SUPER CAPACITOR MODULE FOR ENERGY STORAGE APPLICATION

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Abstract: A new technology, the super capacitor, has emerged with the potential to enable major advances in energy storage. Super capacitor s are governed by the same fundamental equations as conventional capacitors, but utilize higher surface area electrodes and thinner dielectrics to achieve greater capacitances. This allows for energy densities greater than those of conventional capacitors and power densities greater than those of batteries. As a result, super capacitor s may become an attractive power solution for an increasing number of applications. This brief overview focuses on the different types of super capacitor s, the relevant quantitative modelling areas, and the future of super capacitor research and development.

IndexTerms – Capacitor, Etc.

I. INTRODUCTION

In response to the changing global landscape, energy has become a primary focus of the major world powers and scientific community. There has been great interest in developing and refining more efficient energy storage devices [1]. With the growing demand of energy efficient systems, the requirement for better electrical storage substitute is increasing. One such device, the supercapacitor, has matured significantly over the last decade and emerged with the potential to facilitate major advances in energy storage. It has one specific property that makes it an interesting component in some applications, which is its high power density that enables it to handle fast fluctuations in energy level. When comparing supercapacitors with batteries the main difference is in energy and power density. Supercapacitors have a significantly lower energy density than the batteries but on the other hand they have a higher power density compared with batteries [2]. Conventional capacitor has low energy and power density than supercapacitor but supercapacitor has higher power density and lower energy density than battery,sosupercapacitor holds properties of both conventional capacitor and battery.

II. FUNDAMENTALS OF SUPERCAPACITORS

Supercapacitor is energy storage device consisting of three main components- Electrode, Electrolyte and Separator . The capacitance of supercapacitor depends mainly on the electrode and electrolyte material, therefore proper combination is necessary for obtaining the maximum capacitance.

III. LITERATURE REVIEW

B. Cultura II Electrical Engineering Department Mindanao University of Science and Technology Z. M. Salameh Department of Electrical and Computer Engineering University of Massachusetts Lowell -This paper presents the electrical and mathematical model of the supercapacitor. The equivalent mathematical model derived from electrical model was used to simulate the voltage response of the supercapacitor. The model has been implemented using Matlab software program. Simulation and experimental results of the voltage charging/discharging of the supercapacitor are compared. It was found out that the results obtained using the model is in good agreement with the experimental one. Moreover a mathematical model for the efficiency as a function of discharge time was developed and presented. The effect of charge/discharge rate on the supercapacitor's temperature is also experimentally considered. Experiments show that during charging the temperature rises more than during discharging(2).

M Jayalakshmi, K Balasubramanian-The renaissance of electrical/electrochemical double layer capacitors is occurring at a phenomenally high rate as the significant role of these power storage devices in traction, space flight technology, power electronics and other related fields is recognized. The needs of to-day's computer world cannot be fulfilled by the conventional capacitors such as electrostatic and electrolytic capacitors as their utility is limited to certain specific applications. Electric double layer capacitor (EDLC) uses carbon as the electrodes and stores charge in the electric field at the interface. (3).

P.B.Karandikar, Dr.D.B.Talange -Development of any new product involves many factors such as system design,development of prototype, material selection, and optimization of process. However manufacturing requirements are often neglected at the design and development stages which lead to failure in commercialization of the product. Hence, in this paper it has been decided to focus on some issues of supercapacitor in the presented paper .

IV. PROBLEM STATEMENT

After reviewing the literature a number of problems in design and fabrication of SC, such as – maintaining low ESR, varying the porosity to get more capacitance, varying the composition of the electrolyte etc., were studied.
Therefore the problem 1statement converged to "Modeling and Simulation of SC comprising of Diffused Capacitance with Low Internal Resistance", considering prototype/model fabrication, testing through statistical method and available measuring instruments to develop the relationship with reference to physical and electrical parameters of SC.

3.1 Supercapacitor and Its Fundamentals

Supercapacitor fundamentals The basics of a supercapacitor are no different from those found in a conventional capacitor. An electrical field develops between two electrically charged electrodes. One electrode is positively charged, the other is negatively charged. The potential difference V is directly proportional to the distance between the plates d and to the strength of the electric field E, through the relationship: V = E d. The ratio of charge Q to the potential difference defines the capacitance of the capacitor. Thus

$$C= \frac{Q}{V} \quad \cdots\cdots 3.1$$

Differentiating this equation with respect to time and reformulating gives

$$\frac{dv(t)}{dt} = \frac{1}{C}\frac{dQ}{dt} = \frac{1}{C}I \cdots\cdots 3.2$$

From above equation, provided a constant current, the voltage will rise linearly with a slope equal to the inverse of the capacitance from equation 3.2.

There will be a maximum voltage limit for a capacitor defined by the so called breakdown voltage. In conventional capacitor, dielectric material has higher value of breakdown voltage while in SC, electrolyte has lower value of breakdown voltage. Hence voltage rating of supercapacitor is less (2-2.7V).

The potential energy stored in the electric field is given by

$$w = \frac{1}{2}CV^2 \cdots\cdots 3.3$$

When the capacitor is discharged, the voltage drops from the initial voltage V1 to the voltage V2, and in the process it releases some of the stored potential energy according to:

$$\Delta W = \frac{1}{2}C(V2 - V1)^2 \cdots\cdots 3.4$$

The state of charge of the supercapacitor, (SoCSC), is defined as the ratio between the remaining energy and the maximum stored energy of the supercapacitor. The state of charge expressed in terms of terminal voltage becomes:

$$SOCsc = \frac{W}{Wmax} = \frac{V1^2}{V2^2} \cdots\cdots 3.5$$

where V is the terminal voltage of the supercapacitor and Vmax is equivalent to the rated voltage of the supercapacitor.

For supercapacitors it is common to specify its effective power density. The volumetric density is power per volume and the gravimetric density is power per mass. The peak gravimetric power density is defined as the instantaneous power delivered at full rated voltage Vr with an internal resistance, ESR, specified at 1 kHz frequency.

$$Pmax = \frac{Vr^2}{4ESR}[\frac{W}{Kg}] \cdots\cdots 3.6$$

The capacitance varies directly with the area A of the parallel plates and inversely with the distance between the plates through the relation.

$$C = \frac{\epsilon o \epsilon r A}{d}[F]\ldots\ldots\ldots 3.7$$

Where ϵo is the permittivity constant of vacuum and ϵr is the relative dielectric constant of an eventual insulating dielectric between the plates. A is area of electrode and d is thickness of ion-charge layer at electrode-electrolyte surface.

3.2 Supercapacitor Physics And Design

From eq(3.7), we can say that the capacitance can be increased by maximizing the effective area and reducing the effective electrode separation. Supercapacitors achieve their high capacitance values in order of thousands of Farads by using sophisticated porous electrode materials with large effective surface area instead of homogeneous conductor plates, and an electrolyte with mobile ions instead of a dielectric.

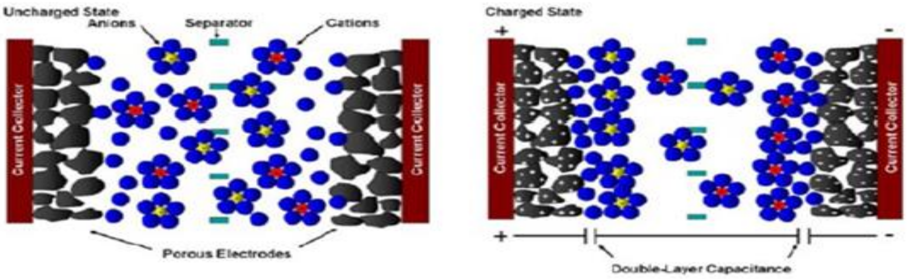

Fig 3.1 Super Capacitor Structure

V. MATERIAL CHARACTERIZATION

Electrode and electrolyte are the main two components of the supercapacitor. Performance of supercapacitor is decided by characteristics of electrode and electrolyte materials .This chapter deals with various aspects of electrode and electrolyte materials used for manufacturing of supercapacitor.

Electrode material

Selection of electrode material plays crucial role in determining electrical properties of supercapacitor. Carbon is most widely used for electrode material. But research is being conducted into metal oxides and conducting polymer.

Electrolyte

In case of electrochemical capacitor of double layer type, the behavior of dielectric of capacitor has special significance since it is the solvent of electrolyte provides shell of ions in medium. Double layer at an electrode-solution interface consists of one real, electromagnetically conducting plate (semiconductor, metal oxide or activated carbon) and a second plate that is the inner inter-facial limit of conducting electrolyte solution phase.The double layer distribution of compact layer having dimensions of about 0.5 to 0.6 nm corresponding to the dimensions of solvent molecules and ions that occupy it and a wider region of thermally distrthis very small thickness of the compact molecular inner layer, very large specific capacitance of 20 to 40 _farad=cm2 can be obtained. The choice of electrolyte in supercapacitor is as important as the choice of electrode material.

Separator

The separator prevents the occurrence of electrical contact between two electrodes but it is ion-permeable, allowing ionic charge transfer to take place. Polymer or paper separators can be used with organic electrolytes and ceramic or glass fiber separators are often used with aqueous electrolytes. For best supercapacitor performance, the separator should have high electrical resistance, a high ionic conductance and low thickness. Terminal and container are made up of acid resistance material and can be same as used in lead acid batteries. The different types of separators commercially available are given in Table along with their properties.

VI. MAIN CHARACTERISTICS OF SUPERCAPACITOR

In order to use supercapacitor, it is important to know the device behavior. Important characteristics of supercapacitor are as follows:
1. Very high capacitance
2. High power and moderate energy density
3. Very fast charging and discharging
4. Linear charging and discharging (up to 0 Volts)
5. State of charge present is a direct function of output voltage
6. Very high shelf and working life more than (10 Years)
7. Direct short circuit is not final
8. It is non-explosive
9. Small over charging is not a problem for this device
10. Available up to few thousands of Farad e.g. 600F, 56V
11. Series current limiting resistor is not required, as it charges as much as, they are given.

DRAWBACKS

1. Each capacitor can give 1V to 2.5V (Limit due to electrolyte stability)
2. High cost
3. Very last discharging
4. Low energy density
5. Peak power is limited by internal resistance
6. Time constant is small(1 -2 sec only)
7. Rapid discharge at severe rate increases temperature.
8. Complete discharge takes few hours
9. Operating temp is up to 65 degree Celsius
10. It loses 2% energy per day in self discharge.

PRECAUTIONS TO BE TAKEN WHILE USING SUPERCAPACITOR

1. Do not exceed maximum voltage rating of capacitor
2. Contact with any adjacent metallic device can short the capacitor
3. Capacitor has no polarity
4. Do not keep capacitor near heat emitting device
5. Do not open the capacitor.

IV. CONCLUSION

In this report the basics of supercapacitor modeling were studied in details which forms the basis for the procedure to be followed during prototype development. Along with this a brief overview of supercapacitor’s analysis, application and drawbacks were reviewed. Modeling in the scope of work will include only activated carbon modeling and supercapacitor as device modeling.

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