ZTEK ADVANCED PLANAR SOLID OXIDE FUEL CELL FOR DISTRIBUTED GENERATION

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INTRODUCTION

Ztek's Planar Solid Oxide Fuel Cell (SOFC) system has exceptional potential for electric power generation because of: simplicity of components construction, capability for low cost manufacturing, efficient recovery of very high quality by-product heat (up to 1000°C), and system integration simplicity. Applications of the Solid Oxide Fuel Cell are varied and include distributed generation units (sub-MW to 20MW capacity), repowering existing power plants (i.e. 20MW to 100MW), and multi-megawatt central power plants.

A TVA/EPRI/ZTEK collaboration program involved functional testing of the advanced solid oxide fuel cell stacks and design scale-up for distributed power generation applications. The emphasis was on the engineering design of the SOFC modules which will be the building blocks for up to megawatt scale power plants. The program had two distinctive subprograms: Verification test on a 1kW stack and 25kW system for utility demonstration. A 1kW Planar SOFC stack was successfully operated for 15,000 hours as of December, 1995. Ztek completed the hardware development of a 25kW SOFC Power System for TVA, which was installed at Huntsville Utilities Host Site for demonstration since the first quarter of 1998. The 25kW module in this power system is Ztek's intended building block for the commercial use of the Planar SOFC. Multiple 25kW modules will be packaged in Ztek's market entry product, a 250kW SOFC/Gas Turbine hybrid system with 175kW of the output power produced by fuel cells and the remainder by the gas turbine. The 250kW hardware development is underway, aiming for the mid year 2000 for its initial operation. Key technical features essential for the hybrid system integration have been tested and verified in the 25kW Power System.

The Ztek SOFC Power System Technology offers the benefits of clean, low cost electricity resulting from low capital cost and ultra high efficiency. In addition to the potential for competitive low cost of electricity, the following additional benefits apply: Maximum megawatt capacity per distributed site; Maximum use of renewable fuels when landfill gas and biogas are utilized; High power quality; Low NOx, SOx and HC emissions; and Ease of CO_2 capture. The above leads to significant utility benefits such as: response to global warming concerns, repowering opportunities, and applications of distributed generation which will result in a low cost of total energy.

25KW SOFC POWER SYSTEM DEMONSTRATION

The 25kW SOFC Power System, **Figure 1,** includes four main subassemblies which are described below:

1. SOFC Utility Module Subassembly

2. Reactant Supply Subassembly

3. Operation Control Subassembly

4. Power Conditioning Subassembly

The power generating SOFC Utility Module subassembly consists of the SOFC array, the reactant distribution piping, the required thermal insulation, and the power connections. The reactants heating is implemented utilizing the efficient, compact, and cost effective Internal Thermal Integration (ITI) feature, which is an integral part of Ztek's SOFC components.

The fuel cell module configuration is an axi-symmetric stack array which has been devised to accommodate the immediate atmospheric test and the anticipated pressurized operation. The resulting cylindrical enclosure configuration also provides the benefit of favorable thermal symmetry in the module setup and a unified design scale-up. The 25kW module comprises a gas start-up heater, fuel cell and internal pre-reformer stacks. The plate-type internal pre-reformer is responsible for partial reforming up to 50% of the CH_4 with steam or air. The SOFC stacks perform the remaining reforming internally, utilizing the in-situ availability of heat and water molecules from the electrochemical reaction of the fuel cell.

The reactant and operation control subassembly includes reactant flow piping and valves, reactant treatment hardware (for water and fuel), and process control and display electronics.

The control electronics utilizes an Allen-Bradley PLC with Panelview display. Additional display and data acquisition software was incorporated, with remote accessibility, to facilitate the development of operational procedures.

The function of the power conditioning subsystem is the conversion of the direct current (DC) produced by the SOFC power generating subassembly to an alternating current (AC) that is consistent with the interface requirements for electric grid connection. Following examinations of cost, size, ease and flexibility in operation, an inverter was selected that uniquely offers DC to AC power inversion for utility connection, stand-alone operation, and automatic switching between the two modes of operation. The multi-mode capability is also advantageous in assisting to establish the proper operation of the fuel cells.

SYSTEM DESIGN SPECIFICATION

Plant AC Output	25	kW	Net
Grid Voltage Regulated	208	Vac	
Current, 3-Phase	70	A	
Auxiliary Load	1	kW	
FC/Invertor AC Output	26	kW	Gross
Invertor Loss (5%)	1.5	kW	
Fuel Cell DC Output	27.5	kW	Gross
	500	Vdc	
	55	A	
Net Plant Heat Rate	7,454	Btu/kWh	LHV
Net Plant Efficiency	45.8	%	

SYSTEM INSTALLATION AND OPERATION

The 25kW SOFC Power System was installed on and transported to the Huntsville Utilities Host Site in a van, which constitutes a mobile power system, **Figure 2.** The purpose of the van is to allow transporting the fuel cell system to the site where it can be made immediately available for operation. The Power System will remain on the van and operate during the demonstration period. Connections are made between the van and stationary interface boxes at the site for fuel, water, power and telecommunication connections.

Important milestones have been accomplished as a result of the start up and exercises performed on the 25kW SOFC Power System at the Host Site in Huntsville, Alabama. The startup and shutdown procedures have reached a refined and reliable status. Steam generation has operated successfully and demonstrated its ability to accompany the carbon free operation of the reformer and heater. System maintenance at operating temperature is achieved using air flow as a coolant when the fuel cell is in its operating mode. This allows the fuel cell output to be sustained with control of fuel and air flow, while cooling is utilized to accurately maintain an operating temperature of 950°C to 1000°C.

At the time of this reporting, the fuel cell system has achieved an uninterrupted operation up to 2,500hr, with 8,000hr as the program goal. The effort to achieve full power operation is coordinated with refinements for the simultaneous maintenance of stability in four quantities: temperature of operation, steam introduction, reforming reaction, and fuel cell power output. This exercise is closely related to the implementation of Ztek's patented features, e.g. Radiant Thermal Integration (RTI) and Internal Thermal Integration (ITI) in obtaining significant performance advantages over conventional power systems or other fuel cell systems.

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Figure 1 25kW SOFC Power System in Testing

Figure 2 25kW Mobile Power System at Host Site