SciEssence Intl. & the Sustainable Methods Institute

An Introduction to GigaCapacitor Energy Storage Systems

Introduction:

Prof. David Rivkin, PhD (the Principal Investigator), Chief Scientist of SciEssence LLC has developed a significant change in energy storage focus with the GigaCapacitor. The GigaCapacitor is a high voltage capacitor designed to store electrical energy electrostatically. As the only capacitor capable of operating at 115KV, 230KV and even higher with a high dielectric strength core and small plate gap, the GigaCapacitor is able to provide energy densities of 50MegaJoule per Liter (MJ/l), 100MJ/l or higher. As a capacitor, power density is extremely high. For example, one design for a 115KV GigaCapacitor is capable of discharging at a rate over 250Amps with not significant temperature rise in the busbar due to resistive heating. As there is no chemical reaction, charging and discharging do not create any heat other than that from conductor resistance. Since each plate in the GigaCapacitor is capable of providing 200Amps, it is only the bus bar that limits the maximum current, and as such, a simple modification to the design could increase the total maximum current and power density. At this current, the GigaCapacitor is capable of providing 28.75 MegaWatts of peak power with nearly 100% discharge possible, only limited by the power electronics not the device. Considering the GigaCapacitors ability to operate up to 250^{o}C (minimum), this is an insignificant temperature increase and can be easily dissipated since the GigaCapacitor is mostly Aluminum and ceramics, thus very thermally conductive. In addition, the materials make-up of the GigaCapacitor is non-flammable and environmentally safe. In fact the GigaCapacitor can be made mostly from recycled materials and recyclable. Even the processing chemicals needed to modify the ceramics are non-toxic and commonly used in households and the core materials are found nearly everywhere, hence not having any material controlled by a hostile or politically unstable country. The GigaCapacitor is exceedingly “Green” and stable for many decades of consistent and reliable use.

With both energy densities and power densities that batteries are not capable of, as well as superior safety, the GigaCapacitor is an ideal energy storage system for grid-tied, off-grid (micro-grid) and high energy pulse systems. For example, pulse energy weapons need both the energy density and power density of the GigaCapacitor, even over existing capacitor based systems, due to lower cost and energy densities that conventional capacitors are not capable of. For propulsion systems, GigaCapacitors exceed the energy density of gasoline and diesel fuel and they are not flammable; they are a superior choice for vessel propulsion. In fact, GigaCapacitors were invented with military applications in mind. A bank of GigaCapacitors can be directly hit by missile, for example, and the damaged modules taken off-line, while the remaining undamaged GigaCapacitor modules can remain to continue providing power, all without the fire or explosion of chemical fuels or hazardous gases and materials discharge of batteries. The GigaCapacitor, combined with electric motor propulsion, could make a zero thermal profile vessel making infrared seeking missiles ineffective at targeting such a vessel.

The GigaCapacitor is now a viable possibility for energy storage due to the innovation by Prof. David Rivkin, PhD in functionalized composite nanostructured materials developed at SMI, John Hopkins University, ITU, and Ohalo College over the past 9 years.

Fundamentally, the GigaCapacitor exploits the Voltage Squared term in the Energy Storage of a Capacitor Equation (given below) by using a material capable of retaining charge (ie preventing dielectric breakdown) that is 50 to 75% stronger than diamond or quartz due to its' nanostructure and heterogeneous tightly-coupled-electron components.

$$E = \frac{k\varepsilon_0 A V^2}{2d}$$

Relevance:

The GigaCapacitor is designed specifically for high energy density, high power density, high temperature performance (with no performance degradation), long lifespan (with no performance degradation), non-toxic, non-flammable electricity storage needs. Its capabilities far exceed that of any battery or other energy storage technology except nuclear power. It has been designed with military needs and issues in mind as well as Green Chemistry, safety and long life.

Recent relevant technical breakthroughs:

In the 1960s, the goal of having high voltage electrostatic devices like capacitors, generators and motors was given up on due to dielectric breakdown of every known material. Prof. Rivkin has been working in the field of charge barrier development for nearly a decade and leads global efforts in this field due to his expertise in nanotechnology. He has already developed and tested materials in the 3 categories listed above. His work has been based on both successes and "failures" of others to achieve their goals. Specific recent discoveries include the identification of high dielectric strength polymers used in the semiconductor industry, the discovery of doped crystalline materials that double their dielectric strength, the discovery of the dielectric strength of material interfaces, electroplating of crystalline and amorphous materials, and Prof. Rivkins two most important discoveries: High-interface-count, small-distance nanostructured composites and tightly coupled electron heterogeneity, both of which are used in this work. It is the integration of all these technologies that makes dielectric materials with greater than 1500V/micron dielectric strengths possible, and an ultimate goal of 2KV/micron.

Utility Energy Storage Systems:

GigaCapacitors are ideal for the HVDC grid as they can be directly connected with DC-DC semiconductor transformers or similar technologies. AC systems can be connected with inverting semiconductor transformers from 32KV to 110V AC for output. Such systems are available from a number of vendors presently with newer, more efficient and compact designs coming soon from SciEssence and its' partners. A typical system today can provide over 1MWH in a 19inch rack format including storage and DC-DC semiconductor transformer.

Specifications:

To summarize, the lowest performance GigaCapacitor currently designed by Prof. Rivkin has the following specifications:

Operating Voltage:	>115,000 Volts
Current Capacity:	>250 Amps
Energy Density:	>50MegaJoules/Liter (13.8 KiloWattHours per liter)
Peak Power Density:	>28.75 MegaWatts/Liter
Specific Energy:	> 5 KiloWattHours/Kg
Depth of Discharge:	98.5% for 38KV output, 99.995% for 880V output, etc.
Efficiency:	Depends on controller. See Depth of Discharge
Response Time:	< 1picosecond. Controller determines system response time (Typically <50ms)
Cost (approx.):	$125/KWH (not including controller)
Cycle/Calendar Life:	>1Million Cycles/50+ Years with No Maintenance
Lifespan:	No known limit (> 50 years)
Cycle Rate:	Tested to 100 Hz but no known limit with appropriate RC values.
Flammability:	Non-Flammable (Flammability Rating 0)
Toxicity:	Non-Toxic (EPA Class IV)
Op. Temp Range:	-100 to 250^{o}C for Gen I -100 to 350^{o}C for Gen II -200 to 650^{o}C for Gen III
Puncture Safety:	There is no fire risk from a puncture. There is risk of electrocution upon puncture.
Green Chemistry:	100% Class A “Green Materials”
Recycling:	Fully recyclable with Class B “Green Materials”

Future designs will improve on these specifications are production methods become available for Generation II and Generation III materials.