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Supercapacitor construction, principle, operation, characteristics, advantages, disadvantages and applications

Rishabh Kumar Singh[1], Sudhanshu Kumar Mishra[2], Prof. Vishal V. Mehtre[3]

Student, Department of Electrical Engineering, Bharati Vidyapeeth (Deemed to be) University College of Engineering, Pune, Maharashtra, India[12]

Assistant Professor, Department of Electrical Engineering, Bharati Vidyapeeth (Deemed to be) University College of Engineering, Pune, Maharashtra, India[3]

Abstract— Supercapacitors had resolved the limitations of lead acid batteries and provided excellent power performance. Continuously researches are going on to increase energy density and voltage of supercapacitor. Due to their benefits they are being used worldwide in various application for automotive, consumer electronics, renewable energy, railways, defence, power industries etc. I have mentioned about Supercapacitors its construction, principle, operation and characteristic along with their advantages and disadvantages at the end I mentioned the applications of Supercapacitor in different field.

Keywords: Supercapacitor, energy density, automotive, electronics, renewable energy, railways, defence, power industries.

1. INTRODUCTION

Supercapacitors are electronic devices which are used to store extremely large amounts of electrical charge. They are also known as double-layer capacitors or ultracapacitors. Instead of using a conventional dielectric, supercapacitors use two mechanisms to store electrical energy: double-layer capacitance and pseudocapacitance.

Double layer capacitance is electrostatic in origin, while pseudocapacitance is electrochemical, which means that supercapacitors combine the workings of normal capacitors with the workings of an ordinary battery. Capacitances achieved using this technology can be as high as 12000 F. In comparison, the self-capacitance of the entire planet Earth is only about 710 μF, more than 15 million times less than the capacitance of a supercapacitor. While an ordinary electrostatic capacitor may have a high maximum operating voltage, the typical maximum charge voltage of a supercapacitor lies between 2.5 and 2.7 volts.

Supercapacitors are polar devices, meaning they have to be connected to the circuit the right way, just like electrolyte capacitors. The electrical properties of these devices, especially their fast charge and discharge times, are very interesting for some applications, where supercapacitors may completely replace batteries. discovery of the possibility of storing an electrical charge in surface arose from phenomena associated with rubbing of amber during the ancient times.

In the mid eighteen century that was when the effect of such phenomena was understood during the period when physics of so-called ‘’static electricity’’ was being investigated and various ‘’electrical machines’’ were being developed.

In 1957 a group of General Electric Engineers were experimenting with devices using porous carbon electrode when they noticed electric double layer capacitor effect. Their observation at the time was that energy was store in the carbon pores and it showed an exceptionally high capacitance.

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2. CONSTRUCTION OF SUPERCAPACITOR

Conventional Supercapacitors are constructed somewhat like electrolyte capacitors. They have two electrodes that are made up of porous active carbon coating or carbon nanotubes. The coating is implemented on metal foils i.e. aluminium which serve as current collectors. The current collector coated with electrodes are immersed in an electrolyte.

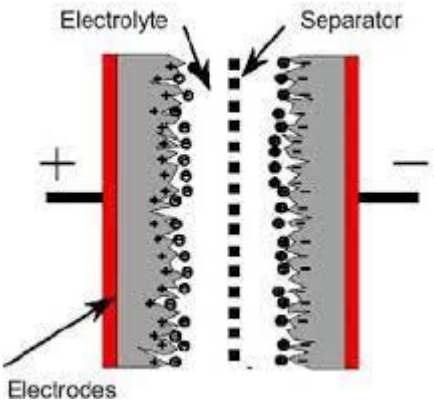

Figure 1

The electrolyte can be liquid or solid. In most ultracapacitors, solid electrolytes are preferred due to higher terminal voltage. The solid electrolyte is generally a solvent mixed with conductive salts. Typically, Acetonitrile or Propylene Carbonate is used as a solvent and Tetraalkylammonium or Lithium salts as solutes. The electrode coated current collectors are separated by a separator (paper membrane) which is transparent to the charge carriers but avoid direct shorting between the electrodes. Due to the double-sided electrode coating of current collectors, these capacitors are also called Electrical Double Layer Capacitors (EDLC).

The highly porous nature of electrode material these capacitors to attract a large number of charge carriers from the electrolyte. Due to the use of activated carbon, the effective surface area between the current collectors is increased manyfold. The internal resistance (ESR) of the capacitor depends upon the electrolyte. The lower the resistance offered by the electrolyte, the greater is the power density of the capacitor.

Supercapacitors generally have a very low voltage rating that may range from 1V to 3V. The following equation gives the electrical power stored by a supercapacitor.

$$P = V^2/4R$$

Where

P is the power stored by the Super Capacitor,
V is the applied voltage (or Voltage Rating),
R is the resistance

3. PRINCIPLE OF SUPERCAPACITORS

When the supercapacitor is mainly composed of many parts, like current collectors, electrodes, electrolytes, and separators. The role of the separator has the same function as the separator in the battery. It isolates the two electrodes to prevent short circuit between the electrodes and allows ions to pass through.

The basic principle of supercapacitor energy storage is to store electrical energy through the electric double-layer capacitance formed by the charge separation on the interface between the electrolyte and the bath solution.

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4. OPERATION OF SUPERCAPACITORS

When a potential difference is applied across the terminals of a supercapacitor, the electrodes start attracting opposite charge carriers from the electrolyte. The positive ions get accumulated at the negative connection, and negative ions get accumulated at the positive connection.

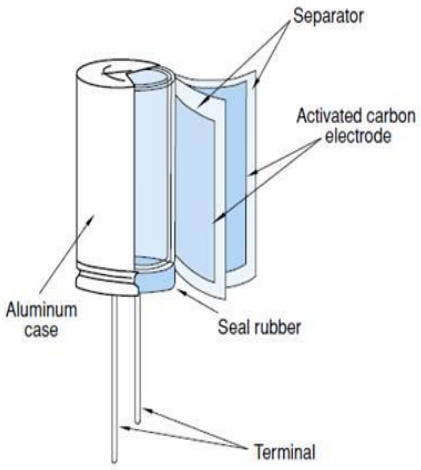

Figure 2

The charge carriers are stored at the current collector plates. Due to accumulation of opposite charges at the current collectors, an electrostatic field is set up between them. Charging current flows through capacitor until the electrostatic field between the current collectors equals and opposite to the applied voltage. The charge carriers are retained by the current collectors until the applied voltage decreases or changes polarity.

Whenever the applied voltage decreases, a proportional number of charge carriers are passed back to the electrolyte from the current collectors. During this process, an equivalent current flows through the capacitor in reverse direction. When the polarity changes, the supercapacitor goes through a similar cycle of charging and discharging.

You see that the supercapacitor, despite its electrochemical construction, still stores charge in the form of an electrostatic field. It works exactly like any other capacitor. That is why, despite battery-like construction, supercapacitors are classified as capacitors and not batteries. Compared to batteries, supercapacitors can go through several thousands of charge-discharge cycles. Therefore, they can serve as an excellent source of charge or power backup in battery-operated circuits.

5. Characteristics of Super-capacitors

- Charge/ discharge time : milliseconds to seconds.
- Operating temperature: -40 degree Celsius to 85 degree Celsius.
- Operating voltage: aqueous electrolyte ~1V; organic electrolytes 2-3 V.
- Capacitance : 1mf to >10,000F.
- Operating life: 5,000 to 50,000 hrs.
- Power density: 0.01 to 10 kW/kg.
- Energy density: 0.05 to 10 Wh/kg.
- Pulse load: 0.1 to 10 A.
- Pollution potential: no heavy metals.

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6. Advantages of Super-capacitors

- Provide Backup power and peak power.
- Enhance run time of battery and prolong its life.
- Helps to reduce size, weight and cost of battery.
- High range of temperature operation is possible.
- Parallel operation with battery improves load balancing.
- Energy storage with energy harvesters.
- Reduces pulse current noise.
- Less space requirement achieved.
- It eliminates DC/DC which reduces the RF noise.
- Environmental friendly.

7. Disadvantages of Super-capacitors

- They have higher self discharge rate.
- Individual cells have low voltage.
- Amount of energy stored per unit weight is considerably lower comparable to electrochemical batteries.
- It offers low energy density compare to battery.
- It can’t be used in AC and higher frequency circuit.

8. Applications of Super-capacitors

- As electrical equivalents of flywheels in machine.
- Connected to batteries to regulate the power then supply.
- In wind turbines.
- Electric and hybrid vehicles.
- In regenerative braking in buses, trains, cranes, elevators and automobiles.
- As backup power system for SRAM.
- For quick recharge in MP3 player and flash drive.
- As short term energy storage.
- As burst mode power delivery.

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9. CONCLUSION

This paper details about the Supercapacitor, construction, principle, operation including advantages, disadvantages and application. The purpose of this review is to provide idea about Supercapacitor which will help to understand it better. It is clear from the researched reviewed that a supercapacitor is a specially designed capacitor which has a very large capacitance. Supercapacitors combine the properties of capacitors and batteries into one device. It is important to conduct more studies on the results and reasons.

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BIOGRAPHIES

Shri. Rishabh Kumar Singh, a 4th year Electrical Engineering student at Bharati Vidyapeeth (deemed to be) University College of Engineering, Pune

Shri. Sudhanshu Kumar Mishra, a 4th year Electrical Engineering student at Bharati Vidyapeeth (deemed to be) University College of Engineering, Pune

Prof. Vishal V Mehtre has completed his masters in Electrical Engineering (Power System) from Bharati Vidyapeeth (deemed to be) University College of Engineering and currently as assistant professor in the same. He has industrial experience of about 2 years in Suzlon Power Infrastructure Pvt. Ltd. As Engineer in Power Evacuation department and has teaching experience of more than 5 years. His area of interest is renewable sources of energy specially Wind and Solar with its analysis, optimization and power quality.

