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# DESIGN OF SUPER CAPACITOR WITH TEMPERATURE EFFECTS USING A CONSTANT VOLTAGE SOURCE

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## *ABSTRACT:*

***Super capacitor have lower energy storage but higher power exchanging capability compared to batteries. This paper examines the temperature effects on an super capacitors using a constant voltage source. In new power application, it is very important to understand how super capacitor will perform in various temperatures and charging and discharging methods. By knowing the super capacitor behaviour, system can be optimized for efficiency and minimize internal circuit losses. The performance and lifetime of an ultra capacitor are temperature dependent. The objective of this paper is to develop necessary modelling and simulation tools for evaluating the temperature dependence of ESR in a constant voltage charge and discharge cycle.***

***Keywords –***

***super capacitors, accuracy, storage, efficiency, behaviour, equivalent series resistance, modelling, simulation, temperature, current variation.***

## 1. INTRODUCTION :

Recent concerns of global warming, has led to an international push toward electricity generation from renewable energy sources. In fact, the increasing partition of renewable energy power generation which is an inconsistent generation, have led to a time gap between supply and demand. As result, it appears an increase demand for energy storage.

An super capacitor cell construction consists of two electrodes, a separator, and an electrolyte as illustrated in Figure 1. The electrodes consist of two parts, a metallic current collector and a high surface area active material. A membrane called the ‘separator’ separate the two electrodes [1]. The separator permits the mobility of charged ions but prohibits electronic conduction. This composite is subsequently rolled or folded into a cylindrical or rectangular form and stacked in a container. Then the system is impregnated with an electrolyte, which is either a solid state, organic or aqueous type. The decomposition voltage of the electrolyte determines the maximum operating voltage of an super capacitor [2]. Owing to the very small separation distance between the electrolytes, as well as the large effective surface of the active material, large capacitance magnitudes in terms of Farads are obtainable.

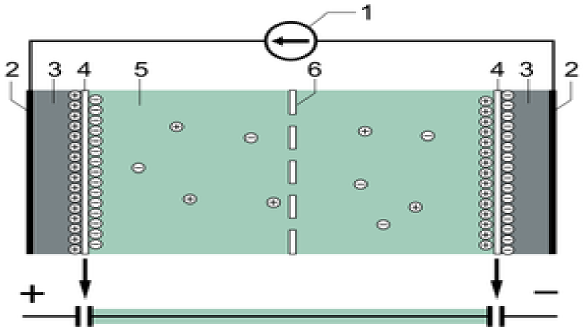

**Figure 1:** Typical construction of a super capacitor

1) Power source, 2) Collector, 3) Polarized electrode, 4) Helmholtz double layer, 5) Electrolyte having positive and negative ions, 6) Separator.

(Source: http://en.wikipedia.org/wiki/Super capacitor)

Electrochemical capacitors (super capacitors) consist of two electrodes separated by an ion-permeable membrane (separator), and an electrolyte ionically connecting both electrodes. When the electrodes are polarized by an applied voltage, ions in the electrolyte form electric double layers of opposite polarity to the electrode's polarity. For example, positively polarized electrodes will have a layer of negative ions at the electrode/electrolyte interface along with a charge-balancing layer of positive ions adsorbing onto the negative layer [3]. The opposite is true for the negatively polarized electrode.

## 2.SUPER CAPACITOR CIRCUIT

There are several propositions of super capacitor model representation. The simplest of all is the classical equivalent circuit with the lumped capacitance, equivalent parallel resistance (EPR) and equivalent series resistance (ESR). Figure 2 shows the classical equivalent circuit with the three parameters. The EPR represents the current leakage and influences the long-term energy storage [4].

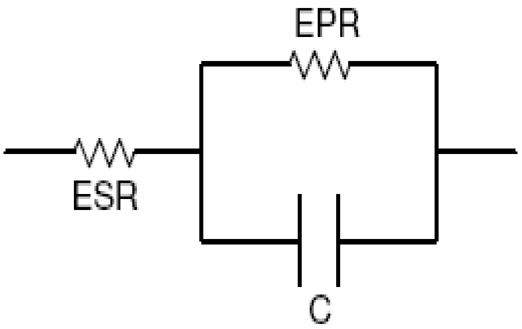

**Figure 2: Classical equivalent circuit of an super capacitor**

### 2.1 Super capacitor power & energy

Sizing of an super capacitor system requires the specification of the power and energy requirements. For a fixed super capacitor bank, these quantities dictate the number of super capacitor needed but do not represent the same constraints.

### 2.2 Super capacitor in series

Developments in super capacitor design and fabrication have led to the achievement of high specific energy density and high power density devices with capacitance values in the magnitude of several hundred Farads having equivalent series resistance (ESR) of less than 1 milliohm (DC measurements). With reference to the series connection of n number of super capacitor as shown in Figure 3.

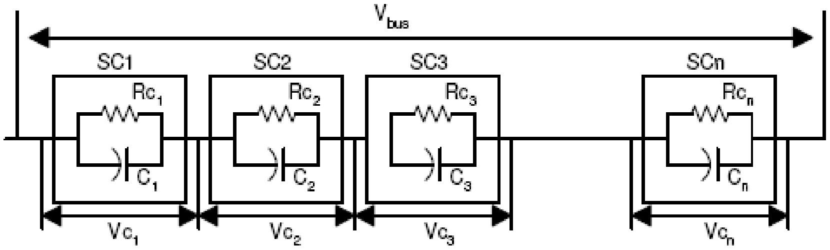

**Figure 3: Super capacitor cells in series**

## 3. ADVANTAGES OF SUPER CAPACITORS

Until now batteries are still more cheaper than super capacitors which are preferred in different applications requiring energy to be charged and discharges in "bursts repeatedly". Super capacitors can be used in any cycle depth without degrading the battery life, for example in a UPS system where they may only be discharged a few times a year, or they might be very often cycled, as in a hybrid vehicle. Other advantages include the:

### *3.1 Efficiency*

Super capacitors 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 super capacitor [5]. This result is translated also by less heating, thus potentially less overhead for cooling the energy storage device.

### *3.2 Current Capability*

In general, super capacitors, with their very low ESR are capable of delivering and absorbing high currents as quickly as the system will allow. Still all this process can be done while the super capacitors can self-limit their charging rate .

### *3.3 Life cycle*

The energy storage process of a super capacitor is nearly a fully reversible mechanism because it only moves charge and ions, then, no chemical reactions are taking place. Thus, it is capable of achieving a million cycles with minimal change in performance.

### *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. There is no hazard regarding the over-discharging of super capacitors [6]. Actually, there is additional safety feature for personals allowing them to fully discharge any super capacitor system before repairing any system problems.

### *3.5 Temperature Range*

Since super capacitors run without depending on chemical reactions, they can operate over a large array of temperatures. The maximum suitable temperature can reach up to 65°C without risk. In opposite at the colder side, they can still deliver power to a temperature limit (with slightly increased resistive losses) as cold as -40°C.

### *3.6 Maintenance*

Super capacitors 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 super capacitor Model shown in Figure 4.

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. 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.

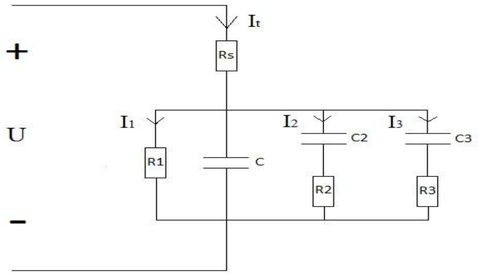

**Figure 4.** Dynamic Temperature Dependent Super capacitor Model

Based on its state space representation, the super capacitor model is implemented on Matlab/Simulink as shown in Figure 5.

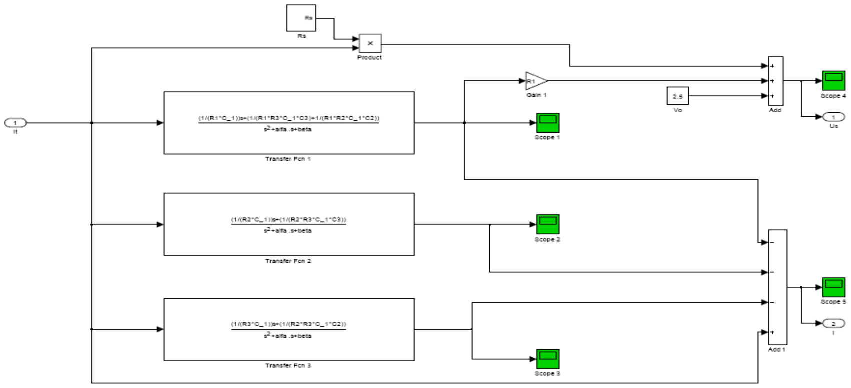

**Figure 5.** Representation of a super capacitor in Matlab/Simulink

## 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 6 and Figure 7, and that of the discharging currents versus time is given in Figure 8 and Figure 9. From Figure 6 and Figure 7, it is clear that the super capacitor 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 Fig 8 and Fig 9.

Figure 6, 7, 8 and 9 shows the charge and discharge voltages for the different super capacitors using a 10 A charging current at different temperatures (35°C, 0,-45°C).

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

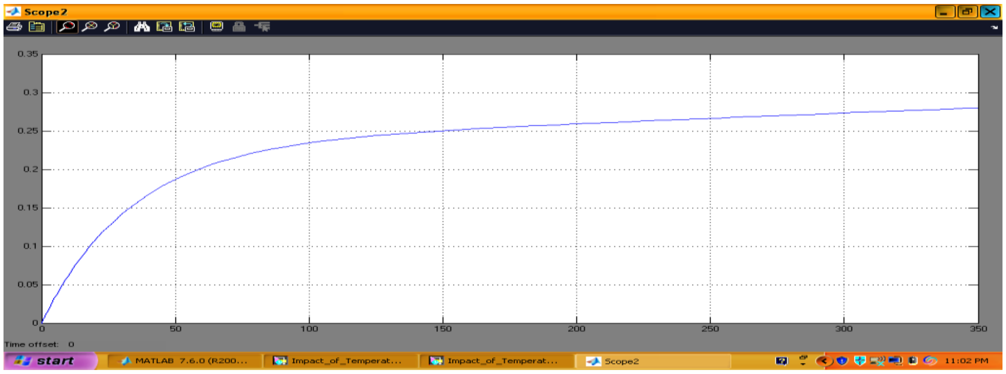

**Figure 6.** Super capacitor charging curves for 10A input currents.

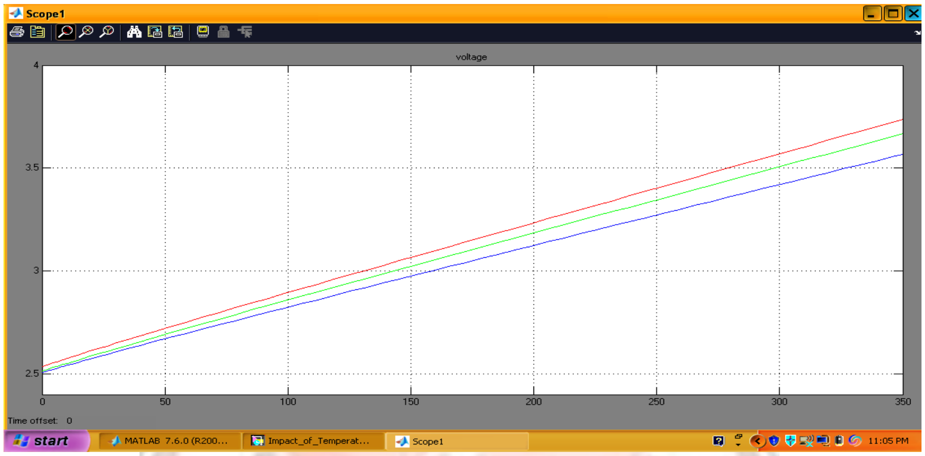

**Figure 7.** Super capacitor charging curves at 10A at different temperature (35°C, 0,-45°C)

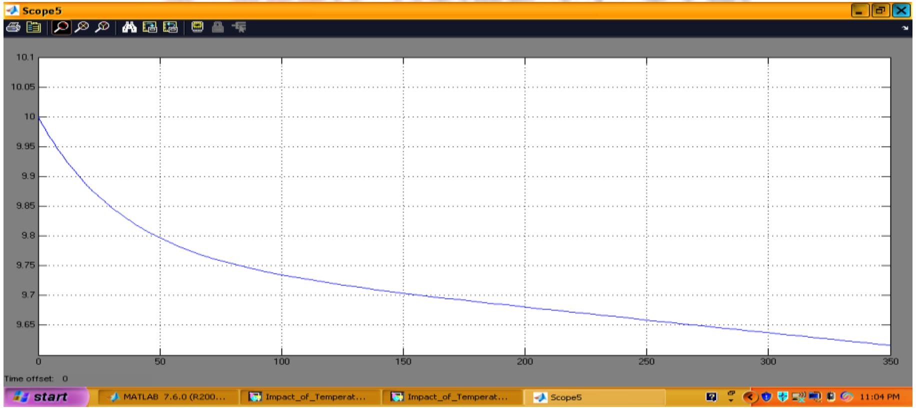

**Figure 8:** Super capacitor discharging curves for 10A input currents.

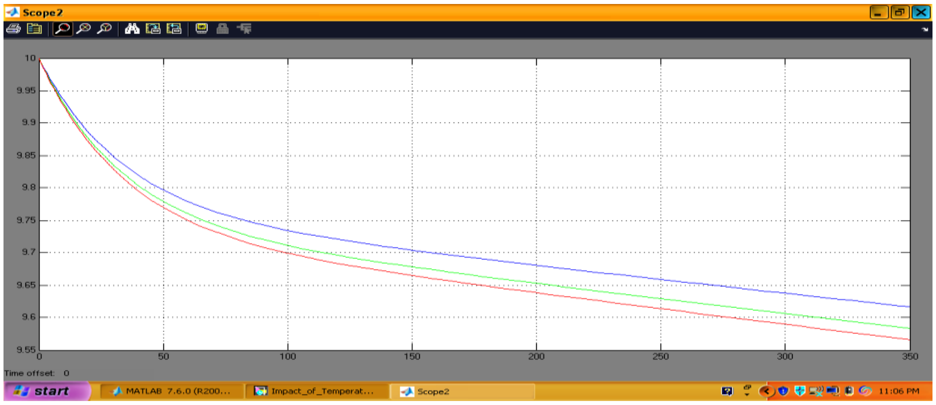

**Figure 9:** Super capacitor discharging curves at 10A at different temperature (35°C, 0,-45°C)

## 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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