Study and Analysis of Supercapacitor with its Applications

Ms. Sujata Rawale [1], Prof. Chandan Kamble [2]

[1] PG Student, Electrical Department, TGPCET, Nagpur, Maharashtra, India
[2] Assistant Professor, Electrical Department, TGPCET, Nagpur, Maharashtra, India

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Abstract - *Supercapacitor is most promising energy storage device. Due to High power, high energy and long-term reliability feature of Supercapacitor, it can be use in various applications as backup power unit, auxiliary power unit, instantaneous power compensation, peak power compensation and energy storage as well. This paper presents the analysis and design of a supercapacitor and also examines the temperature effects on supercapacitors using a constant voltage source . Finally, simulation results are shown and analyzed.This paper presents an overview of supercapacitor showing their advantages as well as their potential applications.*

Key Words: Supercapacitors, energy storage, modelling, charging, discharging, temperature, voltage, current.

1. INTRODUCTION

Supercapacitor is a novel solution for energy storage because of its high power and energy density which is almost 10 to 20 times higher than conventional capacitor and batteries [1]. A recent development concern of global warming has led to push towards electricity generation from renewable energy sources. With renewable energy power generation which is an inconsistent generation led to a time gap between supply and demand [2]. Due to this there is an increase demand for energy storage. Among all the storage devices supercapacitors is relatively new energy storage system that provides higher energy density than dielectric capacitors and higher power density than batteries.

Supercapacitor is composed of two electrodes immersed in electrolyte, and its porous dielectric separator prevents short circuit of two electrodes. Supercapacitor is composed of two electrodes immersed in electrolyte, and its porous dielectric separator prevents short circuit of two electrodes.

By using battery as an energy storage medium, it will operate at severe conditions that are not designed for the system. In addition, a rapid discharge/charge profile reduces the battery lifetime and damages its performance. Inside batteries there are always chemical reactions taking place, but on the other hand due to the lack of chemical reaction inside supercapacitors releasing their stored energy can be done very quickly. It can also release a huge amount of power. Supercapacitors have their capability of being discharge and charge constantly without damaging their life time. It depends upon the load demand current or the source current [3]. The temperature variation can influence on the charge/discharge time.

The supercapacitor, who became a major asset in plenty of applications where energy storage is needed [4]. Supercapacitors, also known as ultracapacitors or electrochemical capacitors, are able to attain greater energy densities compared to conventional capacitors, while still maintaining their fundamental characteristic which is the high power density.

An supercapacitor cell construction consists of two electrodes, a separator, and an electrolyte as illustrated in Figure 1..

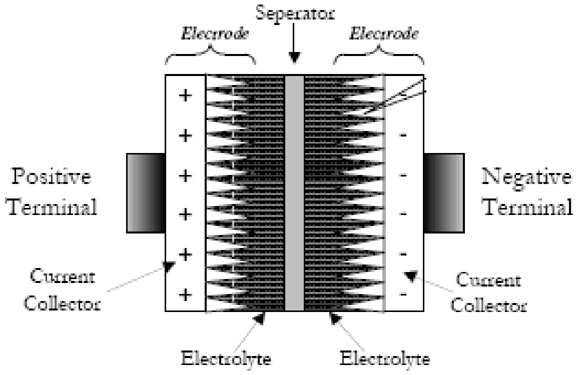

Figure 1 : Basic cell construction of an supercapacitor

2. APPLICATIONS OF SUPERCAPACITOR

Supercapacitors are suitable for applications that needs high peak power for an interval in the range of 10-2 s < t < 102 s because traditional capacitors and batteries have to be "oversized" to meet these "severe requirements" [5]. As discussed in the introduction, supercapacitor can be either used in standalone applications or can be connected to other energy storing devices or electrical sources. Several applications requires a hybrid configuration mainly between battery / supercapacitor, and fuel cell/supercapacitor. In these cases, the high power pulses are provided by the supercapacitor, while the large energy will be provided by the battery or fuel cell. It's an optimization strategy. Battery/supercapacitor hybrid systems are used as an alternative to conventional battery devices by the automotive manufacturers especially for electrical or hybrid vehicles due to possible "size reduction" and potential "enhancement in battery lifetime" [6]. Several studies have confirmed that combining supercapacitors with fuel cells systems can lead to an improved dynamic system response [7]. In order to improve their "efficiency and reliability", ultracapacitors are also being considered for use in renewable energy applications. Applications include, but not limited to low power applications like cameras, mobile phones, TV satellite receivers, rechargeable toys, and also, to UPS and cold start applications.

3. ADVANTAGES OF SUPERCAPACITORS

Supercapacitors can be used in any cycle depth without degrading the battery life [6]. Other advantages are given below:

3.1 Efficiency

Supercapacitors are highly efficient modules owed to the low Equivalent Series Resistance (ESR), even at very high currents; which means that only a little amount of energy is lost while charging and discharging the supercapacitor.

3.2 Current Capability

Supercapacitors, with their very low ESR are capable of delivering and absorbing high currents as quickly as the system will allow.

3.3 Life cycle

The energy storage process of a supercapacitor is nearly a fully reversible mechanism because it only moves charge and ions, then, no chemical reactions are taking place.

3.4 Voltage Range

In order to attain greater voltages, several cells are assembled in series, then, the system can operate at, or below, their total series maximum voltage.

3.5 Temperature Range

Since supercapacitors run without depending on chemical reactions, they can operate over a large range of temperatures. The maximum suitable temperature can reach up to 65°C without risk.

3.6 Maintenance

Supercapacitors do not require any important maintenance. They have no memory effects, cannot be over-discharged, hence if kept within their operating limits of voltage and temperature, no maintenance is requested.

4. MODELLING

The model which is used in this paper is a Dynamic Temperature Dependent supercapacitor Model shown in Figure 2.

C is the main capacitance, and C2, C3 are the two others. In general, C is the primary energy storage component, C2 and C3 model the dynamic behavior [7]. By altering the component values, their time constants change which affects how fast they charge and discharge. R1 represents the auto discharge effect, Rs is the series resistance causing losses during charge and discharge [8]. Before building the state space representation model of this physical system, two assumptions are considered:

- The total current $I_t(t)$ is supposed to be the control vector.
- The state vector is composed of the three currents I_1, I_2, I_3 passing through the resistances R_1, R_2 and R_3 respectively

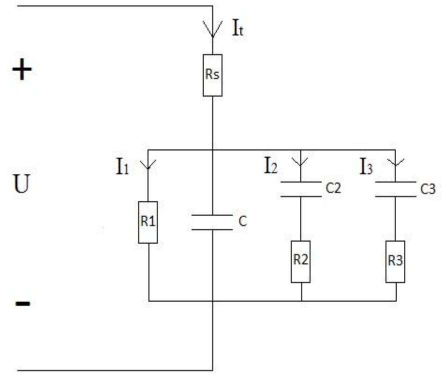

Figure 2 : Dynamic Temperature Dependent Supercapacitor Model.

5. SIMULATION RESULTS

Based on the state space representation, a single cell with a nominal voltage of 2.5V, is simulated in this Section. Thus, for a temperature range (35°C, 0,-45°C), the impact of the variation of the suggested constant charging currents versus time is illustrated in Figure 3 and Figure 4, and that of the discharging currents versus time is given in Figure 5 and Figure 6.

From Figure 3 and Figure 4, it is clear that the supercapacitor charges faster as the current source is even greater, and, it discharges more quickly as the current required by the load is greater as shown in Figure 5 and Figure 6.

Figure 3, 4, 5 and 6 shows the charge and discharge voltages for the different supercapacitors using a 10 A charging current at different temperatures (35°C, 0,-45°C). The different color in the graphs represents the different temperatures

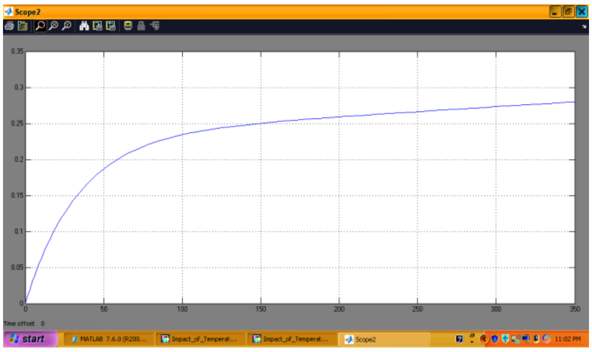

Figure 3: Supercapacitor charging curves for 10A input currents.

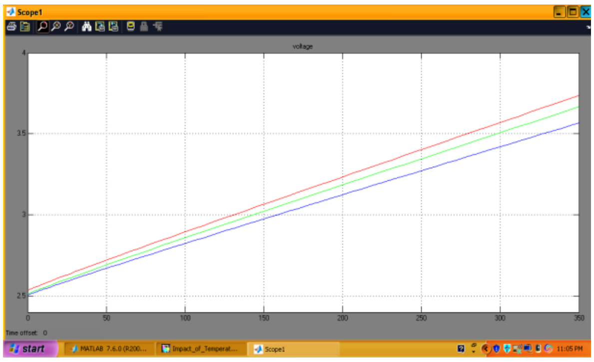

Figure 4: Supercapacitor charging curves at 10A at different temperature (35°C, 0,-45°C)

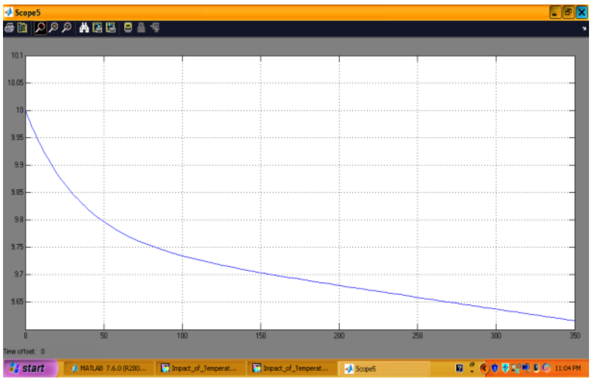

Figure 5: Supercapacitor discharging curves for 10A input currents

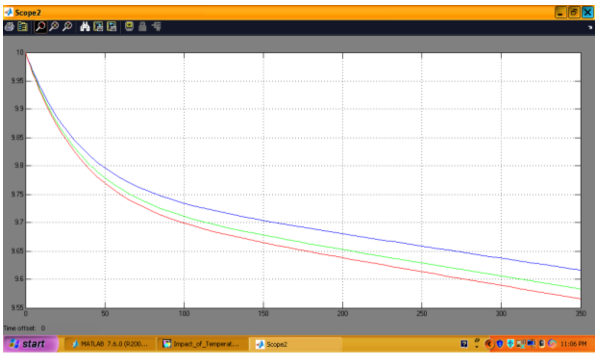

Figure 6: Supercapacitor discharging curves at 10A at different temperature (35°C, 0,-45°C)

Simulation results represent the behavior of the supercapacitor when the temperature varies for a constant charging or discharging current. Consequently, the supercapacitor charges quickly at low temperature and discharges very fast at also low temperature. Thus, due to its important time response in discharging, it is preferable to use supercapacitor in high temperature.

6. CONCLUSIONS

The input current has been varied while leaving the temperature constant. It is observed that the super capacitor charges faster as the current supplied while charging is greater.
The temperature was varied while keeping the current constant. It is advised to charge the super capacitor at the lowest possible temperature because it takes the shortest time to charge completely, It is more desirable to discharge it over the highest possible temperature, so it can last as long as possible before total discharge.

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