Noise in electrical double-layer capacitors (EDLCs)

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Abstract — Methods and problems of noise measurements in electrical double-layer capacitors (EDLC) are presented. Noise equivalent electronic circuit is proposed and two ways of observations of random processes generated in the EDLC structures are studied. We consider noise as a useful tool for characterization of the EDLC structures and their state-of-health.

Keywords — electrical double-layer capacitor, flicker noise, white noise, state-of-health, reliability

I. INTRODUCTION

Noise is a well-known tool applied for electronic devices and systems state-of-health or reliability assessment. It is widely used for semiconductor devices, sensors and electrochemical systems [1, 2]. It may be also used for batteries [3], capacitors [4] and EDLCs as well [5].

Noise measurements in EDLCs are not obvious due to high capacitance and necessity of measurements in low frequency range, below 1 Hz. It means that the measurements require long time of data acquisition and stability to avoid any drifts induced by slow environmental changes like temperature. These issues have been considered in the paper.

II. ELECTRICAL MODEL OF THE EDLCs

The EDLCs may be modelled by a ladder circuit of at least two branches (Fig. 1) [6]. Capacitor C1 and resistor R_{ESR} represent the so-called Helmholtz capacitance with an equivalent series resistance (ESR) while capacitor C2 and resistor R_0 model processes induced by diffusion mechanism [6]. Both capacitance, C1 and C2, have similar values. Resistor R_l represents a resistance responsible for a leakage current. Resistance R_{ESR} is significantly lower than R_0. It means that C1 is charged to a specified voltage much faster than C2. The same remark is valid for discharging process.

![Electrical equivalent model of the EDLC](image)

Fig. 1. Electrical equivalent model of the EDLC

Noise generation in the EDLCs structures is related to ions migration in porous electrodes. Movements of ions within the pores of diameter even less than 1 nm take part in processes of electrical random signal generation. Electric field forces ions to penetrate the pores of electrode material. This process is nonlinear and due to local overheating or electrochemical reactions may block the pores and noise generated there should be very sensitive to the mentioned phenomena, decreasing capacitance of the EDLCs.

III. MEASUREMENT SET-UP

The measurement set-up for low frequency noise observations in EDLCs consists of current/voltage source with galvanostatic/potentiostatic ability to assure the EDLCs charging/discharging process. Noise is recorded by using low noise amplifier and analog-to-digital converter at different polarizing conditions to expose selected noise sources.

Two measurement procedures are proposed to observe two different noise sources. The first one requires charging with a constant current to the specified voltage. Next, the specimen is discharged by loading resistor and voltage across this resistor is recorded. Voltage noise component is identified by subtracting exponential-like discharging curve. This component is related mainly to charges stored in the capacitor C1 and only partially in C2 because the time constant C1-R_{ESR} determines the discharging process. The second procedure requires again charging with a constant current to the given voltage. Next, the sample is short-circuited for a selected time after which the sample terminals are connected to the loading resistor and the voltage drop across this resistor is recorded due to charge migration from still partially charged C2 to C1. Noise component in the recorded time series is determined mainly by fluctuations of charge stored in C2.

IV. CONCLUSIONS

Two methods of supercapacitor low frequency noise measurements were proposed to observe fluctuations related to different mechanisms of charge stored in the EDLCs structures and to different noise sources. We may claim that noise measurements give information about the state of electrolyte-electrode interface.

REFERENCES


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