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The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION.

Barcelona, Spain
17th-20th November 2013

HCV Hybrid Commercial Vehicle

ENEA

Energy storage tailored-test programme for HD hybrid vehicles in a European Project

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Presentation Outline

1. *The HCV Project*
2. *Scope and objectives of HCV Energy Storage Characterization*
3. *Tailored-HCV ESS Test procedures*
4. *Chief test results so far achieved*
5. *Conclusions*

Project general information

HCV
Hybrid Commercial Vehicle

Project full title:	Hybrid Commercial Vehicle
Coordinator:	Volvo Technology AB
18 Project major partners:	Volvo, Altra, AIT, AVL, Bosch, CERTH, CRF, DAF, Kollmorgen, DIMAC RED, ENEA, Iveco, Magna E-car, Univ. Pisa, IDMEC, Solaris, TNO, VERI
Starting Date:	2010-01-01
Ending Date:	2013-12-31
Budget Total/ EC Funding:	17.6 MEUR / 9.9 MEUR
Type of project:	Integrated project

HCV Motivation and objectives

HCV
Hybrid Commercial Vehicle

Motivation

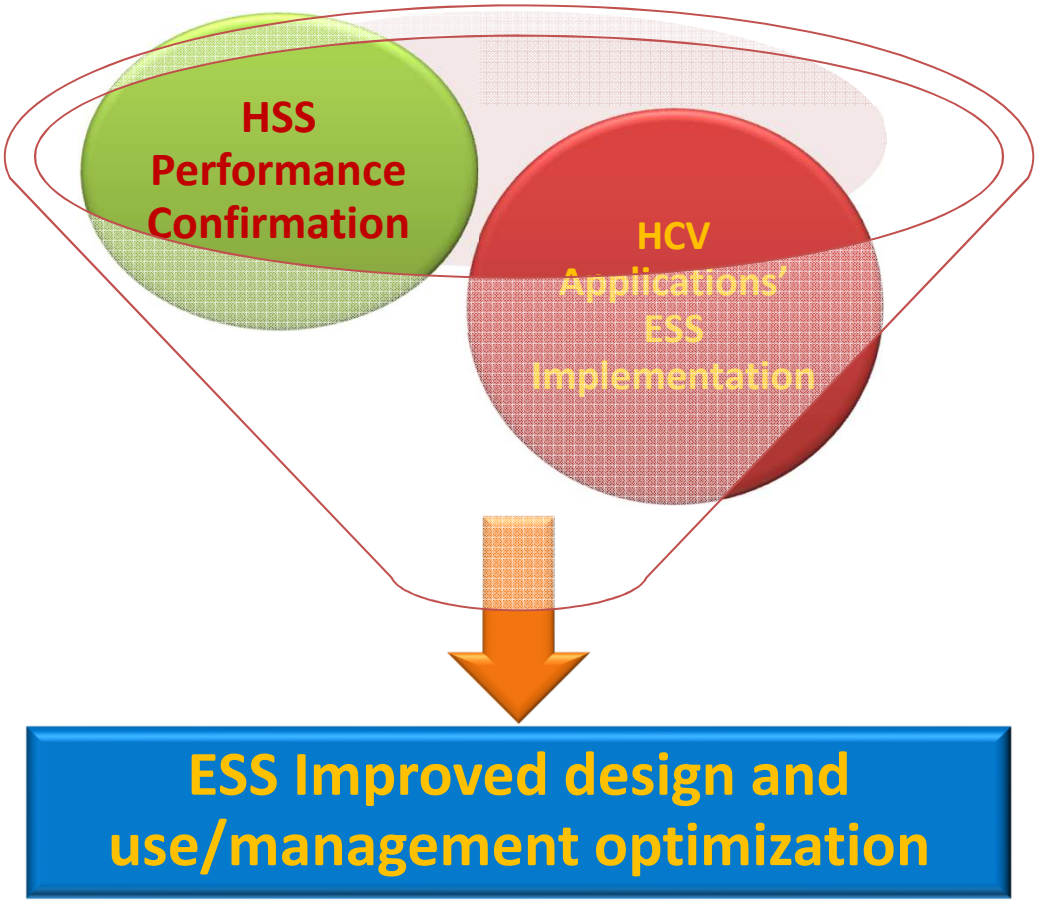
Hybridisation of urban transport vehicles can help to reduce the CO_2 emissions. However, the **purchasing costs** are **high**, and research to **reduce cost and enhance efficiency** is necessary.

HEV Buses and Commercial Vans

Objectives

Development and demonstration of the current HD HEVs for the next generation of lower cost and higher efficiency commercial HCVs

Energy Storage Systems (ESS) SubProject ***Scope***



Rationale behind tailoring test procedures

1. Novel Lithium-ion and Supercapacitors (SC) technology
   - ✓ ***Learning phase (basic standard procedures)***

2. Novel applications in improved HD HEVs with challenging technical and economical targets
   - ✓ ***ESS implementation for HCV Project applications (design and use optimization even with modelling)***

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*HCV **tailoring** ESS test programme approach: **ADAPTATION+RESEARCH***

Existing procedures

- *EUCAR test procedures for Li batteries and SCs*
- *EUCAR procedures for Li accelerated and abuse test*
- *USABC-Freedomcar Test Procedures*
- *Various ISO-IEC standards*

Adapted to HCV expected performances + Modelling

- *Electrical duty cycles*
- *Working temperature windows*
- *Cycle life (tailored + accelerated)*
- *Modelling for BMS , SOC, SOH and SOL*

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Samples to be tested: ***Li-ion technology (Iron Phosphate)***

2 different system configurations: 45 kW (van) and 120 kW (bus) – Tested cells and modules only

Li-ion cells (4,4 Ah, 3,3 V_{nom}, 14,50 Wh, 560 W, about 0,205 kg)

Li-ion module (8,5 Ah, 59,4 , 505 Wh, 11,25 kW, about 10 kg)

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Samples to be tested: ***Supercapacitor technology (EDLC)***

1 system configuration: 45 kW (van)
Tested cells and modules only

SC cells (3000 F, 2,7 V, 3,03 Wh, about 0,55 kg)

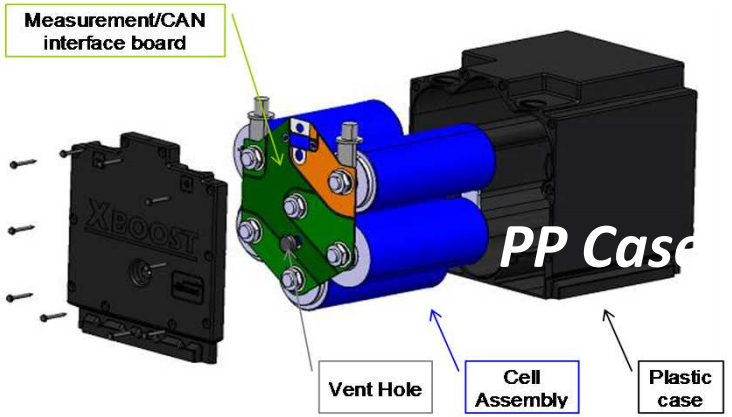

Figure 2, Exploded view of the single supercapacito module XBoost 500

SC module (3 generations: 500 F, 125 V, 136 Wh, about 4,4 kg)

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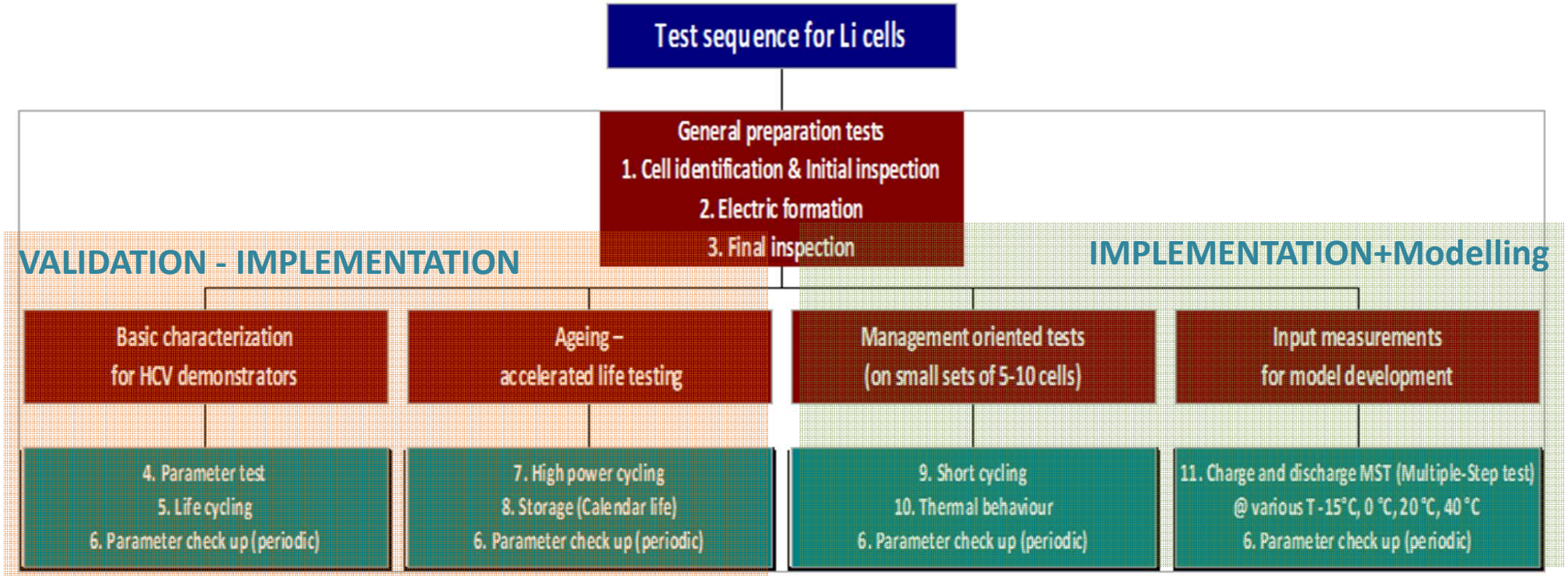
Block diagram for electrical test sequence + abuse testing

Li cells and modules (similar for SC)

HCV Electrical Test Procedures for Li cells adapted to two HEV demonstrators



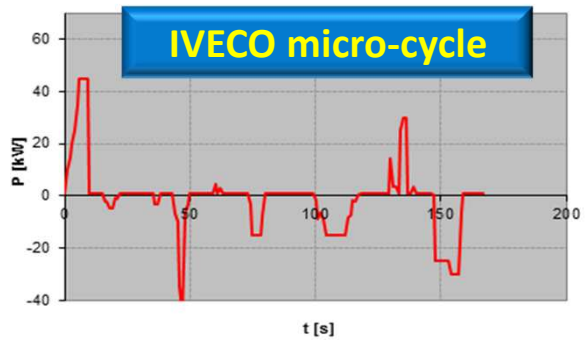
Tailoring of HCV test procedures

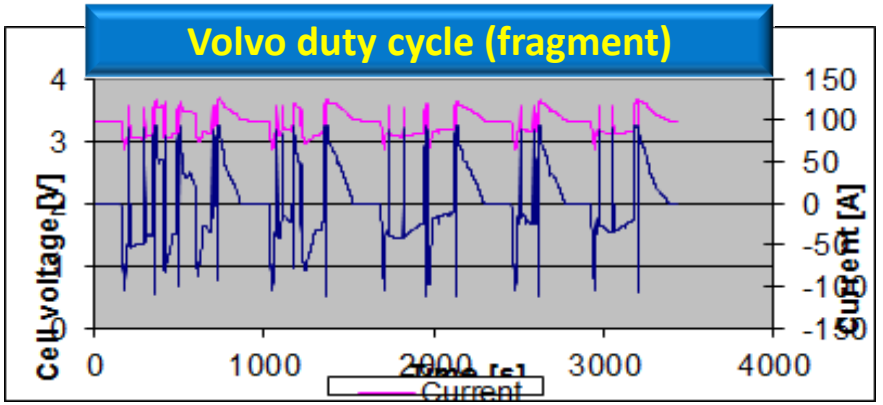
Introduction of HCV-specific operating conditions

1. Definition of temperature windows (20, 30 and 40 ° C) with defined variations in a complete operation year

2. HEV operations in IVECO van: repetition of a micro-cycle lasting 167 sec (1 km travelled) for 45,000 times in a year (180 times in a day)

3. For Volvo bus, an experimental cycle to be repeated continuously





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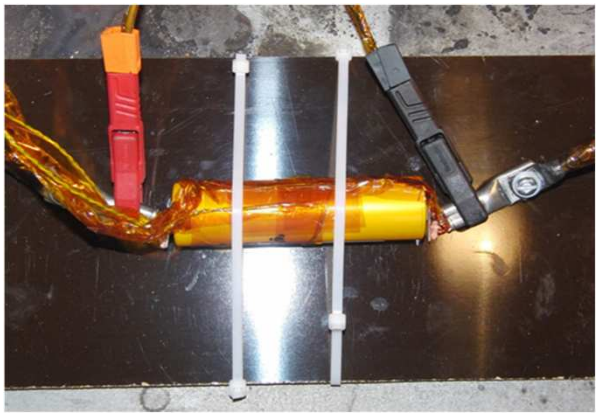
Chief results

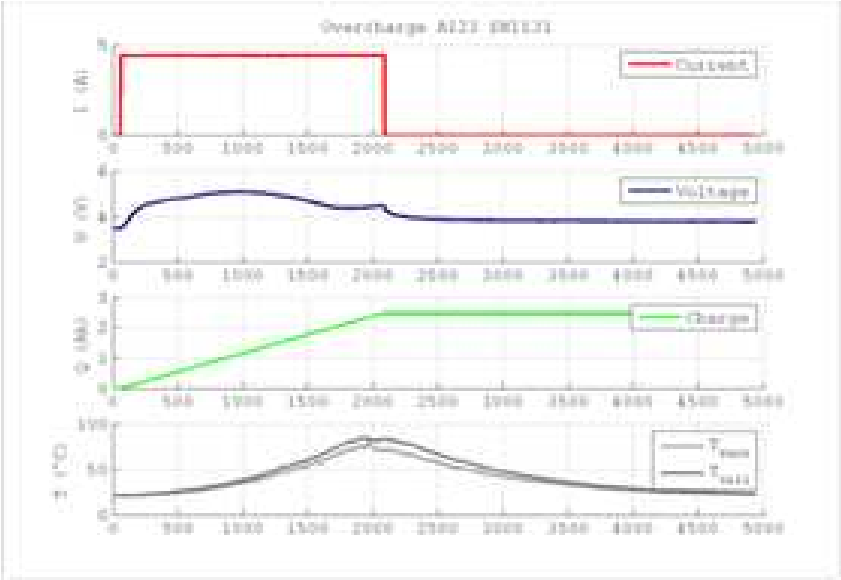
Abuse Testing

1. ***Mechanical (vibration)***
2. ***Thermal***
3. ***Electrical***
4. ***Mixed (for example mechanical and electrical together)***



Setup for overcharge test. 4 wire sensing, 3 thermal sensors (2 surface, 1 valve)

Measured values for SOC=150%



Chief results

Abuse Testing/2

SC in hydraulic press for Controlled Crush Test

SC cell deformation after crush test

Li Cell after thermal stability test. Release of electrolyte through hole in casing

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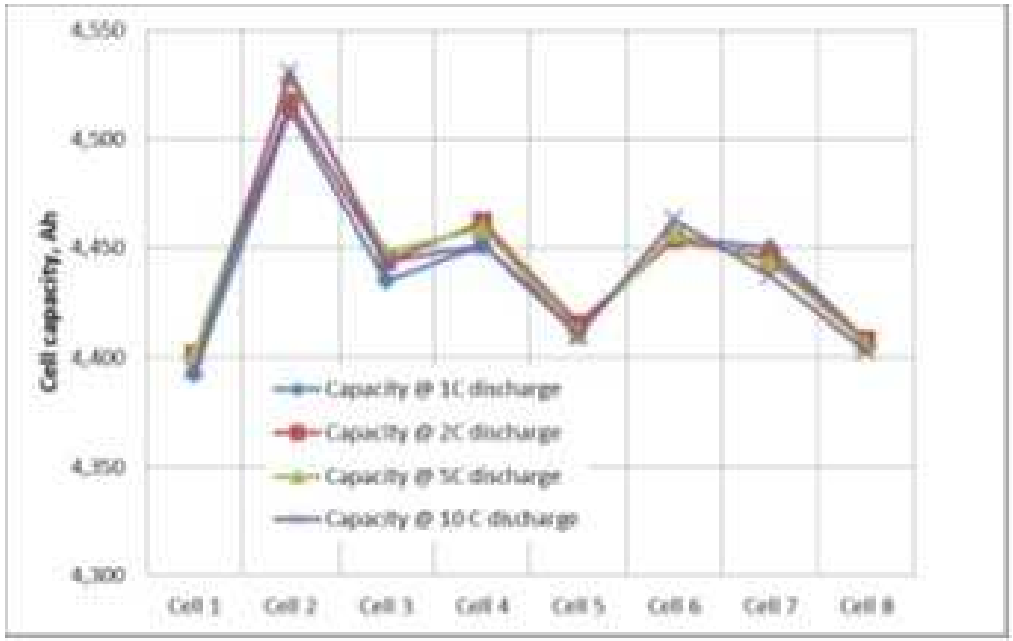
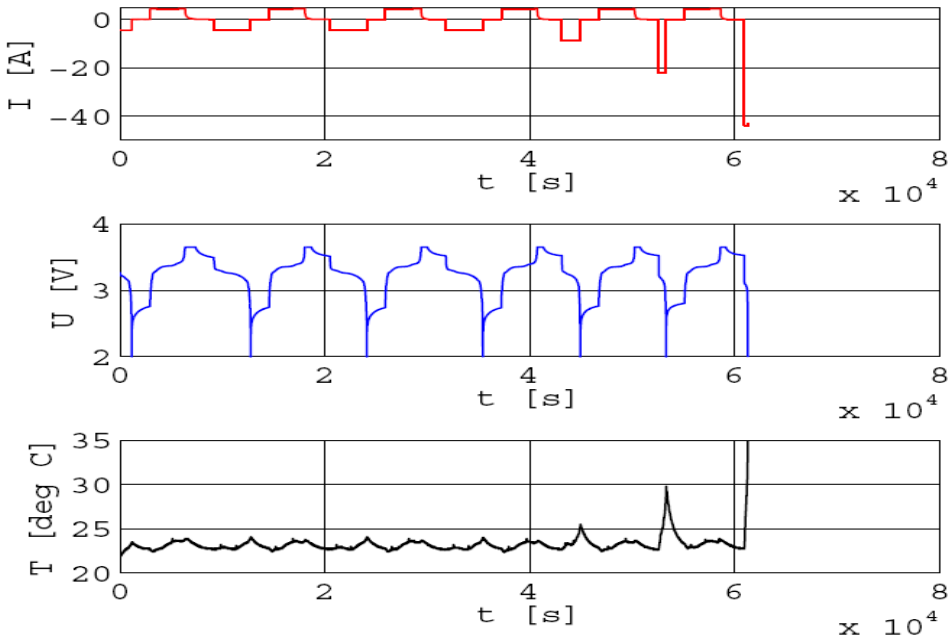
Chief results

Electrical Testing on cells/1



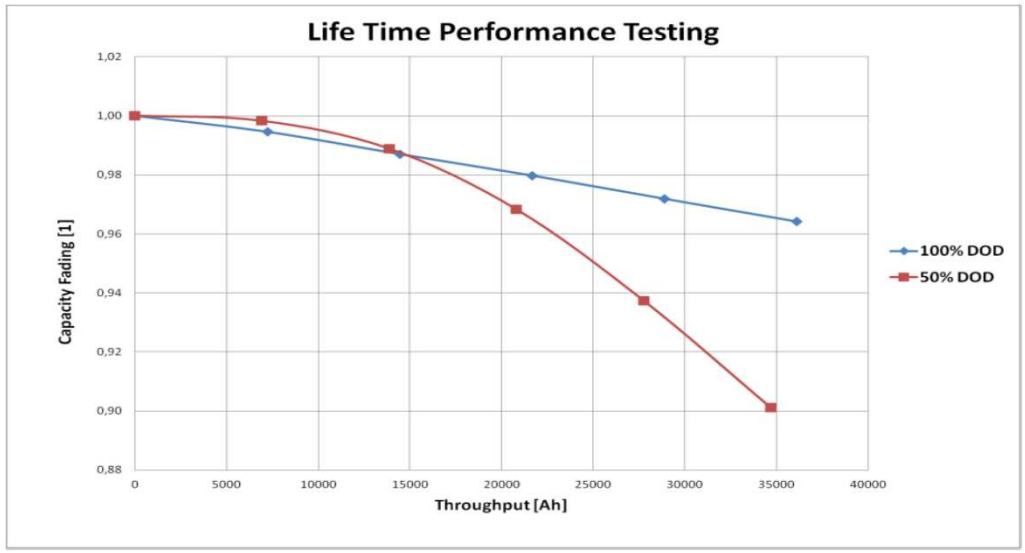
Capacity determination tests At various discharge rates



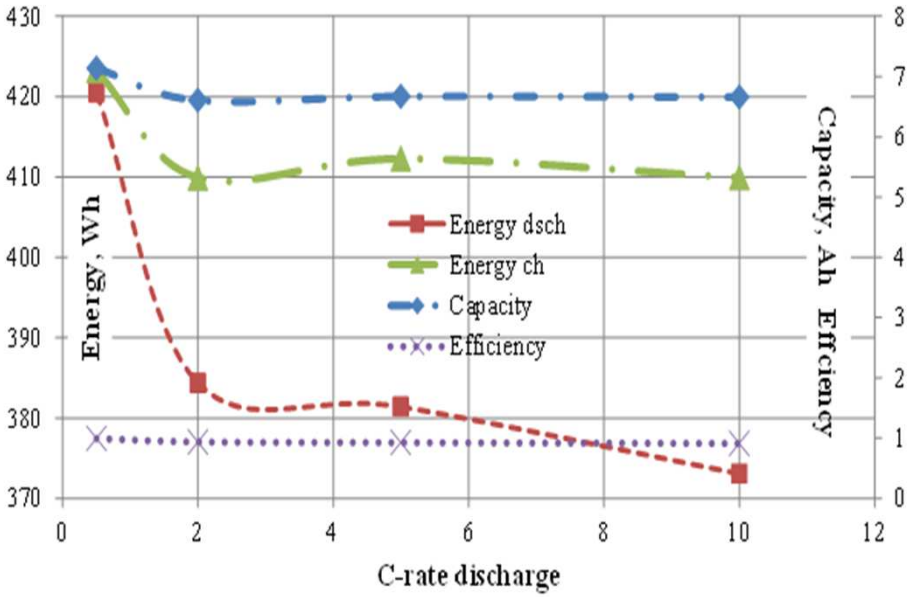
Measured parameters during capacity tests

Chief results

Electrical Testing on Li modules



Comparison of module capacity decline of two Li modules during life testing



Summary of test results on modules

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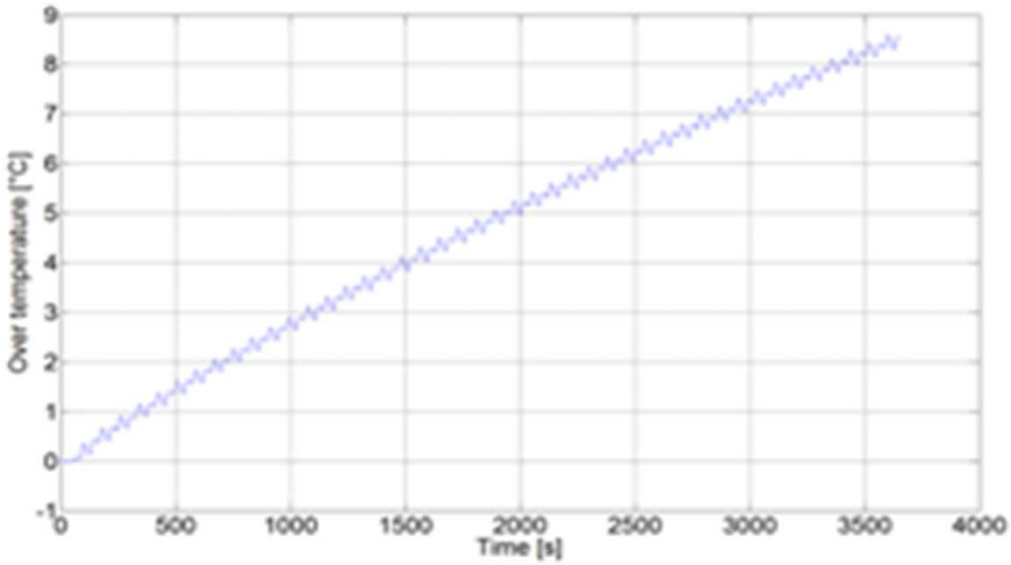
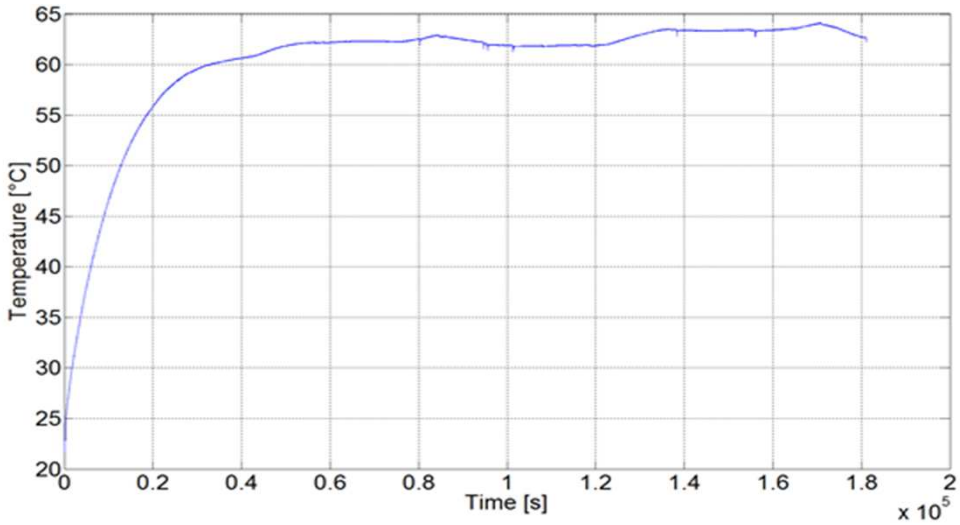
Chief results – Cooling behavior

Electrical Testing on SC modules



Overheating of an SC module after one hour of life cycling test: cooling behavior and needs



Module temperature increase during power cycle: 63 °C well beyond of the limit of 5 °C of variation without cooling system. Is it acceptable?

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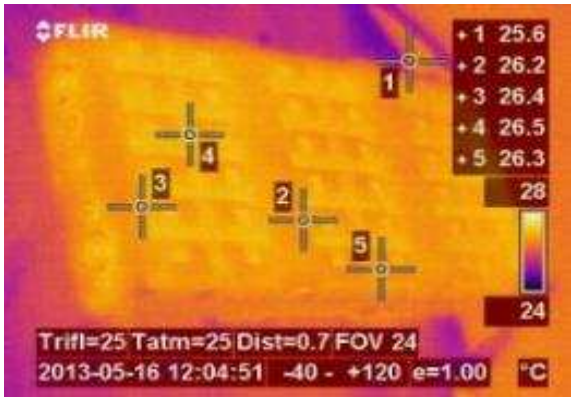
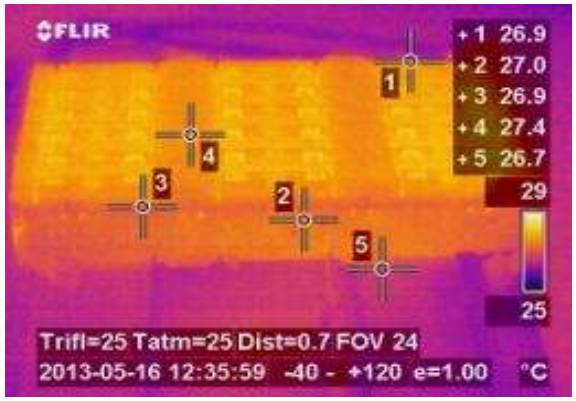
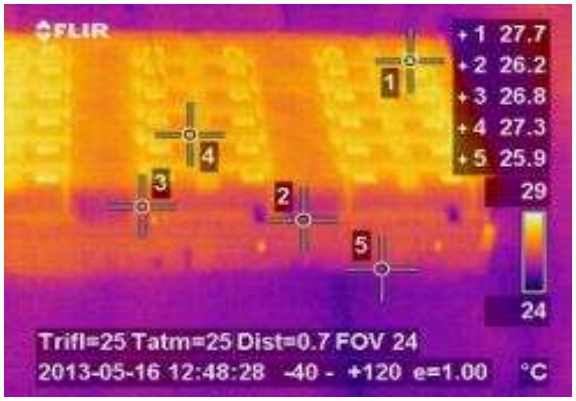
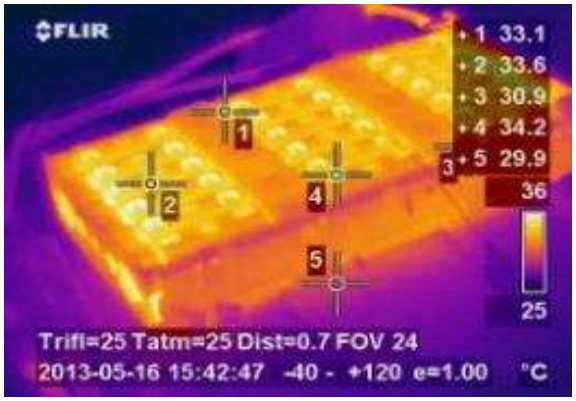
Chief results – Thermal behaviour

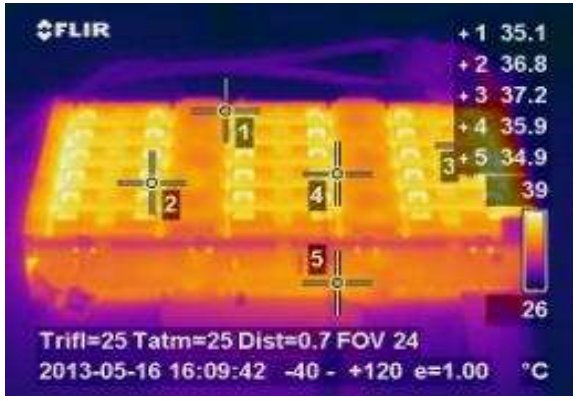
Electrical Testing on Li modules

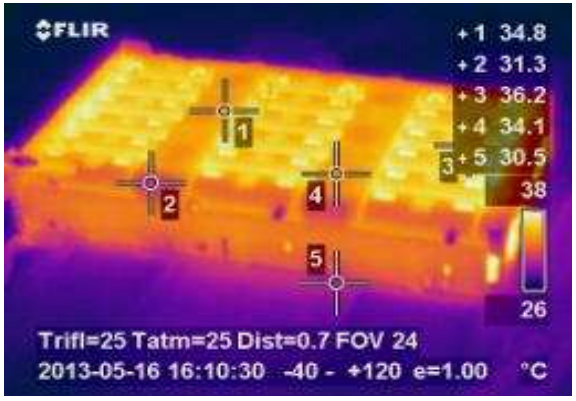












Thermography studies for thermal management optimization

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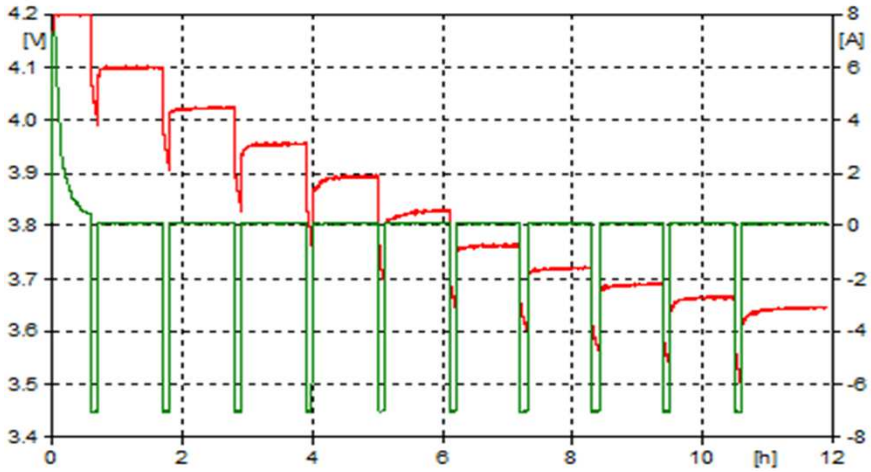
Testing for modelling

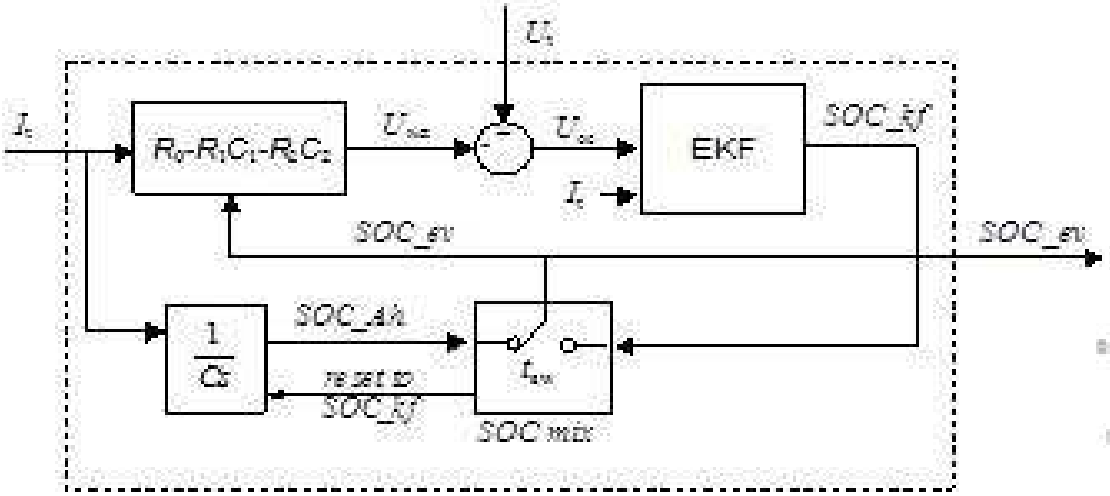
Test matrix for modelling					
temperature/°C test type		15	0	20	40
charge-based MST		X	X	X	X
discharge-based MST-		X	X	X	X

Multiple Step Test for modelling

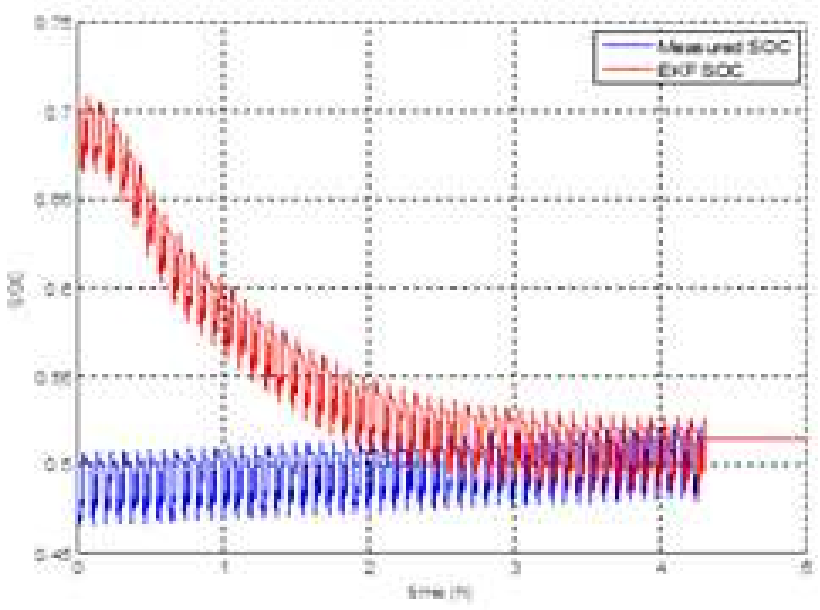


Testing for modelling

Results



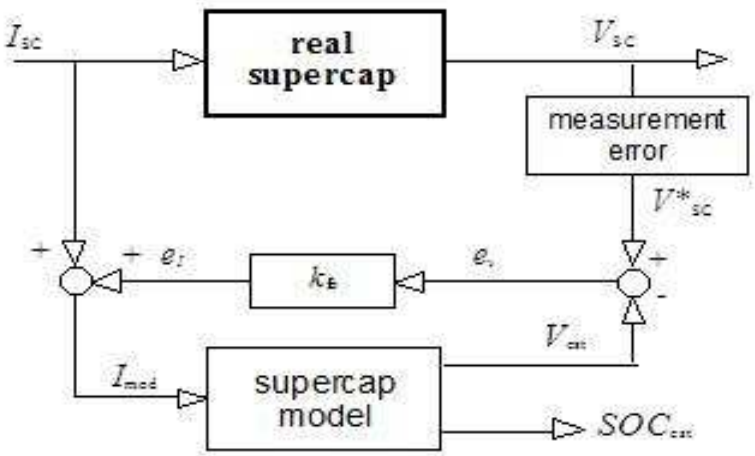
Block diagram for Li cell SOC estimator based on EKF – Extended Kalman Filter



Experimental evaluation of battery SOC estimation using the EKF-based model, applied to an aged cell, for ALTRA road cycle

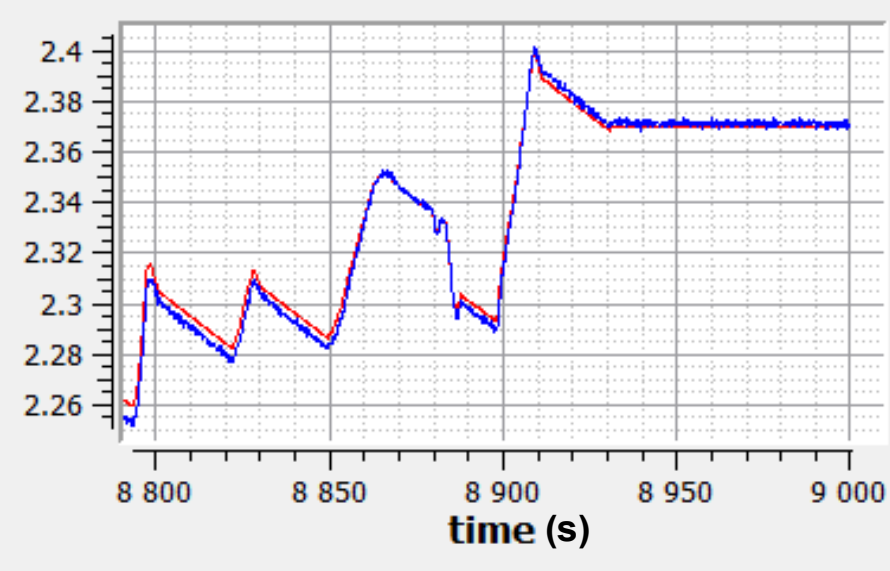
Testing for modelling SC cells

Results



The Luenberger SOC estimation/block diagram in presence of measurement errors on voltage

SOC estimation for an SC cell during transient. VERY GOOD FIT!!!



Conclusions

The ESS tailored testing gives beneficial inputs to HCV vehicle optimization

Abuse testing on Li and SC cells confirmed the high maturity of the used technologies, never showing uncritical behavior.

Thermal management requires attention for both technologies thanks to temperature mapping and thermography

The modelling has been successful in defining and validating algorithms for SOC estimation with high accuracy

Ongoing life and accelerated tests are expected to give further indications for optimization, modelling and cost estimations

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I thank first the organizations contributing to the work described and all of you for the attention !!!

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