STATUS AND MARKET APPLICATIONS FOR THE SOLID OXIDE FUEL CELL IN THE U.S. – A NEW DIRECTION

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ABSTRACT

Solid Oxide Fuel Cell (SOFC) power plants are expected to impact the near-term natural gas stationary power distributed generation (DG) market 100-kilowatt (kW) to multi-megawatt (MW) beginning in 2003. Siemens Westinghouse Power Corporation (SWPC) is the leader in tubular SOFC technology. Several completely packaged and self-contained generators, up to nominal 220kW size, have been manufactured and tested by SWPC. A manufacturing facility currently produces these generators. However, in the long-term, solid state fuel cell technology with stack costs under $100/kW, or lower, promises deeper and wider market penetration in a range of applications including residential, auxiliary power, and the mature distributed generation markets. The Solid State Energy Conversion Alliance (SECA), with its vision for fuel cells in 2010, was recently formed to commercialize solid state fuel cells and realize the full potential of the fuel cell technology. Ultimately, the SECA concept could lead to megawatt-size fuel-cell systems for commercial and industrial applications and Vision 21 fuel cell turbine hybrid energy plants in 2015. In the U.S. more planar designs and developers are emerging. Organizations developing planar designs include the Institute of Gas Technology, Ceramatec, Ztek, Technology Management Inc., Honeywell, Delphi, McDermott, FuelCellCo, Accumetrics, and others. Many of these are in the SECA program. The high-efficiency, fuel cell/gas turbine hybrid with and without staging of fuel cells, represents the most efficient power plant ever conceived, that can also incorporate SOFC’s. Hybrid development is also progressing and is discussed.

NEAR-TERM DISTRIBUTED GENERATION MARKET AND SWPC

SWPC is developing the tubular SOFC technology. SWPC is developing a tubular configuration that has been validated to a far greater extent than any other SOFC technology. Two thin-wall porous support tube cells have been on test for over 7 years (>69,000 hours). The tubes have been scaled up to a nominal 2 meters in length. The porous air support tube has been eliminated; the air electrode now supports the cell. SWPC completed 114 thermal cycles on 2 Air Electrode Supported (AES) cells, which were 50-centimeters (cm) active length and used 2 Electrochemical Vapor Deposition (EVD) steps.
The Kansai Electric Company (Japan) tested a four-cell article and accumulated 10,529 hours of operation at high current densities and completed 101 thermal cycles. These cells were 150-cm active length and used 2 EVD steps. In addition, the cells experienced only minor voltage degradation. Ontario Hydro has accumulated more than 1,725 hours of operation on a single 150-cm AES cell manufactured with two EVD steps. More than 1,475 of the 1,725 hours were operated at 5 atmospheres. This type of cell is typical of the cells that SWPC has used in the 100-kW demonstration unit in late 1997 and will be used in their commercial offerings.

Southern California Edison has operated a 25-kW unit at their High Grove Generating Station in Terrace, California. This unit was moved to the University of California and was restarted after two years of being stored in a warehouse. It has accumulated over 3,200 hours after the unit was restarted (8,800 hours total). SWPC completed testing of a 25-kW unit for the Joint Gas Utilities (JGU) at their Science and Technology Center, Pittsburgh, Pennsylvania, after completing over 13,000 hours of operation and surviving 10 thermal cycles. The 100-kW EDB/ELSAM unit was completed in December 1997 and has over 11,000 hours of operation.

SWPC has brought online a 45,000-square foot Pilot Manufacturing Facility with a production capacity of 4 MW/year/shift. This facility completed cell production for a 250-kW Southern California Edison combined cycle unit in March 1998. SWPC appears to have eliminated two of the three EVD steps in manufacturing. They are currently working on the elimination of the last EVD step (for the electrolyte). To further reduce costs, SWPC is increasing the cell output by cell redesign and pressurized operation, testing low-cost air electrode material, and investigating low-cost air electrode manufacturing. Current cell life is estimated to be 10 years, with 7 years already demonstrated. SWPC believes cell life for commercial cells will be 10 to 20 years. Commercial product size will range from 1 to greater than 50 MW in a combined-cycle configuration.

The U.S. and European growth and replacement market for near-term distributed generation is expected to approach 10 GW/year over the next decade. Globally it is expected to be 20 GW/year by 2010. SWPC, has had impressive test performance, and plans multiple demonstrations within the next few years. Collectively, it could be capturing 1 to 2 GW/year of the global market by the end of the decade.

**SECA AND THE MATURE DISTRIBUTED GENERATION MARKET**

The first SECA Kickoff Meeting and National Roadmapping Workshop was held in Baltimore, Maryland, June 1-2, 2000. Two national laboratories, NETL and Pacific Northwest National Laboratory (PNNL), the driving forces behind SECA, are providing the leadership, focus and integration needed to bring solid state fuel cell technology into the mature distributed generation and auxiliary power markets. In order to obtain national input, these laboratories held an initial kickoff meeting at which there were almost 200 participants with broad representation from industry, national labs, academia, and defense. The SECA is a mechanism to build and integrate the industry base for low-cost fuel cells to penetrate the mature distributed generation market. The SECA will build an alliance of government agencies, commercial developers, universities, and national laboratories to develop SOFCs with the capability for immediate commercial
success. The alliance will provide a focal point, an “organizational center” for the
development of distributed generation and larger stationary power applications, auxiliary
power units for military applications, and auxiliary power units for transportation
applications. All three applications will benefit from the free flow of leveraged fuel cell
technology development.

Long-term cost goals for military and transportation applications for the commodity
and transportation propulsion market are $50 to $200/kW. Efficiencies for all
applications will be greatly improved over current state-of-the-art. The results of this
program will provide early low-cost power systems for mature distributed generation
market applications, and will feed directly into the Vision 21 Fuel Cells Program.

SECA VISION: FUEL CELLS IN 2010

The vision for solid-state fuel cell systems in 2010 is:

• These systems will be low cost: $400/kW in the multi-kW size range, a remarkable
accomplishment in this small size range. The price trajectory will be downward, such
that a $50/kW system for transportation applications is on the horizon.

• Fuel-to-end-use efficiencies will be high: nearly twice as high as today’s conven­
tional technologies, again a remarkable accomplishment in the multi-kilowatt size
range. These high efficiencies translate to reduced greenhouse gas emissions.

• Given a fuel, there will be a fuel-cell system that can operate on it. Fuel cells will be
able to operate on natural gas, gasoline, diesel fuel, landfill gas, hydrogen, and
defense logistics fuels.

By 2010 it is hoped that industry teams will have commercialized solid-state fuel
cells as auxiliary power units for the nation’s cars and trucks, distributed generation units
for homes, and field power units for military operations. The core of this vision is a
5 kW, low-cost, high power-density, solid-state fuel-cell stack. The core module
measures approximately 4 by 4 by 12 inches. It can be mass produced because it can be
used in multiple end-use markets. Because it is a standard core module, the cost to
customize it for multiple markets is cheap. This concept of “mass customization of
common modules” eliminates the Catch-22 of commercialization, that is, high-volume
production is needed to reduce costs, but low costs are needed to create a large market.
The 5-kW core modules can be combined (like batteries) for applications with larger
power needs. This “building block” approach enables low-cost customization. This is
the Gateway or Dell computer concept applied to fuel cells. Gateway and Dell keep
personal computer costs low and meet the exact needs of their customers by using the
concept of mass customization. Ultimately, the SECA concept could lead to megawatt­
size fuel-cell systems for commercial and industrial applications and Vision 21 energy
plants. This vision is achievable, but it will take a new approach to technology
development.
VISION 21: FUEL CELLS IN 2015

Fossil fuels currently provide 85 percent of global and U.S. energy supply. Even under a climate change scenario, we will need to use fossil energy well into the future. However, we need to use it smarter. The goal of Vision 21 is to wring every possible bit of useful energy out of carbon-based feedstocks to produce energy products. The Vision 21 fuel cells segment will develop advanced fuel cell modules that would be integrated with other Vision 21 advanced technology modules, and would be tailored to meet specific market needs. Fuels cells are needed to obtain the 60 percent efficient coal-fueled Vision 21 power plants of the future. To reach these high efficiency targets, a hybridized, high-efficiency fuel cell is required. Getting the cost of the fuel cell power module to $400/kW is a key factor in deploying Vision 21 systems by 2015. If this can be done, fuel cell/turbine hybrids could replace turbines as the power block in integrated gasification combined-cycle applications. These highly efficient combined systems, in multi-megawatt sizes, would have no environmental impact outside their own footprint. The goal is to make these modules ready for use in integrated systems by 2015. This program segment will accept additional technology input from the SECA program segments as solid state fuel cells become available. Fuel cells also have an advantage in Vision 21 sequestration applications. Fuel cells have inherently high efficiency and can also be configured to produce concentrated CO₂ streams. Under the recent DOE Fossil Energy Vision 21 solicitation, SWPC received an award to reconfigure their tubular SOFC to produce a concentrated CO₂ stream for use in enhanced oil recovery and other applications.

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