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SUPERCAPACITORS, A BATTERY REPLACEMENT

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Abstract: *Finding alternatives to current energy storage solutions is related to weight reduction, increase the lifetime of the devices and reduce environmental impact. Supercapacitor can be an alternative but must take in consideration some aspects. For example, even if, there are no problem with current limiting to charge or discharge (it is a perfect solution for high power transfer in a small time interval), must stabilize the output voltage.*

Keywords: *supercapacitor, buck-boost converter, charge and discharge.*

1. INTRODUCTION

In clasical energy storage systems, usually are used battery (lead-acid, Li-ion, Ni.Cd, etc.). There are some disadvantages of using this type of battery: adverse impact on the environment, short life service (1000-1500 charge and discharge), weight, need to maintain the level of charge (if discharge below a certain limit is possible to deteriorate). Figure 1 present an example of using battery in a photovoltaic (PV) panels system (Oancea, Naumof, Nedelcu, Ciulinaru, 2009:485-489).

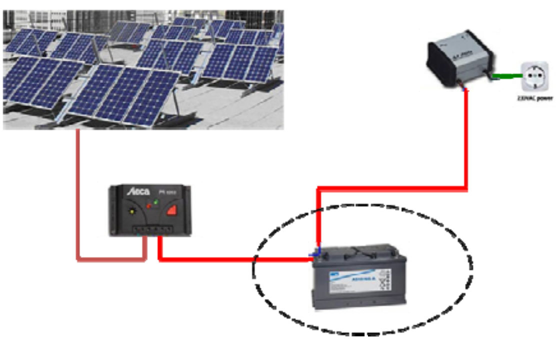

Fig. 1. Placement of battery in a PV system

One solution is to use *supercapacitors* with alternative names: pseudocapacitors, electrochemical double layer capacitors (EDLCs electrochemical double-layer capacitors) or ultracapacitor.

Instead two electrodes separated by a substance like conventional dielectric capacitors have, these capacitors use electrodes which are two layers of the same substrate and their electrical property called electric double layer leads to effective separation of duties in spite of nanoscale separation between layers. The very small distance between layers and the presence of a electrochemical double-layer allows the electrodes to have a much larger area, resulting in large capacities. The main component is carbon.

This work follows an assessment of how to replace of existing storage systems with *supercapacitor* systems, which have primarily benefit a longer use of a higher discharge power.

Because of very large capacity, will develop a method for measuring it. It is important to be able to know capacity precisely because of energy storage, depending of it. Another problem is to analyse how to get a constant voltage from a significant variable voltage across the *supercapacitor*. Applications that can use *supercapacitors*, apart of photovoltaic systems are: aerospace (supply emergency equipment), transport (directly or hybrid; Capa Vehicle, diesel-electric systems, fast braking energy storage), applications in which a rapid charge and discharge energy, defense industry.

2. SUPERCAPACITOR

For *supercapacitors*, current energy density is about 30 W·h/kg and recent research provides a 60 W·h/kg shortly. Other sources provide a perspective of energy density about 400 W·h/kg.

For comparison, conventional lead-acid batteries typically store 30 to 40 W·h/kg and lithium-ion about 160 W·h/kg.

The main advantages of *supercapacitor* are: long life (more than 300000 charging and discharging, but the *supercapacitor* can aging by environmental conditions), good reversibility, high rates of discharge / charge, very low internal resistance, high efficiency (more 90%), high power output, it is safe, possibility of use in remote locations (no maintenance), simple loading methods, maintenance free operation. The discharge curve is a disadvantage (gradient is, initially, to high).

The *supercapacitor* voltage is confined to 2.5–2.7V. Voltages of 2.8V and higher are possible but they would reduce the service life.

Fig. 1. Example of supercapacitor battery (2x400/5F, 13.5V)

To achieve higher voltages, several *supercapacitors* are connected in series. This has disadvantages. Serial connection reduces the total capacitance, and strings of more than three *supercapacitors* require, theoretically, voltage balancing to prevent any cell from going into over-voltage. In practice, it was found that the difference between the capacitor voltages is less than 0.1V if the *supercapacitors* are from the same batch.

2.1 Principle of measurement. Block diagram of measurement system is presented in figure 2 (Oancea, Florescu, 2011:661-665). Central proccessing unit can be a computer system with multifunction board or a micontroller based system. The second option can increase the portability of equipment.

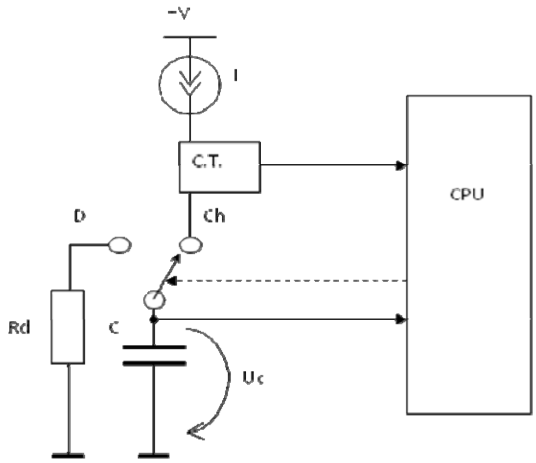

Fig. 2. Principle of operation

Main components are constant current supply (I) and command unit (which switch from charge to discharge the *supercapacitor*. To discharge was choose a simple resistor because the measurement is effective only on charging phase.

This schematic generates *supercapacitor* charge and discharge stages like in figure 3.

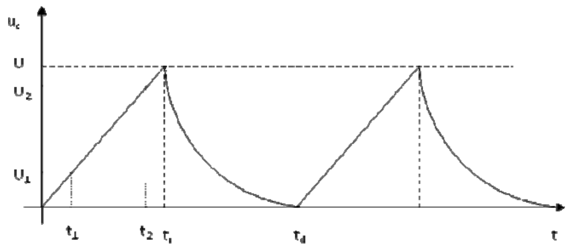

Fig. 3. Variation of supercapacitor voltage

$$C = \frac{\Delta Q}{\Delta U} = \frac{I \cdot \Delta t}{\Delta U} \qquad (1)$$

Figure 4 is presented principle design of constant current source. The final schematics is more complex, to achieve better performances (Oancea, Oancea, 2002:32). Relation 2 and 3 present estimation of schematics parameters.

$$R_2 = \frac{R_1 \cdot I_1}{I_2} = \frac{R_1}{I_2} \cdot \frac{Vcc - V_{BE} - V_{CEsat}}{R_1 + R_3} \qquad (2)$$

$$I_2 = \frac{R_1}{R_2} \cdot \frac{Vcc - V_{BE} - V_{CEsat}}{R_1 + R_3} \qquad (3)$$

The schematic has disadvantages of high power dissipation per transistor and using PNP type bipolar power transistors. The solution is to use an NPN bipolar transistor scheme, cascodă assembly (increase stability).

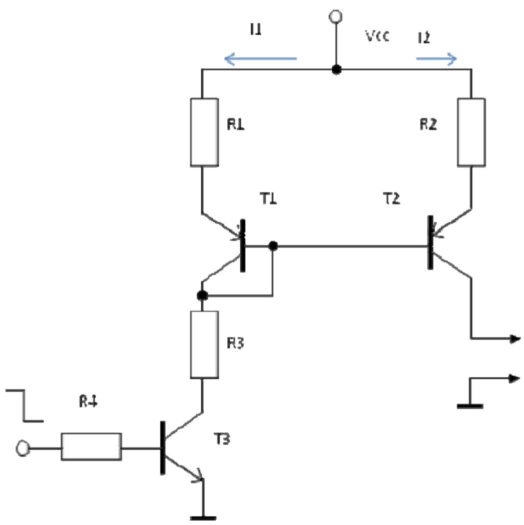

Fig. 4. Example of constant current supply

Example of quantities in this schematic are:

If we have Vcc = 12V, V_{BE} = 0.7V, V_{CEsat} = 0.2V, R1 = 270 ohms R3 = 430 ohms. Intermediar quantitie is I_1 = 0.0158 A = 15.8 mA. If impose I_2 = 1 A => R2 = 4.28 ohms.

The power dissipated in resistor $P_{R2}=R_2 \cdot I_2^2=4.28$ W. Maximum power dissipation per transistor P_{T2} has aproximately 7.72 W. The value of curents are not critical, important is to be steady in time (it is measured by a transducer). Figure 5 is the aspect of constant current supply.

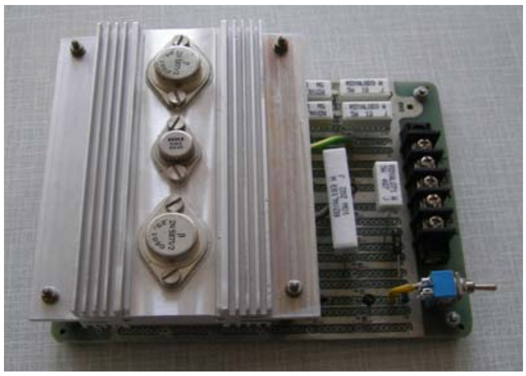

Fig. 5. Aspect of constant current supply module

To have a convenable way to use this principle of operation was develop software which works in conjunction with this hardware and an USB multifunction interface (Oancea, Oancea, 2002:61). The front panel of application is in figure 6.

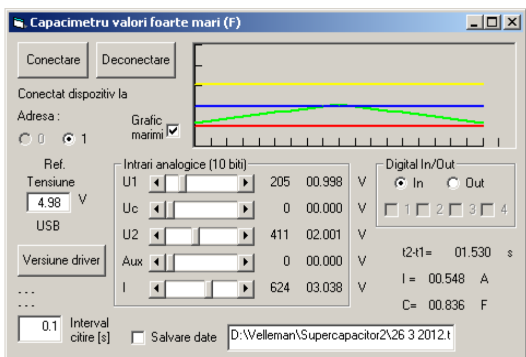

Fig. 6. Front panel of application

On front panel are displayed measured quantities and time evolution of them.

2.2 Constant output voltage. Need to provide a constant voltage and the fact that the supercapacitor voltage has important variation (Fig. 7), it is neccessary to use of a buck-boost type converter, Cúk or SEPIC (Single-Ended Primary-Inductor Converter). Choosing this type of converter, according with the operating principle, can provide an output voltage higher or lower than the input, have not restricted only achieve high efficiencies. In this case the interest is to obtain a constant output voltage when input voltage varies in large limits. When is necessary to have a constant output voltage, it is mandatory to have *supercapacitor* battery coupled with such a converter. Thus the solution chosen is to use the integrated converter with input voltage range as high is possible. An example which was study is MC 34063 (Nomad, 2001).

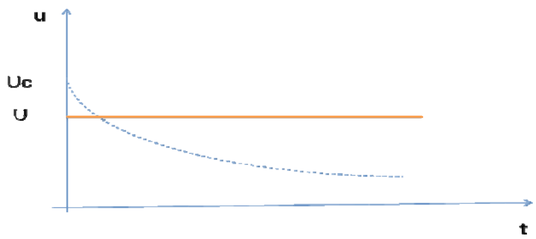

Fig. 7. Variation of output voltage of supercapacitor

One of were studied schematics is present in figure 8, and computed parameters are presented in table 1.

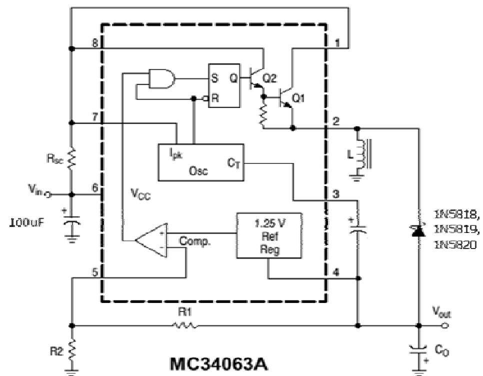

Fig. 8. Designing schematics of buck-boost converter

The values are for input voltage limits. To extend output capabilities it is possible to use a power transistor.

Table 1. Example of parameters computed

Vin=+5V, Vout=-12V	Vin=+14V, Vout=-12V
Ipk=2050 mA	Ipk=977 mA
Lmin=10 µH	Lmin=43 µH
R1=1.5k;R2=13k (12.08V)	R1=1.5k;R2=13k (12.08V)
Ct=202 pF	Ct=130 pF
Rsc=0.146 Ohm	Rsc=0.307 Ohm
Co=1134 µF	Co=732 µF

3. CONCLUSIONS & ACKNOWLEDGMENT

The *supercapacitor* can be an alternative to storage energy. Even its can be used in renewable energy systems or in automotive applications, *supercapacitors* are future competitors of classic battery. At the time of writing this paper, is not a problem to buy supercapacitors of 3000 F or more. The energy storage in *supercapacitor* is huge and is the best solution when is neccessary to transfer large energy in a short time.

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