Theory of Electrical Engineering Education Upgrade: Supercapacitors

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Abstract **This paper deals with the innovation of the electrical engineering education at our department supported by the grant project FRVŠ 378/2011/F1a. It presents our novel approach to implement the modern technology of supercapacitors into power engineering education and describes our new lessons and laboratory experiments dealing with supercapacitors.**

Keywords **Electrical engineering education innovation, Supercapacitors**

I. INTRODUCTION

One of the primary targets of the long-time strategic goals of our university is the modernization of electrical engineering education with the respect to modern trends and technologies used in countries with high-tech industrial level. Our project meets this requirement in the way of supercapacitors and their applications implementation into the power engineering education. Not enough attention is currently paid to this modern technology of capacitors with extremely high capacitance at our university. This project is financed with the help of grant project FRVŠ n. 378/2011.

II. SUPERCAPACITORS – NEW CIRCUIT ELEMENT

Technical advance in the field of nanotechnology allows the production of extremely high capacity condensers (hundreds of Farrad). Supercapacitors (also called ultracapacitors, supercondensers, electric double-layer capacitors and electrochemical double-layer capacitors) are capacitors with very large capacities. They are devices able to store the electrical field energy in their electrochemical double-layer. Positive and negative ionic charges within the electrolyte accumulate at the surface of the solid electrode and compensate for the electronic charge at the electrode surface. Electrodes are made of porous material. The size of these pores is in nanometers. This gives these devices extremely high surface and with it an extremely high capacity of stored charge[3].

Due to physical properties of used double-layer and electrolyte, the operational voltage of one such a layer is around 1,3V. Supercapacitor cells are manufactured as a serious connection of two of these devices, thus their operational voltage is around 2,6V, but serial connection of two capacitors halves resulting capacity. Operating on higher values of voltage damages the devices lowering its capacity. Intense research is being made to improve existing or find new materials to increase the range of accessible operational voltages.

In order to obtain higher values of operational voltages, supercapacitors are being serial connected into supercapacitor batteries. The voltage distribution balancing is crucial in the connections, if a part is exposed to a voltage level higher than its operation voltage, it can be damaged. An active balancing using comparators is used most often, but passive balancing with resistors is also possible for connections of fewer parts.

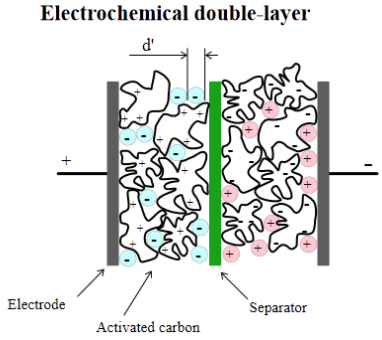

Fig. 1. Electrochemical double-layer of a supercapacitor[4]

Supercapacitors charging and discharging is very fast because of extremely low serial resistance, supercapacitors have high specific power (around 6kW/kg) and long life, their producers present thousands and even millions of charge cycles with very little degradation of internal capacity. They are able to provide high powers very shortly and their charging is really simple, no full-charge detection device is needed[4].

Despite mentioned advantages, supercapacitors have several disadvantages as well. Energy stored per unit weight is lower than of electrochemical battery and their voltage varies with the amount of energy stored just as for classical capacitors. Their self-discharge is high, as already mentioned, their cell voltage is low and their otherwise positive small serial resistance makes them dangerous to the user because of the ability to quickly discharge high powers.

Fig. 2. An example of several types of MAXWELL supercapacitors our department posses

III. SUPERCAPACITORS APPLICATIONS

The most common use of supercapacitors is as a power supply for the recuperation of heavy and public transport vehicles. Another use in automotive technology is as a power supply for hybrid or pure electromobiles or use as motor start-up capacitors, they are able to work even at temperatures around -40^0C. In consumer electronics, supercapacitors are nowadays more and more frequently being used instead of classical batteries due to their ability to fast charge and discharge. In power engineering, a supercapacitor is used as a compensation device in wind power plants in order to get better quality of produced power. Development of multiple supercapacitors applications is expected in the future [3].

IV. OUR SUPERCAPACITORS LESSONS

Supercapacitors lesson were implemented into Electrodynamics for Power Engineering subject, this subject is meant for students of first year of magister programme, these students already posses adequate knowledge needed for successful understanding taught lessons. Average number of students participating on this subject is around 50 per year.

Two main approaches are pursued: first of them is the theoretical explanation of the problem based on physical principle explanation, it´s practical meaning and existing solutions, followed by developing relevant theory, it´s application to a calculation algorithm and building a mathematical model. Illustrative examples of supercapacitors applications are presented for making the understanding of taught lessons easier. Computers and software being at disposal at our department are used for these demonstrations.

Second approach is the experimental or demonstration lessons taught in laboratories during seminars. For this reason, several MAXWELL company Boostcap supercapacitors and measuring devices were purchased. We prepared a set of experimental lessons, namely these:

- Supercapacitors static and dynamic characteristics measurement, charging and discharging of supercapacitors, self-discharging

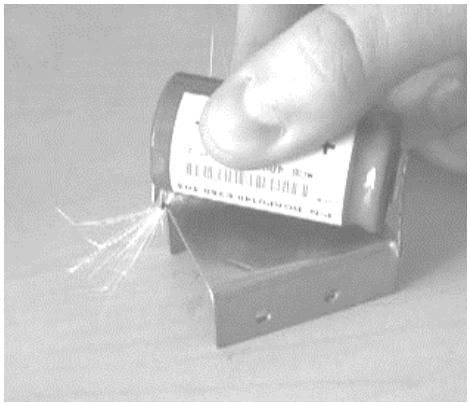

Fig. 3. An arc resulting from 140F supercapacitor shorting

- Electromechanical systems with supercapacitor recuperation (behaviour of a vehicle with economically advantageous supercapacitors recuperation)
- Replacement of conventional energy sources and batteries with supercapacitors, supercapacitors as pulse power sources, supercapacitors using device operation economics

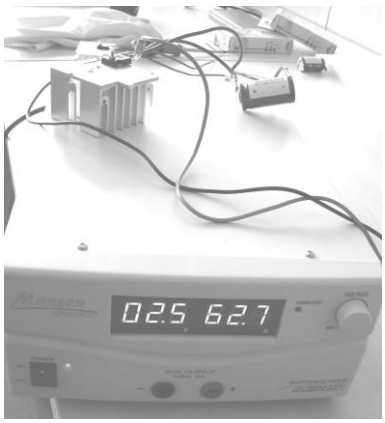

Fig. 4. Supercapacitor charging with the use of a large current source

Materials with instructions to these practical lessons are currently at disposal for the students on our department´s web pages, after acquiring more experience they will be published and opened for the public.

Two bachelor theses dealing with supercapacitors were finished with the help of this project and successfully defended at our department, more bachelor thesis themes are being prepared.

V. CONCLUSION

The modern technology of supercapacitors was implemented into electrodynamics lessons taught at our university with the help of grant project FRVŠ 378/2011/F1a. Study texts and a set of unique experimental and demonstration lessons were prepared and are at disposal not only for inner use, but for our faculty and technical teachings in general propagation. This project is a significant innovation and modernization of existing didactic themes, it´s contribution to the qualification improvement of our graduates is not questionable.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

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