the ENERGY lab
PROJECT FACTS
Fuel Cells

SECA Coal-Based Systems—UTC Power

Background

The mission of the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) is to advance energy options to fuel our economy, strengthen our security, and improve our environment. With the Solid Oxide Fuel Cells (SOFCs) program and systems coordination from the Solid State Energy Conversion Alliance (SECA), DOE/NETL is leading the research, development, and demonstration of SOFCs for both domestic coal and natural gas fueled central generation power systems that enable low cost, high efficiency, near-zero emissions and water usage, and carbon dioxide (CO_2) capture.

UTC Power, in cooperation with the SOFC technology developer Delphi, United Technologies Research Center, and Battelle, is one of multiple SECA Industry Teams developing SOFC technology for integrated gasification fuel cell (IGFC) systems.

A key element is cost reduction, with cost targets of $175 per kilowatt (kW) for fuel cell modules and $700/kW for the IGFC power block (2007 dollars [$]; 250 megawatts [MW] per year). Analysis has shown that IGFC systems are well suited to achieving the DOE Office of Fossil Energy's Advanced (Coal) Power Systems goals. In early 2013, ClearEdge Power acquired UTC Power and has decided to end its participation in the project.

Project Description

UTC Power's approach consisted of integrating Delphi-produced SOFC stacks into larger systems with a focus on durability, reliability, cost, and high volume manufacturability. Phase II work included testing stacks and stack modules, performing system modeling and analysis, and integrating stacks into a thermally self-sustaining stack fixture to validate scaled-up operability and performance of the system. Ultimately this work will facilitate the development of economical SOFC systems, which will eventually yield large-scale SOFC-based centralized power generation.

Goals and Objectives

The overall goal of this project was to advance the development of SOFC technology to significantly advance the nation's energy security and independence while simultaneously addressing environmental concerns, including greenhouse gas emissions and water usage.

Accomplishments

- A Gen 3 stack successfully completed durability testing to 9,700 hours with a degradation rate of 2.2 percent per 1000 hours.
- A Gen 3 stack completed 200 deep thermal cycles from 750 degrees Celsius (°C operating temperature to under 100 °C with a total power degradation of less than five percent.
- A 40-cell Gen 4 stack demonstrated a gross power of 6.4 kW at an average power density of 398 milliwatts per square centimeter (mW/cm^2) and average cell voltage of 0.7 volts, utilizing the SECA simulated coal gas blend.

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PARTNERS

Delphi
United Technologies Research Center
Battelle

PROJECT DURATION

Start Date	End Date
10/01/2008	04/04/2013

COST

Total Project Value
$52,860,053

Base
DOE/Non-DOE Share
$38,887,767 / $13,972,286

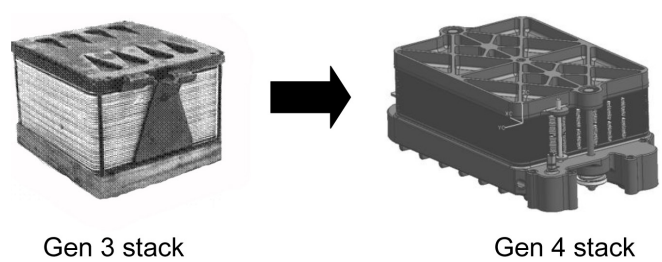
AWARD NUMBER

DE-NT0003894

- Demonstrated a maximum initial power on 50-cell Gen 4 stack of 9.3 kW at a power density of 463 mW/cm^2 and a mean cell voltage of 0.78 V on a 48.5% H_2 – 48.5% N_2 – 3% H_2O fuel.
- A Gen 4 stack has completed a durability test of approximately 3,500 hours at a constant current density of 155 milliamps (mA)/cm^2 and has a degradation rate of about 4 percent in the first 300 hours and no measurable power degradation thereafter. The successful stack results are highly encouraging for the ensuing phases of the program.
- A 30-cell Gen 4 stack was built with several interfacial control concepts and was tested for 5,000 hours with the best treatment combinations exhibiting an average degradation of 0.64 percent per 500 hours.
- A Gen 4 stack has successfully completed over 90 deep thermal cycles from 750 °C operating temperature to under 100 °C with a total power degradation of less than one percent. The successful stack test results provide confidence that the stacks will survive periods of maintenance and shutdowns in larger power plants.
- At a normal operating condition, the cathode pressure drop on the Gen 4 cathode interconnect (from Gen 3) has been reduced by about 20 percent.
- Developed low cost, high volume manufacturable processes for Gen 4 stack components. Fabricated and tested multiple Gen 4 stacks at a variety of test conditions.
- Preliminary cost analysis of the power block hardware for the IGFC power plant shows a cost of $566/kW in 2007$ with a 90 percent confidence interval, which meets the SECA cost requirement of ≤$700/kW.
- Completed the design, development, and installation of a test stand at UTC Power capable of testing a 50 kW SOFC stack.
- Developed three IGFC designs that produce greater than 100 MW net AC power at efficiency greater than 50 percent HHV and capture greater than 90 percent carbon. Sensitivity analyses were carried out demonstrating that the designs maintained their key performance requirements over a wide range of key operating variables.
- Down-selected three power module concepts after detailed investigation of several competing designs. All three systems were designed for 400 kW net AC and achieved efficiency in excess of 60 percent based on fuel lower heating value. Heat-up and power ramp studies were performed on all systems to define internal and external characteristics.
- Completed design and development of the SOFC breadboard power plant that is thermally self-sustaining while operating at 25 kW using natural gas as fuel. The breadboard power plant includes a hydrodesulfurizer, pre-reformer, a low-cost turbocharger, a novel catalyzed wall heat exchanger, and a network of heat exchangers to support thermal self-sufficiency.
- Completed test stand modifications at UTC Power to support natural gas operation of the breadboard power plant.
- Identified high-risk components in the breadboard power plant and demonstrated durability testing of the same as part of risk mitigation.
- Successfully completed integration of the breadboard power plant and Gen 4 stack assembly in the test stand facility at UTC Power.
- Demonstrated successful startups of the breadboard power plant and stack assemblies. Achieved steady state operation at 6.5 kW using natural gas.

Benefits

The SOFCs program will ultimately enable fuel cell-based near-zero emission coal plants with greatly reduced water requirements and the capability of capturing 97 percent of carbon at costs not exceeding the typical cost of electricity available today. Achieving this goal will significantly impact the nation given the size of the market, expected growth in energy demand, and the age of the existing power plant fleet. It will also provide the technology base to enable grid-independent distributed generation applications. Federal funding support of this research is appropriate given the game-changing nature of the technology accompanied by risks higher than the private sector initially can accept. In parallel, SECA Industry Teams will take advantage of the inherent scalability and fuel flexibility of SOFCs in seeking nearer-term, smaller-scale commercial applications for this efficient, environmentally-friendly technology, which has less risk than a first-of-a-kind full-scale IGFC system. Success in these spin-off applications (e.g., distributed generation, military, etc.) will further SOFC technology advancement and widespread commercial deployment through the resultant manufacturing and operational experience.



Scaled-up cells from 105 cm^2 (active area) to 403 cm^2 for Gen 4 stacks.

Test room with SOFC Breadboard for Four Stack Assembly.