CDA-CAP
No. 4, Jifeng Road, Wufeng District, Taichung City, Taiwan
Tel: +00852-51245060 E-mail: zfw@cda-cap.tw
www.cda-cap.com

SuperCapacitors Lifespan Estimation

1. Factors Affecting the Lifetime of Supercapacitors

1.1 Electrode Materials for Supercapacitors
1.2 Electrolyte
1.3 Temperature
1.4 Operating Voltage
1.5 Charge/Discharge Rate

2. Estimation Model for Supercapacitor Lifetime

In the field of energy storage, supercapacitors have gained considerable attention due to their high power density and rapid charging capabilities. However, their lifespan is a critical factor influencing their widespread application. This paper introduces a supercapacitor lifetime estimation model, elucidating its principles and applications.

The proposed supercapacitor lifetime estimation model is based on experimental data and mathematical modeling. Initially, a series of experiments were conducted, including charge/discharge tests at different rates, temperatures, and cycle numbers. Subsequently, the experimental data underwent analysis and processing, extracting key parameters to establish the supercapacitor lifetime estimation model.

- **This model considers the following factors:**

2.1 Charge/Discharge Rate: The rate at which a supercapacitor is charged and discharged significantly affects its lifespan. Experimental results indicate that a faster charge/discharge rate corresponds to a shorter supercapacitor lifespan. This is attributed to the accelerated diffusion of electrolyte ions and increased decomposition of electrolyte and electrode active substances at higher charge/discharge rates.

2.2 Temperature: Temperature also plays a crucial role in the lifespan of supercapacitors. Experimental results demonstrate that higher temperatures lead to shorter supercapacitor lifespans. This is due to the increased speed of electrolyte decomposition and exacerbated loss of electrode active substances at elevated temperatures.

2.3 Cycle Number: The cycle number is a key indicator of supercapacitor lifespan. Experimental results reveal that as the cycle number increases, the lifespan of supercapacitors gradually shortens. This is because, during the cycling process, continuous diffusion and embedding of electrolyte ions occur, resulting in increased electrolyte decomposition and loss of electrode active substances.

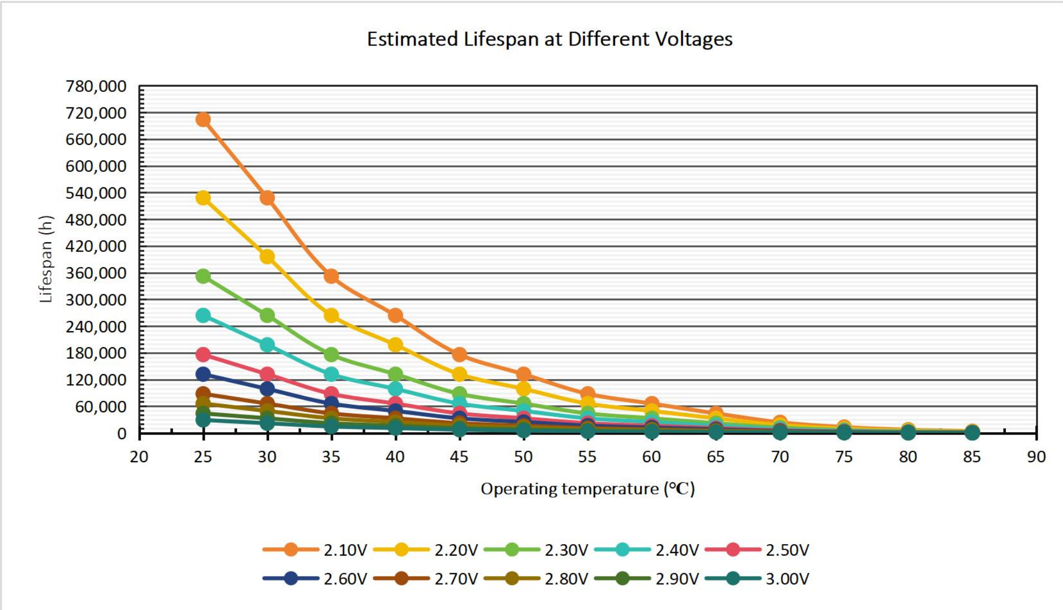
The life of a supercapacitor is affected by the operating voltage and operating temperature,
and conforms to the following equation:

$$\mathbf{L} = \mathbf{L_0} \times \mathbf{3.25}\frac{\mathbf{T_0} - \mathbf{T}}{\mathbf{10}} \times \mathbf{1.52}\frac{\mathbf{V_0} - \mathbf{V}}{\mathbf{0.1}}$$

L : Theoretical lifespan at operating temperature;
L_0 : Operational lifespan at the highest working temperature;
T : Actual operating temperature;
T_0 : Maximum rated operating temperature;
V : Actual operating voltage;
V_0 : Maximum rated operating voltage.

3. Application Examples

To validate the accuracy of the model, we conducted a lifespan estimation experiment on a commercially available supercapacitor. Firstly, based on the technical specifications of the supercapacitor and its actual application scenarios, we set various conditions, including different voltages, temperatures, and operating hours. Subsequently, we employed the model to fit these conditions, obtaining the corresponding model parameters. Finally, we used the model to estimate the lifespan of the supercapacitor and compared the results with the experimental data.The results indicate that the model demonstrates high predictive accuracy and practical utility.



4. Conclusion & Future Outlook

This paper proposes a supercapacitor lifespan estimation model based on experimental data and mathematical modeling. The model takes into account factors such as charge/discharge rate, temperature, and cycle number that affect the lifespan of supercapacitors. Through experimental validation, the model demonstrates high predictive accuracy and practical utility, providing essential reference for the design and application of supercapacitors.

While we have established a reasonably accurate supercapacitor lifespan estimation model, there are still challenges and areas for improvement in practical applications. For instance, our model relies primarily on experimental data, and for novel supercapacitor materials or manufacturing processes, additional experiments and verification may be necessary. Furthermore, our model assumes uniform charge/discharge rates, temperatures, and cycle numbers for all supercapacitors, whereas these conditions can vary in real-world usage. Therefore, it is advisable to refer to the supercapacitor datasheet or consult with Intelligent Beacon Solutions (CDA) for precise guidance in practical applications.

Additionally, we can further enhance the supercapacitor lifespan estimation model through the following approaches:

4.1 Increase Experimental Data: By incorporating data from diverse conditions, we can improve the model's predictive accuracy and generalization capabilities.
4.2 Introduce More Influencing Factors: Apart from charge/discharge rates, temperature, and cycle number, other factors such as electrolyte type and electrode materials also impact supercapacitor lifespan. Including these factors in the model can enhance its accuracy and comprehensiveness.
4.3 Develop More Complex Mathematical Models: Introducing more sophisticated mathematical models, such as neural networks, support vector machines, etc., can enhance the model's prediction and generalization abilities, providing better guidance for practical applications.

In conclusion, the estimation of supercapacitor lifespan holds significant importance for practical applications. Through continuous research and improvement, we aim to establish a more accurate, reliable, and practical supercapacitor lifespan estimation model, contributing to the development of future energy storage technologies.