TECHNICAL PAPER

The Advantages of SuperCapacitors for Power Constrained Backup

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Abstract

In most energy storage scenarios, the tradeoffs between power density and energy density quickly come to the foreground. This is best illustrated in the automotive industry, where power density directly translates to acceleration and driving performance, while energy density translates to the total range achievable on a tank of gas or, for an electric vehicle, on a single recharge cycle. This is true across almost every application, from wearable electronics to microgrid power networks on a college campus.

This whitepaper from KYOCERA AVX will explore the advantages of SuperCapacitors, circuit level, uninterruptable power, and microgrid considerations, and the benefits that make them a more reliable option than traditional batteries.

THE ADVANTAGES OF SUPERCAPACITORS FOR POWER CONSTRAINED BACKUP

INTRODUCTION

This whitepaper from KYOCERA AVX will explore the advantages of SuperCapacitors, circuit level, uninterruptable power, and microgrid considerations, and the benefits that make them a more reliable option than traditional batteries.

POWER VS. ENERGY DENSITY

In most energy storage scenarios, the tradeoffs between power density and energy density quickly come to the foreground. This is best illustrated in the automotive industry, where power density directly translates to acceleration and driving performance, while energy density translates to the total range achievable on a tank of gas or, for an electric vehicle, on a single recharge cycle. This is true across almost every application, from wearable electronics to microgrid power networks on a college campus. In a perfect world, designers could have the best of both worlds, with high-density energy storage and high-density power generation. Unfortunately, as shown in Figure 1, no such technology exists in a usable form, so designers must choose a balance of components to achieve their performance goals.

The dominating energy storage device remains the battery, particularly the lithium-ion battery. Lithium-ion batteries power nearly every portable electronic device by storing energy electrochemically. During discharge, the energy-containing lithium-ion travels from the high-energy anode material through a separator to the low-energy cathode material. The movement of the lithium releases energy, which is extracted into an external circuit. During the recharging process, energy moves the lithium-ion back to the high-energy anode compound.

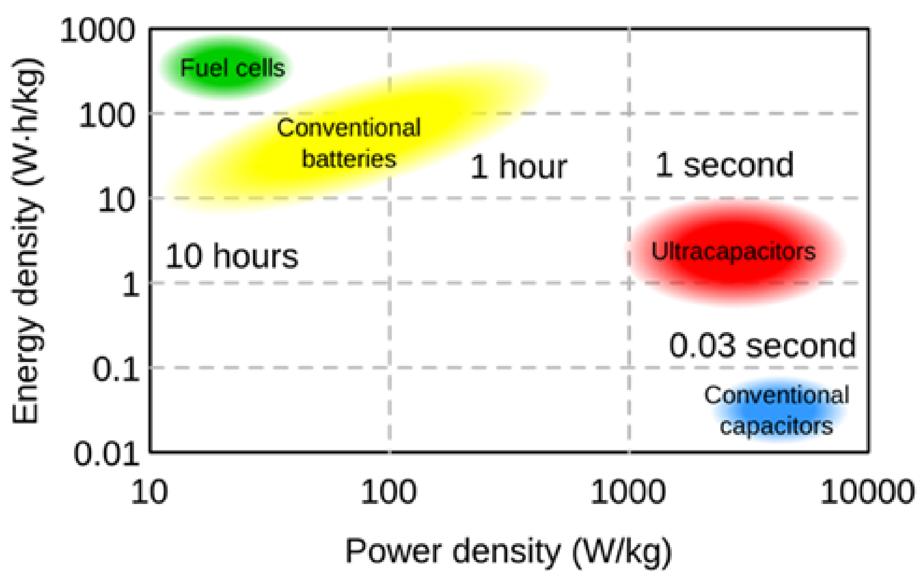

Figure 1: Energy Density & Power Density of Energy Storage Technologies – Image from Wiki provided by KYOCERA AVX
***Ultracapacitors = SuperCapacitors*

POWER VS. ENERGY DENSITY

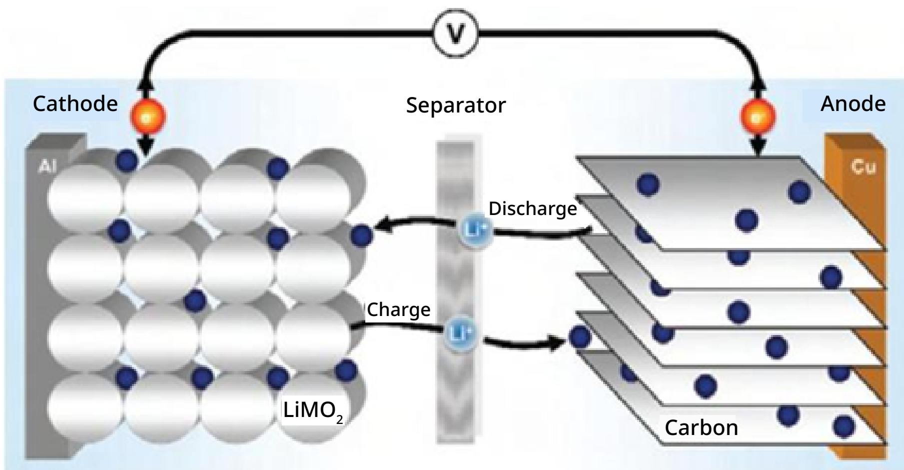

Figure 2: Schematic of Li-Ion Battery. Image from Wiki Commons

The charge and discharge process in batteries is slow and can degrade the chemical compounds inside the battery over time. As a result, batteries exhibit low power density and lose their ability to retain original specified energy ratings throughout their lifetime due to material damage.

The SuperCapacitor is at the other end of the energy-power spectrum, which is based on an electrostatic energy storage mechanism. SuperCapacitors can be charged quickly, leading to a very high power density, and do not lose their storage capabilities–even over millions of charge/ discharge cycles.

SUPERCAPACITOR OVERVIEW

The building blocks of a SuperCapacitor include at least two electrodes, an electrolyte, and an ion-permeable separator. Energy is stored in an electrostatic concept known as the electrical double layer. At the molecular level, the surface interaction between a solid and the ions within a fluid creates an extremely small capacitive layering. If the surface area is large enough, this double layer capacitance becomes significant and can be used for energy storage. Figure 3 depicts the basic SuperCapacitor structure.

Although SuperCapacitors' total energy storage capacity is small compared to batteries, they can be charged and discharged very quickly and can easily meet the design life requirements of almost any product. SuperCapacitors can operate in any energy storage state, even under fully discharged conditions, without adversely affecting the constituent materials.

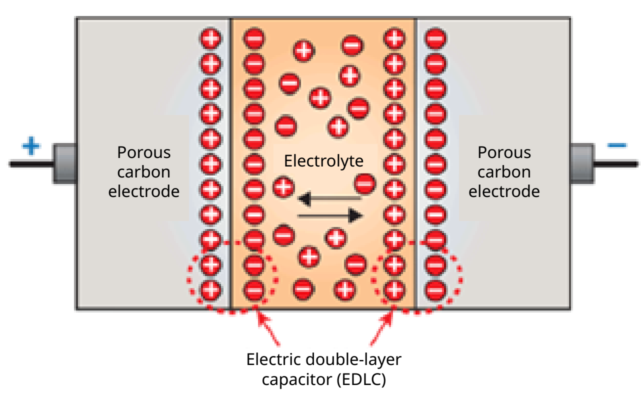

Figure 3: SuperCapacitor structure (Marcelo Gustavo Molina, "Dynamic Modelling and Control Design of Advanced Energy Storage for Power System Applications")

CIRCUIT LEVEL POWER

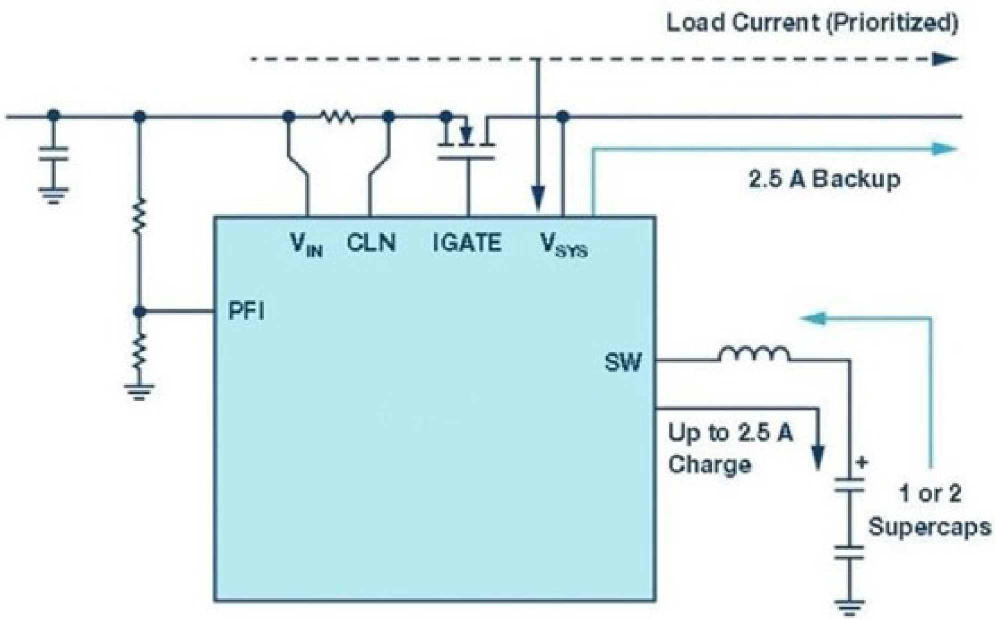

Figure 4: SuperCapacitor backup power application schematic

SuperCapacitors can provide high-power backup for a short period at the circuit level in applications ranging from handheld electronics to enterprise servers. This is extremely useful for "last breath" operations and even temporary power interruptions or instabilities. A typical configuration is shown in Figure 4, where a specialized IC is used to charge a SuperCapacitor bank during regular operation and then quickly switches to backup mode during a loss of incoming power.

Figure 5 shows that the input power source fails at approximately two seconds. The SuperCapacitor backup takes over, and the device can continue operating at a full 1A current draw for an additional fifteen seconds — plenty of time to perform shutdown tasks and ensure data integrity for typical electronic applications.

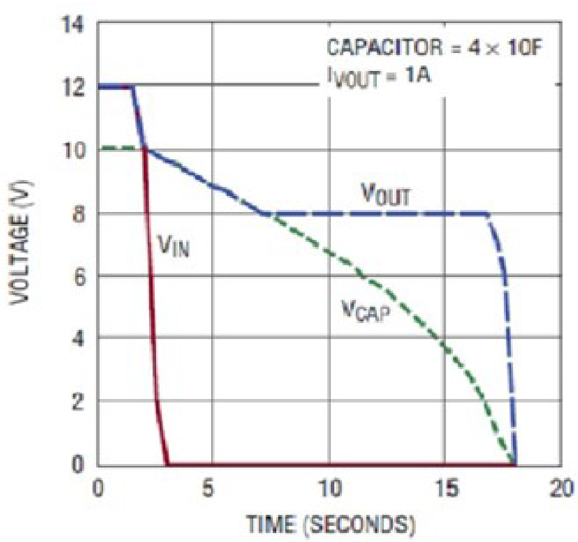

Figure 5: SuperCapacitor backup during incoming power loss

UNINTERRUPTIBLE AND AUTOMOTIVE POWER

Today's uninterruptible power supply (UPS) systems use lead-acid batteries as electrical energy storage devices. The batteries require regular maintenance and offer a relatively short life. Typically, the UPS is required to monitor the status and health of the battery at all times during operation. Additionally, the backup time to ensure data integrity is relatively short. When used for frequent power outages, these quick charge/partial discharge cycles will cause the battery to be sulfated, thus shortening its life even further.

UNINTERRUPTIBLE AND AUTOMOTIVE POWER

The incorporation of SuperCapacitors into the energy storage network of a UPS can overcome these challenges and create a truly maintenance-free product. The SuperCapacitor output current can rise to hundreds or even thousands of amps with almost no delay and be recharged quickly within minutes. Typical specifications include 100,000 charge cycles of life and ten or more years without required care.

A similar case can be made to apply SuperCapacitors in electric vehicles (EVs). Their insensitivity to rapid and partial charge/discharge cycles makes them ideal candidates for regenerative braking systems and during periods of quick acceleration. By reducing the load on the main EV battery, its lifetime can be extended while simultaneously providing improved driving performance.

MICROGRIDS

A microgrid consists of one or more power sources, numerous electrical loads, and various energy storage devices, typically all geographically co-located. An example topology is shown in Figure 6.

There are two typical modes of microgrid operation. Under the normal "grid-connected" mode, the microgrid and a utility power distribution network run in parallel. When a utility grid failure is detected, or power quality does not meet requirements, the microgrid will be disconnected from the grid to run independently in "isolated" mode.

When operating grid-connected, the power fluctuations within the microgrid are balanced by the larger utility grid. When the microgrid is switched from grid-connected operation to isolated operation, the microgrid energy storage

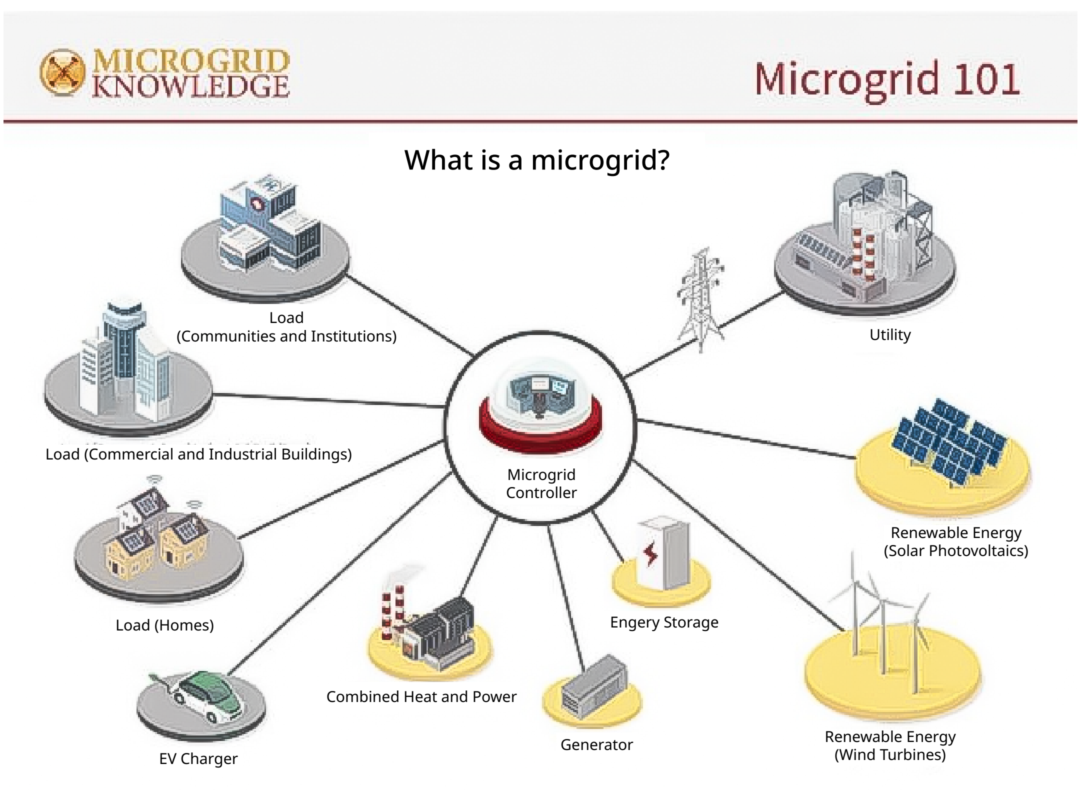

Figure 6: Example microgrid topology (Image from MicrogridKnowledge.com)

MICROGRIDS

elements start to make up for the power shortage immediately. A central energy storage element or many distributed energy storage devices can balance the fluctuation of the load or the change of the micro-grid sources during isolated operation.

Due to the small size of typical micro-grids and their minimal inertia, frequent power fluctuations on the network can become very serious and affect the stable operation of the whole microgrid. SuperCapacitor energy storage systems can effectively solve this problem by storing excess power during load dips and feeding back to the microgrid to adjust power demand during load peaks. The high power density of SuperCapacitors makes them the best choice for handling spike loads, and only as much energy as the spike load needs to be stored using SuperCapacitors.

CONCLUSION

In applications that require high power density backup, especially repetitive ones, the SuperCapacitor shines as a reliable and practical solution. SuperCapacitors offer very high power density with relatively low energy density compared to batteries. This allows them to provide short bursts of energy without any of the typical shortcomings associated with batteries, particularly extreme discharge failure, repetitive discharge damage, and lifetime reliability. KYOCERA AVX offers a wide range of SuperCapacitors in various capacities, voltage, and form factors, as shown in Table 1.

To learn more, visit KYOCERA AVX's website.

KYOCERA AVX Part Number	Diameter (mm)	Length (mm)	Rated Capacitance (F)	Capacitance Tolerance	Rated Voltage (V)	Rated Temperature (°C)	DCL Max @ 72 Hrs (µA)	ESR Max @ 1000 Hz (mΩ)	ESR Max @ DC (mΩ)	Peak Current (A)	Power Density (W/kg)	Max Energy (Wh)	Energy Density (Wh/kg)
Radial Lead													
SCCQ12B105PRB	6.3	12	1	+100%/-0%	2.7/2.3*	65/85*	6	200	500	0.90	2692	0.0010	1.56
SCCR12B105PRB	8	12	1	+100%/-0%	2.7/2.3*	65/85*	6	150	500	0.90	1842	0.0010	1.07
SCCQ15B125SRB	6.3	15	1.2	+30%/-10%	2.7/2.3*	65/85*	6	240	620	0.93	1933	0.0012	1.66
SCCR16B205PRB	8	16	2	+100%/-0%	2.7/2.3*	65/85*	10	100	360	1.57	2113	0.0020	1.76
SCCR20B335PRB	8	20	3.3	+100%/-0%	2.7/2.3*	65/85*	12	95	290	2.28	2080	0.0033	2.30
SCCR25B505PRB	8	25	5	+100%/-0%	2.7/2.3*	65/85*	15	85	220	3.21	2339	0.0051	2.98
SCCS20B505PRB	10	20	5	+100%/-0%	2.7/2.3*	65/85*	15	70	180	3.55	2314	0.0051	2.41
SCCS25B705PRB	10	25	7	+100%/-0%	2.7/2.3*	65/85*	20	60	150	4.61	2243	0.0071	2.73
SCCS30B106PRB	10	30	10	+100%/-0%	2.7/2.3*	65/85*	30	40	75	7.71	3763	0.0101	3.27
SCCT20B106PRB	12.5	20	10	+100%/-0%	2.7/2.3*	65/85*	30	50	75	7.71	3431	0.0101	2.98
SCCT30B126SRB	10	30	12	+30%/-10%	2.7/2.3*	65/85*	30	50	75	8.53	3812	0.0122	3.97
SCCT30B156SRB	12.5	30	15	+30%/-10%	2.7/2.3*	65/85*	50	35	80	9.20	2430	0.0152	3.38
SCCT30B186SRB	12.5	30	18	+30%/-10%	2.7/2.3*	65/85*	55	40	60	11.68	3378	0.0182	4.93
SCCT35B226SRB	12.5	35	22	+30%/-10%	2.7/2.3*	65/85*	58	34	58	13.05	2631	0.0223	3.89
SCCU25B256SRB	16	25	25	+30%/-10%	2.7/2.3*	65/85*	60	27	50	15.00	2397	0.0253	3.47
SCCU30B356SRB	16	30	35	+30%/-10%	2.7/2.3*	65/85*	70	20	40	19.69	2514	0.0354	4.07
SCCT47B406SRB	12.5	47	40	+30%/-10%	2.7/2.3*	65/85*	75	19	29	25.00	4022	0.0405	5.40
SCCV40B506SRB	18	40	50	+30%/-10%	2.7/2.3*	65/85*	75	18	20	33.75	3365	0.0506	3.89
SCCV60B107SRB	18	60	100	+30%/-10%	2.7/2.3*	65/85*	260	15	18	48.21	2430	0.1013	5.06

Table 1: Example KYOCERA AVX SuperCapacitor offerings

NORTH AMERICA
Tel: +1 864-967-2150

ASIA
Tel: +65 6286-7555

CENTRAL AMERICA
Tel: +55 11-46881960

EUROPE
Tel: +44 1276-697000

JAPAN
Tel: +81 740-321250

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