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**DESIGN AND PERFORMANCE OF PEMFC POWER SYSTEM
FOR THE REMOTE AREA POWER PROJECT**

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Introduction

The Schatz Energy Research Center (SERC), working with Teledyne Energy Systems (TES) designed, built, tested, and delivered a fuel cell power system as part of the Remote Area Power Project (RAPP). The project team also included Sandia National Laboratory (SNL) and the University of Alaska, Fairbanks (UAF) and was funded in part by the U.S. Department of Energy.

In this paper, we describe the design process, components, and system configuration. We also report the results of performance tests by SERC and UAF.

Design and Production of the PEMFC Power System

The palletized, prototype fuel cell power system was designed to be incorporated into an integrated fuel cell/reformer system. The system includes two SERC-produced 40-cell, PEMFC stacks utilizing reformate-tolerant platinum-ruthenium MEAs (PRIMEA™ 5510 membrane-electrode assemblies from W.L. Gore and Associates, Inc.), a robust control system, and an inverter capable of producing grid-quality AC power. SERC selected and procured all subsystem components (including the air, water, hydrogen, electrical/control subsystems and power conditioning unit) for the system and laid out and installed all components on a pallet. The integrated control system consists of four independent modules which handle the following tasks: battery management, fuel cell control, cell voltage monitoring, and software independent safety interlocks. SERC developed the software for the modules, specified, procured, assembled, and tested the individual modules, and tested the integrated system with fuel cell power system components. TES and SNL provided project administration and coordination. UAF engineers conducted independent systems tests.

The power system was designed to power a typical home in a remote Alaska location. The system is capable of supporting in excess of a 30 kWh/day dynamic load and can deliver up to 4 kW continuous AC power, with peaking to 9 kW.

Testing of the PEMFC Power System

To determine the net system efficiency, the completed power system was tested at SERC by Dr. Dennis Witmer and Tom Johnson from UAF using UAF-supplied instruments. The system was tested on pure hydrogen. UAF determined the net system efficiency from measurements of the hydrogen flow into the system and the RMS AC power output (see Figure 1). The RMS AC voltage of the inverter output was also monitored to determine if the output was grid-quality power and the current to or from the battery bank was monitored to ensure that the battery bank was not being discharged during testing. In addition, SERC monitored the voltage, current, and temperature of each fuel cell, the ambient temperature, the battery voltage, and the inverter voltage.

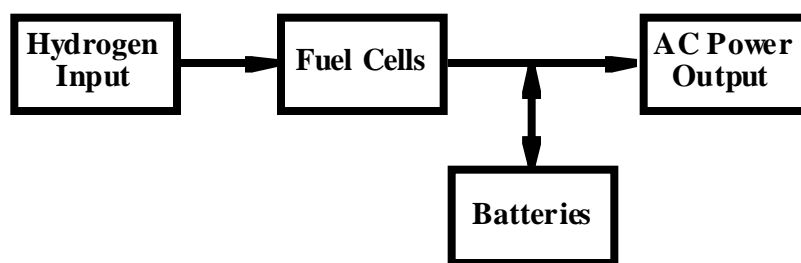


Figure 1: System Energy Flow Diagram

Figure 2 shows the system net power output during one period of testing as the resistive load was stepped up and down through several levels, ranging from 0 to 2950 Watts. The system response was instantaneous and smooth.

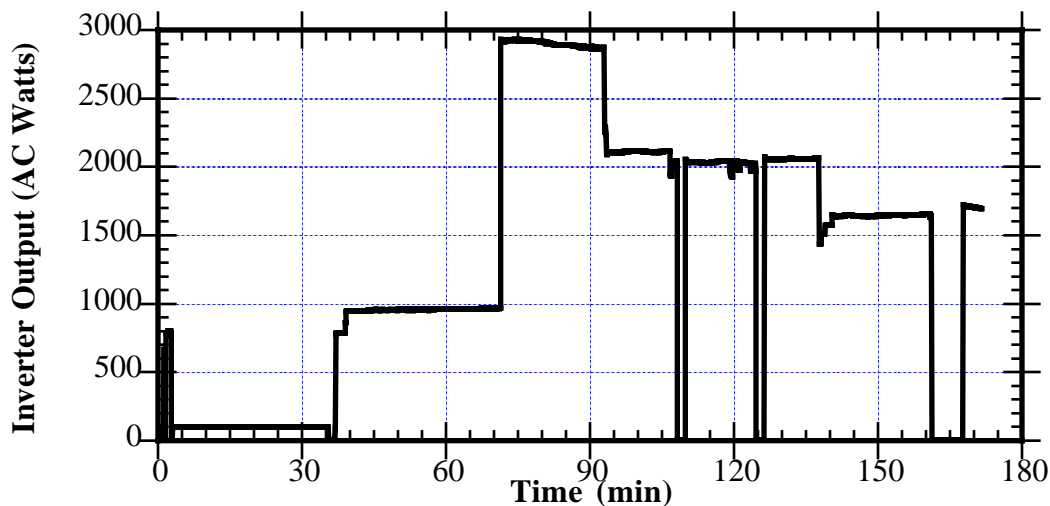


Figure 2: System AC Power Output vs. Time

Figure 3 shows the system response to inductive loads. While the system was supporting an 800 Watt resistive load, a 2 kWp inductive load (a 1/3 HP bench grinder) was added. The system was able to immediately deliver the high but short-term output required to support the inductive load.

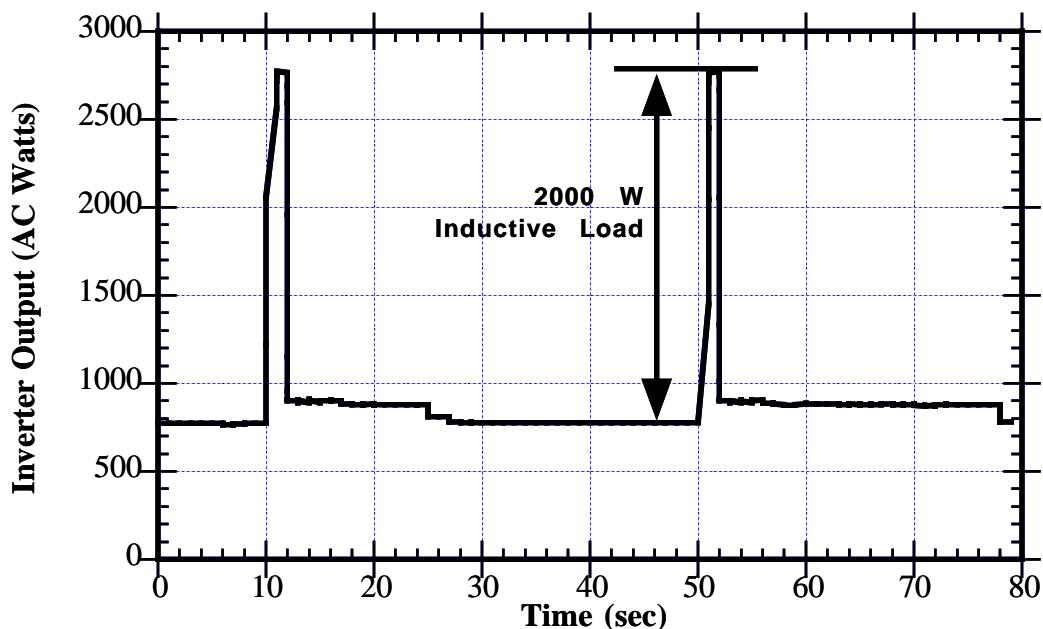


Figure 3: System Response to Inductive Loads

Table 1 summarizes the system performance during two steady-state tests, the first at 4 kW and the second at 2.7 kW DC output power from the fuel cells. Based on the lower heating value of hydrogen (LHV), the gross fuel cell efficiency was 58% during the 4 kW test and 60% during the 2.7 kW test. The net system efficiency was 41% during the 4 kW test and 45% during the 2.7 kW test.

Table 1: Performance of PEMFC Power System

Parameter	During 4 kW Test	During 2.7 kW Test
Fuel Cell Power (Watts)	4000	2700
Inverter Output (Watts)	2950	2060
Gross Fuel Cell Efficiency (HHV)	49%	51%
Gross Fuel Cell Efficiency (LHV)	58%	60%
Net System Efficiency (HHV)	35%	38%
Net System Efficiency (LHV)	41%	45%

Parasitic loads from the blowers, water pump, cooling fan, and other subsystems were low, about 6.5% of the fuel cell power output. Table 2 summarizes losses from subsystems and other parasitic loads. Note that inverter losses and wire and diode losses equal or exceed the subsystems loads. Largest of all are purge losses. Since the fuel cells are run dead-ended on the hydrogen side, periodic purges are required to expel accumulated water vapor and contaminants.

Table 2: Summary of System Parasitic Power Losses

<u>Source of Loss</u>	<u>During 4 kW Test</u>		<u>During 2.7 kW Test</u>	
	<u>Watts</u>	<u>% of Total</u>	<u>Watts</u>	<u>% of Total</u>
Hydrogen Purge (HHV)	325	25%	333	40%
Wire and Diodes	300	24%	155	19%
Subsystems	256	20%	168	20%
Inverter	396	31%	179	20%
Total Parasitic Losses	1277	100%	836	100%
Fraction of Gross Output	32%		31%	

Conclusions

The Schatz Energy Research Center (SERC), working with Teledyne Energy Systems, Sandia National Laboratory, and the University of Alaska, Fairbanks successfully designed, built, tested, and delivered a fuel cell power system as part of the Remote Area Power Project (RAPP). The system met or exceeded all project objectives. Gross efficiency of the fuel cell stacks was high (58 to 60% LHV) and minimizing the parasitic losses made possible a net system efficiency of 41 to 45% (LHV). Analysis of the testing results indicates that the subsystems account for only 20% of these parasitic losses.

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