FIELD TESTING OF A PEM FUEL CELL IN AN INTEGRATED POWER SYSTEM

P.A. Lehman, C.E. Chamberlin, G.S. Chapman, N.T. Coleman, R.A. Engel,
D.A. McKay, M.W. Marshall, A.M. Reis, and J.I. Zoellick
Schatz Energy Research Center
Humboldt State University, Arcata, CA 95521
Phone: (707) 826-4345 Fax: (707) 826-4347 email: pal1@humboldt.edu

For the past 12 years, the Schatz Energy Research Center (SERC) has operated the Schatz Solar Hydrogen Project (SSHP). SSHP is a stand-alone renewable energy system that uses hydrogen as the energy storage medium and a proton exchange membrane (PEM) fuel cell as the regeneration technology [1,2]. Recently, a new 36-cell, 140 cm^2 PEM fuel cell was installed at SSHP. We report operating results, cell voltage decay rates, and general utility of the fuel cell in providing power in this integrated system.

System Description

The SSHP is installed at Humboldt State University's Telonicher Marine Laboratory and powers the Lab's air compressor system (a 600W load) that is used to aerate aquaria. The system consists of an 8 kW photovoltaic (PV) array coupled to a medium pressure alkaline electrolyzer. When PV electricity is available (during the day), it is used to power the compressor directly. Any excess power produced by the array is supplied to the electrolyzer, which produces hydrogen and thus effectively stores solar energy. When the array cannot produce sufficient electricity to power the compressor, stored hydrogen serves as fuel for the fuel cell, which automatically comes on line to supply the load. If storage is depleted, the system shifts to utility power for this critical load. Figure 1 shows a schematic of the system and Figure 2 shows the basic operational control logic.

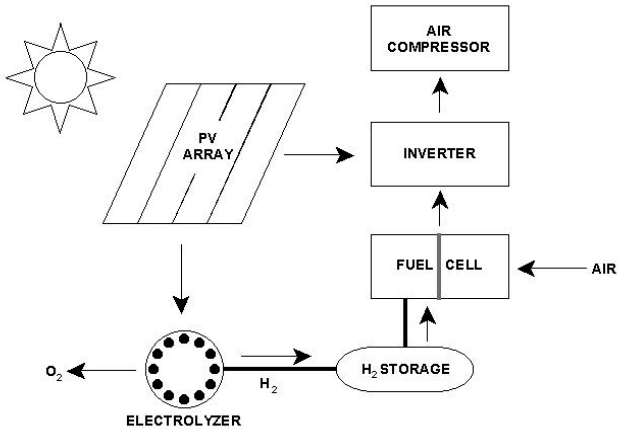

Figure 1. Schematic of the Schatz Solar Hydrogen Project

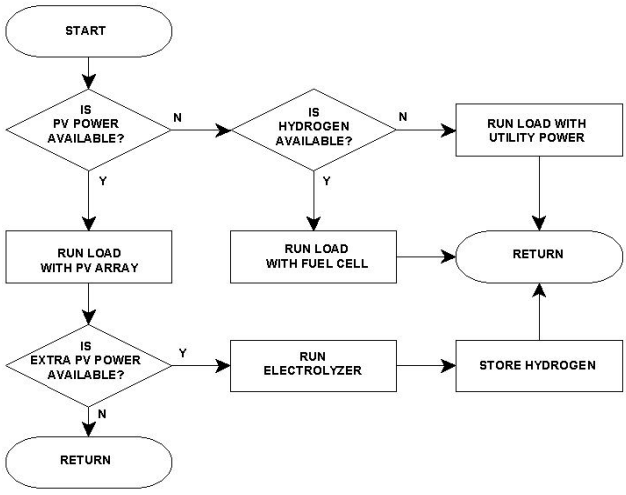

Figure 2. Operational control logic for the Schatz Solar Hydrogen Project

PEM Fuel Cell

In January of 2002, SERC installed a new 36-cell, 140 cm^2 PEM fuel cell at the SSHP. We are reporting on the first 668 hours of fuel cell performance during unattended operation of the integrated power system. The completed stack, as installed, is shown in Figure 3.

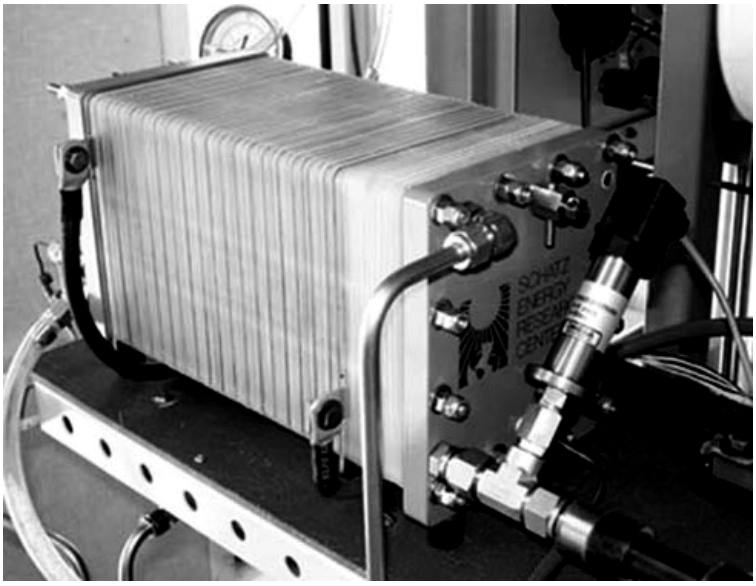

Figure 3. SERC 36-cell, 140 cm^2 PEM fuel cell installed at the SSHP

Figure 4 shows operation of the PV-electrolyzer-fuel cell integrated power system during a sunny 3-day period in March of this year. The time axis begins at midnight of the first day. Since the PV array is not producing power, the fuel cell is running and consuming hydrogen and the storage tank pressure is steadily decreasing. The fluctuations in hydrogen consumption rate are due to periodic purges. As soon as the sun rises, the PV array takes over the load, the electrolyzer begins producing hydrogen, and the storage pressure increases. Hydrogen production peaks at solar noon. At sunset, the tank pressure peaks, the fuel cell begins running, and the cycle repeats.

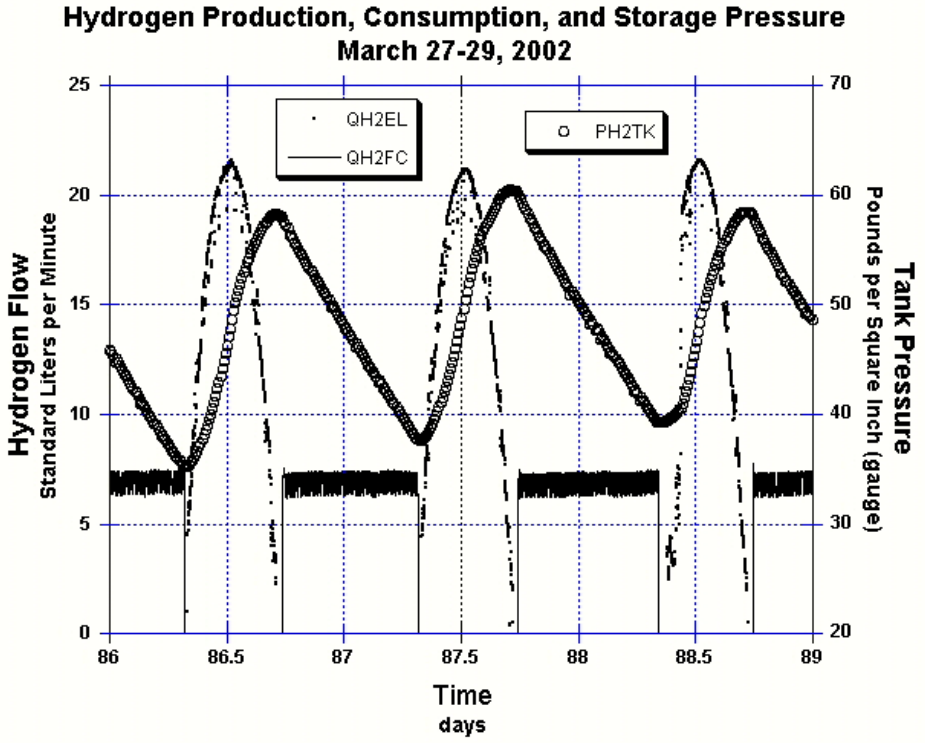

Figure 4. Characteristics of the SSHP operation during a 3-day sunny period

Fuel Cell Performance

The fuel cell operated well. At 100 hours after installation, the stack was supporting the load with 22.8 Amps (current density = 167 mA/cm^2) at 27.3 Volts (average cell voltage = 757 mV). The stack was specially configured to test the performance of two types of membrane-electrode assemblies (MEAs) supplied by W.L. Gore. Blocks of 3 cells alternated between PRIMEA® series 5510 MEAs (odd-numbered blocks) and PRIMEA® 5620 series MEAs (even-numbered blocks). Voltages of the blocks were recorded over time and characterized by their recoverable and non-recoverable decay rates. As defined by Cleghorn [3], recoverable decay refers to the voltage decrease during continuous operation; most of this decay is reversible and is recovered by ceasing and then resuming operation. When operation is resumed, however, the voltage does not quite recover to its previous level; this decrease is non-recoverable decay. These decay rates were measured by plotting average cell block voltages versus time and using linear regression to determine the slope. Figure 5 is based on one 12-hour run period but is indicative of average performance. Figure 6 is based on average values for the first 668 hours of operation.

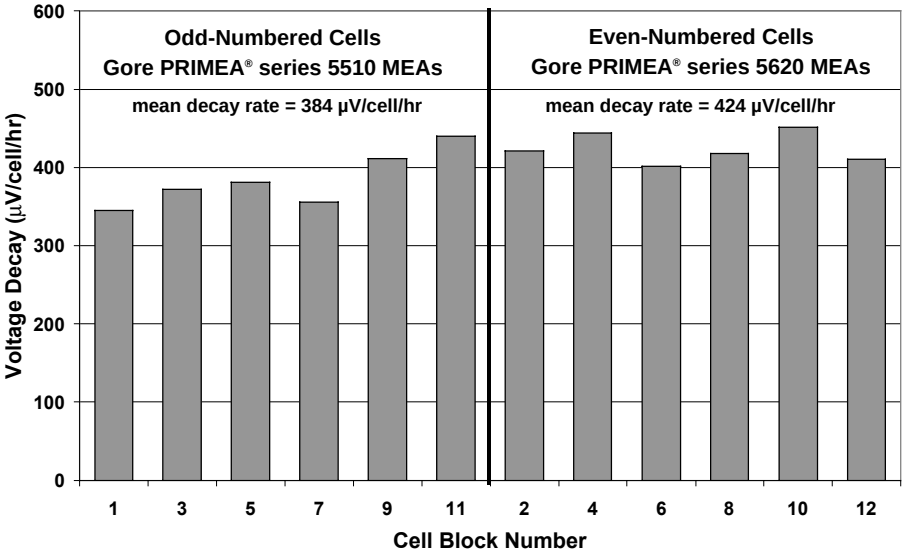

Figure 5. Recoverable voltage decay rates for the SSHP fuel cell MEAs

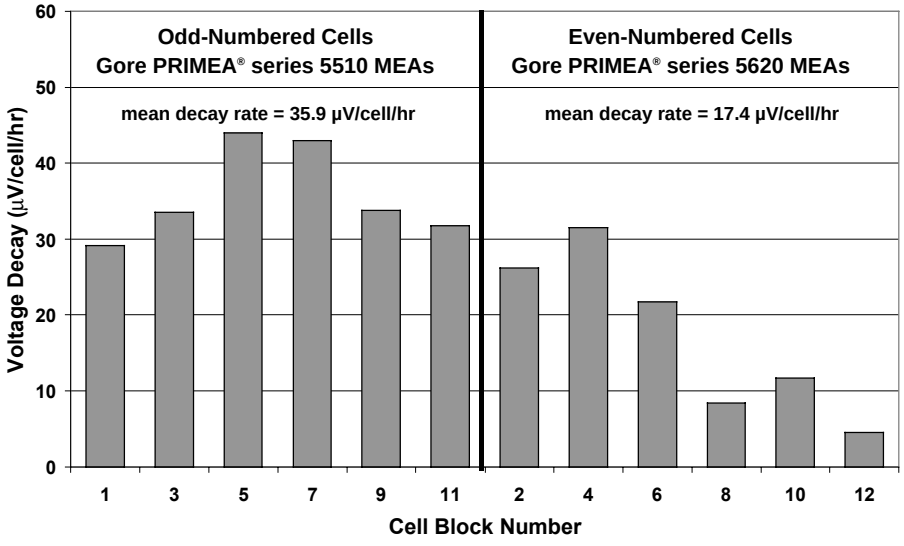

Figure 6. Non-recoverable decay rates for the SSHP fuel cell MEAs

Several conclusions are apparent from Figures 5 and 6. First, it should be noted that the ordinate scale for the recoverable decay rate graph is 10 times the scale for the non-recoverable decay rate. This mirrors the differences in actual decay rates, namely that the recoverable decay is larger than the non-recoverable decay by factors ranging from approximately 10 to 25. Further, the recoverable decay is similar for both types of MEAs and is fairly constant in its distribution throughout the stack.

This is not true for the non-recoverable decay rate. Here the 5620 MEAs decay at only half the rate of the 5510 MEAs. The 5620 MEAs were developed with the intention that they be more durable and this is borne out by these results. Interestingly, those 5620 MEAs closest to the humidification section (cell blocks 8, 10, and 12), and thus presumably the most thoroughly humidified, have the lowest decay rates. Gore recommends that 5620 MEAs be run as close to fully humidified as possible and our results our consistent with this suggestion.

Conclusions

Based on this work, we conclude:

1. A PEM fuel cell works well as the regeneration technology in an energy system using hydrogen as a storage medium for renewable energy. The wire-to-wire efficiency of the storage system, defined as the electrical energy delivered by the fuel cell divided by the electrical energy into the electrolyzer, is 28%.

2. The recoverable decay rates for Gore 5510 and 5620 MEAs are nearly equal and average approximately 400 µV/cell/hour in this system.

3. The non-recoverable decay rates for Gore 5510 and 5620 MEAs average 36 µV/cell/hour and 17 µV/cell/hour in this system, respectively. The 5620 MEAs show twice the durability of the 5510 MEAs.

4. More thorough humidification improves the durability of the 5620 MEAs.

References

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2. Lehman, P.A., Chamberlin, C.E., Pauletto, G., and Rocheleau, M., "Operating Experience with a Photovoltaic-Hydrogen Energy System," *Proceedings of the 10th World Hydrogen Energy Conference*, Cocoa Beach, FL, June 1994.

3. Cleghorn, S., "Production of a Qualified Polymer Electrolyte Fuel Cell Membrane Electrode Assembly for Emerging Commercial Applications," *Abstracts of the 2000 Fuel Cell Seminar*, October 2000, pp. 35-39.