EVS35
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Second Life Batteries in a Mobile Charging Station: Model Based Performance Assessment

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Second Life Batteries in a Mobile Charging Station - Challenges

2 majors challenges for electric mobility

1-The charging station network

2-The EV environmental impact

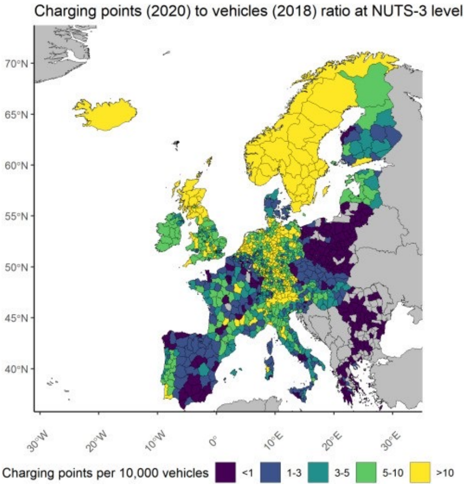
Second Life Batteries in a Mobile Charging Station - Challenges

Challenge : Strengthening the charging station network

"The appropriate average number of recharging points should be equivalent to at least ***one recharging point per 10 cars****"*

Source: Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the Deployment of Alternative Fuels Infrastructure

Second Life Batteries in a Mobile Charging Station - Challenges



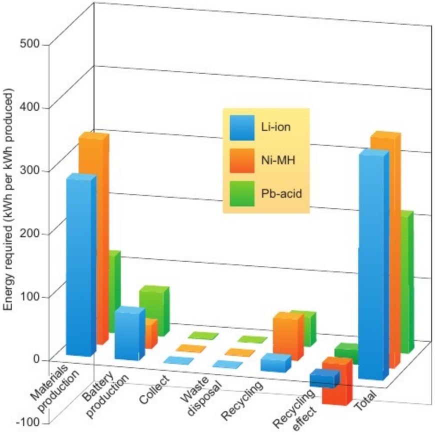
Source: Falchetta,G., Noussan,M., Electric vehicle charging network in Europe: An accessibility and deployment trends analysis. Transportation Research (2021).

Second Life Batteries in a Mobile Charging Station - Challenges

Challenge : Minimizing the electric vehicle environmental impact

Second Life Batteries in a Mobile Charging Station - Challenges

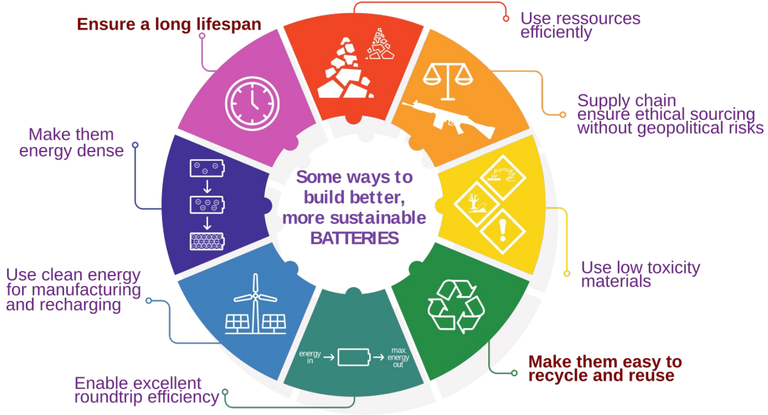
Challenge : Minimizing the electric vehicle environmental impact



Source: Larcher, D., Tarascon, JM., Towards greener and more sustainable batteries for electrical energy storage. Nature Chem (2015).

Second Life Batteries in a Mobile Charging Station - Challenges

Challenge : Minimizing the electric vehicle environmental impact



Source: European Commission, Ways to build better batteries

Second Life Batteries in a Mobile Charging Station - A solution

A solution : The Mob-Energy's mobile charging station

Sources : Mob-Energy, Sophie Jeannin - University Gustave Eiffel

Second Life Batteries in a Mobile Charging Station - A solution

A solution : The Mob-Energy's mobile charging station powered by second life batteries

Sources : Mob-Energy, Sophie Jeannin - University Gustave Eiffel

Model Based Performance Assessment - Research questions

Research questions investigated

1. How performant are second life batteries ?

Model Based Performance Assessment - Research questions

Research questions investigated

1. How performant are second life batteries ?
2. How to model the electric behavior of a second life battery ?

Model Based Performance Assessment - Experimental setup

Module

- Module extracted from a BMW i3
- Bought on the second life battery market
- 12 cells per module

Model Based Performance Assessment - Experimental setup

Module

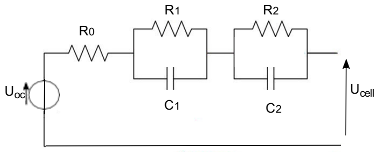
- Module extracted from a BMW i3
- Bought on the second life battery market
- 12 cells per module

Cell

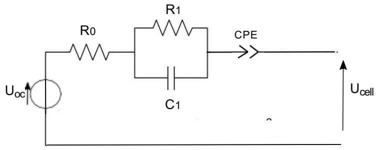
- Second life cell
- Chemistry : Lithium-ion NMC-Ni rich/C
- Nominal capacity : 94Ah

Model Based Performance Assessment - Equivalent circuit models

RC model



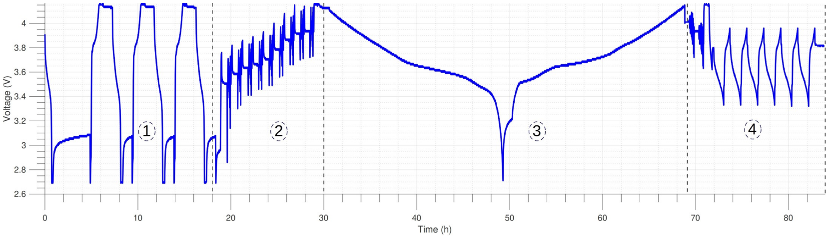
CPE model



Models informations

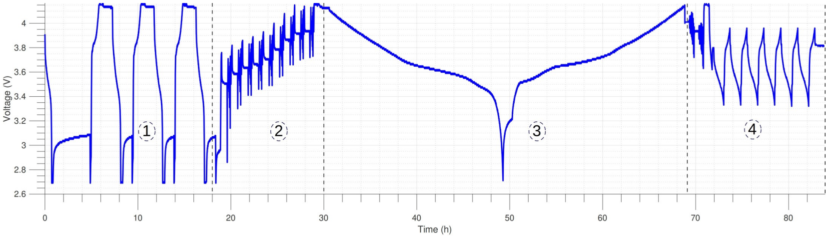
- Equivalent circuit models
- Forward models :
  - Input : Current
  - Output : Voltage or Power

Model Based Performance Assessment - Characterization test



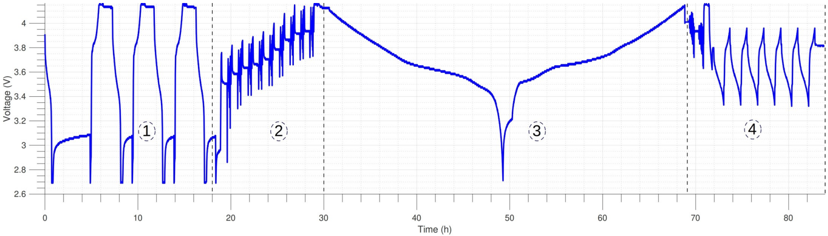
Test step	Test name	Model parameters identified
1	Capacity test	Capacity

Model Based Performance Assessment - Characterization test



Test step	Test name	Model parameters identified
1	Capacity test	Capacity
2	Pulses test	Resistance R0 & impedance R1/C1+R2/C2 or R1/C1+CPE

Model Based Performance Assessment - Characterization test



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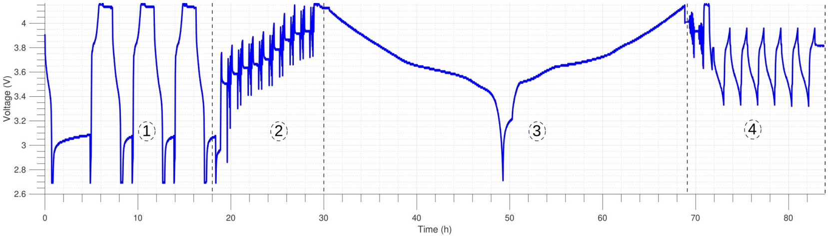
3	Low current test	(Pseudo) Open Circuit Voltage

Model Based Performance Assessment - Characterization test



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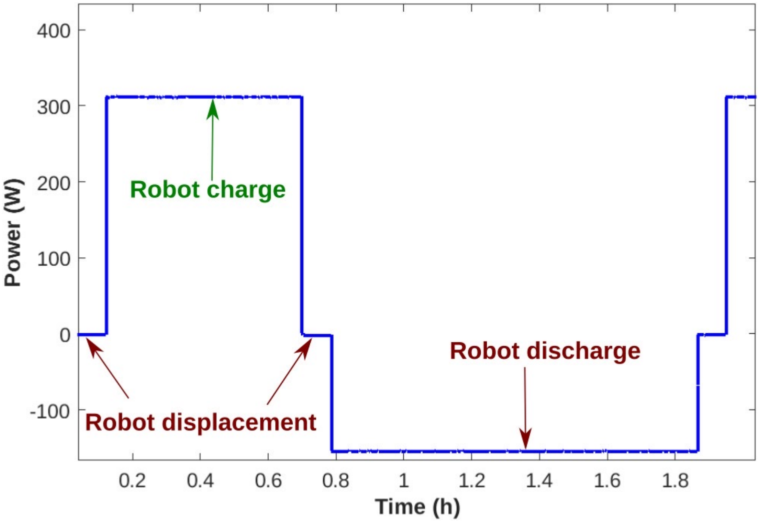
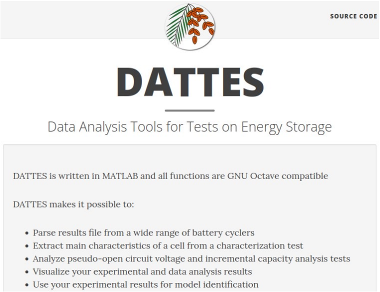
4	Validation profile	-

Model Based Performance Assessment - Validation profile



Model Based Performance Assessment - Data processing



DATTES

- Free and open source software for data test processing
- MATLAB/GNU Octave software
- Developed by Eduardo Redondo-Iglesias and Marwan Hassini

Source: https://dattes.gitlab.io/

Model Based Performance Assessment - Experimental results

Discharge capacity measurement (1C-CC) and state of health at 0, 25 and 40°C

Temperature	Datasheet capacity	Measured capacity	State of health
0°C	No data		

Model Based Performance Assessment - Experimental results

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Model Based Performance Assessment - Experimental results

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25°C	95.2 Ah		

Model Based Performance Assessment - Experimental results

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Temperature	Datasheet capacity	Measured capacity	State of health
0°C	No data	86 Ah	-
25°C	95.2 Ah	92.1 Ah	96.7%

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Temperature	Datasheet capacity	Measured capacity	State of health
0°C	No data	86 Ah	-
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40°C	95.7 Ah		

Model Based Performance Assessment - Experimental results

Discharge capacity measurement (1C-CC) and state of health at 0, 25 and 40°C

Temperature	Datasheet capacity	Measured capacity	State of health
0°C	No data	86 Ah	-
25°C	95.2 Ah	92.1 Ah	96.7%
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Model Based Performance Assessment - Experimental results

Discharge capacity measurement (1C-CC) and state of health at 0, 25 and 40°C

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0°C	No data	86 Ah	-
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Sizing of a mobile charging station battery with data at 25°C

- Nominal energy for fresh cell : $U_{nominal} \cdot Q_{25°C} = 3.68 \cdot 95.2 = 350Wh$

Model Based Performance Assessment - Experimental results

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- Nominal energy for fresh cell : $U_{nominal} \cdot Q_{25°C} = 3.68 \cdot 95.2 = 350Wh$
- Nominal energy for second life cell : $U_{nominal} \cdot Q_{25°C} = 3.68 \cdot 92.1 = 339Wh$

Model Based Performance Assessment - Experimental results

Discharge capacity measurement (1C-CC) and state of health at 0, 25 and 40°C

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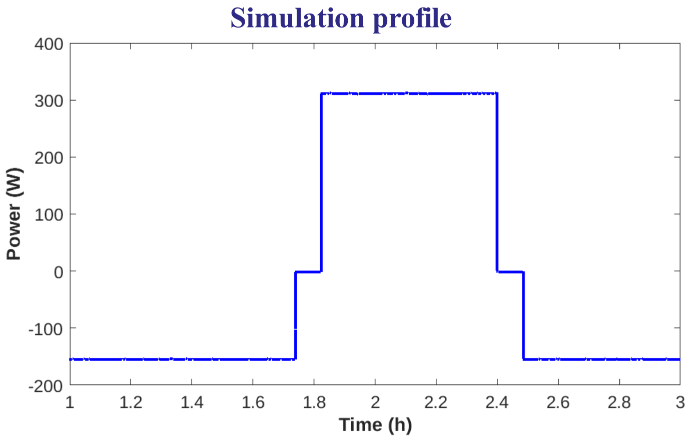
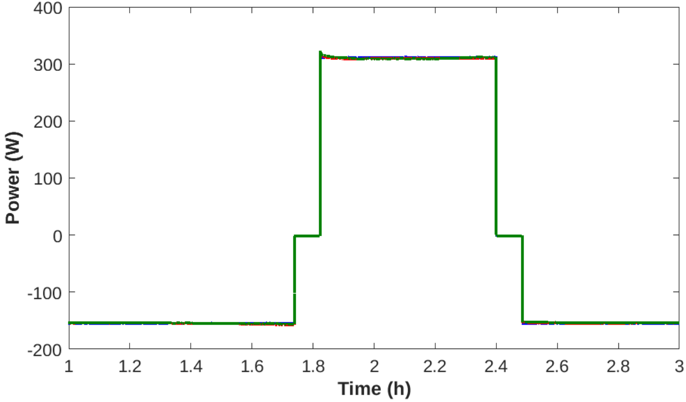
- Nominal energy for fresh cell : $U_{nominal} \cdot Q_{25°C} = 3.68 \cdot 95.2 = 350Wh$
- Nominal energy for second life cell : $U_{nominal} \cdot Q_{25°C} = 3.68 \cdot 92.1 = 339Wh$
- For a 25kWh charger, 72 fresh cells or 74 second life cells are needed

Model Based Performance Assessment - Simulation result



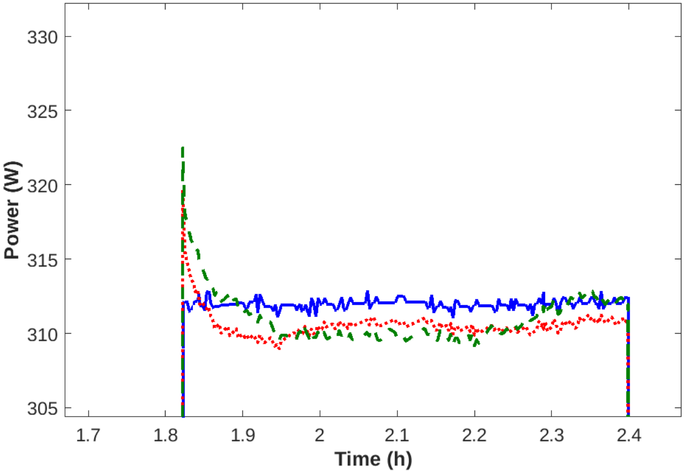
Model Based Performance Assessment - Simulation result

Power simulation result with the CPE model and RC model



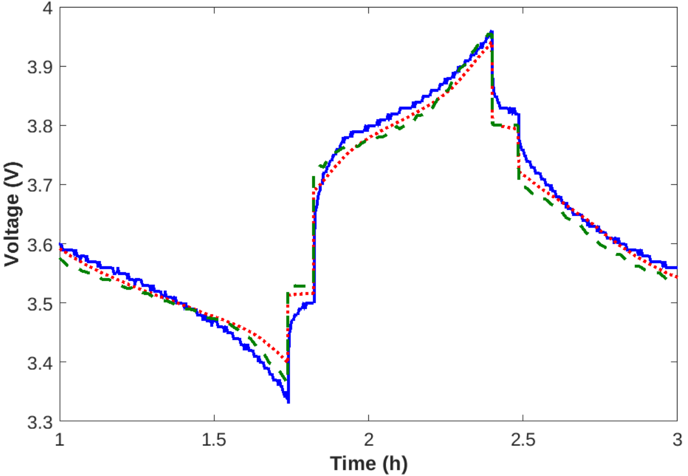
Model Based Performance Assessment - Simulation result

Zoom in on power simulation result with the CPE model (–) and RC model(..)



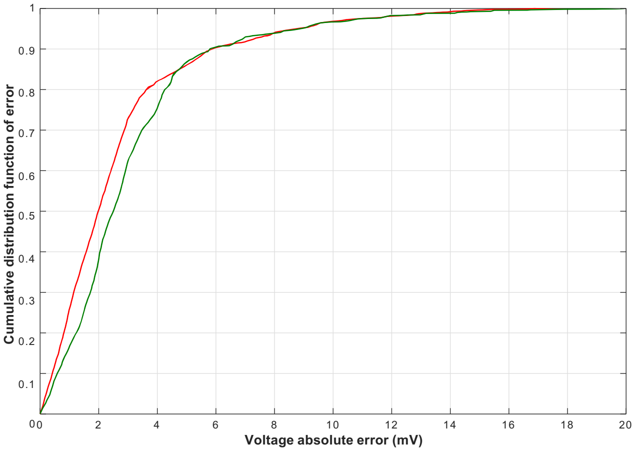
Model Based Performance Assessment - Simulation result

Voltage simulation result with the CPE model(–) and RC model(..)



Model Based Performance Assessment - Model accuracy analysis

Distribution function of error probabilities for CPE model and RC model simulations



Model Based Performance Assessment - Conclusion

Work contributions

- A new second life application have been presented : the mobile charging station

Model Based Performance Assessment - Conclusion

Work contributions

- A new second life application have been presented : the mobile charging station
- Two models capable of emulating accurately the electric behavior of second life cells have been presented

Model Based Performance Assessment - Conclusion

Work contributions

- A new second life application have been presented : the mobile charging station
- Two models capable of emulating accurately the electric behavior of second life cells have been presented
- The performance of second life batteries can be assessed

Reproductible research

Experimental data and datapaper

The Dataverse® Project

Link to the datapaper & experimental data

Software DATTES

Link to the software DATTES

Thank you for your attention

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Université Gustave Eiffel

Questions-Parameters identification

First, the capacity is calculated according to the equation 1. The mean value of the three measurement in step 1 is considered.

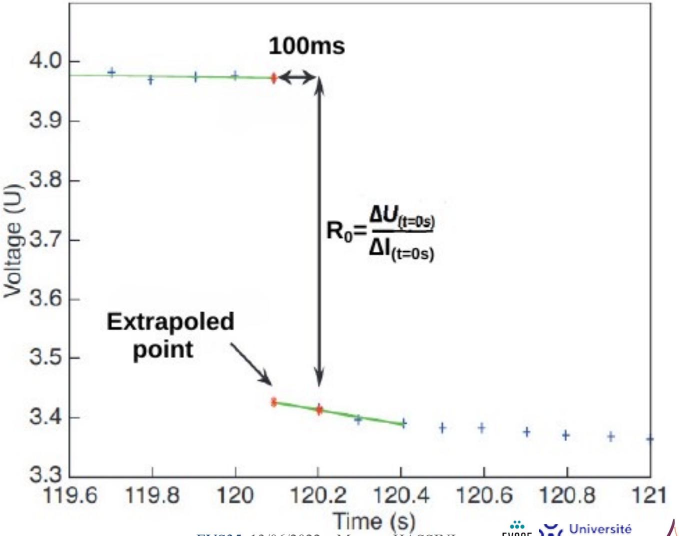
$$Q(t) = \frac{1}{3600}\int_{t_0}^{t} i(t)dt \tag{1}$$

$Q(t)$ is the capacity (Ah), t is the time of a cycle charge/discharge (s) and i is the current in the cell (A).

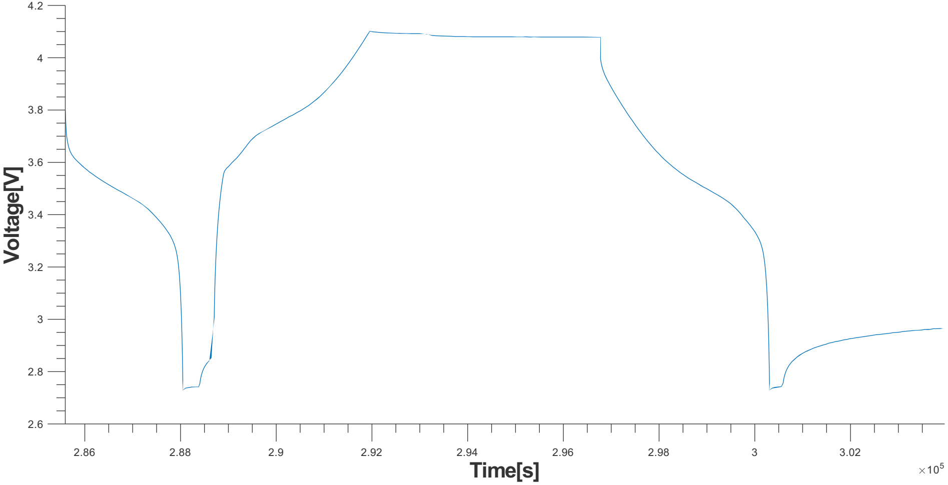
Second, the state of charge is computed according to the equation 2.

$$SoC = 100 * [SoC_{t0} + \frac{1}{3600 * Q_{nominal}}\int_{t_0}^{t} i(t)dt] \tag{2}$$

Questions-Parameters identification



Question-Test description



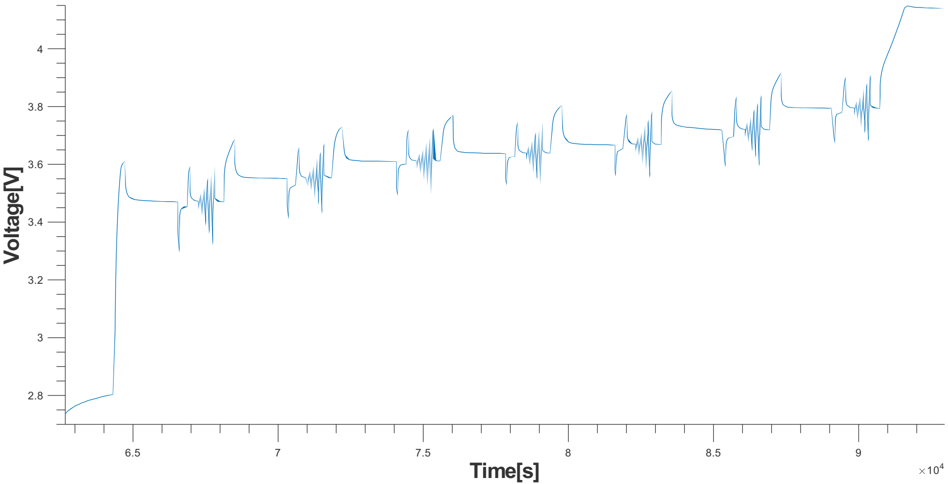
Question-Test description

Capacity test

Table 6. Capacity measure test procedure

Step	Test type	Key parameters	Description
1	Discharge in CC mode	$I_{cc} = 1C = 94A$	Voltage is set to U_{min}
2	Discharge in CV mode	$U_{thres} = U_{min} = 2,7V, I_{cv} = C/20 = 4.7A$	Voltage is set to U_{min}
3	Rest	$t_{rest} = 5mn$	Rest for five minutes
4	Charge in CC mode	$I_{cc} = 1C = 94A$	Full charge at 1C
5	Charge in CV mode	$U_{thres} = U_{max} = 4,15V, I_{cv} = C/20 = 4.7A$	Voltage is set to U_{max}
6	Rest	$t_{rest} = 1h$	Rest for one hour
7	Discharge in CC mode	$I_{cc} = 1C = 94A$	Full discharge at 1C
8	Discharge in CV mode	$U_{thres} = U_{min} = 2,7V, I_{cv} = C/20 = 4.7A$	Voltage is set to U_{min}
9	Rest	$t_{rest} = 1h$	Rest for one hour

Question-Test description



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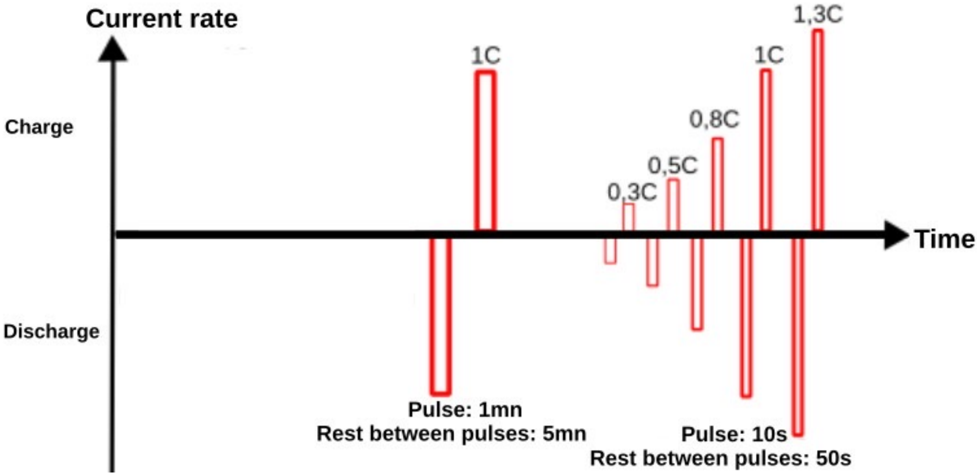
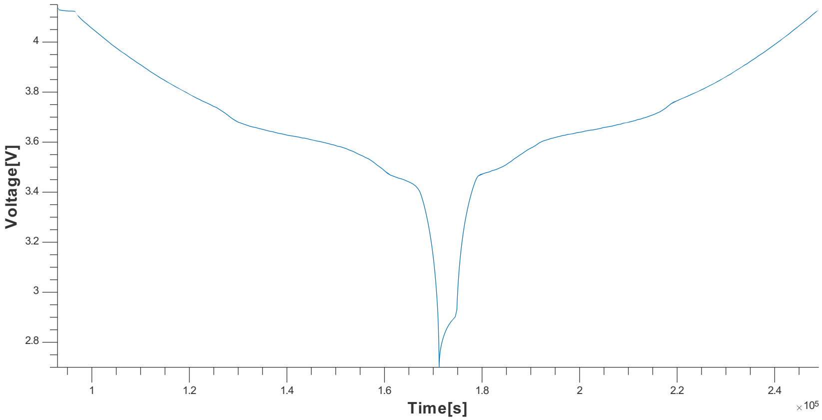


Question-Test description



Question-Test description

Table 8. Low current measure

Step	Test type	Key parameters	Description
1	Rest	$t_{rest} = 5mn$	Rest for five minutes
2	Charge in CC-CV mode	CC : $I_{const} = 1C = 94A$ CV : $U_{thres} = U_{max} = 4,15V, I_{const} = C/20 = 4.7A$	Voltage is set to U_{max}
3	Rest	$t_{rest} = 1h$	Rest for one hour
4	Discharge in CC mode	$I_{cc} = C/20 = 4.7A$	Full low current discharge
5	Rest	$t_{rest} = 1h$	Rest for one hour
6	Charge in CC mode	$I_{cc} = C/20 = 4.7A$	Full low current charge

Question-Test analysis with DATTES

Second life

Second life databank analysis with DATTES

Outline

- Information about the dataset
- Information about the test
- Data analysis with DATTES

Information about the dataset

The “Second life battery databank” provides the data test results made by Marwan Hassini from Licit-Eco7 laboratory, University Gustave Eiffel during his thesis about second life batteries extracted from real electric vehicles.

This dataset have been used in two publications :

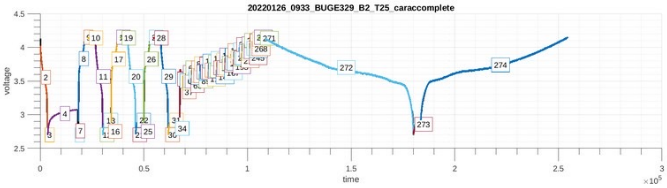
- Second Life Batteries in a Mobile Charging Station : Model Based Performance Assessment
- Second Life Batteries in a Mobile Charging Station : Experimental Performance Assessment

Dataset, test description and data reuse conditions can be found at Univ Gustave Eiffel dataverse

Question-Test analysis with DATTES

7. Plot phases ('Gp' = Graphics + phases):

```
[result, configuration, phases]=dattes(XML_list,'Gp')
```



In this plot each phase is numbered and plotted with a different color. DATTES analyzes the test and cut it into phases depending of the cycler working mode (CC, CV, rest, etc.).

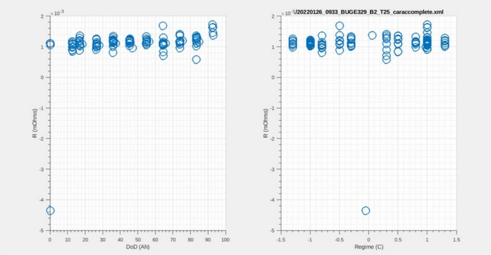
Question-Test analysis with DATTES

11. Calculate the resistance ('Rvs' = Resistance + verbose + save):

```
[result, configuration, phases]=dattes(XML_list,'Rvs')
```

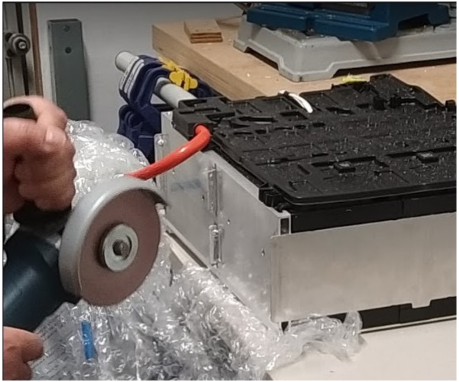
12. Plot resistance ('GR' = Graphics + Resistance):

```
[result, configuration, phases]=dattes(XML_list,'GR')
```



Left subplot shows resistance of different pulses versus depth of discharge (Ah). Right subplot shows resistance of different pulses versus current rate (C).

Question-Second life module teardown



Question-Second life module teardown

Question-Second life module teardown