POWER ELECTRONICS TECHNOLOGY

# PEM Fuel Cells Emerge from Niche Markets

May 1, 2006 12:00 PM
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Fuel cell technology has received a great deal of attention as a vital component in the highly anticipated, though as of yet postponed, emergence of the hydrogen economy. While the first fuel cell was invented by Sir William Robert Grove as early as 1839, polymer electrolyte membrane, sometimes referred to as proton exchange membrane, (PEM) fuel cells are relatively new, having been first developed by General Electric (www.ge.com/energy) in the early 1960s, and appear to be the most likely variety for future high-power consumer applications such as in automobiles.

One of the simplest ways to understand a PEM fuel cell is to visualize its operation in terms of pathways. Normally, when hydrogen is brought in close proximity to oxygen and allowed to mix in the presence of an ignition source, the electrons from the hydrogen will have a strong tendency to transfer to the oxygen. Once that transfer has occurred, the resulting charge imbalance will then create a strong ionic attraction between the hydrogen and oxygen atoms, causing them to bond, resulting in the formation of water and the release of heat energy.

A PEM fuel cell harnesses this strong tendency of electrons to transfer from hydrogen to oxygen by forcing the electrons and protons of the hydrogen atoms to flow through separate and exclusive physical pathways. When the pathway formed by the electrical circuit is removed, the fuel cell is inactive. In this state, the hydrogen and oxygen within the fuel cell are separated by the PEM and are prevented from reacting. When the electric circuit is completed, the electrons flow through the circuit and perform work before they combine with the oxygen.

When the oxygen acquires these electrons, it becomes negatively charged. The protons that remain after the electrons separate from the hydrogen will then flow through the PEM of the fuel cell, driven by ionic attraction to the negatively charged oxygen on the other side of the PEM. After the protons have crossed the membrane, they combine with the oxygen to form water.

# PEM Fuel Cell Advantages

When combined with high-density hydrogen storage such as metal hydride or pressurized canisters, PEM fuel cells can form the basis for power systems with energy densities greater than those of battery-based systems. Furthermore, because the process of recharging a hydrogen fuel cell system is different from the process of converting hydrogen into electricity, charging times can be significantly faster than full-load discharge times, unlike the charge/discharge cycles of a rechargeable battery.

One fuel cell product that illustrates these advantages is the A2 fuel cell flashlight from Angstrom Power (www.angstrompower.com). In this product, shown with its charging system in **Fig. 1**, PEM micro fuel cells are configured to provide a high voltage, which is then stepped down by an internal dc-dc converter to drive a 1-W white LED. The flashlight is recharged with hydrogen in 10 to 20 minutes, and the LED can remain illuminated for more than 24 hours on a single charge, providing full power for the majority of that period. This illustrates another advantage of fuel cell systems over rechargeable batteries, the majority of which experience reduced power capacity as the charge is depleted.

The usage model of the A2 charging system places an emphasis on safety and simplicity, according to Olen Vanderleeden, director of business development for Angstrom Power. A high-pressure source such as a hydrogen cylinder delivers hydrogen to the A2's charging station, which then supplies hydrogen to the A2 flashlight at 150 psi. The A2's charging unit is a passive, entirely mechanical system designed for safe operation, and has been operating in children's hospitals and other sensitive environments. Angstrom Power also has been granted approval to ship hydrogen-charged metal hydride systems within, as well as between, the United States and Canada.

Safety is also a primary feature in Jadoo Power's (www.jadoopower.com) N-Gen PEM fuel cell system as shown in **Fig. 2**. While this system was initially developed to serve the television news crew camera market, a recently developed docking station accessory allows the same system to power laptop computers.

In its original application, the N-Gen system can provide up to three times the energy-storage capacity of the camera battery packs it replaces, and introduces other advantages such as hot-swapping its N-Stor hydrogen canisters. Furthermore, the canisters can indefinitely maintain a full charge when not in use, unlike rechargeable batteries, which are prone to gradual self-discharge that limits their shelf life. The canisters are presently available in 130-Wh and 360-Wh capacities and recharged with Jadoo's FillPoint or FillOne refilling stations.

According to Jack Peterson, vice president of marketing at Jadoo, the company's specially developed sealing technology has earned the N-Stor canisters a U.S. Department of Transportation exemption from the restriction that prevents hydrogen from being transported via air cargo.

Seal integrity is maintained for the entire N-Gen system, and is especially important during the action of hot-swapping canisters. Not only does this system ensure hydrogen containment, but it also allows a small reserve of hydrogen accumulated during normal operation of the N-Gen system to maintain power until the fully charged replacement canister can be inserted.

Peterson stated that Jadoo has focused on the 20-W to 3-kW range for its fuel cell systems. The power requirements for laptop computers, drawing anywhere from 25 W to 90 W, are well situated within this range and continue to increase.

Another application benefiting from Jadoo's power system is the powering of mission-critical radio sets. First responders have learned that in situations where the electrical grid completely fails, as it did in areas hit by Hurricane Katrina, high-performance radio sets are inherently limited by the performance of their batteries. To address this vulnerability, Jadoo recently developed the ISF24 platform as part of a contract awarded by the special operations command of the U.S. military.

# Modularity

One aspect of fuel cell technology that provides the potential for higher power applications is modularity. Angstrom Power's V-60 micro fuel cell modules feature a hydrogen inlet and a separate exhaust port. Several of these units can be mechanically connected in series to supply all the cells from a single hydrogen stream, with the exhaust port of the final cell being sealed.

Multiple series and parallel combinations then become possible for the electrical interconnectivity of the cells for various current and voltage requirements. The energy storage capacity of such a system is completely independent of its output power capacity. If batteries were to be used, the ratio of power density to energy density would be fixed, possibly leading to costly excess in one or the other of these parameters.

Jadoo also is exploring modularity in stationary domestic power supplies, and these systems could accommodate several fuel canisters to meet the power requirements of the user's home. Given the shelf life of the charged cylinders, uninterruptible power-supply systems based on this technology would seem to be a likely application. The next time the grid goes out, you might not even need to reach for your hydrogen-powered flashlight.

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