TRANSCENDING TECHNOLOGY FROM CAPACITOR TO SUPER-CAPACITOR

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ABSTRACT

The renaissance of super-capacitor is occurring at a phenomenal potential is being recognised. The need of today's world cannot be matched with electrostatic capacitors. It took 150 years for a concept established in the 1800s to become a technical reality, and a further two decades to make it commercially available. Here is an attempt, to overview the transition from capacitor to super-capacitor in chronological order of the research and developments made.

1. INTRODUCTION

1.1 Evolution

In today's world, energy has become most important factor of technical community and major power of the world. There is increase in the development of more efficient energy devices and sources and super-capacitor is one of the devices which have proved significant in facilitating the energy sources devices.

These devices are manufactured by Pinnacle Research Institute (PRI), USA, and Nippon Electric Company (NEC), Japan. Ultra-capacitor and Super-capacitor are also manufactured by these companies, where the Ultra-capacitor and Super-capacitor are the trading name of the devices manufactured by these companies respectively.

In technical terms, it is titled as electrochemical double-layer capacitor(EDLC). For energy storage in many applications, Ultra-capacitors or Super-capacitors are widely used.

1.2 Advantages of a super-capacitor:

- Safe
- Virtually unlimited cycle life; can be cycled millions of time
- Charges in seconds; no end-of-charge termination required
- Simple charging; draws only what it needs; not subject to overcharge
- High specific power; low resistance enables high load currents
- Excellent low-temperature charge and discharge performance

II STUDY OF EXISTING TECHNOLOGY

2.1 Capacitor

Fig- 1 Various Types of Capacitors

Capacitor's storage potential is known as capacitance. In other words, the capacitance is said to be the amount of charge "Q" stored in between the plates for an existing potential difference "V" across the plates,

Capacitance,

$$C=Q/V$$

Physical concept of capacitance:

It is defined by the physical characteristics of the two plates, such that the capacitance is equal to the ratio between the square area of a plate (A) and the distance between the plates (d) multiplied by the dielectric of the material in between the plates (ε).

Capacitance,

$$C = \varepsilon A/d$$

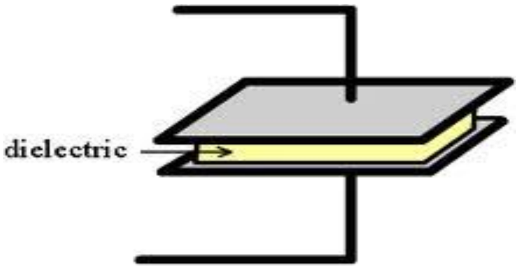

Fig - 2 Basic Capacitor

Capacitor metal plates are partitioned by a dielectric or non -conducting substance. Teflon, mica, porcelain, mylar, cellulose etc are several unique materials used as dielectric material. By the type of dielectric opted a capacitor can be defined. Dielectric material is the foremost substance for storing electrical energy.

2.2 Comparison between capacitor and super-capacitor

Super-capacitor is used to store large amount of charge. In conventional capacitor, on the application of electric field, dielectric material sandwiched between the capacitor plates can be polarized to store large amount of charge. Because of the arrangement of internal dipole within the dielectric an electric field is acknowledged.

Super-capacitors achieve the same outcome, instead of the dielectric dipole alignment but by bulk separation and movement of charges. The mechanism for moving opposite charges to different sides of a separator is electrochemical in nature and very similar to battery technology.

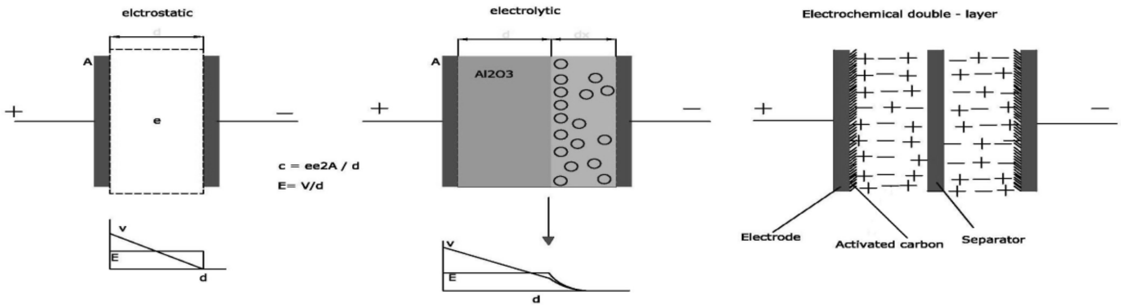

Fig - 3 Schematic representation of electrostatic, electrolytic and electrical double layer capacitor

As it can be seen from Fig- 3, between conventional capacitors and conventional batteries (lead acid battery) ultra-capacitor exists. At high power and cycle life, ultra-capacitors are used where conventional battery fall short and conventional capacitor fails as they lack energy. Depth study can be viewed from the table-1 .

Available Performance	Lead Acid Battery	Ultracapacitor	Conventional Capacitor
Charge Time	1 to 5 hrs	0.3 to 30 s	10^{-3} to 10^{-6} s
Discharge Time	0.3 to 3 hrs	0.3 to 30 s	10^{-3} to 10^{-6} s
Energy (Wh/kg)	10 to 100	1 to 10	< 0.1
Cycle Life	1,000	>500,000	>500,000
Specific Power (W/kg)	<1000	<10,000	<100,000
Charge/discharge efficiency	0.7 to 0.85	0.85 to 0.98	>0.95
Operating Temperature	-20 to 100 C	-40 to 65 C	-20 to 65 C

Table- 1 Battery v/s Ultracapacitor v/s Capacitor

- Good reversibility
- Low cost per cycle
- Extremely low internal resistance
- High output power
- High specific power.
- Simple charge methods—no full-charge detection is needed.
- No danger of overcharging.
- Long life
- Improved safety, no corrosive electrolyte and low toxicity of material.

III TECHNICAL DETAILS

3.1 Concept

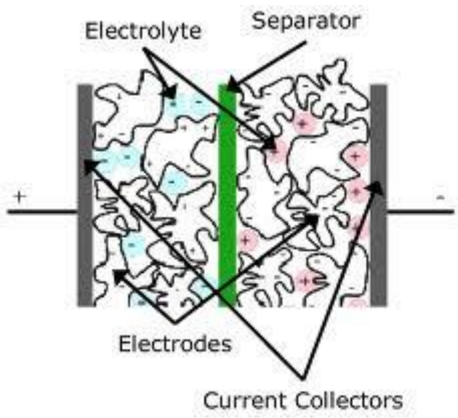

Fig- 5 A Super-capacitor

A new type of capacitor called super-capacitors, also known as ultra-capacitors is formed by Electrical double-layer capacitors (EDLC) with pseudocapacitors . Conventional solid dielectric is absent. Using two high-capacity storage principles the capacitance values can be determined :

- Pseudocapacitance- By redox reactions on the surface of the electrode, Electrochemical storage of the electrical energy can be obtained. It is faradaic in origin.
- Double-layer capacitance -By separation of charge in a Helmholtz double layer at the interface between the surface of a conductor electrode and an electrolytic solution electrolyte, electrostatic storage of the electrical energy can be achieved.(separation of charge is in order of a few Angstroms(0.3-0.8 nm)) and is static in origin.

Both capacitances contribute to the total capacitance value of a super-capacitor. Depending on the composition of the electrolyte and the design of the electrodes, the ratio of the two can be very different.

Pseudocapacitance, are branched into three distinct families, based on the design of the electrodes:

- Double-layer capacitors – are constructed from two carbon-based electrodes, an electrolyte, and a separator. There is no transfer of charge between electrode and electrolyte. Charge storage in EDLCs is highly reversible, which allows them to achieve very high cycling stabilities.
- Pseudocapacitors – stores charge Faradaically through the transfer of charge between electrode and electrolyte. These Faradaic processes may allow pseudocapacitors to achieve greater capacitances and energy densities than EDLCs
- Hybrid capacitors- hybrid capacitors have achieved energy and power densities greater than EDLCs without the sacrifices in cycling stability and affordability that have limited the success of

pseudocapacitors. (e.g. lithium-ion capacitors). It have both the process faradic and non faradic for storage of charge.

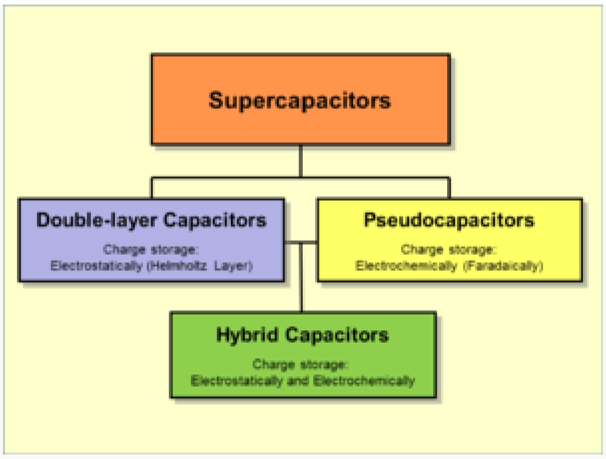

Fig – 6 Hierarchical Classifications of Super-capacitors and Related Types

Super-capacitors energy levels and charge /discharge patterns are extremely predictable. Their stored energy can be calculated by measuring their terminal voltage. The porous material used to manufacture super-capacitor is free of environmentally-harmful ac id and other corrosive chemicals and yields near-infinite life time, implying low maintenance cost and environmental friendly as compared to rechargeable batteries.

3.3 Applications

AC applications are not supported by Super-capacitors. In between general capacitors and batteries, super-capacitor characteristic lies. Because of this property, when it is applied to DC circuit it can be used like a secondary battery.

3.3.1 UPS (Uninterruptable Power Supplies)

It is easier to perform with this capacitor for the limited time energy supply, at a voltage much higher than that of batteries.

3.3.2 GSM applications

For short pulse the voltage of the battery drops considerably. The phone will not be operable if it is below Certain value. But with super-capacitor the voltage drop is reduced and the operation time of the phone is extended.

3.3.3Other applications

- radars in the military
- Memory supplies in computers or phones.

- in the electric transportation domain(cranes, elevators or pallet trucks
- welding and pulsed laser
- Flashlights or hand tools

IV CONCLUSION

According to a market survey by Montana, for brake energy storage in rail vehicles super-capacitors are developing into a good result. The expected technological development outside railway sector is also shown to be highly dynamic: industrial applications, pallet trucks, diesel electric vehicles, hybrid-electric cars, centenary-free operation, starting system for diesel engines, elevators, etc. The time horizon expected for development is next 5 to 10 years. The main development goals will be:

- increase of the rated voltage
- improvements of the range of operating temperature
- long life time
- increase of the energy and power densities

4.1 Future scope

Very recently, hybrid car is introduced in the market but it is turned to be very expensive and out of common man's reach. Shortage and cost of fossil fuels already instigated alternate technologies viable for traction purposes. In such a situation, EDLCs are also useful to store energy generated from non-conventional energy sources. A future possibility of service centres set up for EDLC supply similar to petrol is not far as the main setbacks in technology development may take a decade for fruitful results.

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