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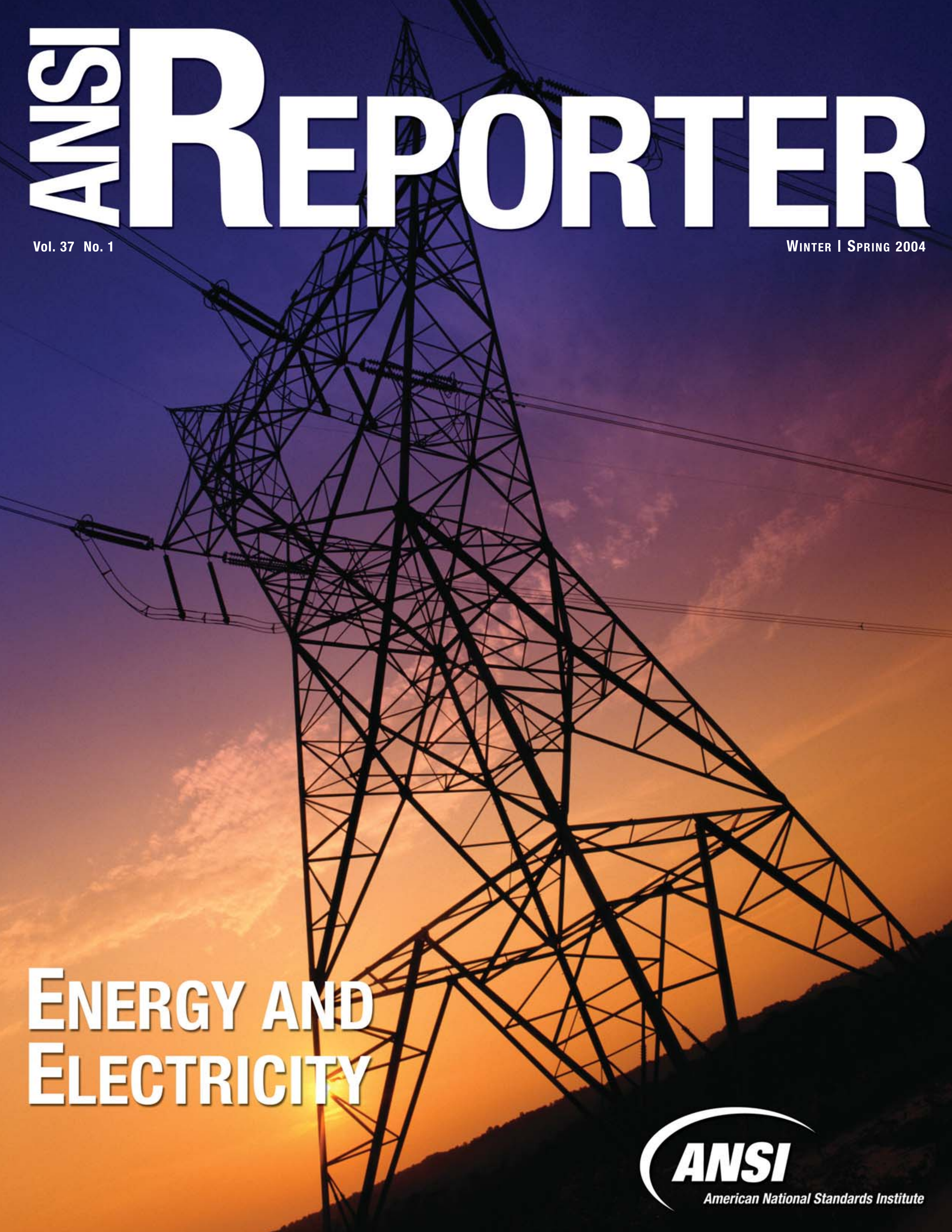

ENERGY AND ELECTRICITY

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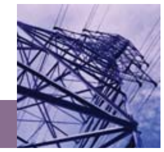

ULTRA-CAPACITOR TECHNOLOGY APPLICATIONS

CHANGING the WORLD

Under the auspices of the Electronic Components, Assemblies and Materials Association (ECA), a sector of the Electronic Industries Alliance, a new standards development activity has been launched that is intended to facilitate the global market access of a new generation of high pulse power and long cycle life energy storage systems.

Claude Letourneau, executive director of KiloFarad International, and **John M. Miller**, chairman of KFI's education working group, introduce the "ultra" or "super" capacitor technology and explain its application for the electrotechnology industry.

Increasing demand for high power regenerative energy storage has opened the door for innovation in the development of electrochemical component systems. Stepping forward to meet existing and new application requirements for production-intent design needs are the manufacturers of the latest generation of electrochemical double layer capacitors (EDLC) — also known as ultra-capacitors or super-capacitors.

Ultra-capacitors combine high bursts of power and a very high capacitance for energy storage. Capacitance is the property of a circuit element that permits it to store an electrical charge.

Already available from major production firms in Europe, Asia and the United States, and with price points that are now within the cost targets of many automotive systems, these devices have received renewed interest as an energy storage system component for automotive and utility applications. Additional uses are anticipated within the transportation industry, as well as in telecommunications; uninterruptible power supplies; renewable energy resources; and other industrial, electronics and medical applications.

Ultra-capacitor testing and specification, however, is not consistent. There is a need for standardization and accountability in manufacturing, tolerance selection, capacitance drift, leakage, temperature coefficients and parameter specification.

Under the auspices of the Electronic Components, Assemblies and Materials Association (ECA), a sector of the Electronic Industries Alliance, the KiloFarad International (KFI) organization has been chartered to foster the commercialization of ultra-capacitors around the world. By leveraging the expertise and network of the ECA infrastructure, KFI and its members are helping the industry focus its efforts on addressing key market access issues such as performance testing standards and shipping regulations, so that ultra-capacitors can be clearly recognized as a viable alternative in advanced energy storage systems.

What makes a capacitor "Super" or "Ultra"?

The electrostatic storage of electrons has been known since the time of Ben Franklin. The earliest electrostatic capacitor, known as the Leyden jar, was a parallel plate electrode structure separated by a thick glass plate. A simple accumulator of charge, the electrostatic capacitor stores its charge via the polarization of the dielectric separator and with a voltage withstand capability limited by the thickness of the separator. Because capacity is limited by the ratio of plate area to separator thickness, all electrostatic capacitors were inherently limited to relatively low capacity, albeit at substantial voltage levels, because of manufacturing limits on the separator thickness.

Later advancements in technology saw capacitor plate metal foils etched, anodized and immersed in an electrolyte solution. These capacitors redefined capacity and had a much higher ratio of available plate area to charge separation distance. Capacity jumped from micro-farads to milli-farads. A farad, named for Michael Faraday, is the unit used to measure capacitance.

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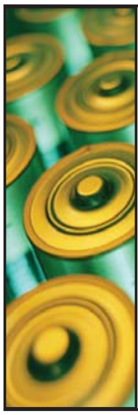
Later still, in the early 1960's, the electrochemical double layer capacitor (EDLC or DLC) marked the entry of another game-changing technology into the capacitor arena. Capacities jumped this time from milli-farads to kilo-farads. Representing highly refined versions of the early Leyden jar, current multi-layer ceramic (MLC) and polymer multi-layer (PML) capacitors function via a highly parallel structure using ultra-thin separators.

With the very recent innovation of the NanoGate Capacitor originated by Dr. Michio Okamura *(continued on page 20)*

(*continued from page 19*) of Japan, DLC voltage ratings increased yet again from 2.7V to 3.8. Noting that energy storage is determined by combining voltage rating with capacity, a comparison of electrical storage systems was conducted by plotting energy density versus power density, yielding a result that conventional ultra-capacitors have 1/10 the energy density of mature lead acid batteries, but 10x their power density, whereas the NanoGate Capacitor is virtually on par with Lithium-Ion chemistries.



> ... the new generation of ultra-capacitors will be considered as a serious contender for energy storage applications.

This breakthrough improvement of the energy density of existing DLC indicates that the new generation of ultra-capacitors will be considered as a serious contender for energy storage applications. As demonstrated by the two examples cited below, the potential benefits open the door to a single device capable of delivering high pulse power and long cycle life.

Transportation Applications of Ultra-capacitors

A significant amount of attention is now being given to ultra-capacitors as energy storage system (ESS) components in hybrid electric and fuel cell vehicles; ESS components in a hybrid electric vehicle constitute approximately 40% of the installation costs of hybridizing. When considering the U.S. Department of Energy's FreedomCAR goals, today's conventional ultra-capacitor can easily meet the specific power goal but not the specific energy goal unless combined with an advanced battery or fuel cell. This in fact is what is being done in the industry, the synergistic combination of advanced batteries with ultra-capacitors to optimize the ESS while minimizing its overall mass, volume and cost. What is more interesting is that the new ultra-capacitors, if they prove manufacturable at a low cost, can meet the goals stated.

One manufacturer already uses an ultra-capacitor-only ESS in their FCX fuel cell hybrid vehicle, packaged in such a way that sufficient margins exist for high pulse power regenerative braking and also for aggressive launch assist. On a large scale, DLC are well suited to many transportation applications. The endless cycles of acceleration, followed by braking, of mass transit train, subway, and metro systems are ideal for ultra-capacitor technology.

Industrial and Power Utility Systems

Several industrial applications are already combining ultra-capacitors into large power modules with integrated balancing. These applications span outages in all power categories, including elevators, pallet trucks and uninterruptible power supplies for critical loads such as hospitals, banking centers, cell towers, and airport traffic control.

In power electronics, ultra-capacitors are particularly suitable for backup in operation independent of the grid connection. Today, some utilities opt for large banks of lead-acid batteries for this short-term peaking power. Ultra-capacitors are superior to lead-acid storage systems because they easily tolerate long-term use at a partial state of charge and have the potential to be cycled for 500,000 to 1,000,000 times at full power. This means that once installed, such an energy storage bank would last for 10 to 15 years before needing service.

The U.S. Department of Energy (DoE) and Sandia National Laboratories are working on a project that would boost the electrical transmission industry using a newly developed Emitter Turn-Off Thyristor (ETO) fast power switch that can withstand 16 MW of instantaneous power. The ETO can turn off 4,000A in less than 5 microseconds while blocking up to 4,500V. During the transition, it handles both high current and high voltage simultaneously.

Electricity outages are due primarily to lack of quick voltage support, leading to voltage collapse in many regions of the network and poor quality of power. By combining the ETO switch and ultra-capacitors, electric utilities can use this high frequency power switching system to improve quality and capacity of the transmission grid.

Developing the Standards Needed for Testing and Specification

The formation of KFI as a new trade association for the ultra-capacitor industry helps to foster the commercialization of these devices around the world. With a membership that includes manufacturers, systems integrators, Original Equipment Manufacturers (OEM) customers, materials suppliers, scientists and educators, and government representatives, KFI provides a forum in which the ultra-capacitor industry can work together on non-competitive activities. In addition to the development of uniform technical standards, these activities include education programs and advocacy with governmental agencies to create an appropriate regulatory framework.

Specifically, the standards working group will develop draft standards for testing and design. The group will coordinate its activities within existing standardization bodies such as the International Electrotechnical Commission (IEC), the American National Standards Institute (ANSI), and ANSI-accredited standards bodies including EIA (the Electronic Industries Alliance — via the ECA), IEEE (the Institute of Electrical and Electronics Engineers), SAE International (the Society of Automotive Engineers), and others.

The steps that are now being taken by the standards working group, KFI, and the ultra-capacitor industry are seen as critical milestones in the process of promoting and representing the global ultra-capacitor industry and of establishing ultra-capacitors as mainstream ESS for transportation and power generation applications. ■