Stacking up new energy storage options

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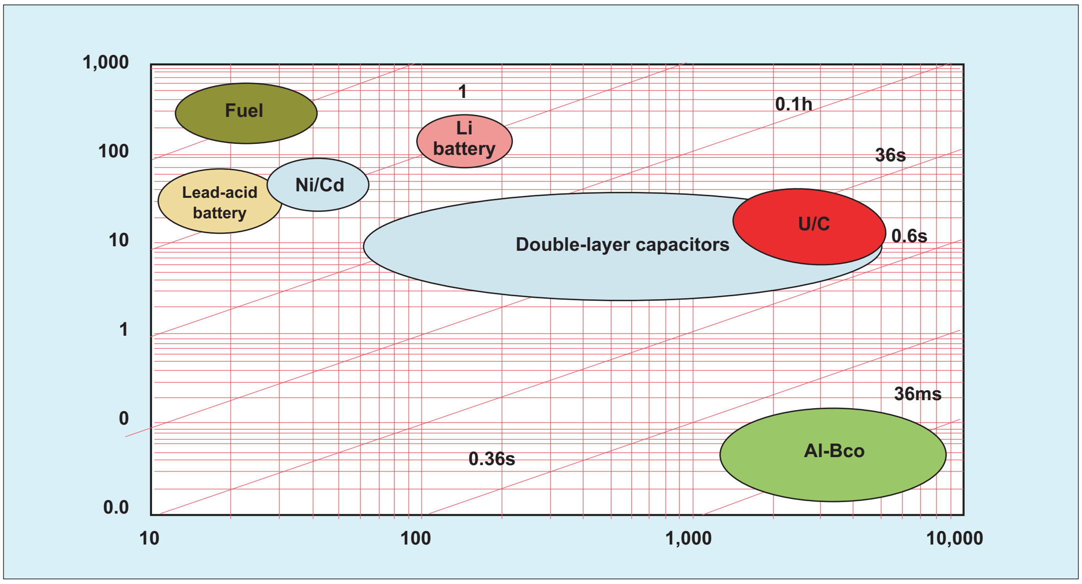

Figure 1: Ultracapacitors have power densities of up to 20kW/kg and less energy than in batteries.

For engineers, energy storage has always been the Achilles' heel of a design. In the past, lead-acid batteries have been the predominant solution to backing up power. Today, engineers have more options to address power requirements, including advanced battery technologies (Li-ion and NiMH), fuel cells, solar cells and double-layer capacitors.

Li-ion, NiMH and other battery technologies have made great strides in providing reliable energy storage solutions, having found their way in many designs and worked out many of the early cost issues. But in the end, designers are faced with the same dilemma they had when using lead-acid batteries. All these technologies are based on a chemical reaction and they eventually suffer from limited life and temperature restrictions. High current demands will also directly affect their longevity.

Fuel cells are an attractive alternative. These devices have lately been publicized and are found in many applications. The final frontier for these devices is automotive applications, although backup power markets have embraced these devices. Key issues in using fuel cells for backup and main power are the startup time and dynamic power reaction of these devices. Although they have good energy density, they do suffer from low dynamic power. Thus, they need an augmenting technology for power assist and startup.

Based on an existing technology, ultracapacitors or electrochemical double-layer capacitors possess high power and energy density compared with electrolytic capacitors. In recent years, these devices have found their way into consumer electronics, industrial and automotive applications.

Today, the best ultracapacitors are extremely high-power devices with power densities of up to 20kW/kg and energy that is still a fraction of that found in batteries.

Compact in size (small-cell ultracapacitors are often the size of a postage stamp, or smaller), ultracapacitors can store much more energy than conventional capacitors and can release that energy quickly or slowly. They have long life and are designed to last the lifetime of the end-product.

Although there are several ultracapacitor manufacturers around the world offering a variety of products, most double-layer capacitors are similar in construction. In ultracapacitors, the electrode is based on carbon technology that allows for a large surface area. The combination of this surface area and a very small charge separation gives the ultracapacitors high energy density. Most ultracapacitors are rated in Farads and can typically be found in the 1-5kF range.

Depending on the application needed, ultracapacitors may be used as battery replacements or enable smaller, economical battery selection. Ultracapacitors have low equivalent series resistance (ESR), allowing them to deliver and absorb high currents. The "mechanical" rather than chemical charge-carrier mechanisms enable long, predictable life with a smoother performance change over time. Applications benefiting from these characteristics include regenerative braking and other quick-charge scenarios such as in toys and tools.

Some applications are suited for battery/ultracapacitor systems. Designs can be optimized to prevent battery oversizing for power demands. Examples include applications in consumer electronics such as digital cameras, in which an inexpensive alkaline battery is combined with an ultracapacitor (rather than using expensive Li-ion batteries), and automotive applications such as hybrid power trains.

Another fuel-cell technology is the proton exchange membrane (PEM), which is a high-efficiency energy conversion device that can operate continuously for as long as hydro-

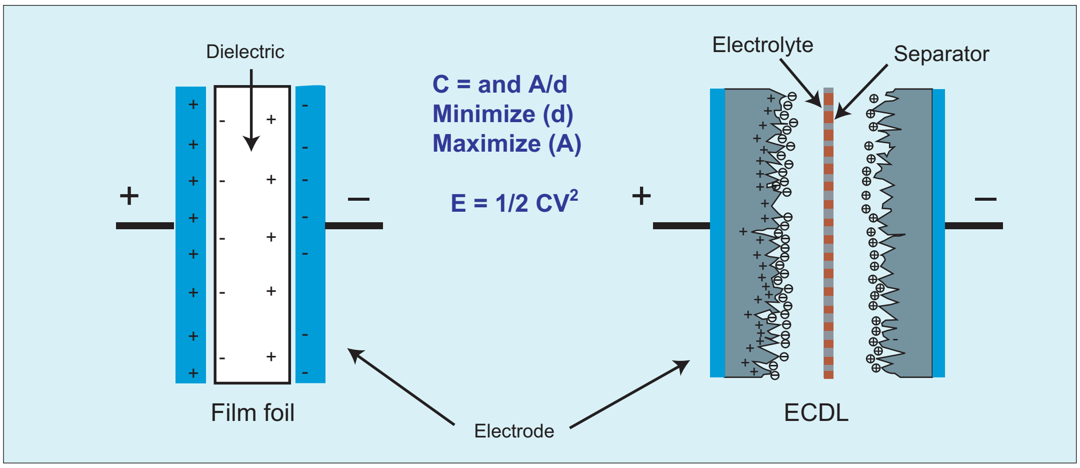

Figure 2: Ultracapacitors are similarly constructed with electrolytic capacitors or batteries.

gen fuel is available. It is environmentally benign and can provide a reliable source of backup power for many applications. Several characteristics of PEM fuel-cell/ultracapacitor systems make them complementary components. Both are low-voltage, high-current components. With low ESR and high charge-storage capacity, the ultracapacitor can ramp up large currents with minimal change in voltage, creating a short-term buffering response to peak power demands. This permits the fuel cell to maintain its quiescent operating point without inefficiency.

In all backup fuel-cell applications, the need for power is immediate after the loss of main power. Since fuel cells typically have a 10-60s startup time to reach full power, there is a need for an energy buffer. This can be achieved with either batteries or ultracapacitors. Since the amount of energy needed is limited and reliability is an absolute must, ultracapacitors are a better choice for this application. Today, more fuel-cell companies are looking at the ultracapacitor as an integral component of their total package for backup power requirements.

Ultracapacitor manufacturers offer a variety of cells and modules for the power-backup market. These cells and modules can be placed in series or parallel formats to satisfy different capacitance and voltage requirements.

Ultracapacitors are becoming a standard component in the backup power world. Viewed as a lab experimental product about 10 years ago, these devices were only sold in handfuls each year with prices in the $1 to $2 per F range.

Today, these components are in mass production, driving the prices down to $0.01 to $0.02 per F. With such availability and lower prices, ultracapacitors have become a standard energy storage option for high-power needs and high-reliability backup power requirements. □