EEStor, Inc. Enhanced Processing, CMBT Powders & Stacking Process

November 2016 - EEStor, Inc. ("EEStor") has developed high relative permittivity composition-modified barium titanate (CMBT) powders. These CMBT powders, when built into a multilayered capacitor in EEStor's patent pending stacking architecture, which incorporates floating electrodes and induced field effect leakage buffering, have displayed in testing only a moderate reduction in effective resistance as capacitance is added. If successfully incorporated into commercial products, this would represent a significant market advantage over existing technologies as it would allow capacitor stacks to be built with increased capacitance, while at the same time increasing the time constant. The recent round of testing from Intertek Group plc ("Intertek") and MRA Laboratories Inc. ("MRA") show that capacitors built with this architecture would likely store more energy while at the same time increasing the time that the energy is stored. This effect is scalable and we believe will allow capacitive stacks to be built with time constants measured not in minutes or hours, but in days.

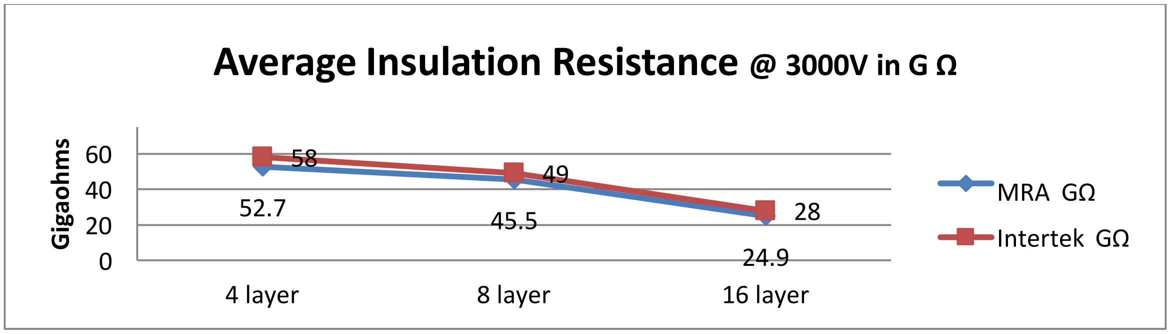
EEStor has developed a stacking method that assists in lowering leakage current, which in turn increases the effective insulation resistance. This technique, described in EEStor's pending patent, provides a field barrier to leakage current. The reverse field induced in the floating electrode, significantly reduces the amplitude of leakage current. As leakage current is reduced, the insulation resistance effectively increases. As additional layers are added to the stack, each added layer assists in further reducing leakage current and in keeping insulation resistance high.

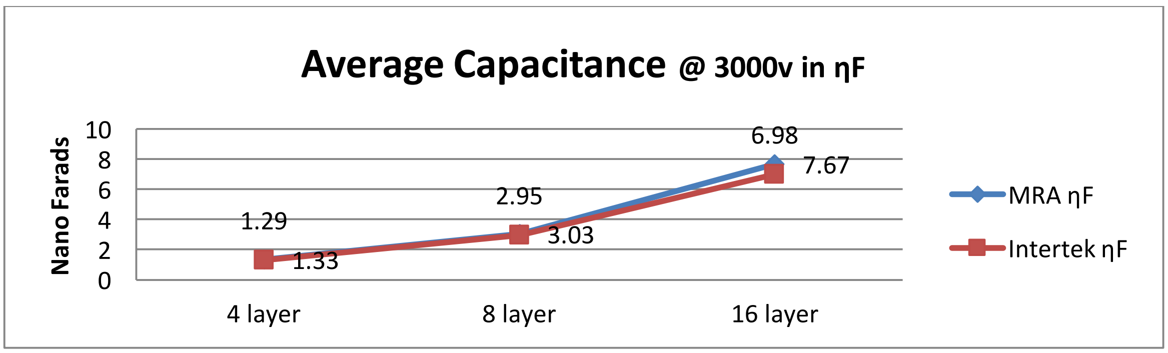
In the high voltage capacitor markets, achieving high insulation resistance is very important due to the need for long energy storage delivery times. This capacitor characteristic is measured by time constants. Time constants are calculated by multiplying the insulation resistance by the layer's capacitance. EEStor has developed a design that allows insulation resistance to remain high as capacitance layers are stacked, resulting in enhanced time constants.

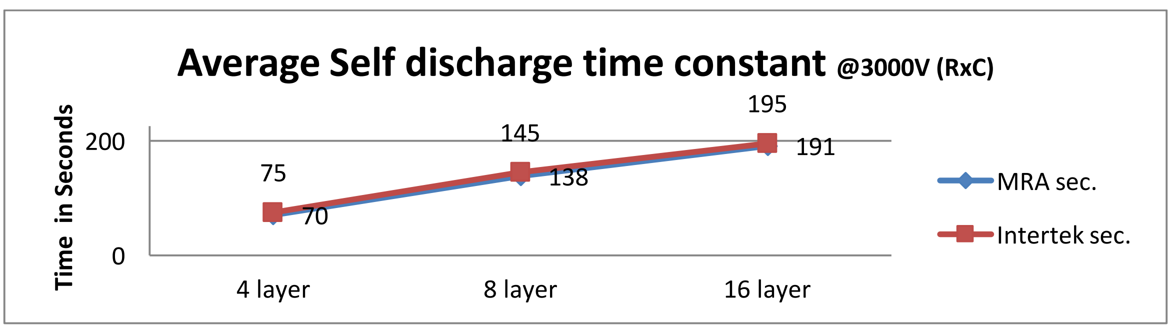
In a normal stacking process, as layers are added, the resistance of each layer will be in parallel with the next layer. As resistors are placed in parallel the resistance is divided by the number of resistors in the parallel circuit. For example, if two 100 ohm resistors are placed in a parallel stack, the parallel resistance will be 50 ohms. However, with EEStor's CMBT technology and stacking methodology, the resistance of the combined stack as tested does not behave in this manner. Instead, the effective resistance of stacked CMBT-based layers is reduced by significantly less. As a result, and because of dependency of time constants (t) on Capacitance (C), Resistance (R), as the number of layers or area of the capacitor is increased the resistance stays significantly higher than expected. This means that time constants increase with the increase in capacitance resulting from stacking of layers.

$$\tau = R \times C$$ (**t** in seconds, R is in ohms and **C** is in **Farads**.)

Independent reports from Intertek and MRA show that EEStor product samples created using CMBT-based capacitor layers, having an individual area of 0. 44 in.^{2} and average thickness of 69 microns (for the 16-layer sample), had an average resistance of 25 GΩ, an average capacitance of 7.67 ηF, a time constant of 195 seconds and a dielectric constant (K) of 32 - all at 3000Volts. $(K=(Cd)/(A\varepsilon_0))$.







EEStor calculates that using the stacking methodology to keep resistance high, a stack of 320 layers would have a capacitance 140ηF and a time constant of 64 minutes giving the device a discharge duration of over 5 hours.

Time constants of this magnitude potentially open up many new markets for EEStor beyond grid power factor correction. These results show that parts made from EEStor's current dielectric formulation have the capability to provide energy storage solutions to all segments of the grid storage market. The following table ES-1 from the 2010 report by Sandia National Laboratory, *Energy Storage for the Electricity Grid Benefits and Market Potential Assessment*[1], estimates the United States market for grid storage technology based on discharge duration .

Table ES-1. Summary of Key Assumptions and Results

		Discharge Duration*		Capacity (Power: kW, MW)		Benefit ($/kW)**		Potential (MW, 10 Years)		Economy ($Million)†	
#	Benefit Type	Low	High	Low	High	Low	High	CA	U.S.	CA	U.S.
1	Electric Energy Time-shift	2	8	1 MW	500 MW	400	700	1,445	18,417	795	10,129
2	Electric Supply Capacity	4	6	1 MW	500 MW	359	710	1,445	18,417	772	9,838
3	Load Following	2	4	1 MW	500 MW	600	1,000	2,889	36,834	2,312	29,467
4	Area Regulation	15 min.	30 min.	1 MW	40 MW	785	2,010	80	1,012	112	1,415
5	Electric Supply Reserve Capacity	1	2	1 MW	500 MW	57	225	636	5,986	90	844
6	Voltage Support	15 min.	1	1 MW	10 MW	400		722	9,209	433	5,525
7	Transmission Support	2 sec.	5 sec.	10 MW	100 MW	192		1,084	13,813	208	2,646
8	Transmission Congestion Relief	3	6	1 MW	100 MW	31	141	2,889	36,834	248	3,168
9.1	T&D Upgrade Deferral 50th percentile††	3	6	250 kW	5 MW	481	687	386	4,986	226	2,912
9.2	T&D Upgrade Deferral 90th percentile††	3	6	250 kW	2 MW	759	1,079	77	997	71	916
10	Substation On-site Power	8	16	1.5 kW	5 kW	1,800	3,000	20	250	47	600
11	Time-of-use Energy Cost Management	4	6	1 kW	1 MW	1,226		5,038	64,228	6,177	78,743
12	Demand Charge Management	5	11	50 kW	10 MW	582		2,519	32,111	1,466	18,695
13	Electric Service Reliability	5 min.	1	0.2 kW	10 MW	359	978	722	9,209	483	6,154
14	Electric Service Power Quality	10 sec.	1 min.	0.2 kW	10 MW	359	978	722	9,209	483	6,154
15	Renewables Energy Time-shift	3	5	1 kW	500 MW	233	389	2,889	36,834	899	11,455
16	Renewables Capacity Firming	2	4	1 kW	500 MW	709	915	2,889	36,834	2,346	29,909
17.1	Wind Generation Grid Integration, Short Duration	10 sec.	15 min.	0.2 kW	500 MW	500	1,000	181	2,302	135	1,727
17.2	Wind Generation Grid Integration, Long Duration	1	6	0.2 kW	500 MW	100	782	1,445	18,417	637	8,122

*Hours unless indicated otherwise. min. = minutes. sec. = seconds.
**Lifecycle, 10 years, 2.5% escalation, 10.0% discount rate.
†Based on potential (MW, 10 years) times average of low and high benefit ($/kW).
†† Benefit for *one year.* However, storage could be used at more than one location at different times for similar benefits.
http://www.sandia.gov/ess/publications/SAND2010-0815.pdf

The markets identified by Sandia labs, along with the results of EEStor's Phase 4 testing, indicate there is potentially a total addressable market for EEStor's current technology of over one trillion-dollars in the field of grid storage in the United States alone. Based on Phase 4 test results, EEStor believes it currently has the technology, scaled to the appropriate configurations, to provide low cost, long lifetime, high voltage, energy storage solutions with long discharge times for many segments of the grid applications listed above.

Additionally, the Sandia Laboratory report, "DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA" [2] breaks down the cost of current energy storage systems for the grid by system type, services provided and discharge duration (see fig. 19 , 20).

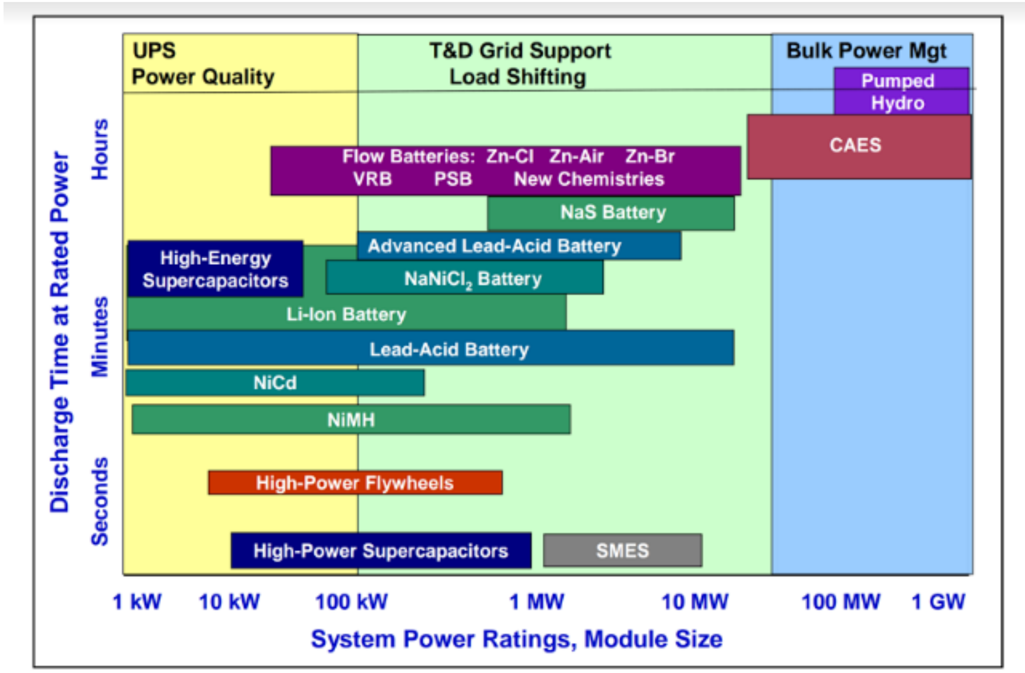


Figure 19. Positioning of Energy Storage Technologies

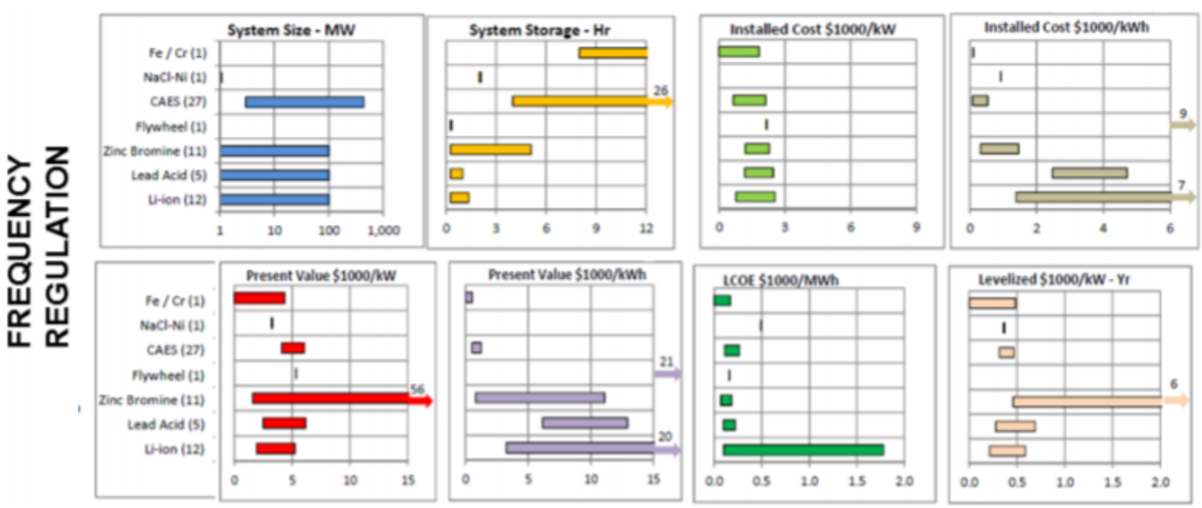


Figure 20. Frequency Regulation Systems [2]

The cost and complexity of current energy storage systems is staggering. Appendix B page B-44[3] details a 200 flywheel facility that provides frequency regulation support. It is only 85% efficient, provides 5,000 kilowatt-hours of usable power for a duration of 15 minutes over an expected 15-year life time for an installed cost of US$43,189,100. EEStor technology, with solid state efficiency, is expected to be able to compete with this technology on a dollar per kilowatt-hour basis over its lifetime today. As the stacking effect is explored further and stacks of 1000 or more are built, and/or the polymer research paths increase capacitance, other segments of the nearly US$2 trillion-dollar market could open up in a cost effective manner.

FOOTPRINT OF A 200 FLYWHEEL FACILITY[3]

Denis Zogbi, an independent consultant to the EEStor, has pointed out in his report "EEStor Capacitor Technology: Opportunities in The Global Capacitor Market: 2014" that EEStor technology is expected to be disruptive in the 2-billion-dollar power factor correction market[4]. With the increased voltage and time constants due to the resistance boosting "stacking effect", EEStor believes it currently has the technology to competitively address the following US$23 billion dollar additional markets: area regulation US$1.4 billion, voltage support US$5.5 billion, transmission support US$2.6 billion, electric service reliability US$6.1 billion, electric service power quality US$6.1 billion and short duration wind integration US$1.7 billion This means with phase 4 testing EEStor technology is ready to address directly and lead on performance and cost in an expected US$25 billion dollar market.

1 http://www.sandia.gov/ess/publications/SAND2010-0815.pdf
2 www.sandia.gov/ess/publications/**SAND2013**-**5131**.pdf
3 http://www.powermag.com/milestones-for-flywheel-lithium-battery-grid-scale-projects/
4 EEStor Capacitor Technology: Opportunities in The Global Capacitor Market: 2014 Written for ZENN MOTOR COMPANY/EEStor, INC. http://www.eestorcorp.com/assets/eestor-zogbi-report.pdf

Forward-looking Statements

Certain statements and documents referred to in this paper, other than statements of historical fact, may include forward-looking information that involves various risks and uncertainties that face EEStor; such statements may contain such words as "may", "would", "could", "will", "intend", "plan", "anticipate", "believe", "estimate", "expect" and similar expressions, and may be based on management's current assumptions and expectations related to all aspects of the capacitor and energy storage industries, consumer demand for such solutions and the global economy. Risks and uncertainties that may face the Company include, but are not restricted to: EEStor may not be able to replicate test rests in mass produced commercial products; the EEStor capacitor and energy storage technology may not be successfully commercialized at all, in a manner providing the features and benefits expected while under development, or on a timely basis or EEStor may not be able to successfully incorporate this technology into its current or proposed products or the products of others; steps taken by EEStor to protect its proprietary rights may not be adequate or third parties may infringe or misappropriate EEStor's proprietary rights; EEStor has a history of losses from operations and may not be able to obtain financing, if and when required or on acceptable terms due to market conditions or other factors, to fund future expenditures for general administrative activities, including sales and marketing and research and development, expansion, strategic acquisitions or investment opportunities or to respond to competitive pressures; competitors may develop products which offer greater benefits to consumers, have greater market appeal or are more competitively priced than those offered by EEStor; EEStor may be exposed to product liability claims which exceed insurance policy limits; EEStor is dependent on the ability and experience of a relatively small number of key personnel; new products introduced by EEStor may not be accepted in the market or to the extent projected; new laws and regulations may be enacted or existing ones may be applied or governmental action may be taken in a manner which could limit or curtail the production or sale of EEStor's products; and EEStor may be negatively affected by reduced consumer spending due to the uncertainty of economic and geopolitical conditions. These risks and uncertainties may cause actual results to differ from information contained in this release, when estimates and assumptions have been used to measure and report results. There can be no assurance that any statements of forward-looking information contained in this paper will prove to be accurate. Actual results and future events could differ materially from those anticipated in such statements.

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