ON THE USE OF SUPER CAPACITORS FOR ELECTRIC MOTORS POWER SUPPLY

Constantin Daniel OANCEA*, Sabin CODREA, Adrian-Mihai ALEXEI**, Marin DUMITRU**, Daniel ŞUTEU****

*Politehnica University, Bucharest, Romania (oancea@ieee.org)
**Military Equipment and Technologies Research Agency, Romania (codrea_d@yahoo.com)

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Abstract: *Finding more efficient solutions for storing electricity is an objective of present research. The sources for powering the electric motors are characterized by the need to provide from time to time high peaks of power. Thus, the power supply is overloaded, with implications for its lifetime and performances. The solution analyzed in this article for power supply is to use super-capacitors instead of chemical batteries especially for high power density demands . The experiments are done with current components on the market. Super-capacitor technology is under development, it is not excluded that in the future it will become a viable alternative to the power supply along with classical chemical batteries.*

Keywords: *super-capacitor, UAV, propulsion, battery*

1. INTRODUCTION

Current trends in the field of electrical mobility, whether on land, on air, or on naval (especially for drones) - are close related to the storage capacity of batteries even as a systemic - integrative approach. The hybrid car or drone can be considered in the full-electric approach of the on board power storage and management capability. The technological development of the last decades has generated new opportunities in terms of the possibility of extending the energy of the batteries. These include photovoltaic cells and super-capacitors.

The super capacitor (also called, ultra-capacitor or double layer capacitor) is an electric capacitor type with much greater capacity than a conventional electrical capacitor. This double layer configuration creates the ability to store a higher amount of electro-static energy, more than conventional capacitors. This seems to be the best concept to replace the classical batteries, including lithium-ion or lithium-polymer based, as there are no chemical reactions, the charge-discharge time is very short, and the efficiency is close to 100%. The charge-discharge cycles of this device can reach up to 1 million, which allows the use of it for decades. Additionally, another advantage of the super-capacitor is that it does not destroy if the discharge is complete. For now, the only restriction that is required is that the nominal voltage on the element is not exceeded. It is usually 2.7 V and is due to the technology to achieve them, [1].

The super capacitor differs fundamentally in its internal structure from a normal capacitor. Instead of having two electrodes separated by an insulating layer, an ultra-capacitor uses a porous medium that produces the effect of a pair of gigantic surface plates separated by only a few nanometers gap.

As a result, the ultra-capacitor has a much higher capacity than any conventional high-capacity component (such as an electrolytic capacitor). The main constituent element is carbon (in the graphite structure), [1].

2. TECHNICAL DESCRIPTIONS

Super capacitors store electrical energy by physically separating positive and negative charges, different from classic batteries that make this chemically. The electric charge they have is much higher due to the extremely large surface of the interior materials, [2].

An advantage of the super capacitor is the very high charging and discharging speed; it is determined exclusively by physical properties. A classic battery is based on a slower chemical reaction to store and release energy, [2].

The super capacitor is unbeatable at the power density (W/kg) compared to the batteries, but the energy density is, commercially, still behind the batteries, but increasing.

A super capacitor can be seen as a device consisting of two non-reactive plates or collectors suspended inside an electrolyte with a voltage potential applied over the collectors. In an individual super capacitor cell, the potential applied to the positive electrode attracts negative ions from the electrolyte, while the potential on the negative electrode attracts positive ions, [2]. A dielectric separator between the two electrodes prevents discharge between the two electrodes, Fig. 1.

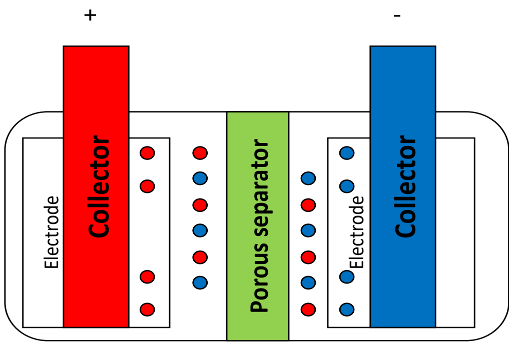

FIG. 1. The internal structure of a super capacitor

Power storage devices, such as capacitors, store electrical charge on an electrode. Other devices, such as electrochemical cells or batteries, use the electrode to create an electrical charge on the electrodes through the chemical reaction. In both cases, the ability to store or create electrical charge is a function of the surface of the electrode. For example, in capacitors, a larger surface of the electrode surface increases the storage capacity of the energy.

As a storage device, the super-capacitor is based on the microscopic separation of the electric charge. Because the capacity of these devices is proportional to the active surface of the electrode, increasing the surface of the electrode will increase the capacity, thus increasing the amount of energy that can be stored. This large surface design uses materials such as activated carbon or sintered metal powders.

However, in both situations, there is an intrinsic limit to the porosity of these materials, that is, there is an upper limit of the amount of surface that can be achieved simply by making particles smaller and smaller. An alternative method should be developed to increase the active surface of the electrode without increasing the size of the device, [2].

3. SPECIFIC ISSUES

One of the disadvantages of super-capacitors is the very low voltage at which they work (2.7V).

To remedy this situation, several such super-capacitors can be connected in series. It is obvious that if there are small differences between the values of the super-capacitors connected in series, this will be reflected on the voltage distribution at their terminals, Fig 2. To estimate the voltage difference at the capacitor terminals, let us suppose we have three super-capacitor connected in series. The individual nominal value is 400F with a working voltage of 2.7V. Suppose real values are: C1 = 390F, C2 = 400F and C3 = 410F. Supply voltage U = 7.5V. Relationships (1) - (6) describe the calculation of the voltage distribution. Cs represents the equivalent capacity of the series and Q is the electrical charge accumulated on the armatures.

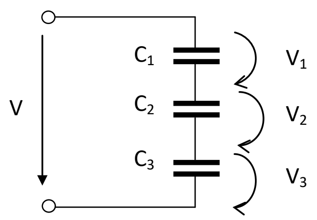

FIG. 2. Distribution of voltage in a series group

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \tag{1}$$

$$C_s = 133.27\ [F] \tag{2}$$

$$\mathrm{Q} = \mathrm{C_s} \cdot \mathrm{V} = 133.27 \cdot 7.5 = 999.58\ [C] \tag{3}$$

$$V_1 = \frac{Q}{C_1} = \frac{999.58}{390} = 2.56\ [V] \tag{4}$$

$$V_2 = \frac{Q}{C_2} = \frac{999.58}{400} = 2.49\ [V] \tag{5}$$

$$V_3 = \frac{Q}{C_3} = \frac{999.58}{410} = 2.43\ [V] \tag{6}$$

Thus, a variation in the capacity of 2.5% of the nominal value, will be reflected as a variation of 2.8% of the voltage at the terminals. There are several voltage equalization methods, from passive balancing networks with resistive dividers to active circuits, with integrated devices that act at 2.7V at the super-capacitor terminals.

Another problem is measuring the actual value of the super-capacitor. The easiest method is to measure the charging time with a constant current between two preset voltage limits followed by a simple calculation according to the formula (7).

$$C = \frac{Q}{\Delta V} = \frac{I \cdot \Delta t}{\Delta V} \tag{7}$$

4. TESTING THE POWER SUPPLY PERFORMANCE OF SUPER-CAPACITOR BATTERIES

For the experimental setup Fig. 3 two super-capacitors batteries were set. Their parameters are summarized in Table 2. The first battery consists of 10 super capacitor Heter 400F each.

Their bonding is mixed to achieve required voltage (~ 13V) but also a higher capacity. The second battery consists of 6 super-capacitor GreenCap connected in series but equipped with protection/balancing circuits for individual voltage limit.

Table 2. Super-cap battery parameters used

Super-cap battery type	Rated voltage [V]	Rated capacity [F]	Measured capacity [F]	Notes
Heter (2x400/5 [F])	2.7x5 = 13,5 [V]	160	~133	It has no surge protection circuit
GreenCap (1x500/6 [F])	2.7x6 = 16,2 [V]	83.3	~120	It has surge protection circuit on each element

As external load, an scale-model wood propeller driven by an out-runner brushless motor has been used. The two blade propeller has 12 x 8 inch characteristics. Tests have been carried out for an absorbed current of about 1 A. The engine speed-controller has been designed for electrochemical accumulators (Li-Po or Ni-MH). Therefore, it stops the motor supply when the voltage at the input terminals drops below a certain voltage threshold in order to avoid deep discharge phenomena.

FIG. 3. Super Capacitor Batteries (Heter, left, Umax = 13.5 V; GreenCap, right, Umax = 16.2 V)

In the present case, the threshold was somewhere between 8 and 10 volts. Figures 4 and 5 shows the evolution of the current and the voltage at the terminals of the super-capacitor battery until the power supply was automatically cut-off.

Figure 5 shows the start-up time of the engine (the characteristic suddenly starts at the beginning) and the final moment when the speed-controller disconnects the motor. The voltage value increases slightly due to the phenomenon of voltage return as a result of dielectric absorption.

Data was collected through a National Instruments, USB 6008 acquisition board, the application being developed in LabVIEW, Fig. 6.

A calibration phase was required before experiments started. This procedure is required because voltage and current are not harvested directly. The voltage, since it exceeds 10 V (maximum limit for the input data acquisition card), was taken over by a resistive divider. For voltage there was no need to correct the offset, except find the calibration constant for voltage.

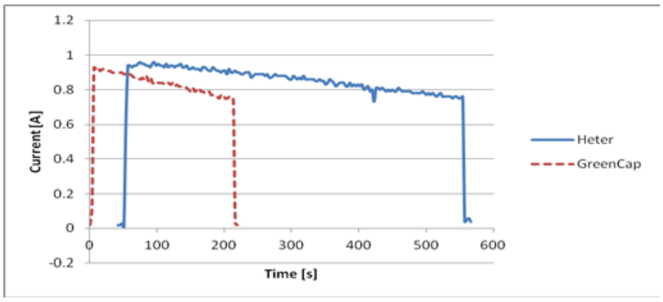

FIG. 4. Evolution of current absorbed from super capacitor batteries

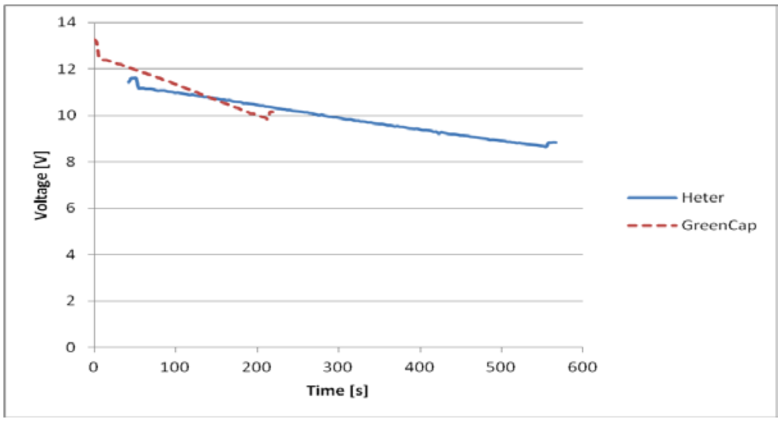

FIG. 5. Voltage evolution at super-capacitor battery terminals

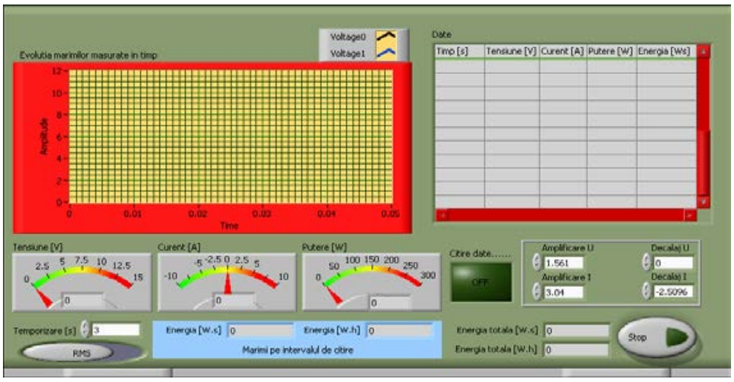

FIG. 6. Front panel of the data acquisition application

A LEM LTS 6-NP type transducer, was used for the current harvest. It supplies at 2.5V output for a null current. Thus, in order to obtain the real value of the current, an offset correction was needed, and then the result was multiplied by a calibration constant. Primary quantities are the voltage of the super-capacitor battery and the current transferred by it. The calculated quantities are power and energy consumed.

CONCLUSIONS

The use of super-capacitors as power supply, has gone from simple back-up applications for safety devices to primary storage means, used to replace electrochemical battery. Already there are vehicles, which by their nature have an intermittent operating mode, which can be loaded after a few minutes of operation (urban transport).

Charging can be done for any super capacitor batteries used in these experiments from any power source or voltage, and the charging time depends only on the charging source parameters.

Super capacitors used in experiments are currently commercialized, with no special preference (preferably from the same manufacturing batch). A source with a current limit of ~ 29A was also used in the experiments, and the super-capacitors charged without problems in less than a minute. The only precaution is related to not exceeding the maximum allowable voltage on the super capacitor. Any overshoot leads to rapid heating, followed by damage of the super-capacitor. It has also been observed during the experiments that the speed-controller for the brushless motor is also sensitive to the variation in voltage from (voltage gradient) charged from the super-capacitor battery terminals.

If the power of the super-capacitor battery is higher and the discharge slower, it can go below 9 V. When voltage decreased quickly (high gradient), the speed-controller protection engaged at 10V.

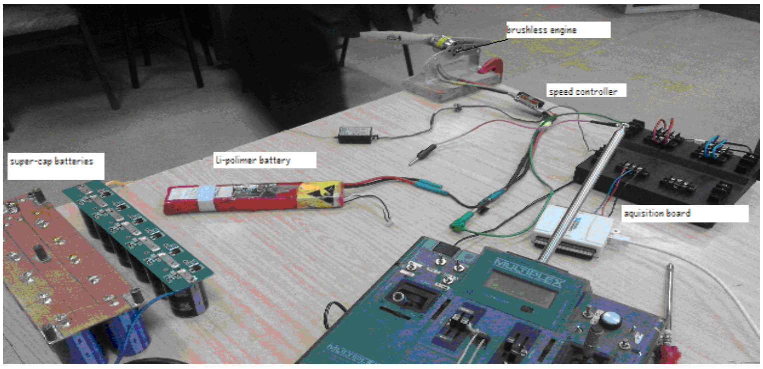

FIG. 7. Experimental setup

Experiments have demonstrated the feasibility of using super-capacitor batteries for situations where it is necessary to provide a high power in a relatively short time. Hybrid power solutions (electrochemical battery + super-capacitor battery) can be imagined to dedicated applications. One of them could be the power supply for electric driven fixed wing UAV’s with classical flight pattern – in which the supper-capacitor battery is used on first stage of ascension, while the chemical battery could be used for cruise at lower currents characteristics for optimum use.

In order to be able to use a reasonable time, it is necessary for the variable power supply to be designed so that it can supply the constant demand parameters (voltage, current) even if the voltage supplied by the super-capacitor battery has an important variation. One solution would be to use a buck-boost converter. In the future, larger capacities will be developed, preliminary tests indicating the possibility of supplying over 40 amperes to the electric propulsion of an electric fixed-wing UAV.

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