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Modeling and Simulation of Super Capacitor for Application in Consumer Electronics

***Naheed Hossain*[1]*, Ferdous S. Azad*[2]*, Syed Raihan Hossain*[3]**
Faculty members
Department of Electrical and Electronic Engineering
Sonargaon University, Dhaka, Bangladesh
***Corresponding Authors' email id**: naheedalif@gmail.com*

Abstract

Power exhaustion is one of the biggest problems faced by consumer electronics users. Energy storage should be more and more sustainable. The energy-saving option of a consumer device is accepted and welcome, but modern facilities in consumer electronics need more power. Super-capacitor can help manufacturers to allow their devices to reserve more power. Super-capacitor has high surface electrodes with extremely large capacitance. It can deposit energy in the electric field of the electrochemical double layer.

Keywords: *Power-storage, super capacitor, Consumer electronics, long-lasting power supply*

INTRODUCTION

The supercapacitor, also known as a double layer electrochemical capacitor, is a storage device that has a very high power density compared to the conventional battery and is capable of storing a large amount of electrical energy in short periods. The main advantages of a super-capacitor are the ability to store electrical energy in a short time and to generate a very high current in real time. The charging phase of the super capacitor is very fast. The charge flow stored in the super-capacitor depends on the mobility of the ions and the orientation of the dipole which takes a long time. This results in a self-discharge process during a long resting phase [1].The supercapacitor consists of porous electrodes with an electrolyte in the middle. The porous structure of the electrodes provides more space for the fusion and absorption of the charged ions, which gives the supercapacitor a great capacity to store electrical energy in short times [2]. The positive and negative ionic charges within the electrolyte accumulate on the surface of the solid electrode and compensate for the electronic charge on the surface of the electrode. The thickness of the double layer depends on the concentration of the electrolyte and the size of the ions, and is of the order of 5-10 A, for concentrated electrolytes [3]. As batteries have a higher energy density than the supercapacitor, the combination of hybrid battery and supercapacitor provides great power and prolongs the life of the battery, which saves maintenance costs and ensures a very stable power quality [4 -5]. The supercapacitor operates in a very wide temperature range of -40-85 ° C, compared to that of batteries between 0 and 40 ° C [6].Supercapacitors can not only be discharged in seconds, but also be loaded in such a short time. This is an important advantage for the energy recovery system. Another great advantage of supercapacitors is their lifespan. These devices can withstand millions of cycles through their charge storage mechanism, which does not involve irreversible chemical reactions, storing charges physically on the surface of the electrodes in a double electric layer. This makes it possible to exceed the life of the batteries, which are at best able to withstand a few thousand cycles [7].This is the reason why the super capacitor can be installed in closed compartments of consumer devices such as mobile phones.

CLASSIFICATION

Supercapacitors can be classified into different types. In the case of dual layer electrode materials, the supercapacitors may be classified as an activated carbon electrode, a carbon nanotube electrode or a graphene electrode supercapacitor. However, metal oxides or conductive polymer electrodes may constitute pseudo-capacitors. Researchers are also working on hybrid supercapacitors.

ARCHITECTURE

A supercapacitor cell comprises two electrodes with a separator between. The electrodes may be identical for symmetrical cells or different for asymmetric cells. The separator is soaked in the electrolyte and prevents electrical contact between the electrodes. The separator material must be ion-permeable to allow ionic charge transfer, while simultaneously having high electrical resistance, high ion conductance, and low thickness to achieve the best performance. Typically, polymer or paper separators are used with organic electrolytes, while ceramic or fiberglass separators are usually coupled to aqueous electrolytes [8-15]. The potential for breakdown of the electrolyte at one of the electrodes limits the achievable cell voltage, while the equivalent series resistance (ESR) of the cell is highly dependent on the conductivity of the electrolyte[7]. Aqueous electrolytes generally have a breakdown voltage of about 1 V, which is significantly lower than that of organic electrolytes (about 3 V), but the conductivity of aqueous electrolytes is higher than that of organic electrolytes, which is desirable. Aqueous electrolytes also have important advantages such as reduced cost and ease of handling [16-17].

BACKGROUND PHYSICS

Physical calculation for super capacitor is quite different from general capacitor. For general capacitor the capacitance, C, will depend on the dielectric constant of the electrolyte,ε_r, the effective thickness of the double layer, d (separation between charges), and the accessible surface, A, as follows:

$$C = \frac{\varepsilon_o \ \varepsilon_r \ A}{d}$$

Where ε_o is the dielectric constant of the vacuum.

On the other hand, for supercapacitor there have been numerous attempts to properly describe the capacitance of carbon materials depending on the pore shape and size and the specific character of their interaction with electrolytes. For mesoporous carbons with cylindrical pores, the traditional model is used [18]

$$\frac{C}{A} = \frac{\varepsilon_o \ \varepsilon_r}{b \ln(\frac{b}{b-d})}$$

Where, b is the pore radius and d is the distance between the ion and the carbon surface. But for micropores, it is assumed that the ions line up in the center of a cylindrical pore, so the capacitance is calculated from [18]

$$\frac{C}{A} = \frac{\varepsilon_o \ \varepsilon_r}{b \ln(\frac{b}{a_o})}$$

Where a_o is the effective size of the ion. This ionic radius was found to be close to the bare ion size, which means that the ions could be fully desolated.

However, as the more realistic approximation to the pore shape in carbons is a slit, not a cylinder, a sandwich capacitance model was later proposed [19]

$$\frac{C}{A} = \frac{\varepsilon_o\ \varepsilon_r}{b - a_o}$$

Where, b is the pore radius and a_o is the effective size of the ion.

EQUIVALENT CIRCUIT

The simple equivalent circuit of a super can be represents by an R-C circuit. Here the value and combination of these Resistors and capacitors can be established a circuit as a supercapacitor system. Figure 1 represents a possible equivalent circuit of a super capacitor.

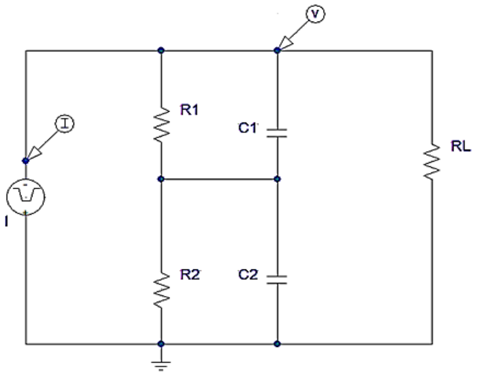

Fig.1:- possible equivalent circuit of a super capacitor

An impulse current source has been used for more than 1kiloseconds. Two R-C parallel combinations and leakage resistance helps to form a true mirror of a supercapacitor. Three-branch-model may assist to estimate the value of these electrical elements [1]. Table 1 states the value of these resistors, capacitors and current source for performed simulation.

Table1:- parameters of the electrical elements in the model

Electrical element	Parameter
Impulse Current source I	30A
Resistance ,R_1	1.0 Ω
Resistance ,R_2	5.0 Ω
Resistance ,$R_{Leakage}$	10.0 Ω
Capacitance, C_1	110 F
Capacitance, C_2	210F

RESULTS

During simulation there were no initial voltage and a 30A impulse current has been used to charge up the capacitor. Impulse current source serves for 30seconds and during this time capacitors raise its voltage up to 11volt and then starts to discharge. In the figure 2, the proposed super-capacitor model takes more than 1kiloseconds to decay under 1volt.The main difference between a capacitor and a supercapacitor is that super capacitor discharges slowly and charges like a normal capacitor.

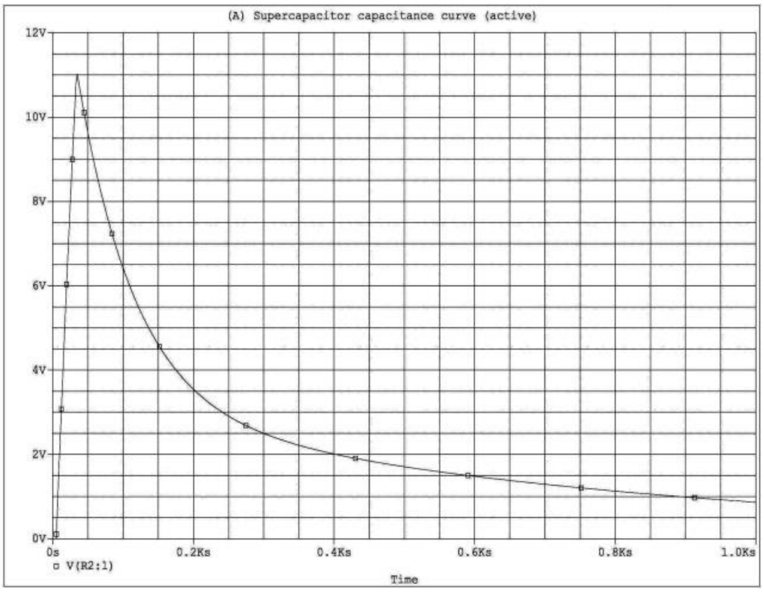

Fig.2:- discharging time of the proposedsuper capacitor model

CONCLUSION

The main disadvantage related to the charge storage mechanism is the operating voltage of a supercapacitor cell, which should be kept low in order to avoid the chemical decomposition of electrolytes [7]. Simulated results shows, when 30A impulse current source supply for 30seconds, the proposed supercapacitor model can work as a source of power even after 1kilosecond. However, at 1kilosecond the voltage of this proposed capacitor decays below 1volt, which is less than 10 percent of the peak charged voltage. Moreover, for consumer electronics needs a constant and higher power supply. The future work will be devoted to insure a steady voltage input for consumer electronics. Consistency and optimized voltage drop of a supercapacitor can solve the power storing crisis of daily necessary electronic appliances.

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