Frequency and Temporal Identification of a Li-ion Polymer Battery Model Using Fractional Impedance

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Introduction

Why modelling is not an easy task

- battery's behaviour are not stationary,
- they are systems highly non-linear regarding to the current,
- their dynamic behaviour depends on many parameters like SOC, temperature, recent history, age.

Which technics could be used

- Chronopotentiometry :
  - High current intensity as in normal use,
  - current profil (intensity, length), acquisition frequency.
- Impedance spectroscopy :
  - Wide frequency spectral at low current intensity,
  - With and without polarization current, Problem of SOC and voltage deviation at low frequencies.

Model of the battery

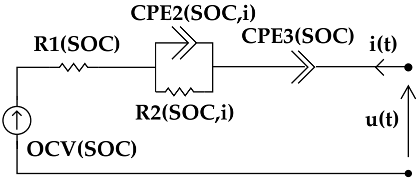
Principles

- Localised parameters depending on SOC, T, I.

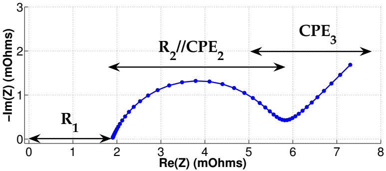
Model characteristics

- Capacity of storage at 1C ;
- Open circuit voltage : OCV=f(SOC, T) ;
- Impedance : Z=f(I,SOC,T) ;
- Inductive phenomenon is neglected.

Model

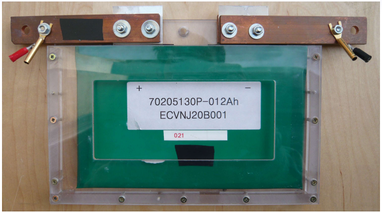


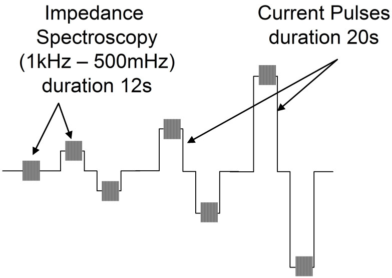
Nyquist plot of battery's impedance

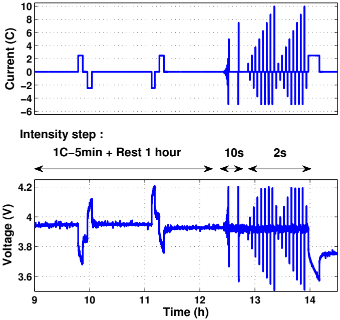


Battery and experimental protocols

- Battery tested : Li-Pol Kokam 12 Ah ;
- Impedance spectroscopy at various levels of current ;
- Chronopotentiometry.

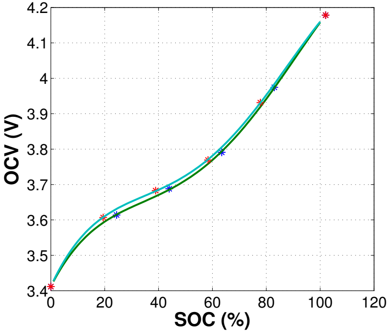




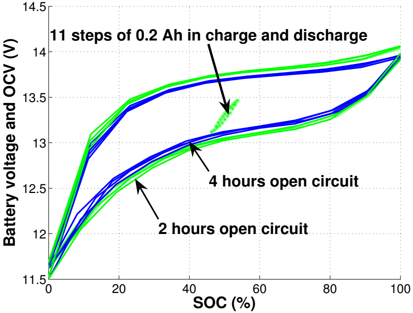


Identification of the Open Circuit Voltage OCV

Lithium KOKAM 12 Ah



NiMH SAFT NHP 34Ah

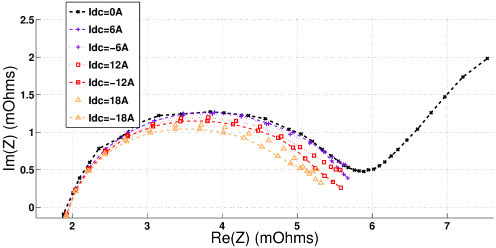


Description

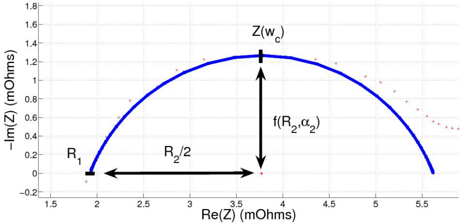
- No hysteresis phenomenon for the lithium,
- OCV=f(SOC) used for battery voltage correction.

Identification of $R_1 + R_2 / / CPE_2$ at low current (1/2)

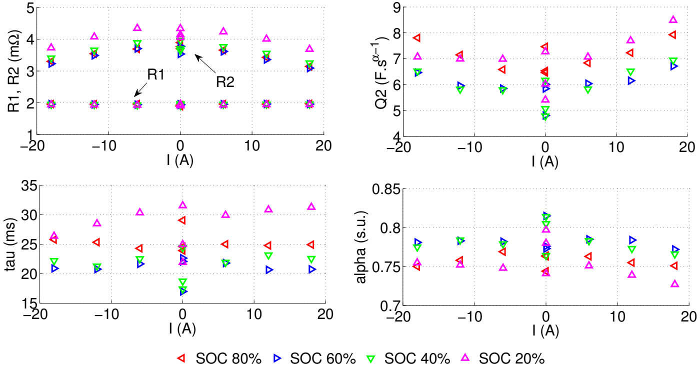
Impedance spectroscopy measurements at different current intensities



R_1 is constant when the current intensity varies



Identification of $R_1 + R_2 // CPE_2$ at low current (2/2)



- $CPE_2(s) = \frac{1}{Q_2 s^{\alpha_2}}$ with s Laplace operator
- $\tau_2 = R_2 Q_2$ and R_1 are constant when current intensity varies
- R_2, Q_2 = f(I).

Identification of R_2 at high current

Model simplification

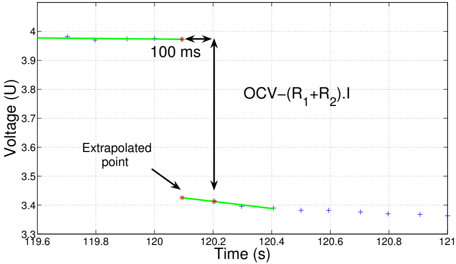
- τ_2 between 20 and 30 ms
- Frequential acquisition 10 Hz

$\Rightarrow$ CPE_2 is neglected

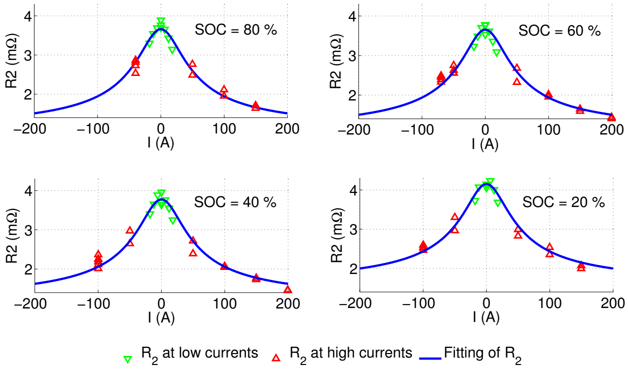
Measurements at high current

- 2s current pulses at 50 to 200 A

Example of voltage drop for high current intensity



Fitting of R_2 for low and high currents



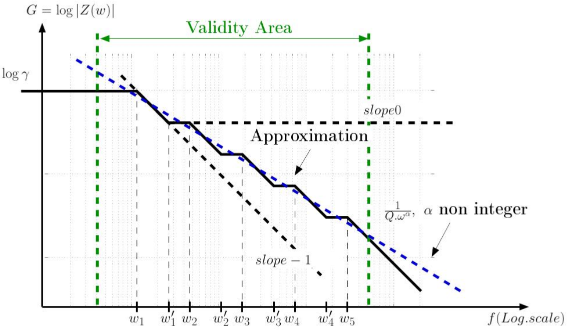
- No transport limitation ⇒ Butler-Volmer formalism :
  $$R_2 = \frac{1}{a\ b\ \sqrt{1+(\frac{I}{a})^2}} + c$$
- R_2 symetrical according to I

Approximation of the diffusive impedance CPE_3

- $CPE(s) = \frac{1}{Qs^{\alpha}} = \frac{\sigma}{s^{\alpha}}$ with s Laplace operator
- Approximation by a limited frequency band impedance : sum of 5 first order transfer functions.
- 4 variable needed to define the impedance : γ, ω_1, ω_5 and p.

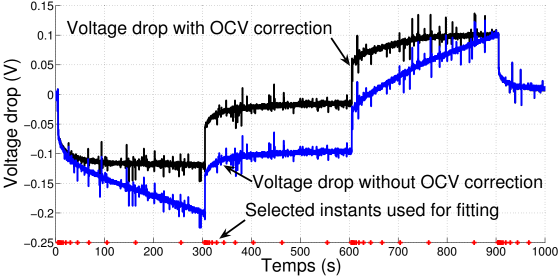
  Only γ is used for error minimisation
  $f_1 = {}^{w_1}/_{2\pi} = 1$mHz, $f_5 = {}^{w_5}/_{2\pi} = 5$Hz and p=-1/2.

Approximation in the Bode diagram



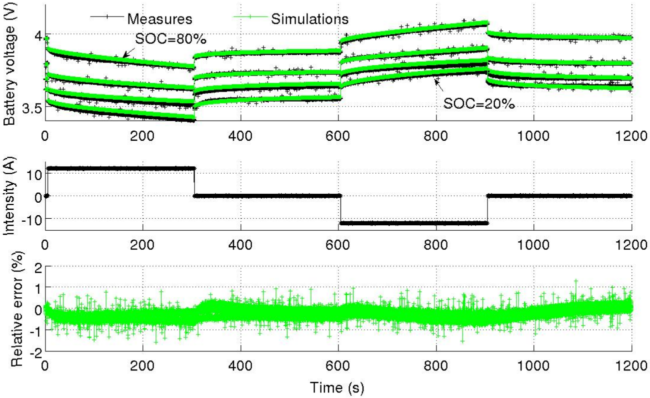
Identification of CPE_3 on temporal domain (1/2)

- Temporal identification on $\pm$ 1C - 5min , $\Delta SOC = 8.3\%$
- Correction of battery voltage by OCV=f(SOC)



Identification of CPE_3 on temporal domain (2/2)

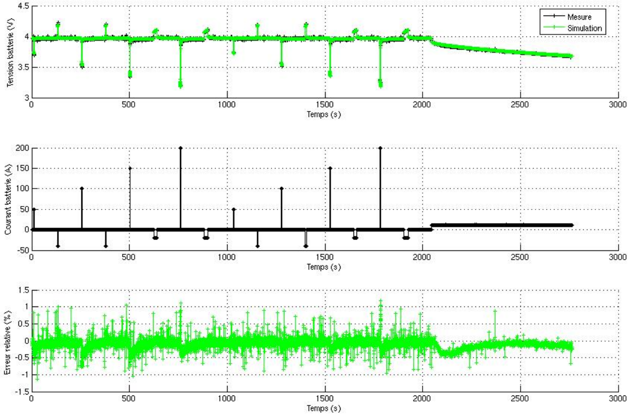
Identification results for different SOC



$\Rightarrow$ Relative error $\leq \pm 1\%$

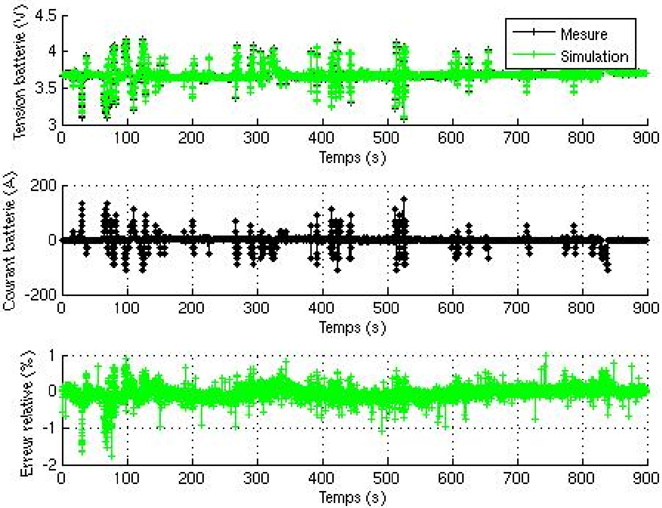
Verification

Verification on 2s pulse



$\Rightarrow$ Relative error $\leq \pm 1\%$

Validation on usage cycle at SOC=40%



$\Rightarrow$ Relative error $\leq \pm 2\%$

Advantages and Perspectives

Advantages

- Non linear model ;
- Good accuracy on validation ;
- Not too long tests : 3 days / battery / T° for a complete model

Perspectives

- Study of sensibility of identified parameters ;
- Tests at different temperatures ;
- Influence of the CPE_3 slope on precision ;
- Standarization on other elements :
  - Li-pol Kokam 40 et 100 Ah
  - Valence
  - NiMH including hysteresis phenomenon

Thanks for your attention