University of California, Irvine, as a sub-contractor to leverage their extensive expertise in this area. Cost and sizing optimization can now be done for different control strategies utilizing the modules built. In addition, NREL is working cross-center within the lab, drawing extensively on the expertise of the commercial buildings research group within NREL to provide model building profiles.

RESULTS

The modeling effort this year focused on adding GHG emissions reporting and on refinements to other modules, which rounded out the features needed for future optimization, design, and analysis work.

The GHG emissions reporting covers CO_2, SO_2, and NO_x, and is based upon data from the Environmental Protection Agency Acid Rain Program and State Implementation Plans [1]. Hourly data allows the model to compare the fuel cell operation to the grid emissions. The hourly data compares well for most states to annual emissions factors from eGrid and is within 10% of the annual totals for 48 of the 50 states [2]. It is assumed that the fuel cell emissions can be compared to these grid factors when aggregated over a year. This hourly data is important due to differences in grid emissions by region and season (Figures 1 and 2). The emissions reporting has allowed modeling of GHG minimization control strategies whereby the fuel cell is dispatched based on day and night averages of grid emissions and is sized between the building peak and base load to minimize total annual emissions.

Several different functional methods for sizing and dispatching the fuel cell within the integrated building

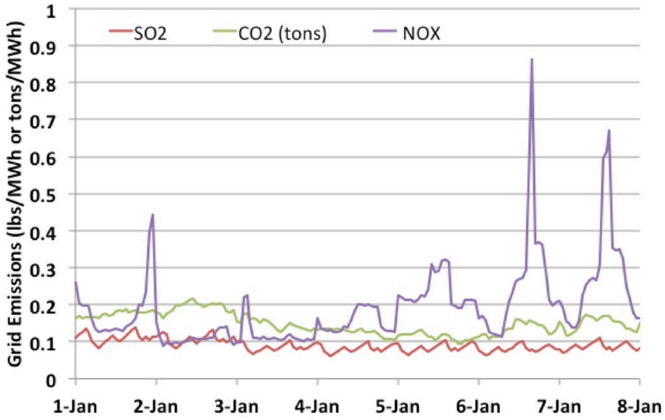

FIGURE 1. Example Grid Emissions Seasonal Variation, Winter

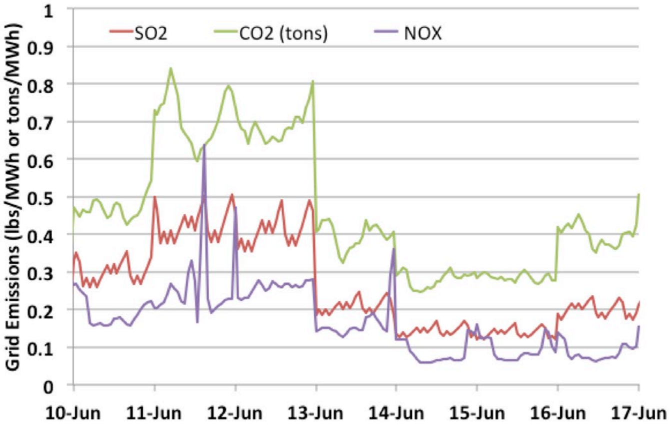

FIGURE 2. Example Grid Emissions Seasonal Variation, Summer

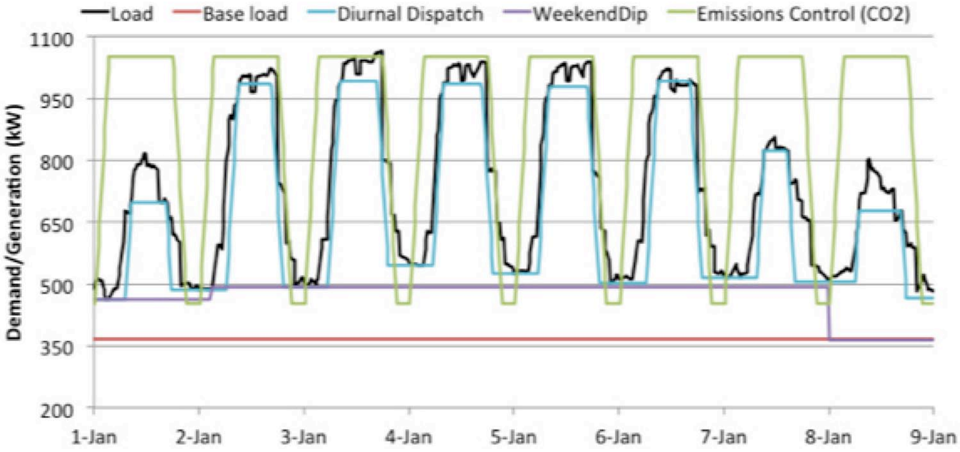

FIGURE 3. Example Fuel Cell Dispatch Strategies

system have been modeled. There are four sizing methods: fixed, 100% of summer peak demand, cost optimal, and emission minimizations. These are complemented by five fuel cell dispatch strategies that range from fixed usage (base load) to more structured usages (diurnal peak, weekend dip, emissions control) to full-load following (Figure 3).

The model can now do more detailed cost and emissions analyses (Figure 4) in which we can work towards a national survey of different types of building in the regions that span the United States.

CONCLUSIONS AND FUTURE DIRECTIONS

A strong model foundation is now in place for implementing component sizing optimization strategies and other future analysis. The model can now manage integration of fuel cells into building systems which can include chillers, energy storage technologies, and renewable energy systems. A number of sizing and control strategies are implemented. The new building profiles cover a significant percentage of the U.S. commercial building stock and will be invaluable for a national survey of fuel cell integration.

Future work for the remainder of FY 2014 and beyond could include:

- Assess requirements for an encompassing optimization strategy for sizing building components and implement dynamic control strategies.
- Implement a strategy for engaging the user's group in a more organized manner which includes regular beta software releases and collection of feedback for model development (both functionality and input data).
- Continue to refine and gather input data and develop a validation plan.
- Investigate code requirements for including the OpenEI utility rate database.
- Work towards a national survey of buildings to help target where fuel cells may make the most sense and impact.

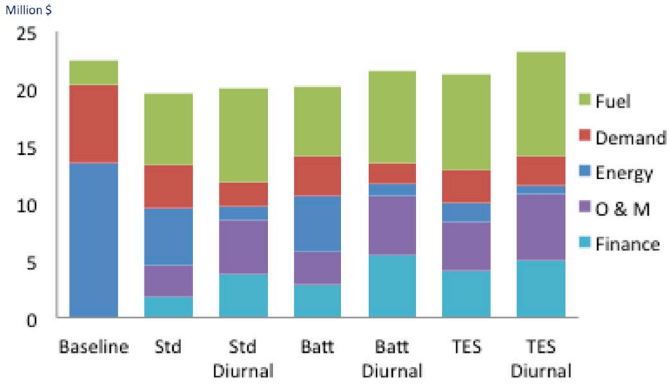

FIGURE 4. Example Cost Analysis Comparing Different Dispatch Strategies

FY 2014 PUBLICATIONS/PRESENTATIONS

1. Wipke, K. "Modeling and Optimization of Commercial Buildings and Stationary Fuel Cell." Fuel Cell Seminar, published October 2013. (presentation)

REFERENCES

1. http://ampd.epa.gov/ampd

2. http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html