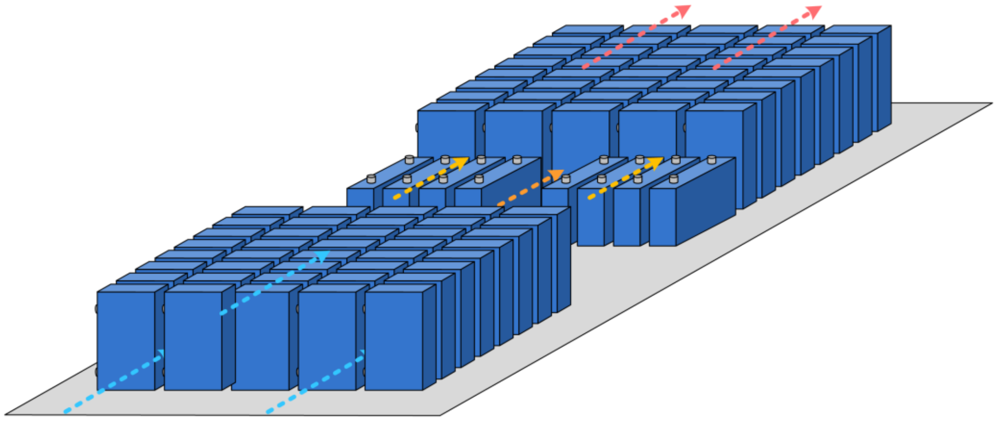
AIT Austrian Institute of Technology

Thermal Battery Stack Modeling and Simulation for Optimizing Vehicle Operating Strategy



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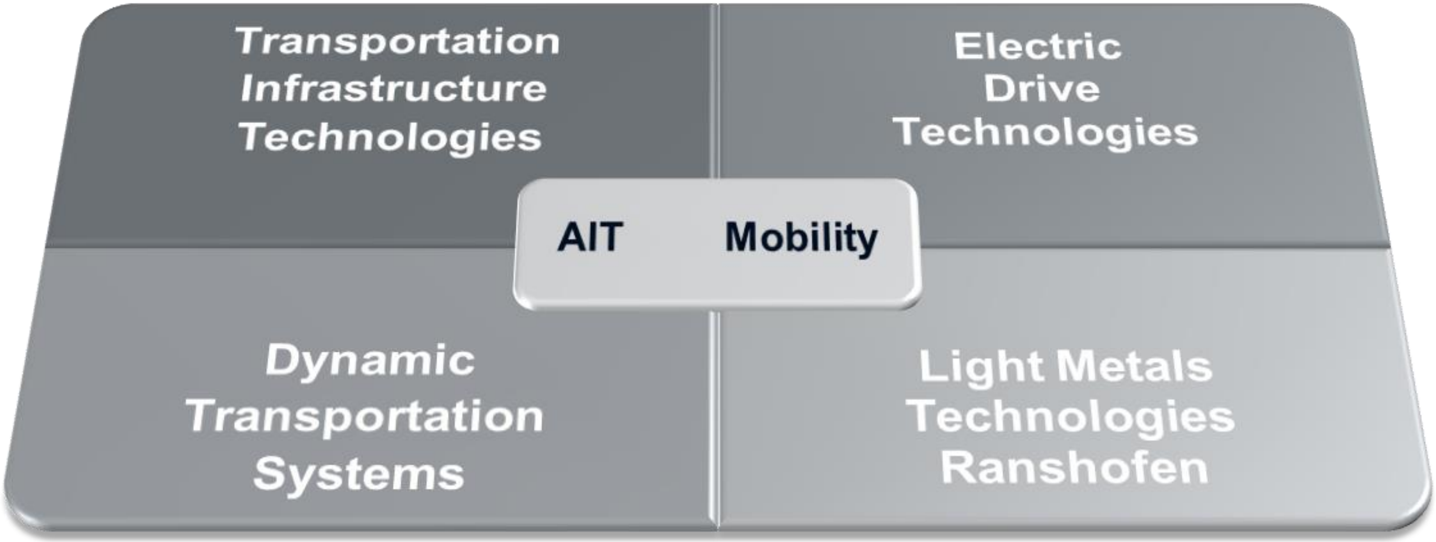
AIT Mobility – Research Activities



Expertise in infrastructure, transport technologies and multi-modal mobility systems is the basis for addressing mobility needs from a systemic and integrated perspective. Research activities at AIT Mobility are organized in four business units.

Modeling and Simulation

- Modeling and simulation are commonly used tools in the automotive sector
- Investigating the operating behavior of multiphysical systems
- Analyzing in different application scenarios and environmental conditions
- Simulations eliminate the need to perform protracted real-life tests

- In the field of electric vehicles: energy efficiency is one of the main topics
- Target: improve maximum range
- Reduce energy consumption of auxiliary components

- Development and simulation of an electric vehicle traction battery model
- Focus on electro-thermal model and cooling circuit
- Modeling based on practical example
- Optimize the vehicle operating strategy

Practical Example

- Off-the-shelf electric vehicle
- Battery stack consisting of 88 interconnected cells
- Cell temperature must not exceed a critical temperature level during operation:
  - Consider cooling circuit and strategy
  - During electric load cycle
  - Under specific ambient conditions

- No general solution
- Determine level of abstraction
- Need proper simulation model

source: http://media.caranddriver.com/images/10q1/335484/mitsubishi-i-miev-battery-pack-photo-335601-s-520x318.jpg

Simulation Language and Tool

- Modelica / Dymola:
  - Modern object-oriented modeling language
  - Modeling complex multiphysical systems
  - Algebraic and ordinary differential equations can be used
  - Simulation tool
  - GUI for Modelica

- Python / Spyder:
  - Open source programming language
  - Post processing
  - GUI for Python

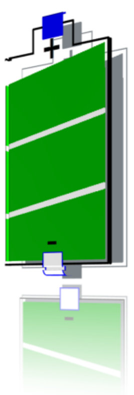
source: https://modelica.org/logo.jpg

source: https://www.python.org/static/community_logos/python-logo.png

Solution Approach

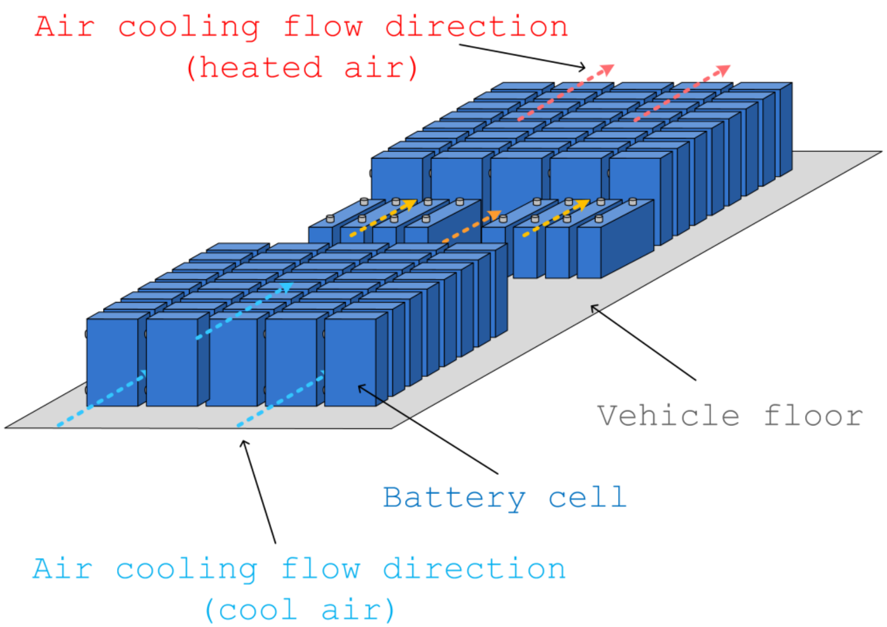
- Electro-thermal model of the battery system
- Cooling system model including cooling strategy

- SmartCooling library:
  - Convective heat transfer in pipes
  - Prescribed mass flow, pressure and volume flow
  - Pump and fan models
  - …
- ElectricEnergyStorages library:
  - Electric equivalent circuit models
  - Cell and stack level
  - Scalable prismatic and cylindrical thermal cell models
  - Aging effects
  - …



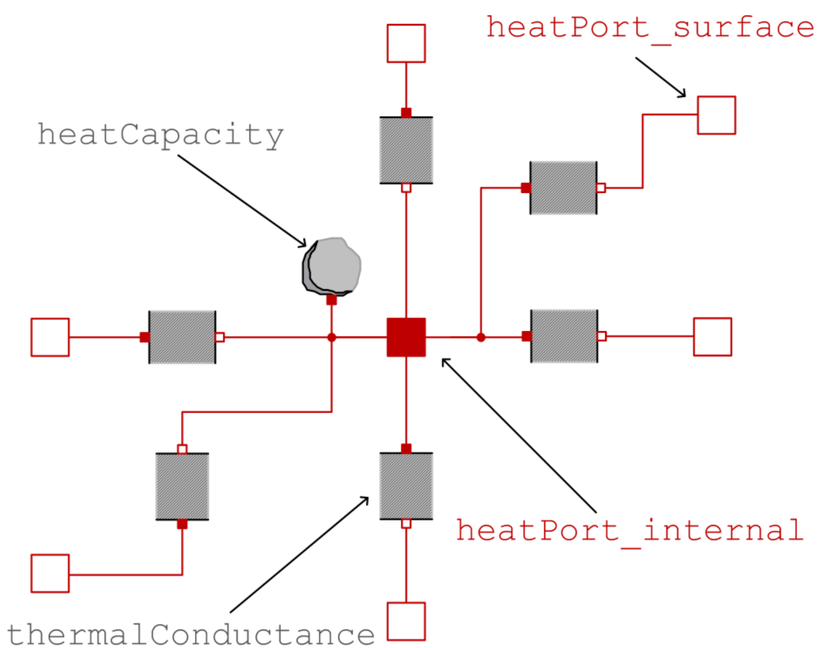
Battery Model Concept

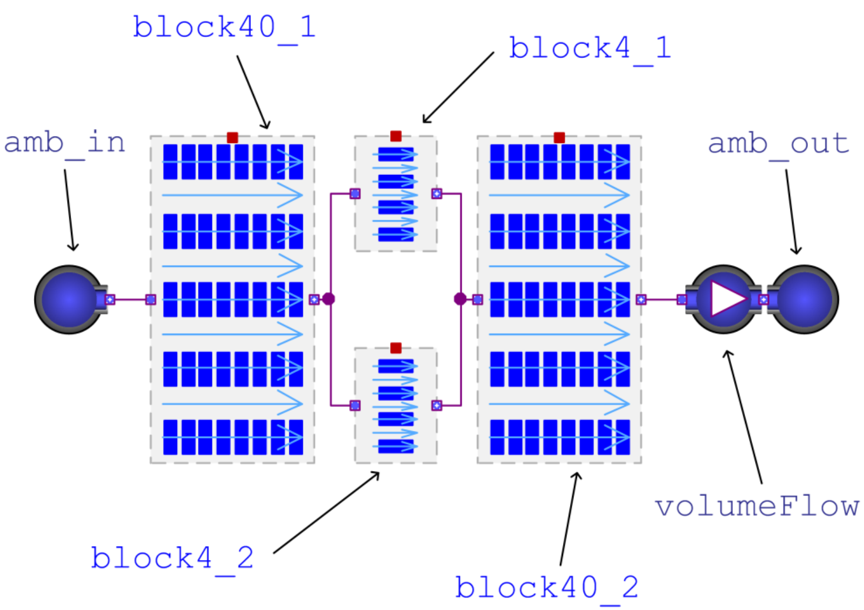
- Simplified electric model: 88 cells connected in series
- Focus on thermal model including cooling circuit
- Air cooling flow between and above the cells
- Overview of the chosen HV-battery including cooling concept:



Implementation – Thermal Model

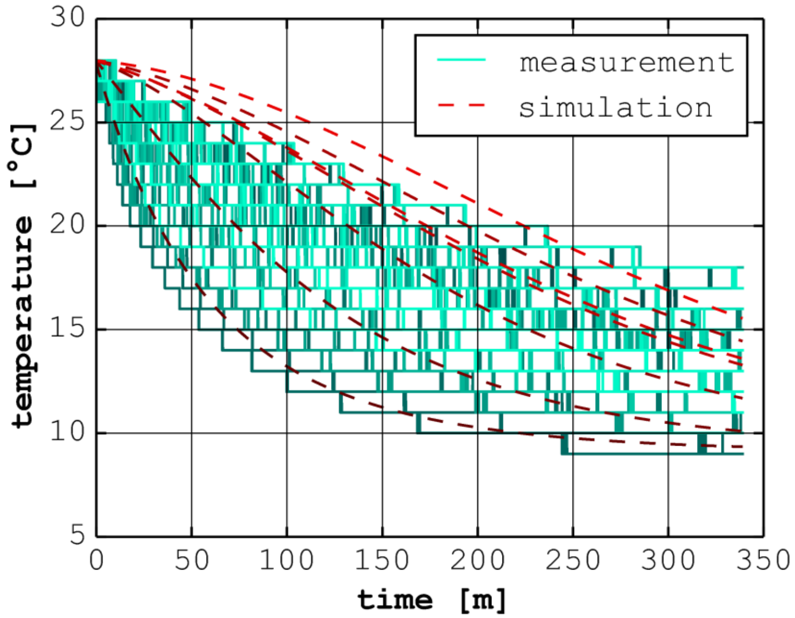
- Cell model:
  - Heat capacity
  - Thermal conductance to surfaces
- Stack model:
  - Spatial cell interconnection
  - Cooling circuit





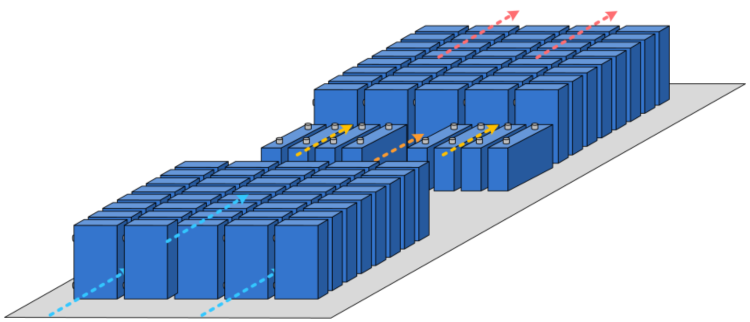
Parameter Extraction

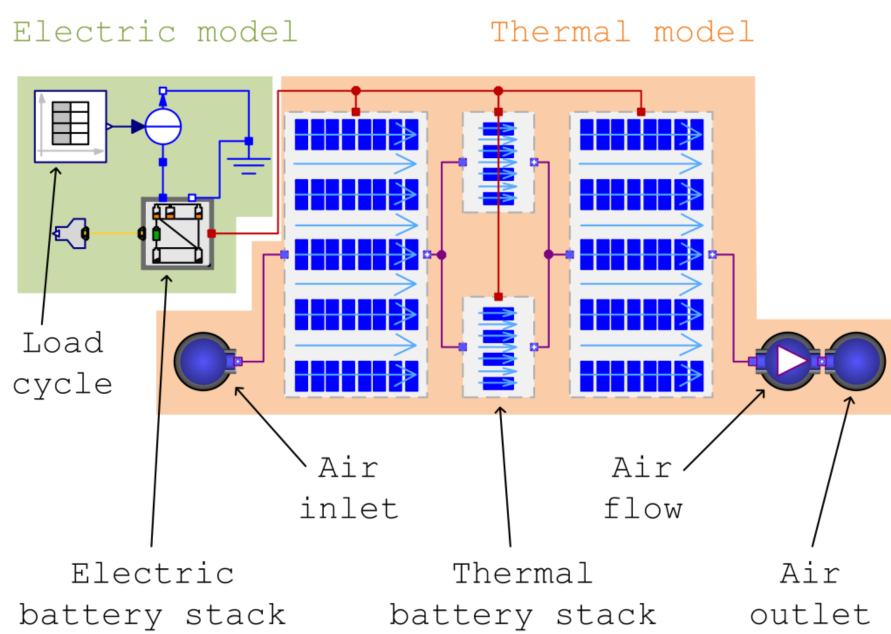
- Testing laboratories:
  - Vehicle in idle mode
  - Log CAN bus data
- Cooling down of battery cells by air conditioning system
- Analyze thermal response of the battery system



Simulation

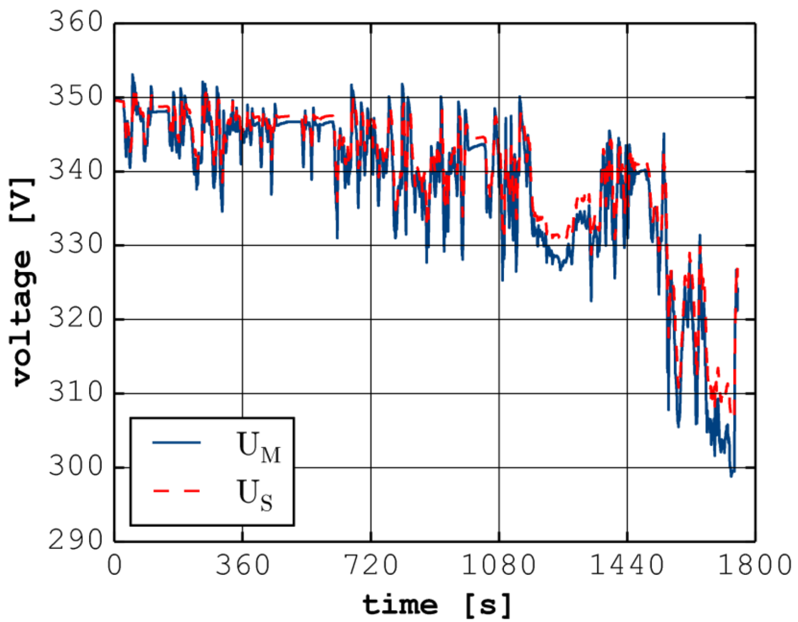
- Example scenario: cell temperature trend during specific load cycle
- Parameterization of the model
- Scenario assumptions:
  - Coolant temperature at inlet: 6 ºC
  - Load cycle: FTP72
  - 88s1p configuration

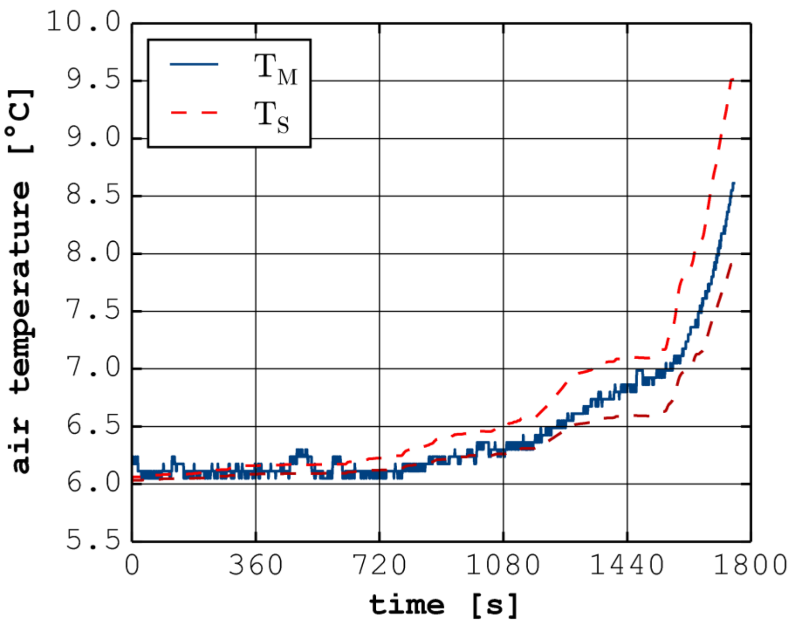




Results Discussion

- Preliminary Results:
  - Electric system response during FTP72 load cycle
  - Thermal system response during load cycle
  - Cooling permanently on





Conclusion and Outlook

- Conclusion:
  - Developed and implemented thermal model of EV battery including cooling circuit
  - Calibrated thermal battery model based on measurements
  - Proved applicability of the model via a practical application example
- Outlook:
  - Further vehicle measurements for validation and parameter extraction
  - Add reversible effects: state of charge dependency
  - Add irreversible effects: aging model
    - In different load scenarios
    - Using different operating strategies
  - Discretization of thermal cell models
  - Thermal influence of the battery container
  - Integration of the thermal battery stack in entire vehicle model

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