Stanford | SCHOOL OF EARTH, ENERGY & ENVIRONMENTAL SCIENCES

Homework 3 (100 points)

ENERGY 295 - Electrochemical Energy Storage Systems: Modeling and Estimation

Fall Quarter 2021

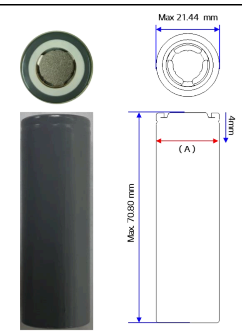
Dr. Simona Onori

Due ~~November 4,~~ November 9, 2021 at 11 AM (Electronic pdf copy in CANVAS)

<u>Please include your MATLAB code in the final submission</u>

This assignment is aimed at assessing your understanding of equivalent circuit battery models and parameter identification methods. Data sets from experiments conducted on an INR21700 M50T lithium-ion cell will be utilized in this assignment. The technical specifications of the cylindrical lithium-ion battery used in this project are tabulated below:

Table 1: Battery technical specifications

Battery Name	INR21700 M50T	
Manufacturer	LG Chem	
Rated Capacity	4.85Ah	
Nominal Voltage	3.63V	
Maximum Voltage	4.2V	
Minimum Voltage	2.5V	
Cathode Chemistry	NMC	
Anode Chemistry	Graphite	

You will be provided the following data sets in the folder "Files":

- Open Circuit Voltage – from Capacity Test at C/20 Discharge

INR21700_M50T_T23_OCV_W8.xlsx	100%	1sec

- Hybrid Pulse Power Characterization (HPPC) test at the beginning of life:

Excel filename	**Initial SOC**	**Sampling Time**
INR21700_M50T_T23_HPPC_N0_W8.xlsx	100%	1sec

- Urban Dynamometer Driving Schedule (UDDS) profiles discharging the battery from 80% down to 20% SOC. The two UDDS cycles are preceded by a sequence "CCCV charging-CC discharging", where the CC-CV charging is to bring the battery at 100% SOC) and the CC discharging is to bring the battery from 100%SOC down to 80%SOC.

Excel filename	**Sampling Time**
INR21700_M50T_T23_UDDS_W8_N1.xlsx	1sec for the CCCV-CC and 0.1sec for the UDDS

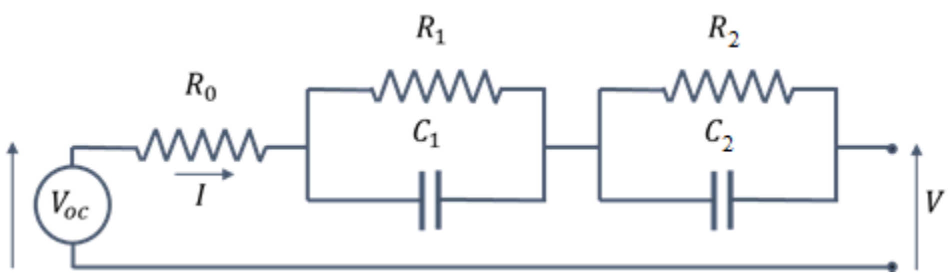
Problem 1 (5 pts)

- Use the "Open Circuit Voltage – from Capacity Test at C/20 Discharge" data set to calculate:
    - Cell nominal capacity
    - OCV vs SoC

Problem 2 – Parameter Identification (60 points)

For this part of the HW you must use the HPPC test

The dynamic response of a battery can be described using a second-order Randles model (equivalent circuit model) as shown in the figure below.



Implement a second order equivalent circuit model in MATLAB.

In particular, identify the 5 parameters of the second order equivalent circuit model, $\theta = [R_0, R_1, C_1, R_2, C_2]$, as a function of the cell SoC over the HPPC test. A Root Mean Square (RMS) voltage error of less than 5% is expected to be achieved. The percentage RMS error must be calculated using the expression

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(V_{exp}(i) - V_{sim}(\theta; i)\right)^2} \cdot \frac{100 \cdot N}{\sum_{i=1}^{N} V_{exp}(i)},$$

where V_{exp} is the experimentally measured voltage response, V_{sim} is the model-predicted voltage response that is a function of θ, N is the total number of data samples, and i is the time index.

The portion of the identification profile (HPPC at 23°C) that is relevant for this task begins at 100% SoC (just before the beginning of the first discharge) and terminates at the end of the test profile around 10% SoC. For this profile, the following tasks are to be conducted:

a) Use the graphical method studied in class to generate the initial guesses for the first three parameters: R_0, R_1, C_1. Tabulate the initial guesses of the three parameters from the graphical method at each SoC only during the discharge pulse.

b) Use the genetic algorithm (*ga*) optimization method discussed in class to identify the elements of the vector θ as a function of the cell SoC and current directionality. Tabulate the results obtained from this approach. (Hint: Use initial guesses for the parameters from Problem 1.a to initialize the optimization algorithm.)

c) Provide plots of the 5 model parameters as a function of SoC ad current directionality from the results obtained using *ga*.

Problem 3 – Model validation (35 pts)
For this part of the HW you must use the UDDS test without the CCCV portion of the data

Validate the identified model against the UDDS driving cycle profile. Report the % RMS voltage error obtained from model validation and provide a plot comparing the experimental and the model-predicted voltage response. Also, plot the error between the experimental and the model-predicted voltage response with respect to time. In addition, perform the following tasks:

1. Plot the overall variation of the cell SoC from the beginning to the end of the UDDS cycle as a function of time.
2. Based on the overall variation of the cell SoC from the beginning to the end of the UDDS cycle, what type of vehicle could this driving cycle have been obtained from? Explain your answer, if you can.

Note: All the experiments are conducted using an Arbin BT-2000 tester, for which the current convention is positive during charge and negative during discharge.