whitepaper

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RIELLO ELETTRONICA riello ups

RIELLO UPS: SUPERCAPS FOR UNINTERRUPTIBLE POWER SUPPLIES

INTRODUCTION

At present, **electricity can be stored** using technologies that differ both in physical operating principles (electrostatic and electrochemical) and in performance characteristics (specific power, energy density, storage and conversion efficiency).

The **solutions** that seem to be most suitable for this purpose are **electrochemical batteries, storage systems with hydrogen accumulation** and electrochemical and electrostatic condensers - also called supercapacitors or ultracapacitors.

In this white paper we will discuss supercapacitors, which operate in a similar way to normal capacitors – **what makes them "super" in comparison is the amount of energy they can accumulate**.

FEATURES

Supercapacitors represent an innovative and green storage technology, characterized by relatively **low energy density** (less than storage with electrochemical batteries) combined **with extremely high power density.** Since the accumulation of electricity is based on almost reversible electrostatic processes, they also have a **high efficiency and long life span** (an estimated 1,000,000 life cycles at 25°C).

Due to their operational characteristics, supercapacitors can be used effectively in storage systems and to power short-lasting power peaks.

The diagram in figure 1 highlights how supercapacitors occupy a region of the plane between the electrochemical batteries and traditional capacitors.

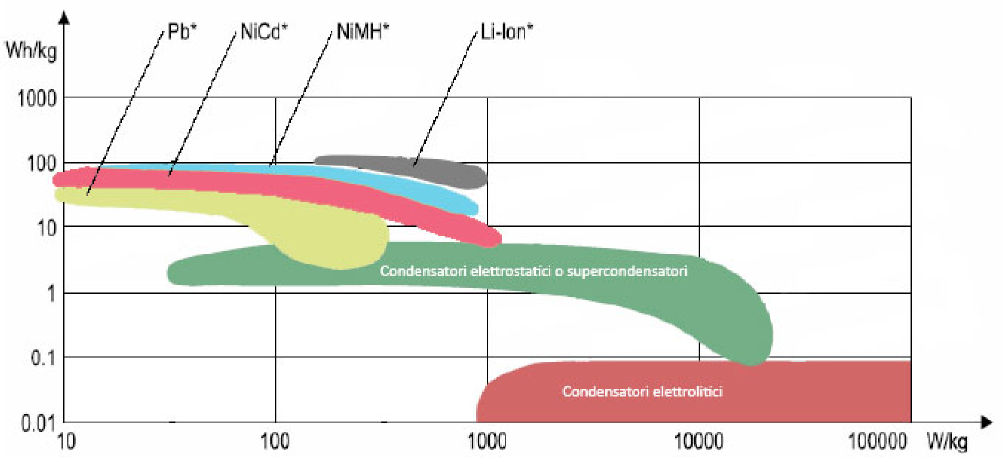
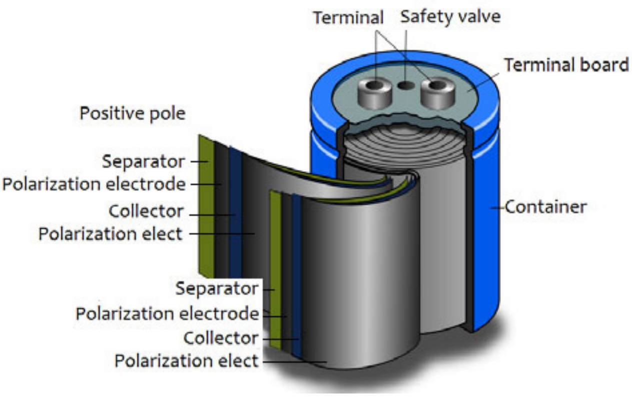


Figure 1

INTERNAL STRUCTURE AND FUNCTIONING

Supercapacitors store electrical energy through electrostatic fields: an elementary cell essentially consists of two porous electrodes, characterized by a high ratio between the surface of the plates and weight, immersed in an electrolytic solution.



A capacitor is characterized by its capacity (measured in Farad) which is the index of the amount of charge, or better the electrons, which it is able to accumulate. The capacity grows as the area of the plates increases and the distance between them decreases. **Supercapacitors differ from standard capacitors because they are able to accumulate millions of times the number of electrons**.

As already mentioned, supercapacitors do not require chemical processes to make the accumulated energy available, therefore the time they need to accumulate electrons on a plate, and to subsequently charge the capacitor, are very short. For this reason, supercapacitors are widely used in applications where large quantities of energy are required in short times, or with devices capable of charging in a few minutes.

APPLICATION FIELDS

Thanks to their high capacity levels and currents, supercapacitors can be used for energy storage solutions that can be installed in small spaces. When used as auxiliary power sources in peak currents, they allow you to reduce the size of the power supplies and act as a function that can produce higher current and improve overall performance.

Some examples include:

- **Braking with recovery of metropolitan trains**: the kinetic energy when trains brake can be fed directly into the main driving line that powers the train as it accelerates. Instead of dissipating, any excess is accumulated in supercapacitor batteries arranged in electrical power stations to supply other critical loads.

- **Hospital diagnostic equipment**: many radiological devices are characterized by large short-term power absorptions - the examination time - interspersed with periods of more modest absorption. The introduction of supercapacitor batteries allows the power peaks taken from the network to be contained, avoiding oversizing of the power systems.

- **Improvement of electricity supply quality**: uninterruptible power supplies tend to operate in environments of critical loads with intermittent power withdrawals and short-lasting peaks. The introduction of supercapacitor banks enables the UPS to be optimized without being forced to oversize the batteries to cope with the delivery of the required powers even if for short periods of time.

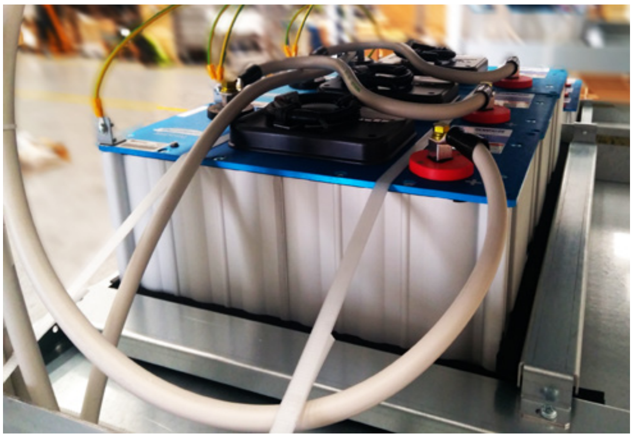
- **Renewable energy applications**: in photovoltaic solar applications it is necessary to replace the batteries every 3-7 years as they decline in performance. Supercapacitors charge and discharge quickly and support multiple cycles, so they can be replaced every 20 years. By reducing the frequency of maintenance interventions, life cycle costs are also reduced, which increases efficiency too.

WHY CHOOSE SUPERCAPACITORS?

In critical settings like modern Data Centers or with electromedical and industrial applications, the installation of a system with traditional batteries provides insufficient time to solve some of the most common failure problems when starting the generator set, such as the fuel block or a failure in the starter battery.

- A Data Center can take 3 to 6 hours to transfer its operations to a mirroring site or to shutdown
- Medical electrical installations require safe and continuous energy to guarantee lifesaving services
- Automated production processes require uninterrupted power supply to prevent machinery or equipment failure

In each of these and in many other cases, a generator set supported by a UPS with supercapacitors that offers relatively short autonomy is the most efficient and effective continuity solution.



A supercapacitor offers benefits including:

- High power density
- Instant charge/discharge
- Very slow deterioration
- Not sensitivity to fluctuating temperatures
- No toxic and flammable components
- Up to 15 years or 1,000,000 charging cycles
- A long lifecycle translates into a reduction in disposal costs and a mitigation of the environmental impact

On the other hand, its shortcomings are

- Low energy density means it requires frequent recharging
- Costs are still quite high, in part due to the materials used which are essentially carbon and graphene

COSTS

The main obstacle to widespread adoption of supercapacitors to uninterruptible power supplies its initial cost. To understand the current state of use of supercapacitors, compared to normal batteries, there needs to be an analysis of life cycle costs and a comparison on the return on investment (ROI).

The hypothesis below refers to:

- a power requirement of 5 kW for 20 seconds;
- the calculation is based on the additional cost incurred for a system that uses supercapacitors;
- the assumption that the initial cost of the battery is zero;
- the assumption that the cost of replacing the supercapacitor and battery is equal to the initial price (hardware cost 100%);
- maintenance of optimal battery conditions and its duration of 20 years;
- battery maintenance carried out every 2 years, and for supercapacitors every 10 years.

Capex in UPS systems: Supercapacitors vs. Classic batteries			
Solution required			
5 KW of power required for 20 seconds V max 300 - V nominal 240 - V min 160			
Initial hypothesis of costs and maintenance			
UPS life = 20 years			
Supercapacitors		Batteries	
n° supercapacitors cost for each total initial cost	6 405 € 2.430 €	number of batteries cost for each total initial cost	20 0 € 0 €
maintenance period single maintenance cost total maintenance cost	every 10 years (1 time) 442 € 442 €	maintenance period single maintenance cost total maintenance cost	every 2 years (9 times) 442 € 3.978 €
replacements hardware cost replacement cost total replacement cost	1 100% 884 € 884 €	replacements hardware cost replacement cost total replacement cost	3 100% 884 € 2.652 €
disposal cost total disposal cost	85 € 85 €	disposal cost total disposal cost	384 € 1.152 €
Total cost 3.841 €		Total cost 7.782 €	
Savings 3.941 €			

Figure 2. Better battery life vs. life expectations supercaps. Cost of the UPS excluded from the counts.
The values and costs described are by way of example, should not be considered as list prices, in case of contacting the company.

In this second hypothesis, a UPS life of 30 years is assumed and that the price of the supercapacitors has decreased by half within the first required replacement period.

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maintenance period single maintenance cost total maintenance cost	every 10 years (2 btimes) 442 € 884 €	maintenance period single maintenance cost total maintenance cost	every 2 years (14 times) 442 € 6.188 €
replacements hardware cost replacement cost total replacement cost	2 50% 884 € 884 €	replacements hardware cost replacement cost total replacement cost	5 100% 884 € 4.420 €
disposal cost total disposal cost	85 € 170 €	disposal cost total disposal cost	384 € 1.920 €
Total cost 4.368 €		Total cost 12.528 €	
Savings 8.160 €			

Figure 3. Worse Battery Life vs. life expectations supercaps
Cost of the UPS excluded from the counts.
The values and costs described are by way of example, should not be considered as list prices, in case of contacting the company.

Total cost of Ownerships (TCO) Supercapacitors vs. Classic batteries		
200 kW UPS Replacing the batteries every 3 years		
Batteries	Flywheel	Supercapacitors
Requirements life: 15 anni potenza: 200kW bridge time: 15 seconds	Requirements life: 15 anni potenza: 200kW	Requirements life: 15 anni power: 200kW bridge time: 15 seconds
Input typical duration: 2 years Float voltage: 560V Min voltage: 440V Discharge time: 30 sec	Input typical duration: 15 years Float voltage: 560V Min voltage: 440V Discharge time: 30 sec	Input typical duration: 15 years Float voltage: 600V Min voltage: 330V Discharge time: 30 sec
Initial cost 15.190* € Annual cost** 3.976 €	Initial cost 42.891 € Annual cost** 1.912 €	Initial cost 53.613 € Annual cost** 491 €
Annual cost 74.867 €	Annual cost 71.619 €	Annual cost 61.021 €
		Savings 13.846 € **(About 18%)**

* includes € 8,935 for the monitoring system
** includes space, electricity costs, maintenance and replacement

SUPERCAPACITORS AND NANOTECHNOLOGY

The exceptional capacity of a supercapacitor is essentially due to the enormous surface area of the plates from which it is composed, for which activated carbon is currently the most used material. However, activated carbon, has low voltage and geometric limitations, with the effect of making most of its cavities inaccessible to electrolytic ions.

Much research work is focusing on the development of supercapacitors combined with nanotechnology. Some studies suggest it possible to create prototypes composed of millions of microscopic filaments coated with materials capable of butterflying electrons much faster - reducing recharge times - and coated with capacitive nanomaterials to provide superior density and therefore allow a greater accumulation of energy and power.
The goal is to obtain a new structure of nano tubes - tending to carbon - capable of greatly increasing the energy density of supercapacitors while guaranteeing the same power characteristics. In other words, we want to get to have less bulky and more compact devices.

SUPERCAPACITORS ARE ECO-FRIENDLY DEVICES

Thanks to the high number of charge-discharge cycles, the supercapacitor has a lifecycle similar to that of the UPS. Its extraordinarily low internal resistance (ESR) and consequent high cycling efficiency (95% or more) added to less heat production make it possible to use fewer, simpler and cheaper cooling systems.

FORECASTS

Supercapacitors are therefore a very important topic for energy storage, there is a lot of research going on all over the world and the developments seem really promising; there are those who even predict that supercapacitors will be able to absorb up to 50% of the market today of Li-Ion applications within the next 15 years.

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