A Smart Control Strategy for a Battery Thermal Management System: Design, Validation and Implementation

Authors:

• Mikel Arrinda	CIDETEC Energy Storage. marrinda@cidetec.es
• Gorka Vertiz	CIDETEC Energy Storage
• Christophe Morel	CEA
• Nicolas Hascöet	CEA
• Pierre Woltmann	AUDI AG
• Alois Sonnleitner	Miba eMobility GmbH

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Author introduction

Mikel Arrinda received the B.S. in Industrial Electronic Engineering in 2012 from MU, Mondragón, Spain. In 2013 he received the M.S. in Integration of Renewable Energy Sources into the Electricity Grid by UPV, Bilbao, Spain. After three years of activity in a private company, in 2017, he began his current career as a Scientific Researcher at the Energy Storage Unit of CIDETEC. He received his PhD in engineering in 2020 where his research focused on degradation, life prediction, and sizing of lithium-ion battery-based energy storage systems. He is currently the technical coordinator of i-HeCoBatt European project, grant agreement 824300. His current interests are SOX estimators, aging modelling, thermal modelling, thermal control, diagnosis, prognosis, and the application of machine learning tools in each of the aforementioned interests.

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Research activity ongoing

EU Projects through the value chain:

Running EU Projects as Coordinator:

- ✓ i-HeCoBatt
- ✓ e-magic
- ✓ INNPAPER
- ✓ DEFACTO

Running EU Projects as a partner:

- ✓ BATTERY 2030+
- ✓ Si-DRIVE
- ✓ SPIDER
- ✓ VIDICAT
- ✓ SAFELiMOVE
- ✓ BIG MAP
- ✓ CoFBAT
- ✓ ICARUS
- ✓ COBRA
- ✓ SPARTACUS
- ✓ ALBATROSS

Li ion › Post Li ion › Li - free › Modelling › Engineering ›

Coord. CIDETEC

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Context

i-HeCoBatt - Intelligent Heating and Cooling solution for enhanced range EV Battery packs

IA
Innovation Action

Grant agreement ID: 824300

Start Date – 1st January 2019

i-HeCoBatt

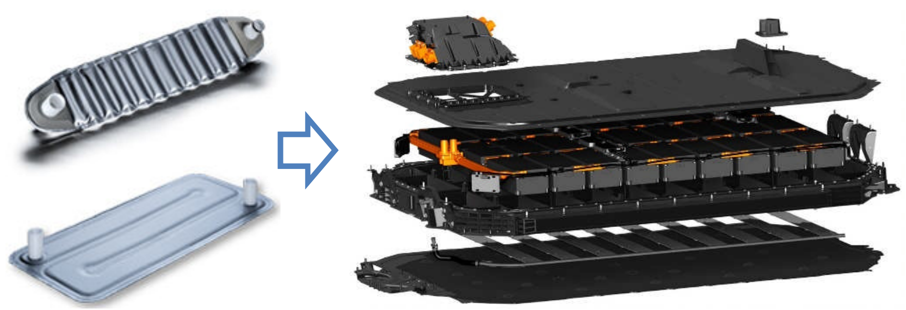
End Date – 30th June 2022

Programme H2020-EU.3.4. - SOCIETAL CHALLENGES - Smart, Green And Integrated Transport

Proposal Call
H2020-LC-GV-2018

Topic: Integrated, brand-independent architectures, components and systems for next generation electrified vehicles optimised for the infrastructure.

- The project team consists of 6 partners from 4 European countries, including **AUDI** (Germany), **CEA** (France), **DATIK** and **LOMARTOV** (Spain), **MIBA** (Austria).
- The project is coordinated by **CIDETEC** (Spain).



*MIBA's FLEXcooler® technology

SO3: To integrate **new components and functionalities** leading to higher user friendliness, reduction of range anxiety and temperature impact on degradation of the BP.

Smart BTMS Control Strategy

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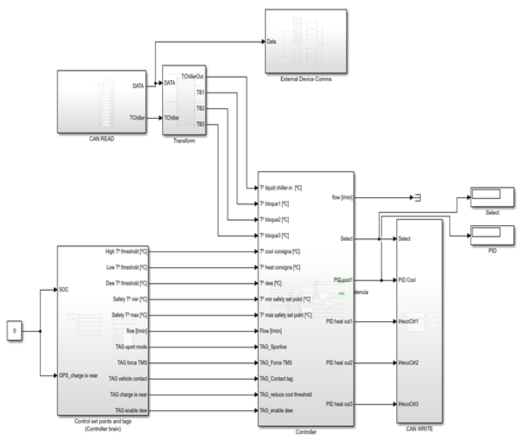
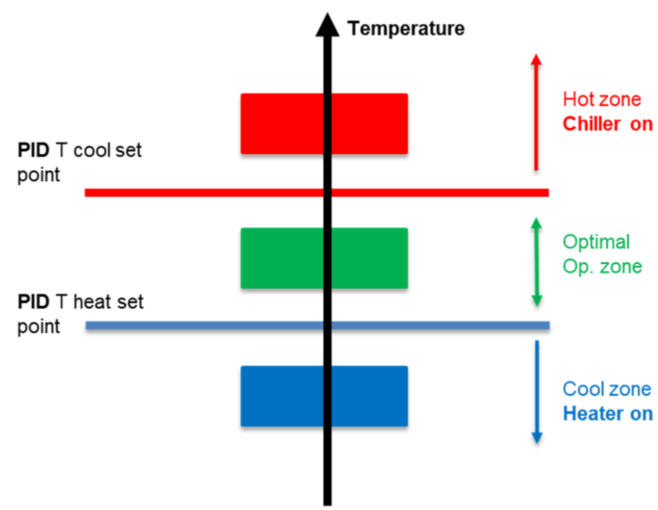
Approach

The designed TMS strategy is a mix of **PID controllers** and **state diagram controller’s concepts**.

The result is a smart control strategy that brings the system to a stable state while adapting smartly to different scenarios and objectives





- **Reduction of Tº chiller set point if low SOC**. The set point is reduced in 10ºC.
- **Aggressive PID control when sportive driving selected**. The controller cool downs faster and it maintains longer.
- **Conservative heating when the vehicle is parked**. Only heat if safety minimum temperature is reached.
- **Forced heating at scheduled hour**. The heating control can be switch on even when parked (ex.: from phones).

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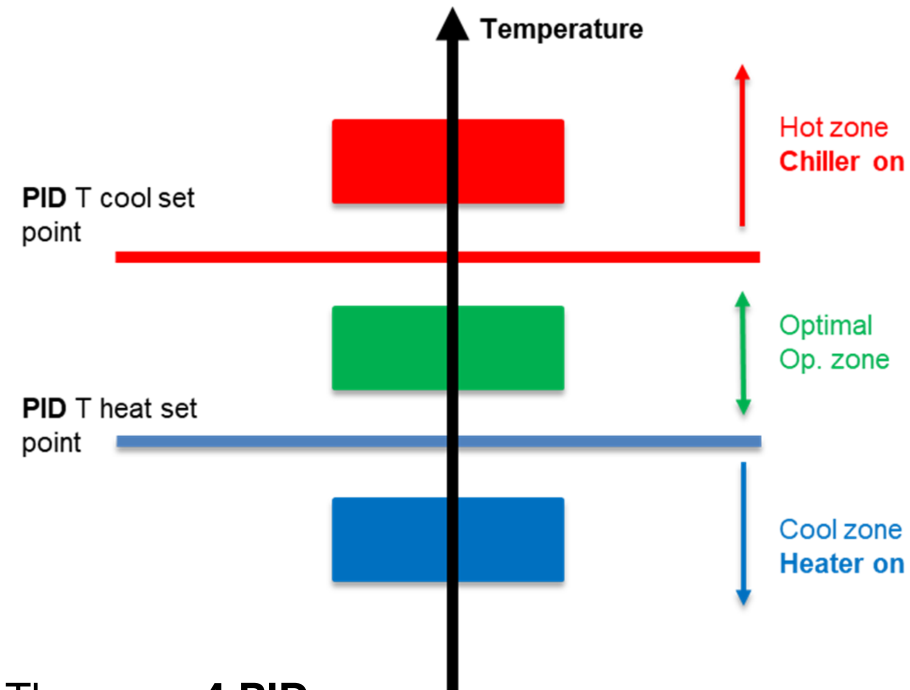
PID controllers

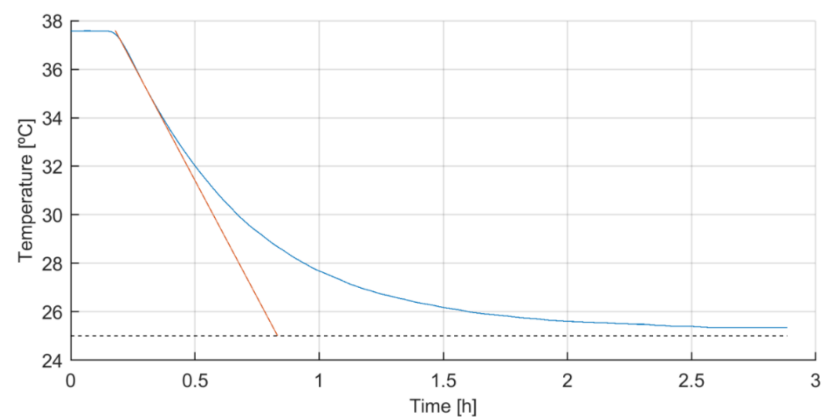


3 main states are defined:

- **Cool zone (heating).**
- **Optimal operation zone (rest).**
- **Hot zone (cooling)**.

There are **4 PIDs**.

- **3** control the three independent heating resistance areas that are in direct contact with the batteries.
- **1** controls the chiller used to cool down the liquid that goes through the heat exchanger.



Parameter	Equation	Heat Exchanger A-sample
P (Kp)	1,2 x T / (L x yf)	10.5945
I (ki)	Kp / (2 x L)	0.0227
D (kd)	Kp x 0,5 x L	1238.3
N (td)	>100	105

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Smart features

- **Reduction of Tº chiller set point if low SOC**. The set point is reduced in 10ºC.
- **Aggressive PID control when sportive driving selected**. The controller cool downs faster and it maintains longer.
- **Conservative heating when the vehicle is parked**. Only heat if safety minimum temperature is reached.
- **Forced heating at scheduled hour**. The heating control can be switch on even when parked (ex.: from phones).

To **lengthen the life** of the vehicle:

- **Optional sport mode**. The aggressivity of the controller is modified at the driver's will. The adjustment of the controller to the driver characteristics decreases the aging.
- **Preconditioning when parked**. The heating when parked is set to the state of having the contact switched on. It reduces the aging that comes from cold or hot starts (depending on the room temperature).

To **lengthen the use range**:

- **Conservative cooling-heating when parked**. The temperature thresholds of the controller are modified to increase the optimal operation zone. Unnecessary energy consumption is avoided when parked.
- **Reduction of temperature set point** if conditions are met. The detection of an imminent charge event leads to reduce the upper temperature threshold. The efficiency of charge events is maximized.

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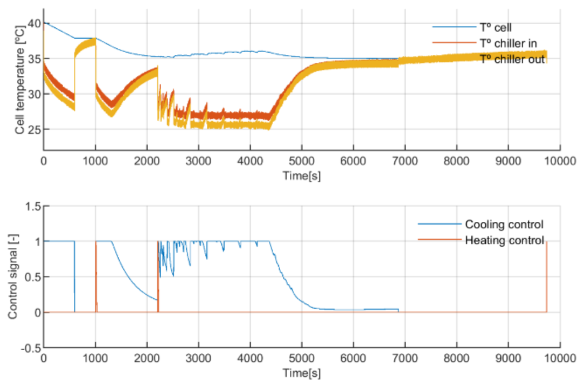
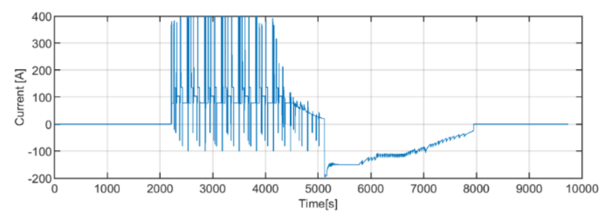


ity of the controller.

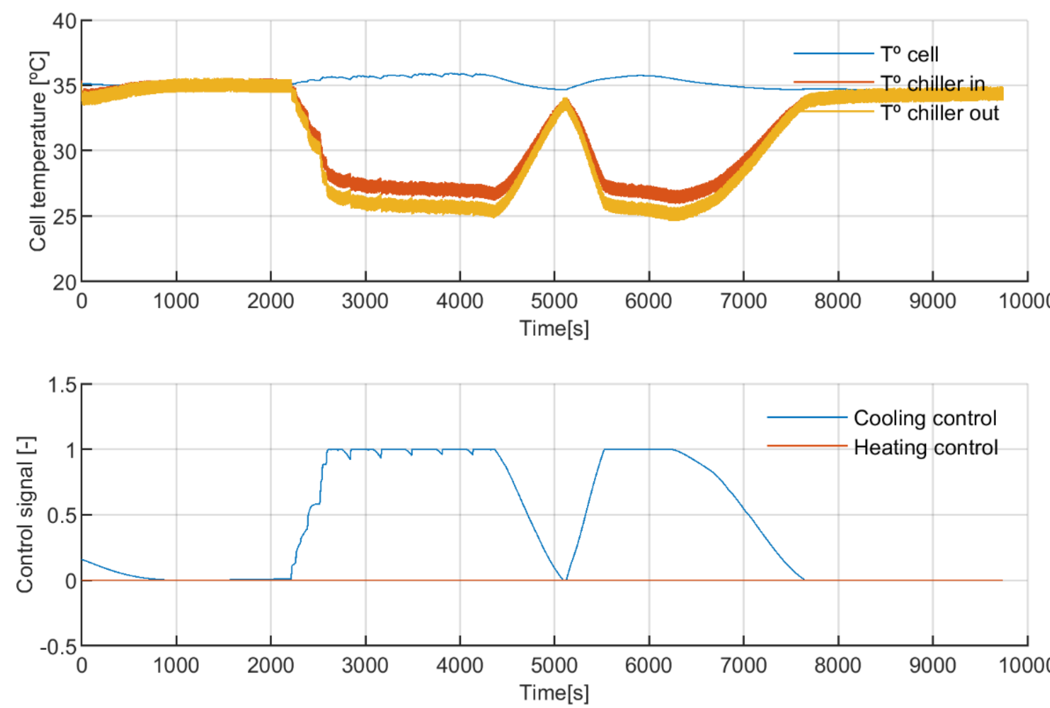
Variables:

- Current:



- Room temperature: 35ºC.
- Sport mode: off.
- Contact: on.
- Pre-conditioning: off.
- GPS tag signal: off.

results



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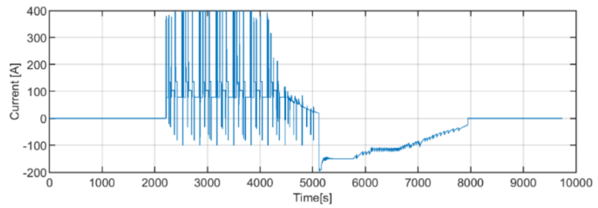
Simulations

2nd: validate the overall stability of the Sport mode used for aggressive drivers.

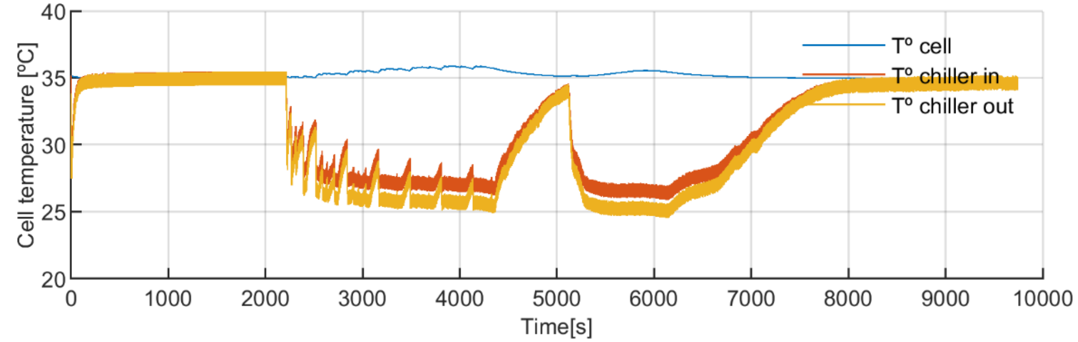
Variables:

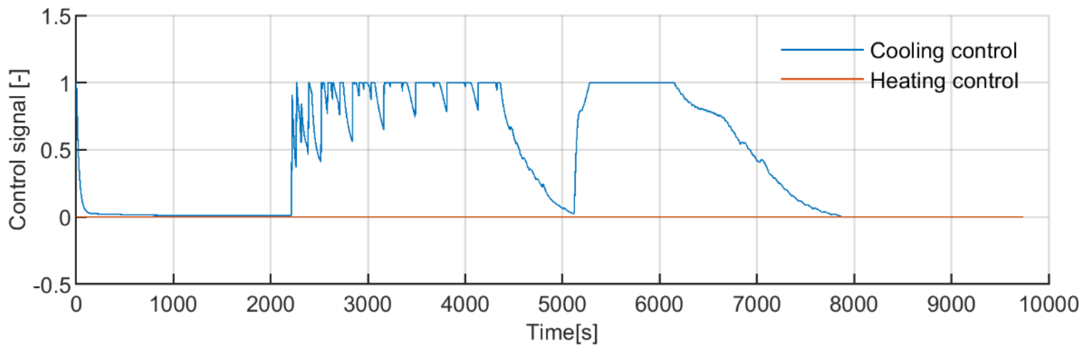
- Current:



- Room temperature: 35ºC.
- Sport mode: on.
- Contact: on.
- Pre-conditioning: off.
- GPS tag signal: off.

results





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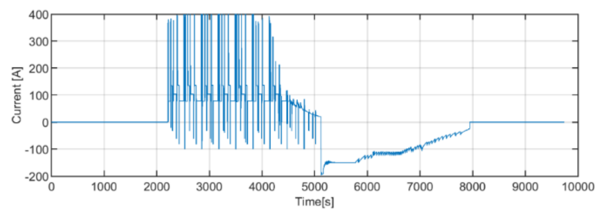
Simulations

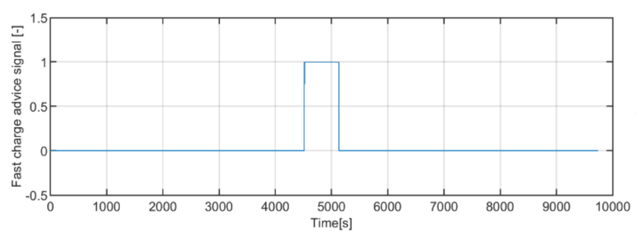
3rd: validate the efficacy of the added feature that maximizes the charge event.

Variables:

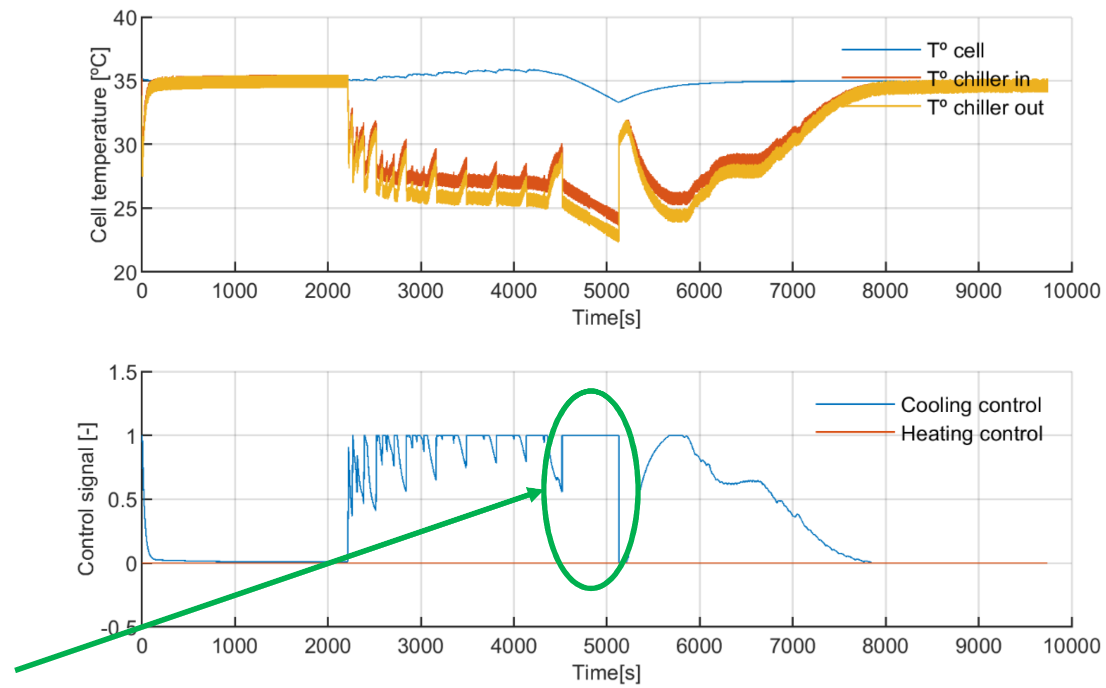
- Current:



- Room temperature: 35ºC.
- Sport mode: on.
- Contact: on.
- Pre-conditioning: off.
- GPS tag signal:



results



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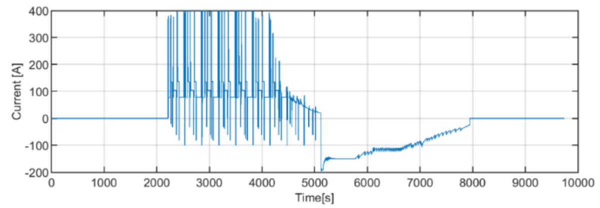
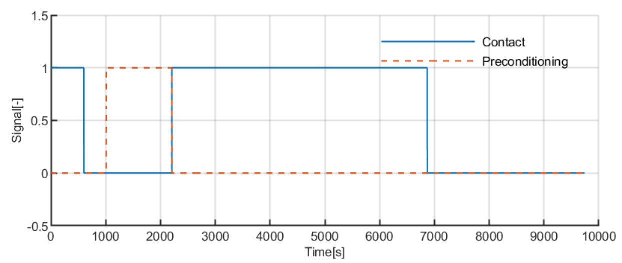
Simulations

4th: validate the preconditioning features.

Variables:
- Current:

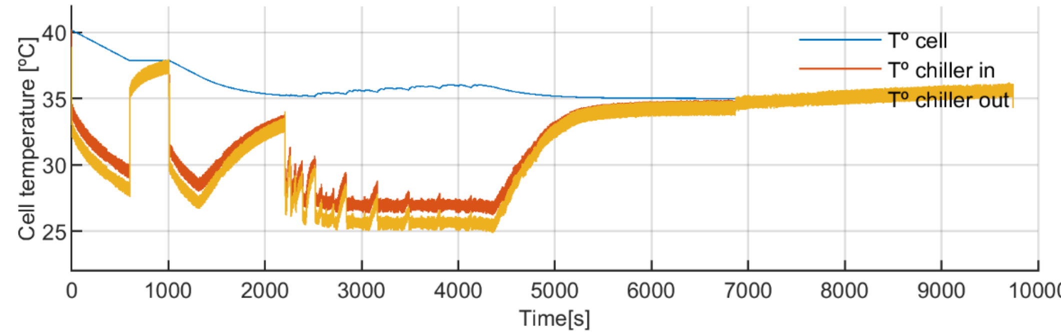


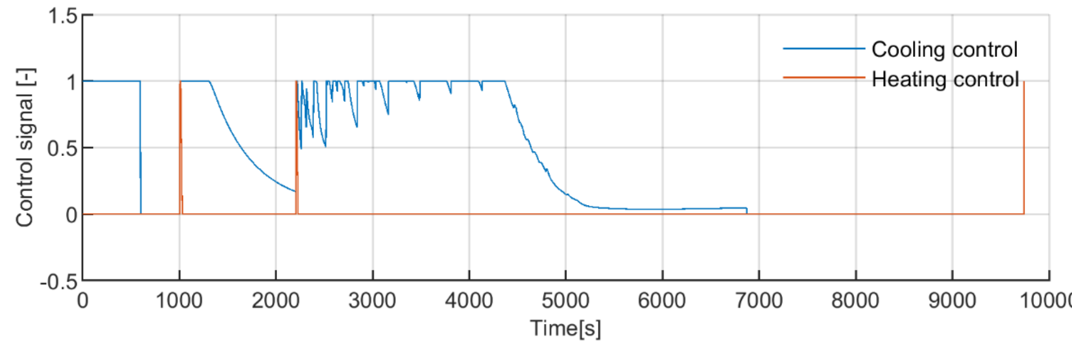
- Room temperature: 35ºC.
- Sport mode: on.
- Contact + preconditioning:



- GPS tag signal: off.

results





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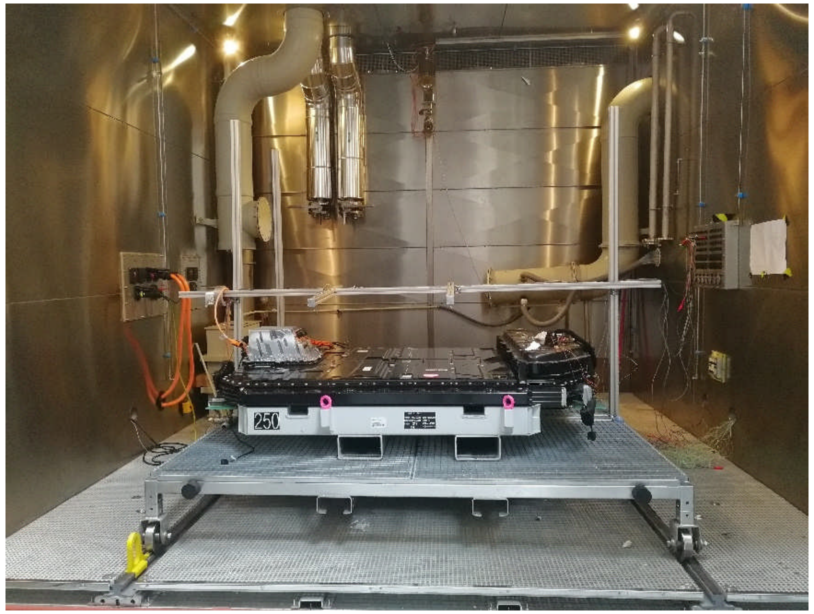
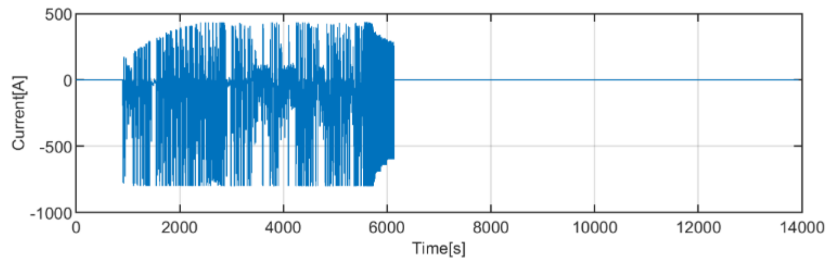
Implementation

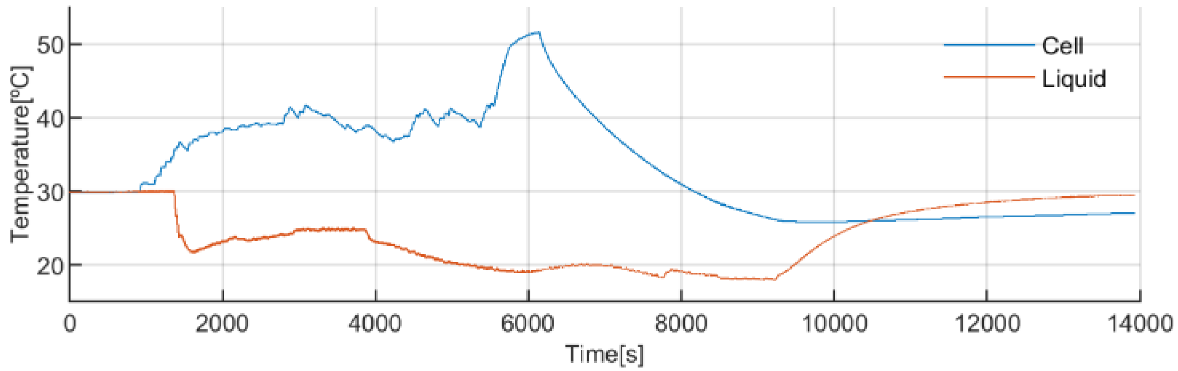


The **inputs** on the test **at lab level**:

- The current profile:



- The room temperature: 30ºC through a climatic chamber.
- Sport mode off.
- Contact on.
- Pre-conditioning off.
- GPS tag signal off.



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Conclusions

- This paper proposes a design of a smart BTMS control strategy that has a continuous and smooth control over the actuators while (1) lengthening the life of the vehicle by minimizing the aging and adjusting the control strategy based on the driving profile and (2) lengthening the use range by minimizing the total energy consumption and maximizing the charge events.

- All the smart features of the controller have been validated through simulations and the stability and the applicability of the proposal has been observed through simulations and through a real test of AUDI's battery pack at lab level.

- To sum up, the design is simple and implementable; the validation has shown its viability; and the tests done at lab level has shown its implementability.

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