Green Design

Fuel-Cell-Powered Vehicle With Hybrid Power Management

Fuel cells and hydride fuel storage are combined with ultracapacitor energy storage.

John H. Glenn Research Center, Cleveland, Ohio

Figure 1 depicts a hybrid electric utility vehicle that is powered by hydrogen-burning proton-exchange-membrane (PEM) fuel cells operating in conjunction with a metal hydride hydrogen-storage unit. Unlike conventional hybrid electric vehicles, this vehicle utilizes ultracapacitors, rather than batteries, for storing electric energy.

This vehicle is a product of continuing efforts to develop the technological discipline known as hybrid power management (HPM), which is oriented toward integration of diverse electric energy-generating, energy-storing, and energy-consuming devices in optimal configurations. Instances of HPM were reported in five prior NASA Tech Briefs articles, though not explicitly labeled as HPM in the first three articles: “Ultracapacitors Store Energy in a Hybrid Electric Vehicle” (LEW-16876), Vol. 24, No. 4 (April 2000), page 63; “Photovoltaic Power Station With Ultracapacitors for Storage” (LEW-17177), Vol. 27, No. 8 (August 2003), page 38; “Flasher Powered by Photovoltaic Cells and Ultracapacitors” (LEW-17246), Vol. 27, No. 10 (October 2003), page 37; “Hybrid Power Management” (LEW-17520), Vol. 29, No. 12 (December 2005), page 35; and “Ultracapacitor-Powered Cordless Drill” (LEW-18116-1), Vol. 31, No. 8 (August 2007), page 34.

To recapitulate from the cited prior articles: The use of ultracapacitors as energy-storage devices lies at the heart of HPM. An ultracapacitor is an electrochemical energy-storage device, but unlike in a conventional rechargeable electrochemical cell or battery, chemical reactions do not take place during operation. Instead, energy is stored electrostatically at an electrode/electrolyte interface. The capacitance per unit volume of an ultracapacitor is much greater than that of a conventional capacitor because its electrodes have much greater surface area per unit volume and the separation between the electrodes is much smaller.

In comparison with conventional power management in which batteries are used to store energy, HPM offers many advantages, including the following:

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Figure 1. This Fuel-Cell-Powered Utility Vehicle has been used to demonstrate the practicability of hybrid power management.

Figure 2. The HPM System of the vehicle shown in Figure 1 differs from the power-management systems of conventional hybrid electric vehicles in several major features, including the use of fuel cells (instead of an internal-combustion engine), the use of hydrogen as the fuel, the storage of hydrogen in the form of a metal hydride (instead of a compressed or liquefied gas), and the use of ultracapacitors (instead of batteries) for storing electric energy.
Current, NASA uses carbon dioxide for fire suppression on the International Space Station (ISS) and Halon chemical extinguishers on the space shuttle. While each of these agents is effective, they have drawbacks. The toxicity of carbon dioxide requires that the crew don breathing apparatus when the extinguishers are deployed on the ISS, and Halon use in future spacecraft has been eliminated because of international protocols on substances that destroy atmospheric ozone. A major advantage to the new system on occupied spacecraft is that the discharged system is locally rechargeable. Since the only fluids used are water and nitrogen, the system can be recharged from stores of both carried aboard the ISS or spacecraft. The only support requirement would be a pump to fill the water and a compressor to pressurize the nitrogen propellant gas. This system uses a gaseous agent to pressurize the storage container as well as to assist in the generation of the fine water mist.

Portable fire extinguisher hardware works like a standard fire extinguisher with a single storage container for the agents (water and nitrogen), a control valve assembly for manual actuation, and a discharge nozzle. The design implemented in the proof-of-concept experiment successfully extinguished both open fires and fires in baffled enclosures.

The proof-of-concept design weighs less than 20 lb (9 kg) and can be easily scaled up or down in size depending on the application. The design is fully self-contained and modular with no complex piping to thread through a crowded habitation module, and mounting is simplified.

The liquid agent is water, or water with additives to enhance the fire suppression capability for specific fire hazards. Compatible gases include nitrogen, argon, or other common nonflammable gases. Each fluid constituent is held in the container by a valve. Design features inside the storage tank make it possible to easily discharge all of the fluid as a uniformly dispersed

### Fine-Water-Mist Multiple-Orientation-Discharge Fire Extinguisher

A fine-water-mist fire-suppression device has been designed so that it can be discharged uniformly in any orientation via a high-pressure gas propellant. Standard fire extinguishers used while slightly tilted or on their side will not discharge all of their contents. Thanks to the new design, this extinguisher can be used in multiple environments such as aboard low-gravity spacecraft, airplanes, and aboard vehicles that may become overturned prior to or during a fire emergency. Research in recent years has shown that fine water mist can be an effective alternative to Halons now banned from manufacture.

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### Fine-Water-Mist Multiple-Orientation-Discharge Fire Extinguisher

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