STATUS OF SIEMENS WESTINGHOUSE SOFC TECHNOLOGY AND DEMONSTRATION UNITS

S. C. Singhal
Siemens Westinghouse Power Corporation
1310 Beulah Road
Pittsburgh, PA 15235

State-of-the-Art Cells

Over three thousand state-of-the-art tubular SOFCs built using air electrode tubes have been electrically tested for up to about 27,500 hours, either as single cells, in cell bundles, or in 25 kW and 100 kW power generation systems. These cells have performed well under a variety of operating conditions with less than 0.1% per 1000 h performance degradation. These cells have also shown the ability to be thermally cycled from 1000ºC to room temperature over 100 times without any mechanical damage or electrical performance degradation.

Cost Reduction

Significant progress has been made in reducing the cost of manufacturing the cells. The electrochemical vapor deposition (EVD) process for fabricating Ni-YSZ fuel electrode has been replaced by a low-cost slurry sintering process; the cell manufacturing now uses EVD process only for the deposition of the YSZ electrolyte. In addition, an in-house air electrode tube manufacturing facility is being constructed. This facility is now nearing completion with tube production scheduled to begin in October 1999. At full capacity, this facility will produce 700 tubes per month, sufficient for pre-commercial demonstration units.

A Cost Reduction Plan has been developed and implemented to focus the development efforts in those areas that can contribute most to reducing system cost. The plan identifies specific materials, components and processes that will be targets for cost reduction. In the cell area, the focus is on evaluating and qualifying lower cost materials, developing alternate manufacturing processes, automating fabrication process steps, and improving power density of the cells. The SOFC module cost reduction focus includes simplifying the generator design, evaluating and qualifying cheaper materials and processes, and automating cell bundling. The focus in the balance of plant is primarily to develop simplified, standardized designs for each product offering, and reduce the number of components in each design.

100 kW Atmospheric SOFC System

A 100 kW SOFC power generation system began operation in December 1997 in The Netherlands under a program with a consortium of Dutch and Danish utilities (EDB/ELSAM). The SOFC stack in this system contains 1,152 cells (2.2 cm diameter, 150 cm active length), which are arranged in twelve rows. Between each cell row is an in-stack radiantly heated reformer. The stack is partitioned in elevation by porous baffles forming a fuel distribution plenum, an active cell zone, a spent fuel plenum, a combustion zone, and an air plenum. An ejector is used to extract a portion of the spent fuel and mix it with fresh fuel before the mixture is introduced into an adiabatic pre-reformer where the higher hydrocarbons are reformed. From the pre-reformer, the predominantly methane stream is routed to the top of the in-stack reformers. The mixture flows downward through catalyst material before exiting within the fuel plenum at the

bottom of the stack. The completely reformed fuel flows upward within the stack along the exterior of cells where it is electrochemically oxidized.

The system passed a factory acceptance test at Siemens Westinghouse facilities in Pittsburgh, Pennsylvania in October 1997 during which it generated electric power for 335 h before shutdown on October 30. The unit was subsequently shipped to the test site near Arnhem, The Netherlands. The unit was restarted in early December 1997, and officially accepted by the EDB/ELSAM on February 6, 1998 after successfully completing a site acceptance test. The system achieved an electrical generation efficiency of 43% (net ac/LHV), using Dutch pipeline natural gas fuel at a net system output of 106 kW ac to the grid at 1000°C and 80% fuel utilization. System operation was suspended at the end of June 1998 after 4035 h of operation because internal voltage measurements indicated an accelerating voltage decline in a segment of the stack. Open circuit behavior upon shutdown showed good cell voltage, hence healthy cells, thereby indicating excessive stack resistance. The generator module skid was shipped to Siemens Westinghouse facilities in Pittsburgh for inspection and repair. Disassembly revealed that the baffle separating the combustion zone from the spent fuel plenum had broken in several places permitting air to enter the spent fuel plenum. Further disassembly revealed areas of nickel felt separation from cell inter-connections at the end of bundles, especially near the end of bundle rows. In addition, five cells, each located at the end of a bundle row, were found to be cracked. Design improve-ments yielding a more robust baffle and reduced mechanical loading of the cells have now been implemented, the stack rebuilt and restarted in early 1999. The rebuilt stack operated for 2166 h providing up to 108 kW ac to the Dutch grid at an efficiency of 46% before being shut down on July 9 due to the apparent malfunction of a static switch in the power conditioning system. The unit will be restarted once the switch is replaced.

250 kW Pressurized SOFC-Gas Turbine Hybrid System

A 250 kW class pressurized SOFC-gas turbine hybrid power system is currently being fabricated under the sponsorship of Edison Technology Solutions for proof-of-concept testing. The SOFC module (1,152 cells of 2.2 cm diameter and 150 cm active length) of the hybrid system will produce approximately 200 kW of power operating at 3.5 atm pressure and the gas turbine about 50 kW. The efficiency of the power system is expected to be about 57% (based on LHV) running on desulfurized natural gas.

The system configuration employs a two-shaft gas turbine and uses a pressurized SOFC stack upstream of the gas turbine combustor. Process air is compressed before being introduced to the pressurized SOFC stack. The stack produces dc electricity and generates a high pressure, high temperature exhaust gas (850°C). This high pressure exhaust is passed through the first turbine stage driving the compressor and then expands through a power turbine connected to an ac alternator. The power turbine exhaust is ducted through a recuperator to heat incoming process air. The system will be installed at the National Fuel Cell Research Center on the University of California at Irvine campus, and is expected to begin operation near the end of 1999.