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DATA-DRIVEN APPROACH FOR SOH ESTIMATION AND ALARMS GENERATION FOR COMPLEX ON-GRID ENERGY STORAGE SYSTEMS







OPTIMAL SYSTEM-MIX OF FLEXIBILITY SOLUTIONS FOR EUROPEAN ELECTRICITY

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National Institute for Solar Energy (INES)



-  ~ 450-500 persons
-  ~ 70 patents per year
-  200 industrial partners
-  Budget ~ 60 M€

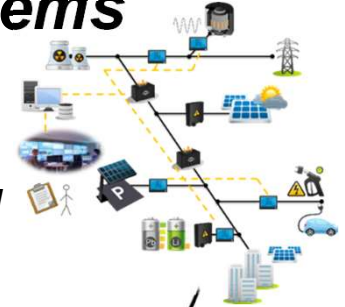
Photovoltaic



material
cells
modules
equipment
process

Systems

software
electronics
storage
grid
mobility & loading



Building

thermal systems
envelope
management



- **CONTEXT : OSMOSE PROJECT**
- **Diagnosis and Prognosis tool**
 - Architecture for diagnosis / prognosis
 - A4 Advanced Data Analysis Tool
- **Battery State of Health (SOH) prediction**
 - 1st approach : with data analysis in A4
 - 2nd approach : with model simulation
- **Conclusions and perspectives**

OSMOSE

Optimal System-Mix Of flexibility Solutions for European electricity

FLEXIBILITY SOURCES



THE CHALLENGE OF ORGANISING THE DEPLOYMENT OF FLEXIBILITY FOR THE INTEGRATION OF RENEWABLE ENERGY SOURCES

FLEXIBILITY NEEDS

- A Balance offer-demand at hourly or half-hourly timeframes optimised by energy and capacity markets
- B Existing and future system services such as frequency control, voltage control, inertia, synchronism.
- C Dynamic control of grid flows in order to extend the operating range of existing assets and to defer investments.

* *The context of this work*

<https://www.osmose-h2020.eu>

Scaling-up & replication (WP7)

- Interoperability for plug & play integration of flexibilities
- Application-specific design & control of BESS
- **Shared field-experience database of BESS**
- TSO-DSO coordinated dispatch of flexibilities

<https://www.osmose-h2020.eu>



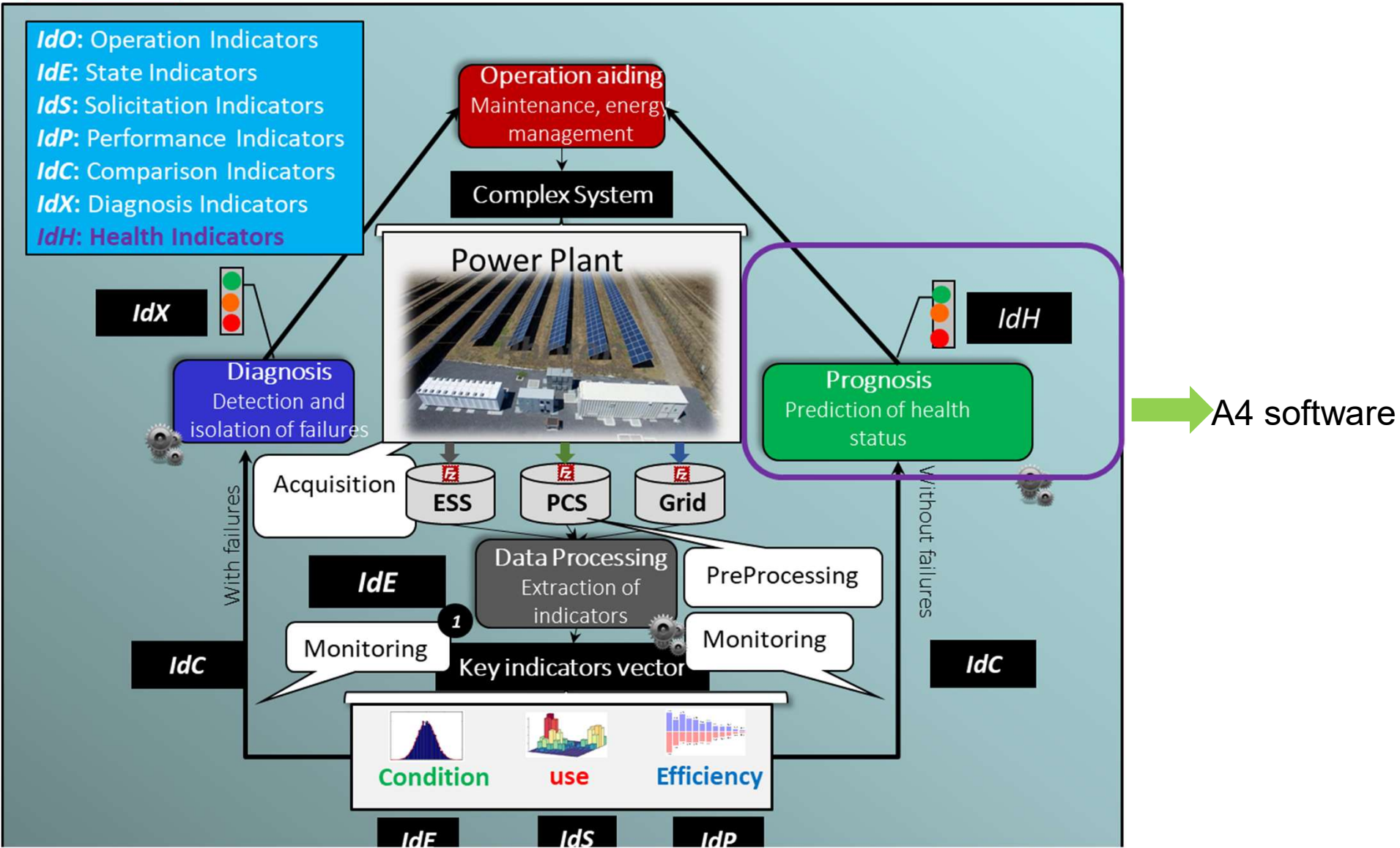
- 3 Li-ion systems and 3 NaNiCl₂ systems monitored in industrial projects and in TILOS H2020 project, **photovoltaic peak shaving application**
- 2 others monitored in OSMOSE



PV + Energy Storage System

F. Karoui, D.-L. Ha, T. Delaplagne, M.-F. Bouaziz, V. Eudier, and M. Lévy, “Diagnosis and prognosis of complex energy storage systems: tools development and feedback on four installed systems,” *Energy Procedia*, vol. 155, pp. 61–76, Nov. 2018.

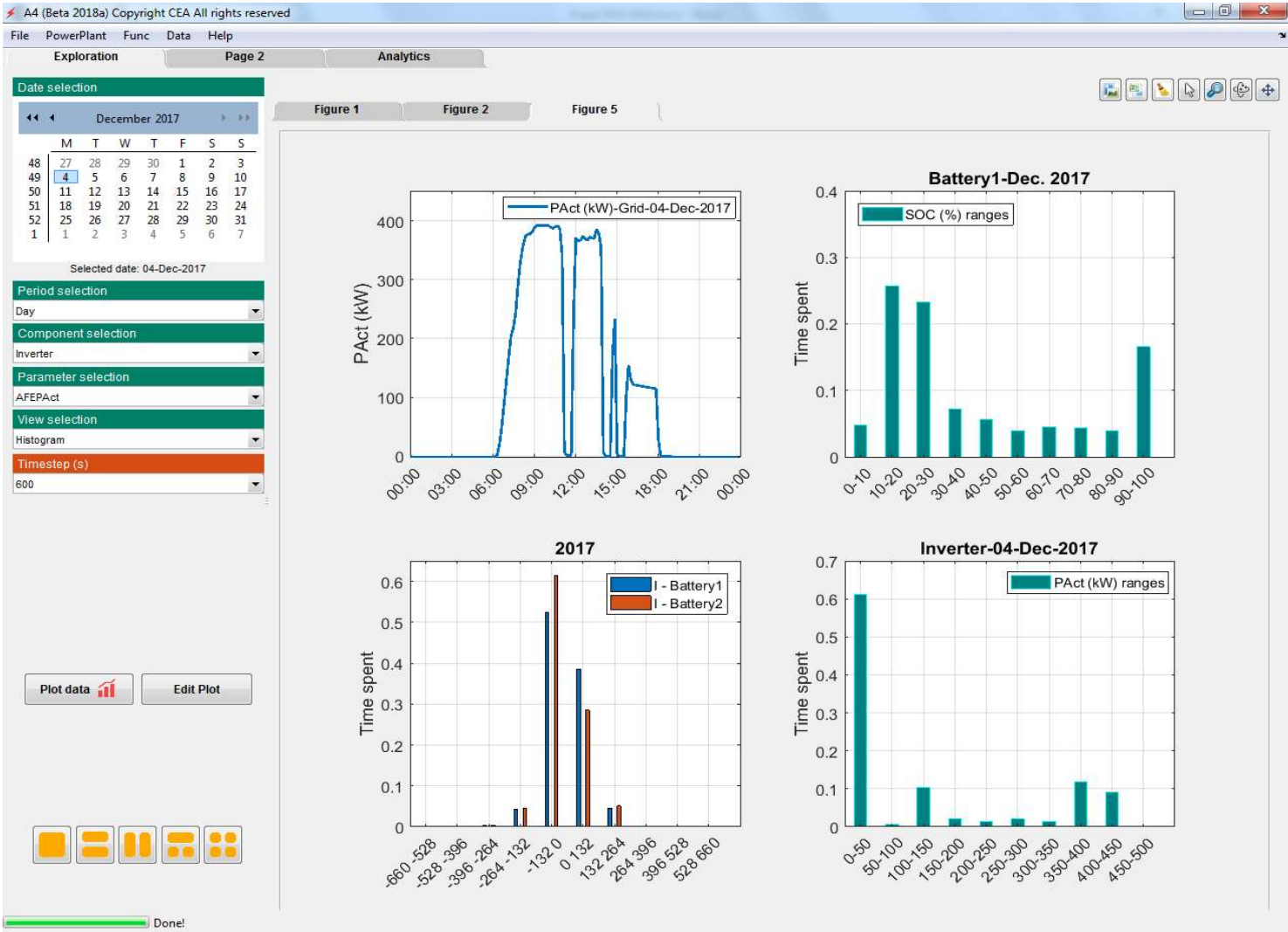
ARCHITECTURE FOR DIAGNOSIS / PROGNOSIS



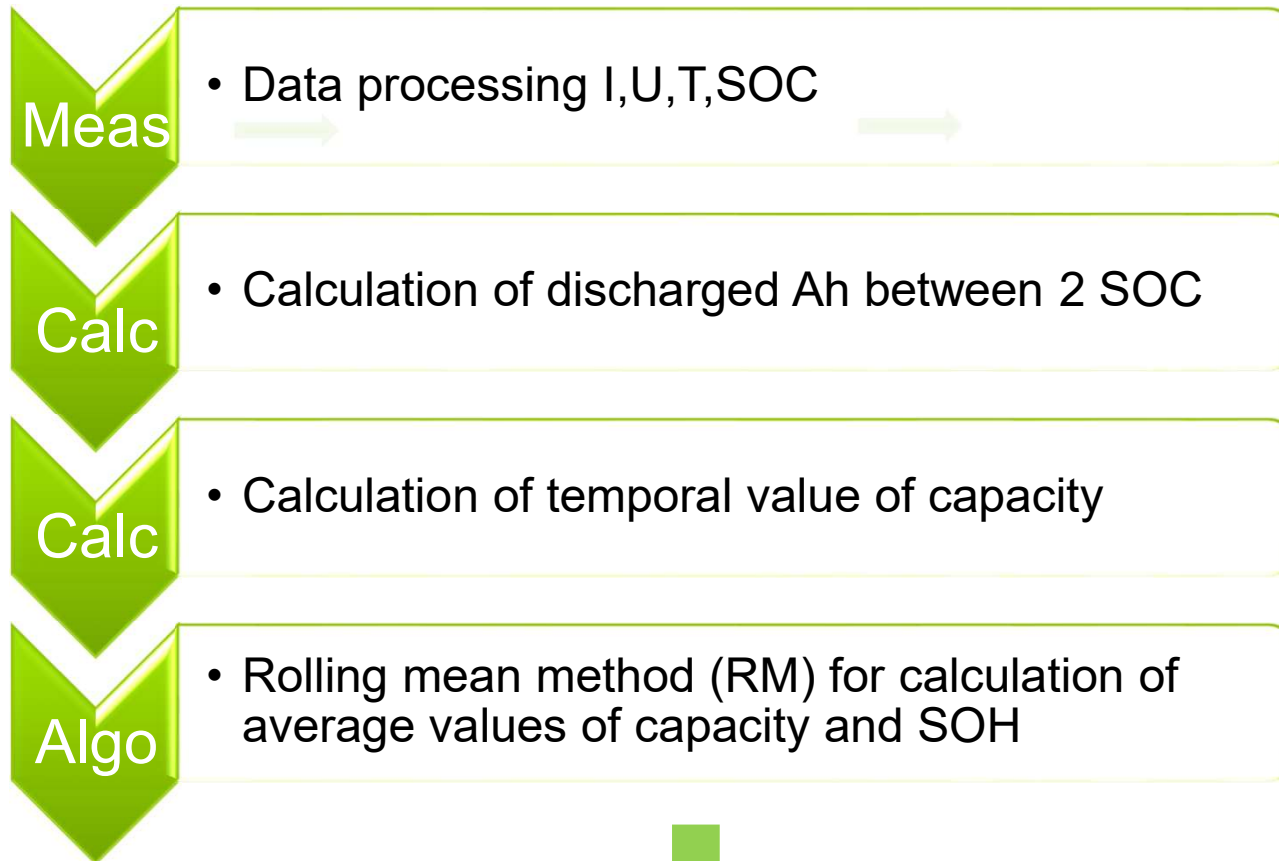


A4 SOFTWARE : ADVANCED DATA ANALYSIS TOOL

Stand alone software available for license or collaboration



1ST APPROACH : BATTERY SOH PREDICTION USING A4 TOOL



$$SOH(\%) = \frac{\text{Capacity at rack level}}{\text{Nominal capacity of the rack}} \times 100$$

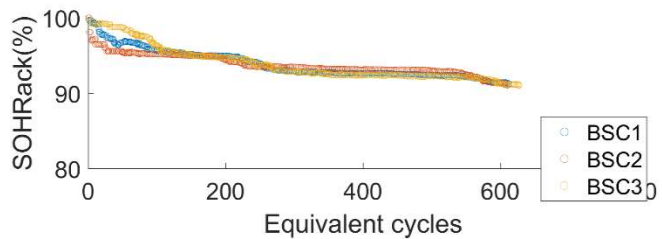
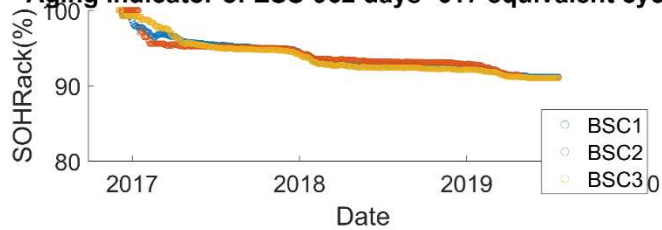


1ST APPROACH : EXAMPLES OF RESULTS ON TWO POWER PLANTS

Polynomial extrapolation for end of life at 80 % SOH

➤ Li-ion ESS

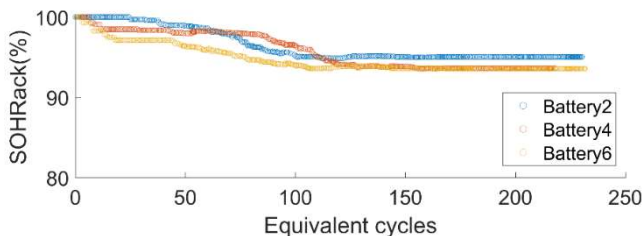
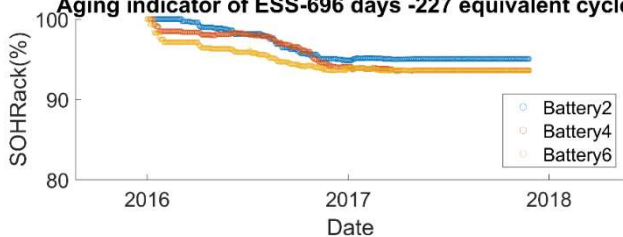
Aging indicator of ESS-962 days -617 equivalent cycles



~ -2,55% / year → > 7 years
~ -0,01% / cycle → 2000 cycles

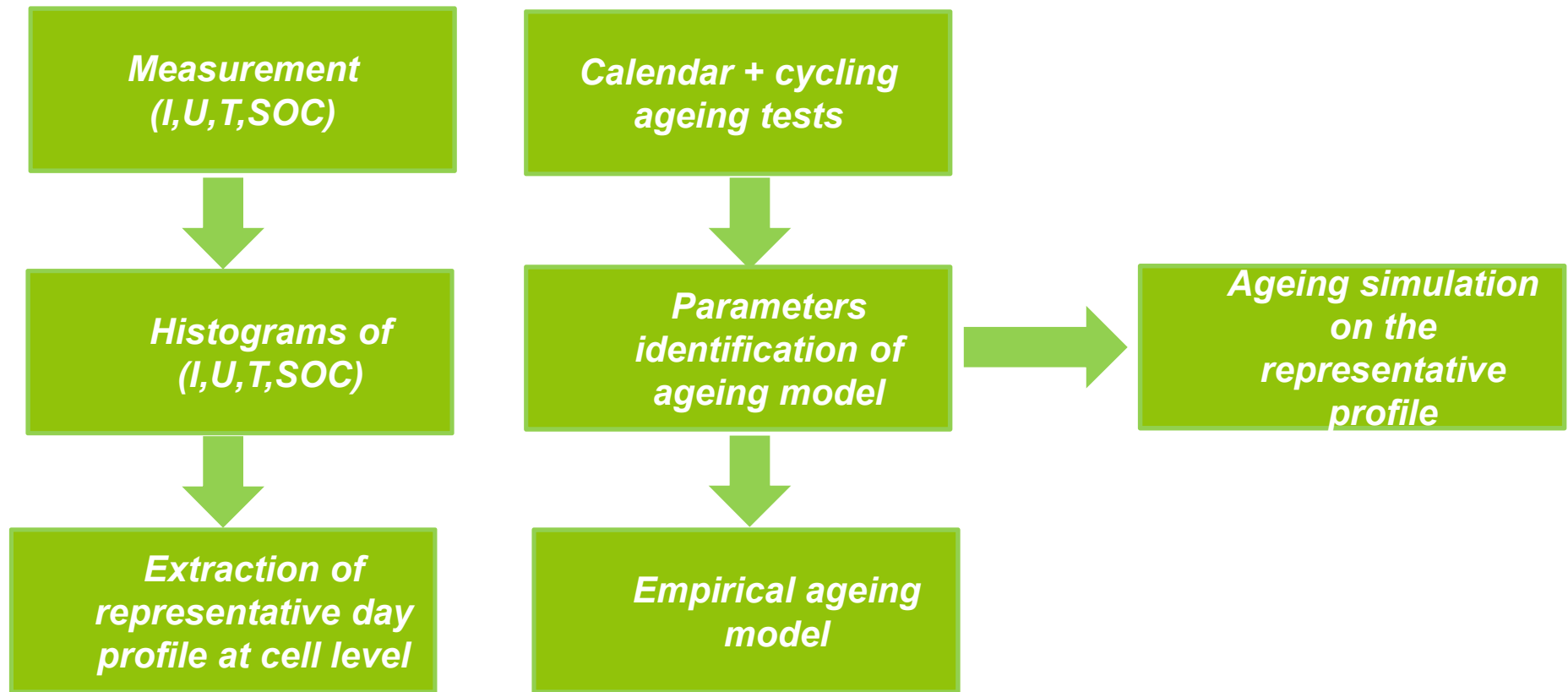
➤ NaNiCl₂ ESS

Aging indicator of ESS-696 days -227 equivalent cycles



~ - 2,23 % /year → ~ 9 years
~ -0,022 % / cycle ~ 890 cycles

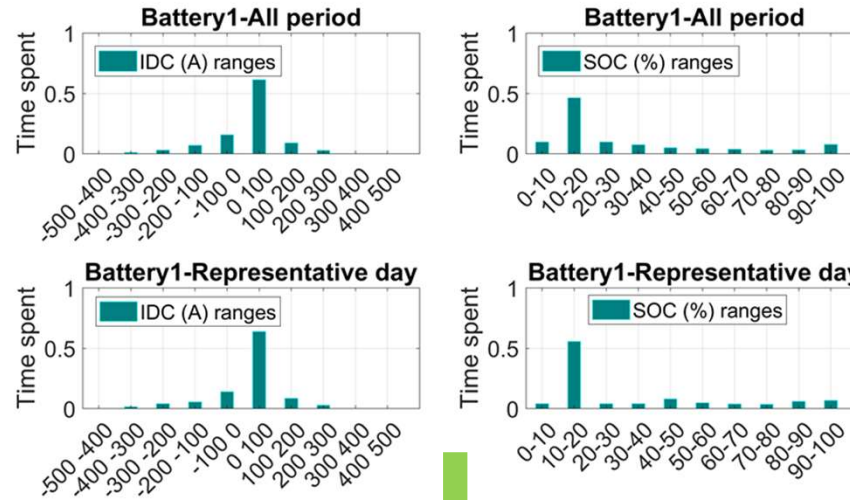
- This approach has been applied on a Li-ion BESS





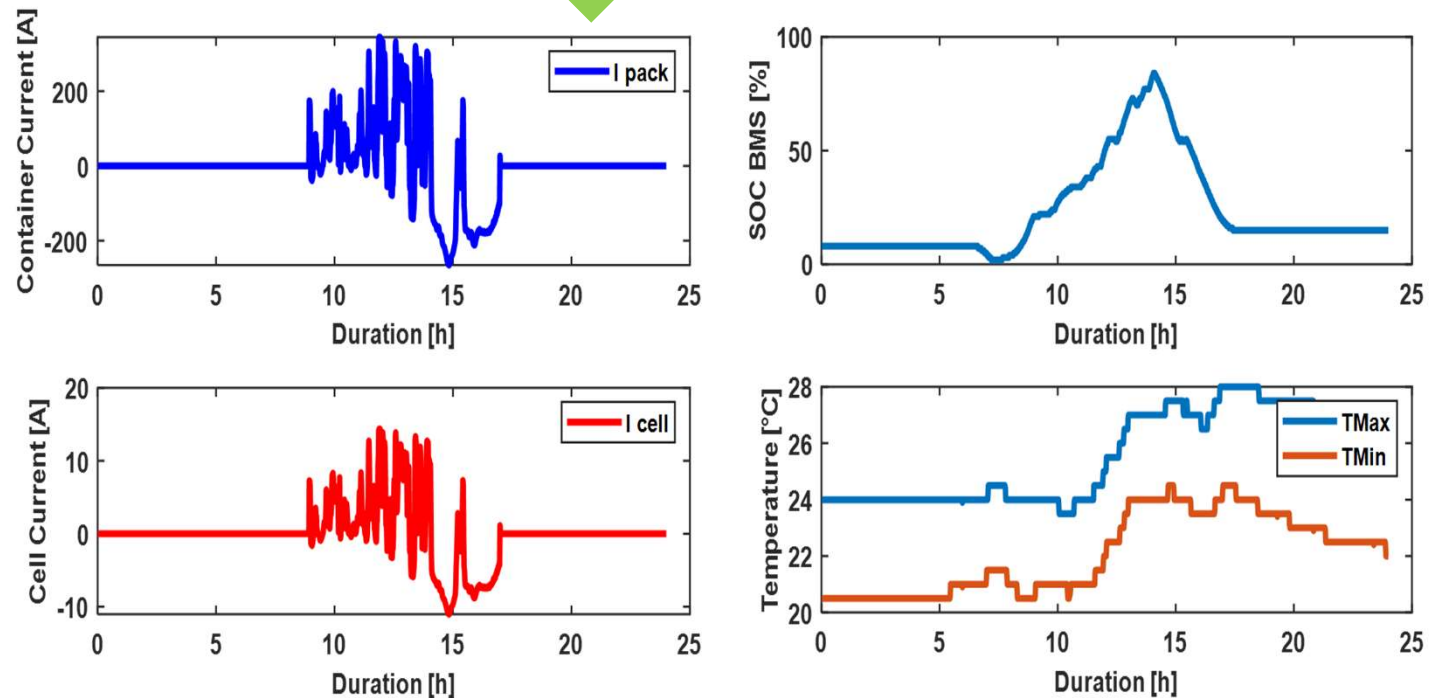
2ND APPROACH : EXTRACTION OF A REPRESENTATIVE PROFILE

➤ 1st Step : histograms



Long period at low SOC and small discharge current

➤ 2nd Step : profile extraction



2ND APPROACH : EMPIRICAL AGEING MODEL

➤ Model equations : cumulate calendar and cycling ageing using degradation laws

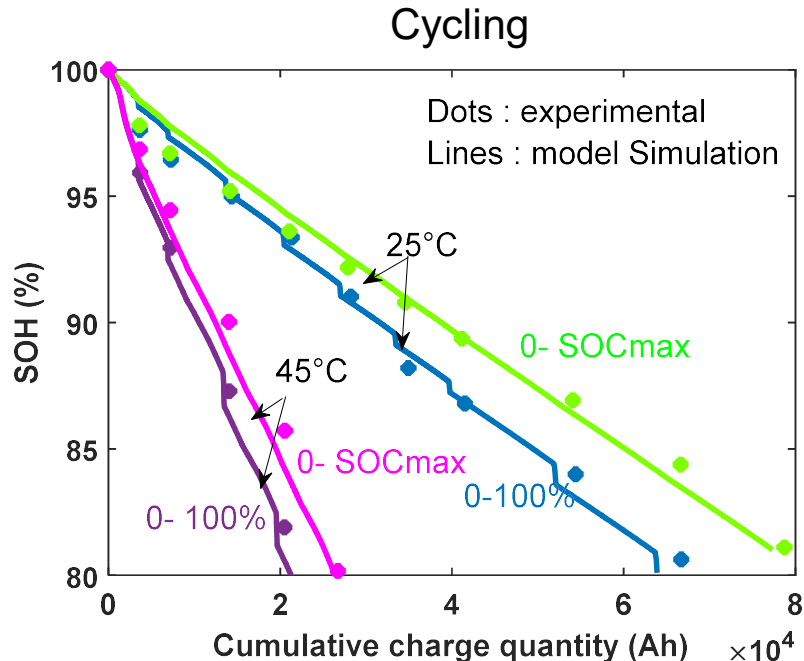
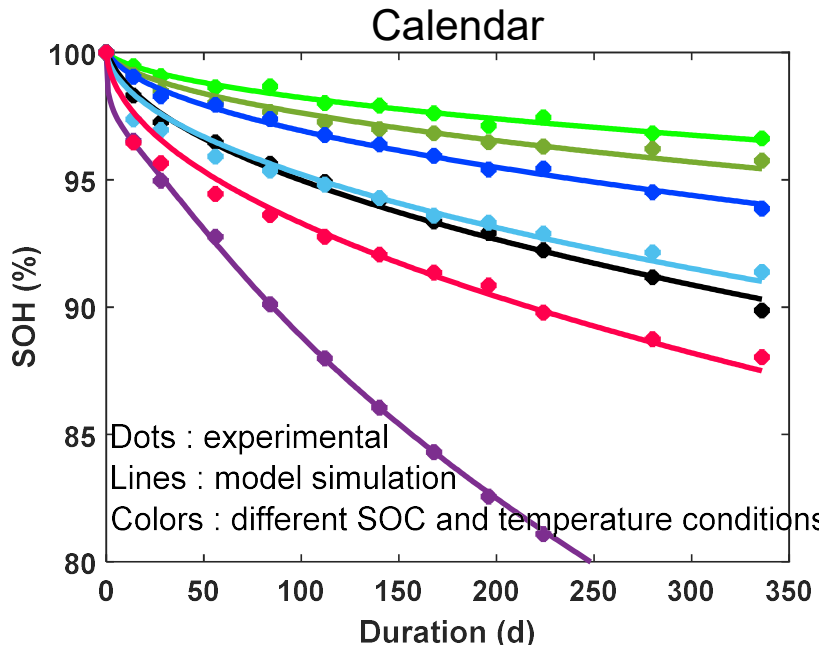
$$dQ_{loss} = \frac{\partial Q_{loss}}{\partial t} dt + \frac{\partial Q_{loss}}{\partial Q_{th}} dQ_{th}$$

$$\frac{\partial Q_{loss}}{\partial t} = \frac{J_{cal}}{1 + A \cdot Q_{loss}}$$

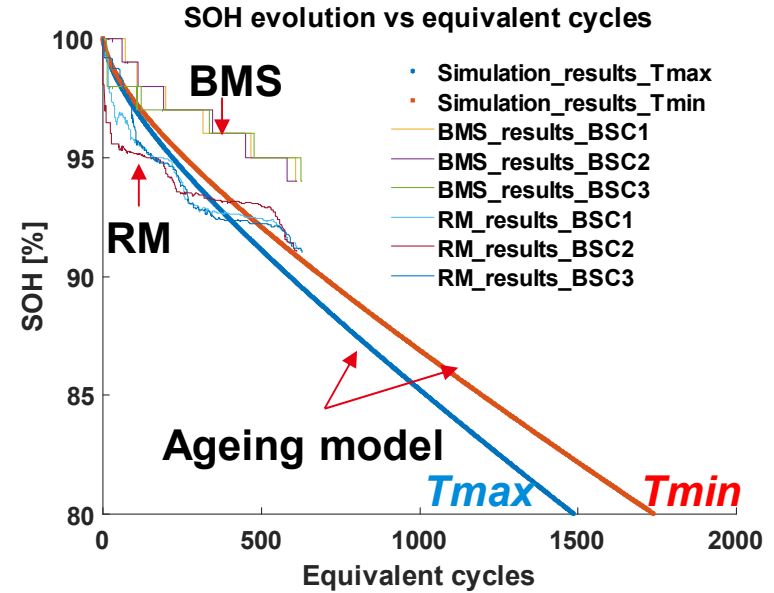
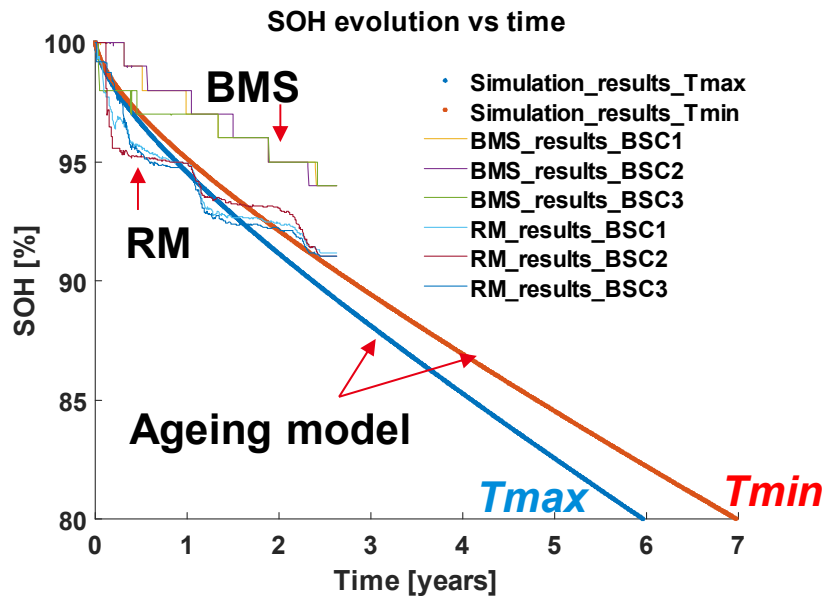
With A and J_{cal} and J_{cyc} to be identified using experiments

$$\frac{\partial Q_{loss}}{\partial Q_{th}} = J_{cyc}$$

➤ Model identification on experimental results



MODEL SIMULATION ON USE PROFILE VS A4 RESULTS



- Good correlation of the model with A4 rolling mean method (RM) results
- Lower ageing from BMS
- Capacity check will be done in order to verify SOH



CONCLUSION AND PERSPECTIVES

- Analysis of on-grid energy storage systems → Advanced data Analysis tool (A4)
- Rolling mean method for SOH prediction in A4
- An empirical ageing model (calendar + cycling) for Li-ion batteries
- Simulation of a representative profile of peak shaving of PV application on a Li-ion BESS
- Correlation between A 4 and ageing model results
- Possibility of prediction of the SOH of the studied Li-ion BESS → 6 to 7 years and 1500 to 2000 cycles before 80% SOH

- Perspectives :
 - Capacity check of the BESS to complete validation of the results
 - Application to the BESS of the demonstrators in OSMOSE project in the framework of WP7
 - Development of other diagnosis and prognosis functions



THANK YOU FOR YOUR ATTENTION !
QUESTIONS?



European
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Horizon 2020
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for Research & Innovation

Commissariat à l'énergie atomique et aux énergies alternatives
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www-liten.cea.fr

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