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Solid State Energy Conversion Alliance

Despite the technical success of fuel cell research and development efforts, current applications of fuel cells are limited primarily due to their relatively high costs. Where premium-quality, reliable, and clean onsite power is critical to a business function - for example, at a bank, an airport, a computer data warehouse - customers may be willing to pay $4,800 per kilowatt or more for a fuel cell. However, a ten-fold reduction in the price of fuel cells is needed to enable competitive applications.

The Department of Energy formed the Solid State Energy Conversion Alliance (SECA) with a goal of producing a solid-state fuel cell module that would cost no more than $700 per kilowatt. At this price, fuel cells would compete with gas turbine and diesel generators.

MORE INFO
- Link to SECA Web Site

The key to the ambitious cost reductions will be the development of a compact, lightweight, "building block" module that can be mass-produced using advanced manufacturing processes. The building blocks would be clustered into a variety of custom-built stacks for a wide variety of stationary applications.

SECA is comprised of three groups: Industry Teams, Core Technology program participants, and federal government management. The Industry Teams design the fuel cells, deal with market penetration issues, and handle most hardware issues. The Core Technology program is made up of universities, national laboratories, small businesses, and other R&D organizations and addresses applied technological issues common to all Industry Teams. Findings and inventions under the Core Technology program are made available to all Industry Teams under unique intellectual property provisions that serve to accelerate development. The federal government management facilitates interaction between Industry Teams and the Core Technology program as well as establishes technical priorities and approaches.

SECA Industry Teams

The SECA program is currently structured to include three Industry Teams focused n developing coal-based systems: FuelCell Energy/Versa, Rolls-Royce Fuel Cell Systems, and United Technologies Corporation/ Delphi. General Electric will continue support R&D.

SECA Fuel Cell Coal-Based Systems

The goal of the SECA program is to develop large (greater than 250 megawatts) fuel cell power systems that will produce affordable, efficient and environmentally-friendly electrical power from coal derived fuel. These systems must achieve at least fifty percent (50%) overall efficiency (higher heating

MORE INFO
- FuelCell Energy [1.37MB PDF]
- UTC Power Corporation
- Siemens Energy, Inc.

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>8th Annual SECA Workshop Proceedings

> More Publications

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value-HHV) to AC power, in integrated coal gasification fuel cell (IGFC) plants with CO2 separation. As with smaller SECA systems, the cost target for the fuel cell system is $700/kWe or less, exclusive of the coal gasification unit and CO2 separation subsystems.

[114KB PDF]

The R&D work is focused on the scale-up of fuel cells and their incorporation into high-capacity fuel cell stacks. When aggregated together, these larger stacks will result in a fuel cell module technically and economically optimal for use as a "building-block" for multi-MW class central power systems. These building-block fuel cell modules will then be clustered together, possibly along with other power generation modules (e.g., a gas turbine as a fuel cell-turbine hybrid), into proof-of-concept systems.

The proof-of-concept systems must operate on a coal synthesis gas and be designed for compatibility with current or "near-term" CO2 separation technology; consequently, the system effluent gas streams must meet all existing regulations with respect to criteria pollutant and any requirements for CO2 separation. The CO2 capture design requirement is ninety percent (90%) of the quantity of CO2 that would result if all of the carbon in the syngas product (e.g., CO2, methane, carbon monoxide, carbonyl sulfide) were converted to CO2.

SECA Industry Teams are continuing cost reduction in their coal-based systems projects to accelerate progress. The Teams are developing coal-based systems for testing at an advanced power generation plant site in the 2012 to 2015 time fame. The fuel cell technology being developed by SECA has application to many stationary power markets with high efficiency, carbon capture, very low emissions, and water conservation. Theses advances will permit the production of power from coal in any state in the U.S. without environmental concern, ensuring a secure and economic energy future.

SECA Cost Reduction

To achieve cost targets, Industry Teams are engaged in refining technology and validating this advanced technology in SOFC modules that can be mass produced, aggregated, and scaled to meet a broad range of applications. This development activity is blending established manufacturing processes with state-of-the-art fuel cell technology advancements in order to leverage the advantages of economies of production (high-volume mass production) and scale. It also requires reaching a full spectrum of large markets, such as auxiliary power units (APUs) for trucks and recreational vehicles--by providing on-board power while the vehicle engine is off, SOFC-based APUs address the challenges of anti-idling legislation enacted in many states and at the same time establishes capacity to reduce cost to enable delivery of large SECA systems to the new breed of coal plants that follow. Additional markets include residential-commercial-industrial power, a wide range of distributed generation, and specialized applications for the military. Producing a common module for these vast markets will create the opportunity for the high-volume production required to reduce cost to the necessary level.

The SECA program's Industry Teams are hard at work on the design and manufacture of a variety of low-cost fuel cell prototypes. Recent testing of these prototypes has demonstrated giant leaps made toward fuel cell commercialization. Manufactured with a scalable mass-production technique, these SOFC prototypes have exceeded all of SECA's Phase I targets for availability, efficiency, and production cost. A typical system demonstrated an availability of 90 percent compared to the SECA target of 80 percent. An efficiency of 35-41 percent was achieved in the small 3-10 kilowatt systems, surpassing the target of 35 percent. This superior efficiency in a small size suggests the achievability of much higher efficiencies for larger systems. Most significantly, the independent audited system costs ranged from $724 to $775 per kilowatt--a major breakthrough toward achieving market-competitive costs. These Phase I numbers represent aggregated results across six industry teams. The once distant vision using clean, low-cost fuel cell technology for everyday applications is now within reach.

FuelCell Energy (FCE) and its subcontractor Versa Power Systems (VPS), made significant progress in scaling SOFCs to sizes amenable

to central generation (greater than 100MWe) applications. In October 2007, VPS successfully completed a 1.3kWe, 6-cell stack test incorporating scaled cells, each with an active area 550 centimeters squared – an increase of over 350 percent compared to the baseline VPS cell (121 centimeters squared). Furthermore, the scaling to larger area cells was achieved with less than 5 percent performance loss compared to the performance of the baseline cell. These cells were manufactured using VPS' existing proprietary manufacturing processes that are both economical and suitable for high-volume manufacturing. Fuel cell active area is an important aspect of fuel cell design which effects stack cost and, ultimately, fuel cell system cost. The larger the fuel cell active area, the fewer non-repeat parts – end plates, manifolds, electrical connections between stacks, and other hardware – will be required. This FCE/VPS accomplishment substantially contributes to achievement of the SECA cost goal of $400/kW fuel cell power blocks by 2010.

The performance of Siemens Energy, Inc. "Delta-8" SOFC cell has surpassed the performance of all previous Siemens cell designs with no noticeable voltage degradation. It is an almost 200 percent improvement over the earlier tubular designs. Furthermore, the cell represents a 58 percent increase in active area over the largest previous cell, and a 124 percent increase over the traditional Siemens tubular cell. The Delta 8 design, the latest within Siemens High Power Density (HPD) cell design series, utilizes a 15cm wide flattened tube (which shortens current conduction paths, thereby reducing cell resistance and increasing performance) with 8 triangular corrugations on one side for increased active area. The cell has achieved a peak power density of 0.28 W/centimeters squared to date – limited by the test stand equipment. This result was achieved at 1,000 degrees C, atmospheric pressure, and 80 percent fuel utilization (humidified H2). Projected performance at 0.65 Volts is expected to be over 0.33 Watts/centimeters squared. The cell test has operated for over 2,000 hours under load and an additional 609 hours at open circuit through April 2008. This performance improvement is indicative of the advancements achieved by Siemens and other Industry Teams under the SECA Program towards the R&D performance goals necessary for commercialization of SOFCs.

SECA Core Technology Program

The Core Technology program provides comprehensive applied research support in ten focus areas: Cathodes, Anodes and Coal Contaminants, Interconnects, Seals, Contact Pastes, Cross Cutting Materials and Manufacturing, Fuel Processing, Power Electronics, Modeling and Simulation, and Balance of Plant. This structure and the provisions in place reduce cost by leveraging resources so that all Industry Teams do not engage in separate applied research programs paying multiple times for the same research done once in the Core program. This approach also ensures that only major issues are addressed. Core program areas are also funded by special topics under Science Initiatives, Small Business Innovative Research (SBIR), Basic Energy Sciences, University Coal Research, and Historically Black Colleges and Universities.

Several recent Core Technology Program accomplishments are noted below:

Argonne Characterizes SOFC Cathode Surface Chemistry with Synchrotron X-rays: Researchers at the Advanced Photon Source at Argonne National Laboratory (ANL), Carnegie Mellon University, Massachusetts Institute of Technology, and Stanford University are collaborating on a project established to understand the chemistry and structure of SOFC cathodes. The four groups are participants in the SECA Core Technology Program. In December 2007, ANL bombarded the surface of model cathodes with synchrotron X-rays to determine their surface chemistry and surface structure. The cathodes were systematically exposed to variations in oxygen pressure, temperature, and electrochemical loading. Preliminary results show that in Strontium-containing cathodes, electrochemical loading can cause Strontium to surface segregate. An unexpected, but very important, result was that the surface chemistry and structure of some cathodes are basically the same under room-temperature laboratory conditions as they are under high-temperature SOFC operating conditions. The

revolutionary finding that the surface chemistry and structure of some cathodes are basically the same at both SOFC operating conditions and room-temperature laboratory conditions suggest that SOFC cathode materials may be studied using analytical techniques that require room-temperature Ultra-High Vacuum conditions. These techniques, known for their spatial and energetic sensitivities, will permit direct access to the electronic structure of the cathodes in addition to establishing a very accurate description of the local chemical and structural landscape. The new data being generated are guiding theoreticians and engineers in their understanding of the role of surfaces in fuel cell cathode performance.

Navy Tests SECA SOFC Under Extreme Conditions: The Naval Undersea Warfare Center (NUWC) provides for independent testing and evaluation of energy systems for naval use. In June 2008, NUWC completed a successful test of an integrated SOFC power system concept for use in Unmanned Undersea Vehicles (UUVs). A 30-cell stack from Delphi Corporation, a SECA Industry Team, was tested under closed anode-loop operation. The steam generated by the fuel cell was recycled and used to drive an InnovaTek steam reformer, which converts diesel fuel to a hydrogen/methane-rich gas stream. A high temperature blower developed by R&D Dynamics, a Core SBIR participant, was used to recycle the hot anode gas. Carbon dioxide sorbent provided by TDA Research, also a Core SBIR participant, was used to prevent fuel dilution and provide additional heating for the steam reformer. Over 1 kilowatt was generated by the stack with only liquid S-8 (synthetic diesel fuel) and pure oxygen being fed to the stack. The following benchmarks were all achieved simultaneously: over 90 percent oxygen utilization, over 75 percent S-8 utilization, water neutral operation, and over 55 percent efficiency based on the electricity generated versus the lower heating value of S-8. This system demonstration was a successful proof of concept and is the culmination of nearly 5 years of Naval research. SOFCs are being targeted by the U.S. Navy as power sources for UUVs because they offer rapid refueling capability, operation with logistics fuel, and high electric conversion efficiency (greater than 50 percent based on the lower heating value of fuel).

NETL Test Skid for Studying the Effect of Coal Contaminants on SOFC: NETL fabricated and completed installation and shakedown testing of the Multi-Cell Array (MCA) test skid at the Wilsonville (AL) Power Systems Development Facility (PSDF) in April 2008. The MCA is a mobile platform developed to enable testing of SOFCs on coal synthesis gas (syngas). The unit is designed to enable testing for up to 12 individual fuel cells over a range of electric load conditions for extended periods of time. It will provide data on the influence of trace coal contaminants such as arsenic, phosphorous, selenium, and mercury on performance of fuel cells operated on coal syngas. These data are critical for development of fuel cells for coal-based power generation. NETL's MCA was designed to be transported to an operating gasifier and operated using a slip stream of syngas. The test skid includes a gas chromatograph inductively coupled plasma-mass spectrometer or GC-ICP-MS that offers part-per-billion sensitivity to inorganic gas phase compounds typically found in trace amounts in coal syngas. This research directly addresses high priority goals of the SECA program, which include evaluating the impact of trace coal syngas species on SOFC performance and degradation and determining efficient methods for mitigation of undesirable effects.

Research Team Develops and Demonstrates Commercial SOFC Interconnect Material - Allegheny Technologies Inc. of Pittsburgh, PA, PNNL, and NETL have successfully identified and tested a cost-effective interconnect material based on ferritic stainless steels for applications in coal-based SOFC systems. The team's development goal was to use an inexpensive metal alloy to eliminate the negative effects of metallic interconnects on electrical conductivity in SOFCs. With funding and direction from the SECA Core Technology program, PNNL achieved success in laboratory tests with a commercial alloy from Allegheny Ludlum Corporation of Pittsburgh, PA. More extensive investigations are in progress to determine whether, with appropriate surface treatment, an alloy of this type can fully satisfy stringent SOFC interconnect requirements.

High-Temperature Blowers Developed for SOFC Systems - Phoenix Analysis & Design Technologies Inc. of Tempe, AZ, and R&D

Dynamics Corporation of Bloomfield, CT, have successfully demonstrated two distinctly different high-temperature pumps and blowers for SOFC systems. Each of the novel technologies successfully separates hot fuel cell gases from temperature-sensitive pump components, such as bearings, magnets, electronics, and motor windings. This work is key to improving SOFC efficiencies, and it supports the achievement of fuel cell systems that can adapt to diverse fuels. The efforts were conducted for SECA under a series of Small Business Innovation Research grants.

Crack-Resistant Compliant Glass Seal Identified - SOFC systems are more robust if their seals can accommodate motion in cell components and recover from stress-induced cracking. The University of Cincinnati has identified a glass composition that does not crystallize at SOFC operating temperatures and remains soft, so that cracks flow shut when the stack cools to room temperature. University of Missouri-Rolla is now working to improve the chemical compatibility of this class of flowable glass and Sandia National Laboratory is examining composites in which ceramic filler particles improve the resiliency of the soft glass seal. Engineered materials systems that utilize novel glass formulations and composite structures hold promise for successful seal solutions.

Cathode Poisoning from Interconnect Chromium Mitigated - Chromium is a common element in cost-effective fuel cell metal interconnects. However, it often migrates from the interconnect to the cathode material, forming compounds that may decrease cell performance. The SECA Core Technology program determined a "chromium poisoning" mitigation strategy through work performed at Argonne National Laboratory, PNNL, and Carnegie Mellon University. This collaborative effort has provided an approach to SECA's Industry Teams wherein chromium transport is slowed by coatings and removed by airflow and cathode structures capture the chromium without significant loss in cell performance.