METHODS OF VOLTAGE BALANCING OF SUPERCAPACITORS AND ITS QUALITY CONTROL BY THERMAL IMAGING FOR USE IN POWER ELECTRONICS

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Supercapacitors are increasingly used in power systems, primarily to improve the quality of delivered electricity, but also for better drive functionality. With the development of the technique for balancing the voltages of serially connected supercapacitors, a great improvement of the HVDC transmission system is expected. The great advantage of supercapacitors in power systems is their high-power density, so they can cover large consumption peaks. The basic supercapacitor cells are designed for low operating voltage, so it is necessary to connect a large number of units in series, which leads to voltage balancing problems. This paper provides an overview of balancing methods and presents the possibility of applying thermovision to check the quality of balancing.

Keywords: supercapacitors, IR thermography, voltage balancing, power electronics application.

Introduction

Due to their exceptional properties, supercapacitors have great potential for use in the power electronic industry. In order to ensure a higher operating voltage, reliability and life of these capacitors, voltage balancing circuits are used on series-connected cells. The high operating voltage and high-power density of supercapacitors allows improving the quality of supplied electricity, primarily covering short-term voltage drops during consumption peaks [1—6]. Most European countries have accepted the CENELEC EN 50160 standard [2] for voltage monitoring at the supply point under normal conditions.

As an example, Fig. 1 shows the configuration of the electroenergy system, the parameters of which were improved by using supercapacitors. Accumulated energy is injected from the supercapacitor battery through the DC-DC converter of the 6-pulse inverter into the AC network in case of a disturbance [3].

In this paper, various methods of balancing are presented [7], as well as the possibility of applying thermal imaging to monitor the quality of voltage balancing.

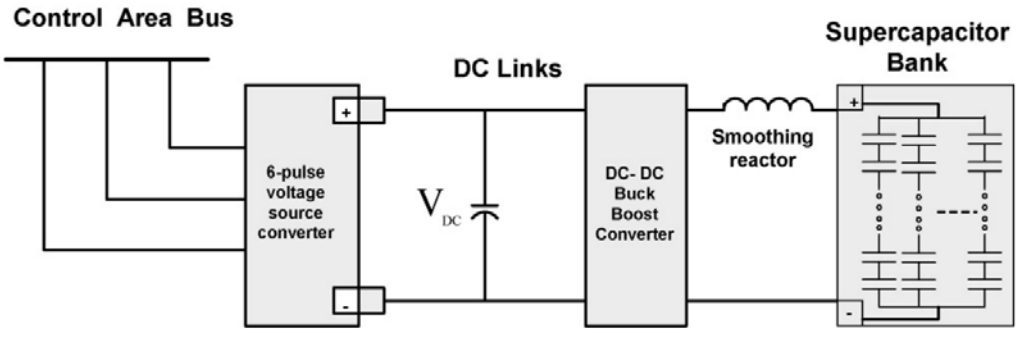

Fig. 1. EES configuration with supercapacitor battery [3]

Voltage balancing methods

Since the tolerance of the supercapacitor parameters is usually 20%, the voltage distribution on the supercapacitors in series connections will not be uniform. The voltage on some supercapacitors can exceed the nominal voltage. In order to prevent it and to equalize voltages, various balancing techniques have been used. Those techniques are divided into two groups: active and passive. Active methods have advantages over passive methods, but they require additional electronic systems (Fig. 2). On the other hand, passive methods are very simple and, despite their shortcomings, are still very often used.

Passive methods are more often applied due to their simplicity and lower price, but active (more expensive) solutions are still used for crucial circuits and higher powers. Larger initial investments pay off quickly through longer supercapacitor life and higher system reliability. The lifetime of the supercapacitor is mostly influenced by the operating voltage and temperature (Fig. 3).

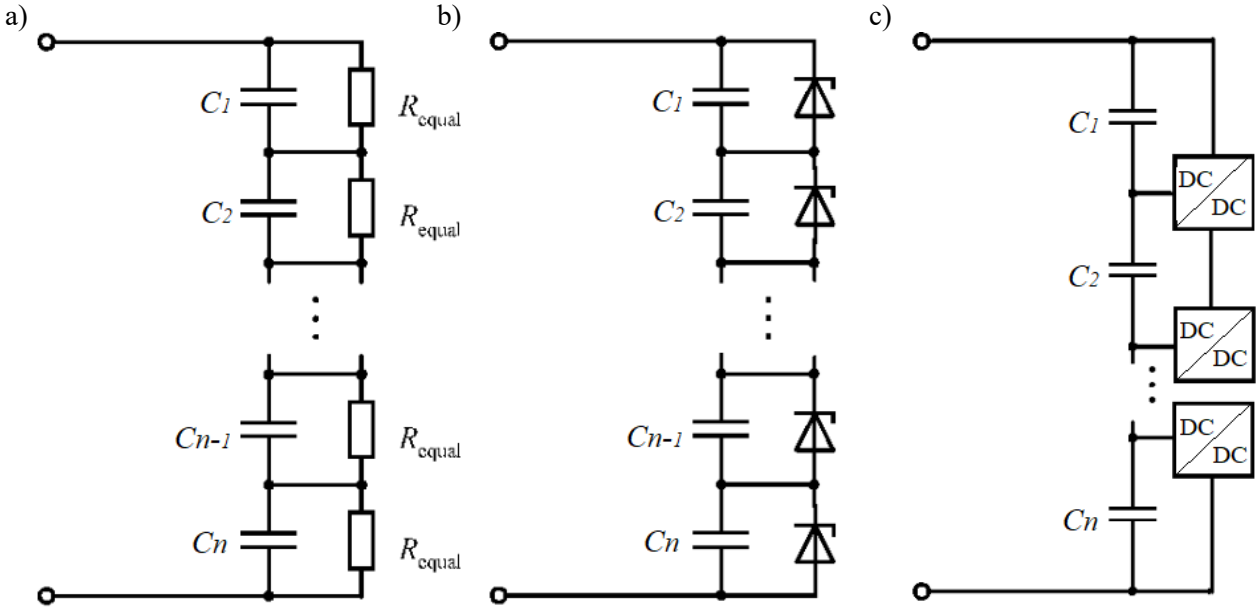

Fig. 2. Voltage balancing [7, 8]:

a — passive with resistors; *b* — passive with zener diodes; *c* — active

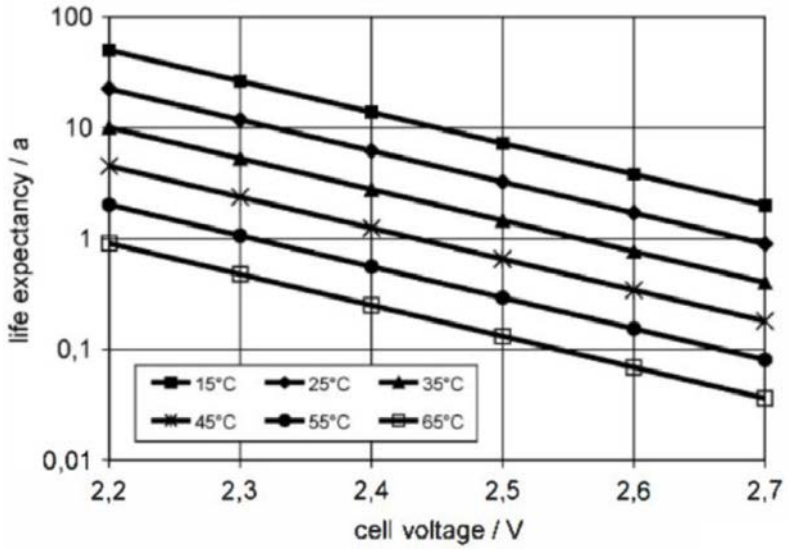

Fig. 3. Life expectancy of a supercapacitor cell under different temperatures and operating voltages [8]

Application of thermography to assess the quality of voltage balancing

In the case of insufficiently adequate voltage balancing, there may be an increased voltage (above the nominal) on some capacitors, which furthermore leads to increased heating and damage. A simple and nowadays affordable way to detect such anomalies is thermography. Today's IR cameras detect differences in temperature below 0.1°C, which is enough to detect even the lowest imbalance.

Experimental validation

A supercapacitor battery with 120 series-connected cells 20 F, 2.75 V has been designed for use in the power electronics industry. It was designed for DC voltage up to 330 V, and the equivalent capacitance is 0.167F. The voltage balancing is passive, and its effectiveness was tested by thermal imaging (Fig. 4). Thermographic recordings were made with an IR camera FLIR E6, and post-analysis has been done using the FLIR TOOLS+ program [9, 10]. It can be seen that at point Sp1 the heating is significantly increased (58.4°C), as well as the increased voltage at that exact capacitor (2.84V). Therefore, the passive voltage balancing should be improved by reducing the resistance of the parallel resistors. Regarding the situation with the more reliable and high-quality batteries, it is certainly better to apply one of the active voltage balancing methods, but thermography still remains a proven method to check balancing quality.

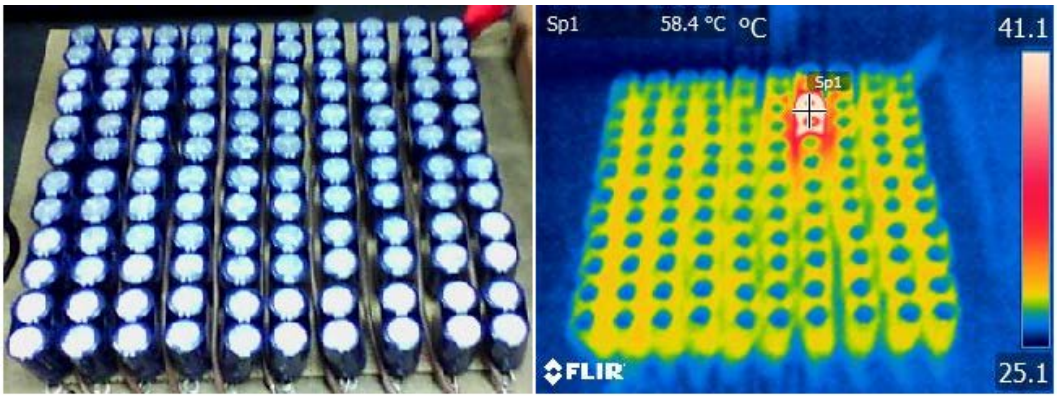

Fig. 4. Photograph and thermogram of the tested serial supercapacitor battery

Conclusion

The paper described different methods for balancing the voltages in a supercapacitor battery and proposed thermal imaging as a method of checking the balancing quality. The method has been validated on an experimental battery, which enables practical application and further research in this area. Further research would focus on the applications of this methods in both on-grid and off-grid smart environments.

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Тепловізійний моніторинг якості балансування напруг суперконденсаторів для застосування в силовій електроніці

Суперконденсатори все частіше використовуються в енергетичних системах, насамперед для покращення якості електроенергії, що постачається, а також для поліпшення функціональності приводу. З розвитком техніки балансування напруги послідовно з'єднаних суперконденсаторів виникає необхідність значного вдосконалення системи передачі HVDC. Великою перевагою суперконденсаторів в енергосистемах є їхня висока питома потужність, тому вони можуть покривати значні піки споживання. Оскільки базові комірки суперконденсатора розраховані на низьку робочу напругу, необхідно з'єднувати велику кількість блоків послідовно, що призводить до проблем балансування напруги. У цій роботі наведено огляд методів балансування та запропоновано використовувати тепловізор для перевірки якості балансування. Метод перевірено на експериментальній батареї, що дозволяє практичне застосування та подальші дослідження в цій галузі.

Ключові слова: суперконденсатори, ІЧ-термографія, балансування напруги, застосування силової електроніки.
