COMPREHENSIVE STUDY OF SUPER CAPACITOR

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***Abstract:* - super capacitor or ultra-super capacitor are electrostatic double layer capacitor (ELDC) are the most promising energy device they offer greater transient response power density, low weight, low volume and low internal resistance which make them suitable for several application. This paper gives brief insight into the design characteristic and application of supercapicator.**

Keywords: - Electrolyte, activated carbon, super capacitor.

I. INTRODUCTION

Super-capacitors are referred to as chemical science Double Layer Capacitors abbreviated as EDLCs or ultra-capacitors. Their capacitance and energy density are very terribly high compared to electrolytic capacitors and their power density is to boot very high as compared to batteries.

Super capacitors devices capable of storing and provision high-powered electricity quickly and for an outsized vary of cycles whereas not showing while not showing performance decay.

The only super capacitor consists chiefly of two electrodes and a solution interposed to that. The electrical charges are organized within the electrode/electrolyte interface, and there aren't any chemical reaction processes. Since the physical method of accumulation is proscribed, the materials should have a high expanse to accumulate several electrical charges.

A super capacitor could be a double-layer capacitance with terribly high capability however with low voltage limits. Super capacitors, compared to capacitors, have a bigger space for storing a lot of charge, with capacitance into the farad (F) vary, and that they store a lot of energy than electrolytic capacitors. They need an occasional discharge current and are appropriate for several applications that may operate within the 1.8V - 2.5V range. The lifetime of a super capacitor is 10–20 years, although the capability may be reduced from 100% to 80% once concerning 8–10 years.

Low equivalent series resistance (ESR), super capacitors offer high load currents and quick charging. When a voltage is applied to a super capacitor, two separate charge layers are made on the surface with a separation distance that's smaller than those of standard capacitors. Typically this can be why super capacitors are often noted as double-layer electrical capacitors or EDLCs.

II. SUPERCAPACITOR STRUCTURE

Super capacitor has emerged as new technology in energy storage. It's same elementary equation as that of standard capacitor. They're conjointly called ultra-capacitors and electrochemical dual Layer capacitor (EDLC). The basic equation for a capacitor is

$$C = \varepsilon 0 \varepsilon r \; A \; D \; …….. (1)$$

From the on top of equation (1) it's clear that capacitance is directly proportional to area of electrodes and reciprocally proportional to distance between electrodes. Super capacitors have low energy density and high power density as compared to batteries, therefore super capacitors may be used wherever there's a fast power demand. Super capacitor is built from two carbon based mostly electrodes, centrifuge between electrodes and electrolyte.

The construction of super capacitor is comparable to the development of electrolytic capacitors in this they carries with it two foil electrodes, associate solution and a foil centrifuge. The centrifuge is sandwiched between the electrodes and also the foil is rolled or folded into a form, typically cylindrical or rectangular. This folded type is placed into a housing, fertilized with solution and hermetically sealed. The solution employed in the development of super capacitors furthermore because the electrodes, square measure completely different from those employed in normal electrolytic capacitors.

Super condenser stores electricity energy. As voltage is applied across system not like charges attract one another. Ions in electrolyte diffuses across centrifuge into the pores of electrodes, however electrodes are thus designed that they prevent recombination of ions. These double layer not to mention a rise in space and reduce in distance between electrodes and achieves high energy density than standard capacitor, as throughout whole method there's no transfer of electrical charge or chemical action, these charges are related to non-faradic method. Because the method is non faradic super capacitor possess properties like sizable amount of charging and discharging cycles, extremely reversible keep charge. Super condenser will have binary compound or organic solution. Binary compound solution includes H2SO4 and KOH. These have typically low ESR and low minimum pore size demand as compare to organic solution.

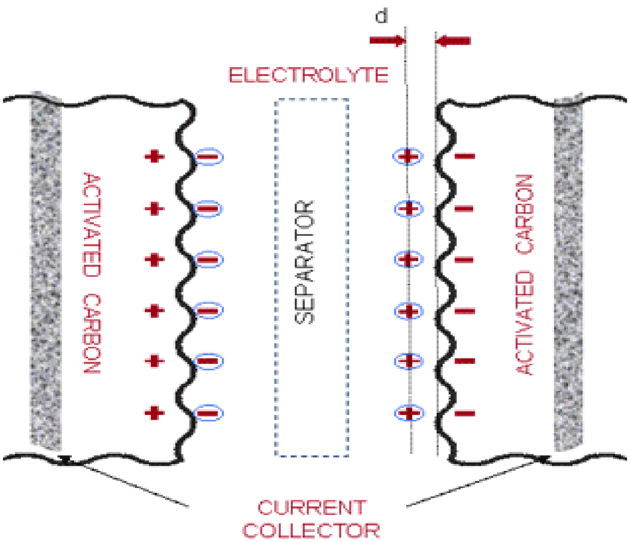


Fig.Internal Structure of a Super-Capacitor

When a voltage is applied, ions present in the solution diffuse through the separator and accumulates at the electrodes of opposite polarity. Accumulation of charge takes place at the interface of electrodes and electrolyte due to the double layer development that is happening between a semiconducting solid and a liquid solution interface. As a result two ionized layers are fashioned with a gap of many angstroms i.e. the physical separation between conductor surface and center of the particle layer. Charge separation at the interface establishes double layer capacitance. High values of capacitance of super-capacitors are achieved as capacitance is directly proportional to the area of conductor and reciprocally proportional to the distance intermediate the two layers.

Most super-capacitors consists of two activated carbon primarily based electrodes (which have an awfully high surface area), Associate in Nursing liquid or organic solution and an apparatus which allows the passing of ions through them, alongside providing insulation between the electrodes.

Fig. Activated Carbon

Super capacitor stores charge at interface between high surface conductor and liquid solution. Charge separation is formed nearly at every solid, liquid interference. It's discovered in super capacitor that distance between conductors is angstroms and area is thousands of sq. meters per gram of electrode. Conventional condenser has low energy and power density than super capacitor however super capacitor has higher power density and lower energy density than battery. Thus super capacitor holds properties of each conventional capacitor and battery. Figure below shows energy and power density of various energy storing devices.

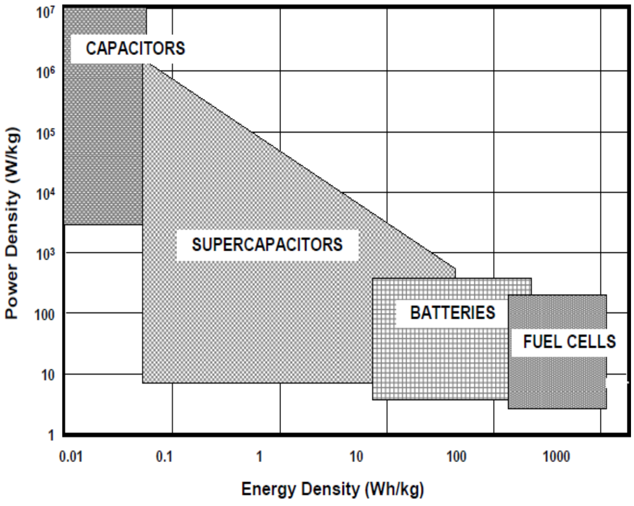


Fig. Power Density of Different Energy Storing Devices

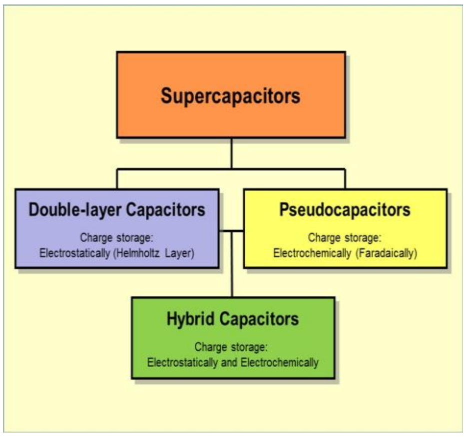
Effective series resistance (ESR)

This is important parameter to be taken care whereas constructing an excellent electrical device. It should be as minimum as attainable. it's pure mathematics total of resistance of internal part of capacitors like electrodes, current collector, stuff material etc. these elements are thought of to own small resistance connected series.

$$P_{max} = V^2/4ESR \ldots\ldots. (2)$$

This relationship in equation (2) shows however the ESR will limit the most power of a capacitor. ESR of standard capacitor is bigger than super capacitor. ESR will increase its quality of solution and conductor material is degraded. Some properties of super capacitor such as: High power density, Moderate energy density, Low ESR, sizable amount of charging and discharging cycles and wide selection of operating temperature makes it appropriate for helping battery for engine beginning.

III. TYPES OF SUPER-CAPACITORS



Super-capacitors don't build use of a standard solid dielectric. They create use of an electrostatic double-layer capacitance or electrochemical pseudo-capacitance or combination of each. Supported this they're divided into three types, they are:

1) Electrostatic double-layer capacitors build use of carbon electrodes or its derivatives whose electricity double-layer capacitance is much higher than electrochemical pseudo-capacitance, so achieving charge separation {in during an exceedingly in a very} Hermann von Helmholtz double layer at the interface between the conductor surface and an electrolyte. The charge separation is of the order of a few angstroms (0.3–0.8 nm), that is way smaller than in an exceedingly typical capacitor.

2) Electrochemical pseudo-capacitors build use of metal oxide or a conducting compound conductor that have high electrochemical pseudo-capacitance. Pseudo- capacitance is achieved by Faradic electron charge-transfer with combination of each reduction and oxidization reactions (i.e. oxidoreduction reactions), intercalation (addition of a molecule or particle into a compound having layered structure) or by absorption on conductor surface (electro-sorption).

3) Hybrid capacitors (example a lithium-ion capacitor) build use of electrodes that have differing characteristics: one showcasing largely electrostatic capacitance and therefore the different largely electrochemical capacitance.

Just in case of super-capacitors, the electrolyte forms a conductive medium between the two conductors that distinguishes it from the electrolytic capacitors wherever the electrolyte acts because the second electrode i.e. the cathode. Super-capacitors are designed in two ways: they're polarized with uneven electrodes, or, just in case of radially symmetrical electrodes, by a possible applied throughout producing method.

IV. SUPERCAPACITOR AS AN ENERGY STORAGE DEVICE

Super-capacitors are special type of electrical energy storage device which can store more energy when compared to electrolytic capacitors, and they offer higher capacitance and power density.

Since ages batteries are used as energy storage device for commercial and domestic applications due to their high energy density, although they have a limited power density. Due to its limited power density they cannot fulfill the required power demand while its open circuit voltage is still retained. With increased voltage drop of the battery load also tends to increase. Often, when a battery needs to supply high power at short pulse widths, the voltage drop may be too high, causing low voltage at the end product. The increasing load decreases the energy storage capacity of the battery, thereby hampering it and reducing its lifespan.

Batteries have very low efficiencies at low temperatures. Their internal resistance increases with slowing down of kinetics of the chemical reaction taking place within the battery. Thus they have to be replaced quite often (say every 2-3 years). Battery-free devices are one of the emerging applications for super-capacitors.

V. CHARGING AND DISCHARGING OF A SUPER-CAPACITOR

The following observations were made regarding charging and discharging of super- capacitor

- the led remained on for longer time;
- there is no particular time that the LED turns off rather it slowly starts fading; and
- It takes less time to charge the super-capacitor than to discharge it.

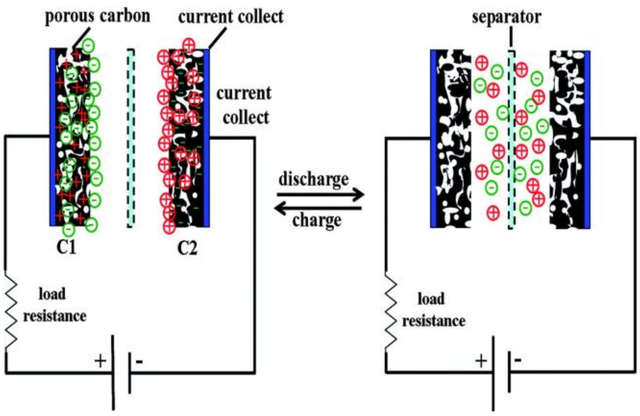


Fig.Charging and Discharging Circuit of a Super-Capacitor

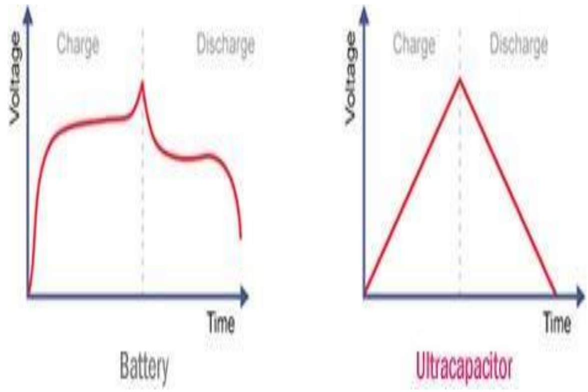


Fig.Charging and Discharging Curves of A Super-Capacitor

VI. EFFECT OF SERIES/ PARALLEL CONNECTION ON PARAMETRES OF SUPER-CAPACITORS

❖ **Voltage**

Series connection: once cells area unit connected serial the general voltage will increase by range of cells serial.
Example: four cells (rated at 2.7V each) connected serial can have a maximum voltage of 10.8V.

Parallel connection: once cells area unit connected in parallel, it'll haven't any have an effect on on the general voltage.

Example: four cells (rated at two.7V each) connected in parallel can have a most voltage of 2.7

❖ **Capacitance**

Series connection: once cells are connected in series the system capacitance reduces by number of cells placed serial.

$$Csys = \frac{Ccell}{n}$$

Example: 4 x 10F cells (rated at 2.7V each) connected in series can have a capacitance of 2.5F and a maximum voltage of 10.8V.

Parallel connection: once cells are connected in parallel the general system capacitance will increase proportionately to number of cells placed in parallel.

$$Csys = Ccell * n$$

Example: 4 x 10F cells (rated at 2.7V each) connected in parallel can have a capacitance of 40F and a maximum voltage of 2.7V.

VII. COMPARISON BETWEEN BATTERIES AND SUPER-CAPACITORS

Super capacitor	Battery
▪ They are able to store large amount of electrical charge than chemical batteries.	▪ They are lose there storage capability over time.
▪ The life span of super-capacitor is long (min 7-10 years)	▪ The life span of battery is short (2-3 years).
▪ Charging cycle of super-capacitor is 10,00,000 cycles	▪ Charging cycle of battery is 3000 cycles
▪ Efficiency of super capacitor is high ranging from 95% to 98%	▪ Efficiency of battery is low about 70%
▪ In super capacitor no danger of over charging	▪ The status of battery has to be continuously monitored to overcharging.
▪ In super capacitor low impedance hence charges at a very fast rate.	▪ In battery high impedance hence take long time to charge about 2 hours
▪ High power density when compared to batteries	▪ The power density of battery is low
▪ Super capacitor Reduced voltage drop when compared to batteries	▪ Higher voltage drop are encountered

VIII. APPLICATION

Super capacitance is has been employed in varied application like electrical drive, traction, electrical vehicle.

Traction: - the traction vehicle must undergoes three completely different phase, acceleration phase, and cruising phase and speed part. Throughout these phases, the ability will be extremely negative yet as positive. This variation of power creates serious problems like supply voltage fluctuation, losses in main power supply. Resolution of this drawback is to integrate super-capacitor as a short storage device with an interface dc-dc converter.

Electrical vehicle: - whereas bracking emf voltage manufacture by the motor is employed to charge super capacitance will charge in precisely few seconds. Super capacitance keep energy is employed to begin the engine.

IX. CONCLUSION

Super capacitor could also be used wherever high power of energy storage is needed. Super capacitance will be used wide as a result of their long life & short charging time. On the opposite hand its limitations because of its high value, self-discharge, packing drawback etc.

IX. ACKNOWLEDGMENT

We are very much thankful to Dr. (Mrs.) S.S Ambekar, Head of Department, Electrical Engineering Department, K.D.K.C.E., Nagpur, & Mr. Sandeep K. Mude, Assistance Prof., Department of Electrical Engineering, K.D.K.C.E., Nagpur, for their valuable guidance and support.

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