FUEL CELL /PHOTOVOLTAIC INTEGRATED POWER SYSTEM FOR A REMOTE TELECOMMUNICATIONS STATION

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The Schatz Energy Research Center (SERC) has designed, built, and operated a PEM fuel cell power system that supplies back-up power to a remote radio-telephone repeater. The repeater, located within Redwood National Park in northwestern California, is part of the Yurok Indian Reservation's telecommunications system. A photovoltaic (PV) system with batteries provides primary power for the repeater. When solar insolation is insufficient to maintain battery state-of-charge, the 100-Watt fuel cell system starts automatically and provides clean, quiet, reliable power.

The system began unattended operation in November 1999. The original fuel cell stack logged 3239 hours of run time. In January 2001, SERC engineers refurbished the original fuel cell stack, incorporating improved membrane-electrode assemblies and gas diffusion media. The original resin-impregnated graphite was replaced with pyrosealed components and a temperature-controlled fan switch was added to protect the stack from sudden temperature increases while minimizing parasitic loads. The system ran continuously though October 2001, accumulating 3836 hours of run time and completing 283 start-stop cycles.

The system and the original stack are described in detail in two earlier papers [1,2]. This paper will focus on the performance of the second stack used in the system.

System Description

Figure 1 shows a schematic of the hybrid power system. Primary power is supplied by the photovoltaic (PV) array, consisting of twelve Siemens SP65 12-Volt, 65-Watt modules. In this 24-Volt system, the modules are configured as six series pairs wired in parallel. Due to National Park Service design requirements, the modules are mounted flush on the wall of the lookout tower, which is inclined 7° from vertical (Figure 2). The location has an excellent solar window, unobstructed from horizon to horizon in all seasons. The array powers the telecommunications load directly, with surplus energy charging a set of ten Solar Electric Specialties 12SC225 12-Volt, 225 Amp-hour deep cycle batteries, arranged as five series pairs wired in parallel. When the solar array is unable to maintain battery state of charge above a voltage setpoint, the fuel cell system is activated automatically and carries the load until the battery voltage is able to recover.

The fuel cell (Figure 3) is a 32-cell PEM stack with 140-cm^2, PRIMEA® 5510 membrane-electrode assemblies from W.L. Gore and Associates, Inc. and E-Tek ELAT gas diffusion media. SERC engineers designed and fabricated the stack in-house. It operates on hydrogen delivered at approximately 3 psig. A solid-state controller switches the stack subsystems on when battery voltage falls below 25.2 V and switches them off when voltage rises above 25.8 V. A second controller allows the fuel cell to deliver power at start-up when stack voltage rises above 28.0 V (open circuit) and disconnects the stack at shut-down when voltages fall below 24.0 V (after the subsystems are turned off). Safety interlocks are included to sense high stack temperature, the presence of hydrogen in the fuel cell enclosure, or a fire. If any of these safety interlocks are activated, both controllers open, thus shutting down the fuel cell system.

Atmospheric air is supplied to the stack with a small centrifugal blower. Cooling is achieved using ambient air blown onto the stack surface from beneath by a pair of muffin fans. A temperature switch turns the cooling fans on when FC temperature reaches 40°C and turns them off when the fuel cell temperature falls below 38°C. The fuel cell power system uses compressed hydrogen in standard industrial gas cylinders. Hydrogen is delivered about every 8 to 9 weeks in the winter. A data acquisition and control system periodically transmits performance data to SERC via a cellular modem to permit remote monitoring and control.

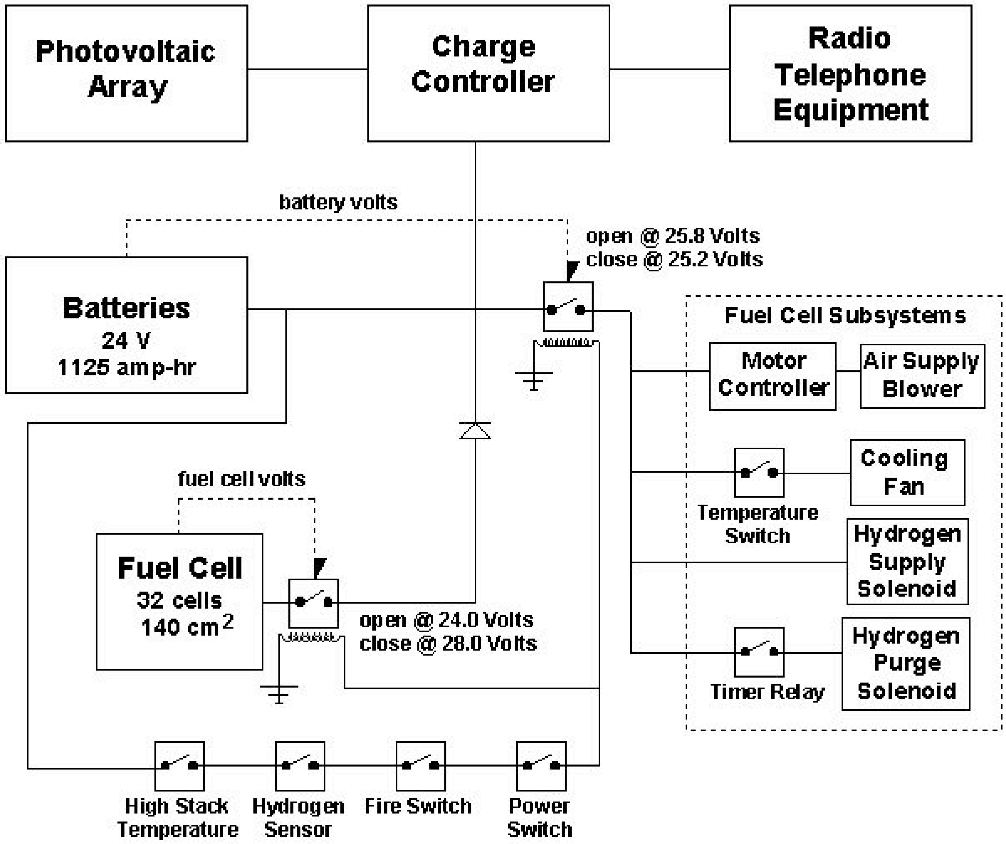

Figure 1. Schematic of the photovoltaic/fuel cell hybrid power system

Figure 2. Fire lookout tower with PV array

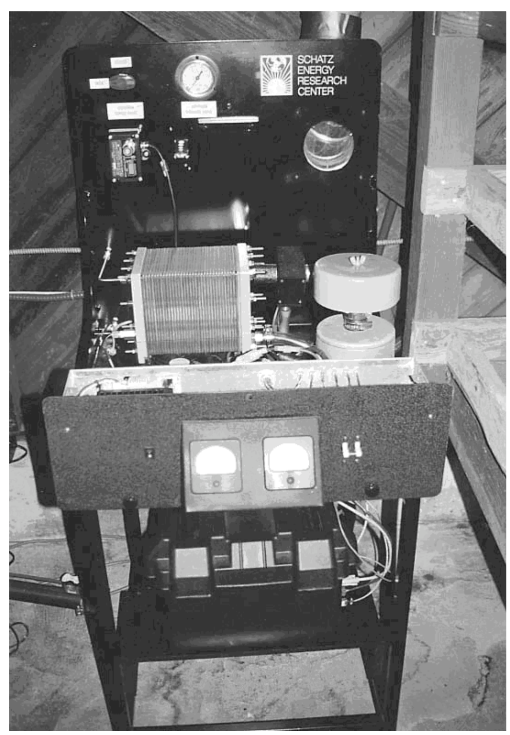

Figure 3. Fuel cell system

System Performance

Although originally designed so that the fuel cell would run only 400-800 hours per year, reduction in the PV array size (coupled with degradation of the battery bank's storage capacity andperiodic increases in the load) resulted in the fuel cell running about 14 hours per day during its operating life. Over a typical daily duty cycle, the fuel cell ran during nighttime and early morning hours (during which time battery voltage was constant or slowly declining) and during daytime hours the PV array supported the load and recharged the batteries. The system produced more than 1 kWh/day during more than 85% of its days of operation. On an average day it produced 1.4 kWh, and on 5% of operating days, it produced over 2.5 kWh.

All PEM fuel cells exhibit voltage decay over time, and the two stacks used in this system were no exception. Figure 4 shows fuel cell stack voltage at three selected narrow bands of fuel cell current (i.e., 3.50 to 3.55A, 4.00 to 4.05A, and 4.50 to 4.05A) plotted vs. hours of fuel cell operation. The trend lines for the voltage decay have been determined by linear regression and are also shown in the figure, along with the corresponding voltage decay rates (i.e. slopes in µV/cell/hr). These rates of long-term decay are very low (all are less than 10 µV/cell/hr) and indicate robust and durable performance of the stack.

Figure 5 shows fuel cell operating voltages and currents during three distinct seven-day intervals near the beginning, middle, and end of the second stack's time in service. These field "polarization curves" show a progressive increase in slope over the life of the fuel cell, which corresponds to increased cell resistance from a slope of –0.30 Ω to –0.49 Ω.

Planned Improvements to System

SERC and the Tribe have implemented a new agreement that will govern renovation and improvement of the power system. The agreement will provide for the replacement of the fuel cell stack and the batteries, as well as expansion of the PV array.

While only one membrane appears to be in need of replacement at this time, SERC has decided to replace all membranes in the stack, since the rebuilt stack has logged nearly 4,000 hours of run time. The batteries will be replaced; four PV modules will be added to the wall-mounted array; and an eight-module sub-array will be installed on the tower's roof. This will bring the total number of modules to twenty-four.

Conclusions

- The project at Schoolhouse Peak is one of the longest-running field tests of a PEM fuel cell to date. All of the peripheral fuel cell equipment, including the hydrogen storage and delivery subsystem, the battery voltage-sensing relay, the safety shutdowns, and the remote data acquisition and control equipment, has performed flawlessly.

- SERC's experiences with the Schoolhouse Peak system demonstrate that PEM fuel cells are a viable alternative to engine generators as a backup for PV power at remote, unattended locations. PEM fuel cell technology, while still facing economic and technical hurdles on the way to becoming a popular energy supply alternative, can now claim to be a durable and reliable choice for specialized applications such as the Schoolhouse Peak telecommunications system.

References

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2. Lehman, P.A., Chamberlin, C.E., Zoellick, J.I., and Engel, R.A., A Photovoltaic/ Fuel Cell Power System for a Remote Telecommunications Station, 2000 IEEE Photovoltaic Specialists Conference Proceedings, pp. 1552-1555.

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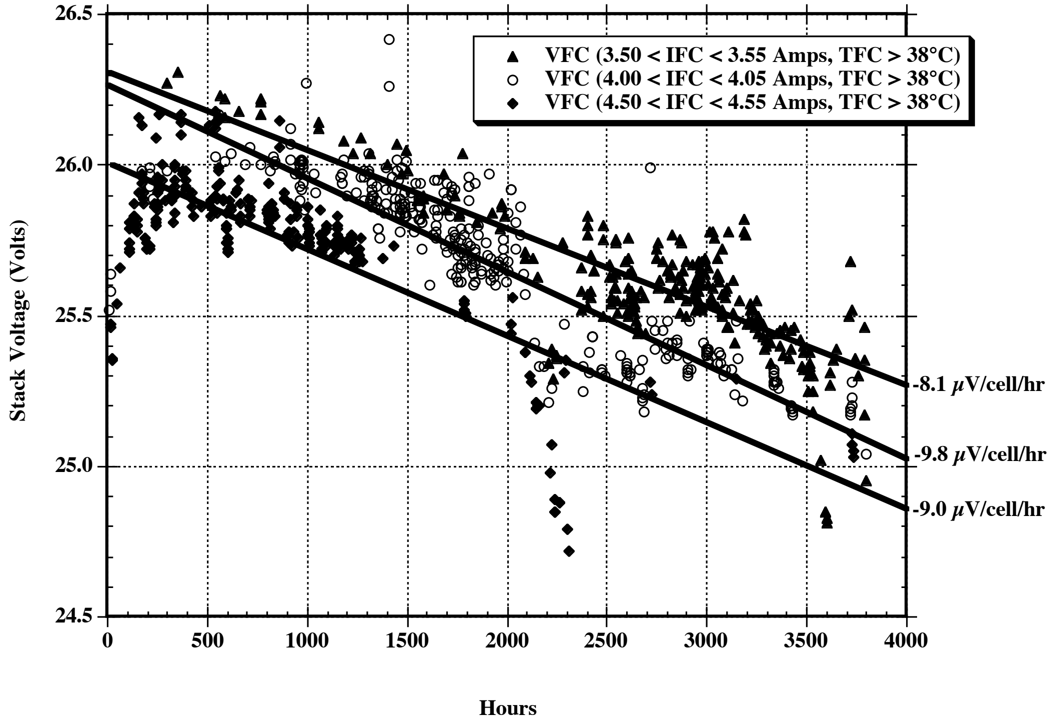

Figure 4. Fuel cell stack voltage versus hours of operation for selected ranges of fuel cell current and temperature. The observed cell voltage decay rates are shown.

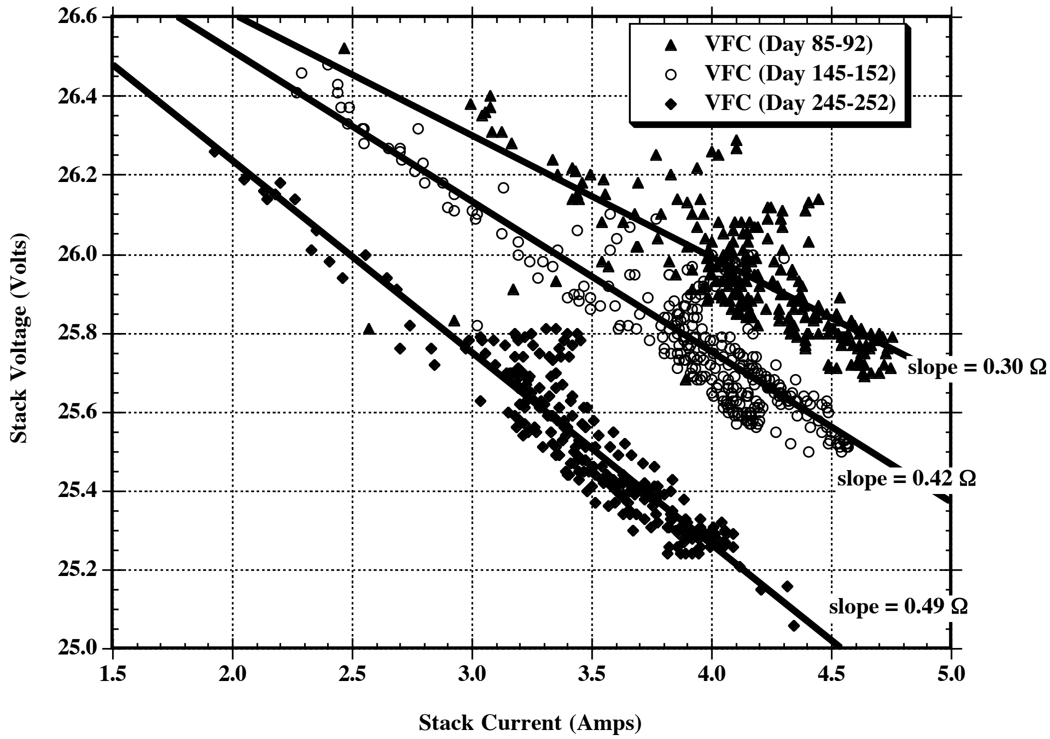

Figure 5. Fuel cell stack voltage versus stack current (quasi-polarization curves) for selected time intervals over the lifespan of the stack. The aggregate resistance of the stack is shown for each time interval.