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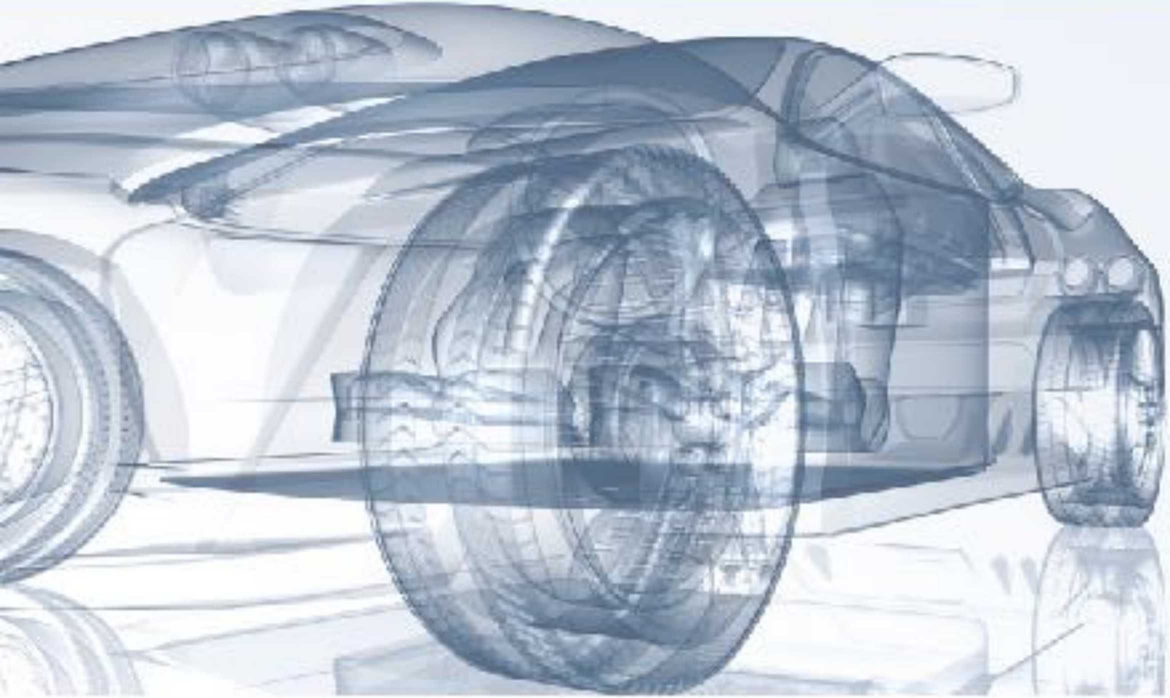

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Liquid Thermal Management of a Lithium-ion Capacitor Module

Presenter: *Joris Jaguemont, Vrije Universiteit Brussel, MOBI research group, Belgium.*

Agenda

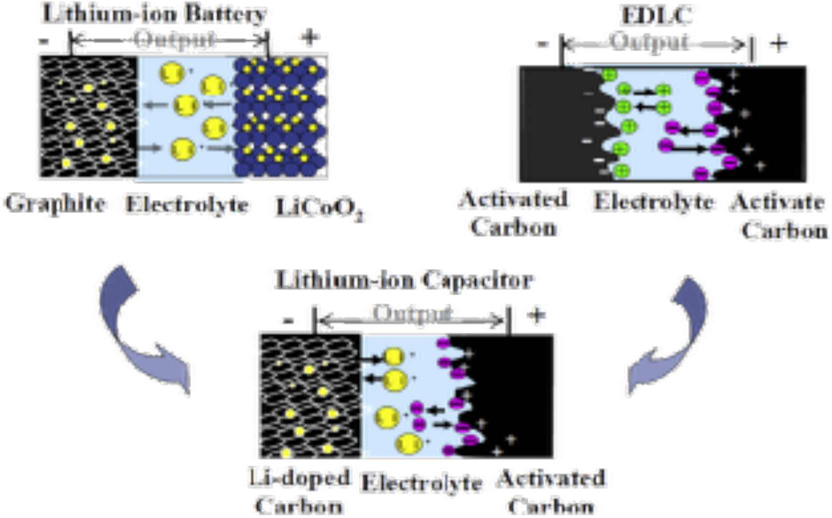
- ***Introduction***
- ***Objectives and problem description***
- ***General methodology***
- ***Thermal management strategies***
- ***Conclusion and future work***

Introduction

- ***Climate change is a fact:***
  - ***COP21 has agreed on a plan that will theoretically limit global warming to 2°C.***
- ***Challenge: reduce fossil fuel consumption***
  - ***Usage of renewable techniques such as hydropower, photovoltaics and wind turbines;***
  - ***Enhance the automotive industry towards electric vehicles (HEV, PHEV, BEV) where electric motors and batteries are primary;***
- ***To cope with these interests: research on battery technologies.***
- ***Lithium-ion capacitor:***
  - ***A promising rechargeable energy storage system (RESS) that combines the working principles of both the electric double layer capacitor and the lithium-ion battery.***

Objectives and problem description

- ***Lithium-ion capacitor chemistry***

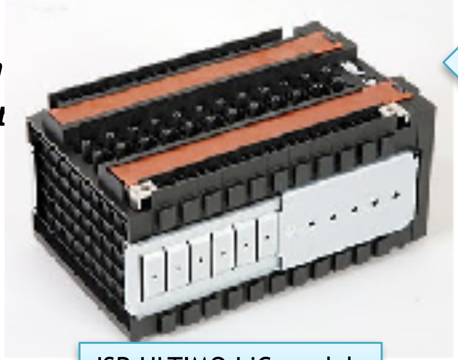


- ***Substitution of the activated anode in the EDLC by a Li-doped carbon;***
- ***Higher power density than LiB;***
- ***Higher energy density than EDLC;***
- ***One problem remains!***

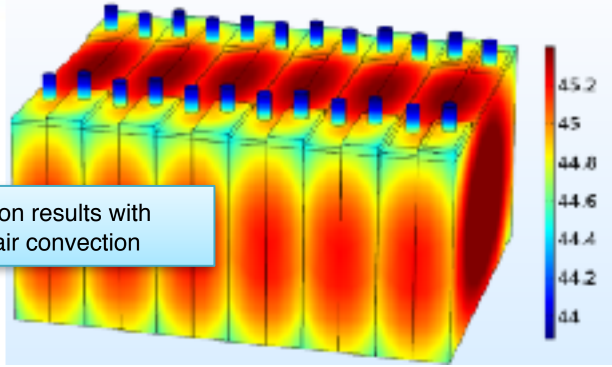
Objectives and problem description

- ***Optimization of the cooling strategy of the JSR module***
  - ***For example, JSR module used for common LiC applications;***
    - ***LiC could be used in automotive application (e.g heavy-duty charger)***
  - ***With natural air cooling, the temperature rises in a fast-rate;***

LiC technical specifications	ULTIMO 2300F LLB
Capacitance	2300F
Nominal voltage	[illegible]
Temperature operating range	[illegible]
Energy density	8 Wh/kg
Size(W*H*D)	150.0x93.0x15.5 mm
Weight	[illegible]

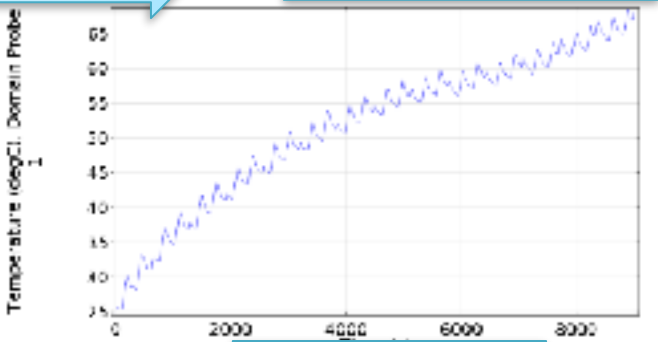


JSR ULTIMO LiC module 48V – 12 LiC



Simulation results with natural air convection

Properties:
- Convective heat transfer: 5W/m².K

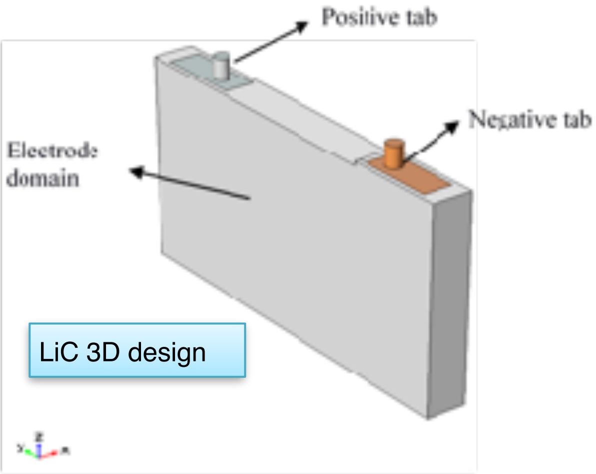


Temperature estimation for **9000s**.

Objectives and problem description

- ***Optimization of the cooling strategy of the JSR module***
  - ***Three different designs are proposed and developed in a 3D-thermal model involving:***
    - ***Liquid-cooling;***
    - ***Passive cooling;***
    - ***Hybrid cooling.***
  - ***Softwares interface: COMSOL/Matlab-Simulink.***

3D-thermal modelling
COMSOL/Matlab interface



The main goal is to develop a thermal management system for a Lithium-ion capacitor module composed of 12 cells connected together in series.

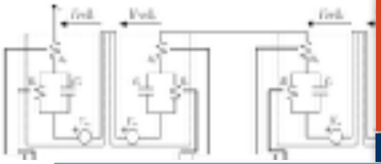
General methodology

- ***COMSOL/Matlab-***

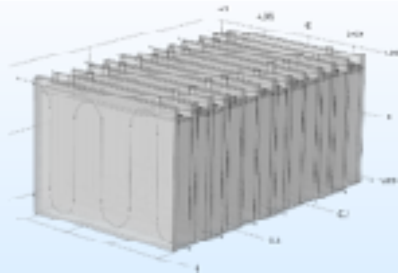
Electro-thermal model activity

Electrical modelling

Thermal modelling



2nd ECM (electrical model) - Simulink



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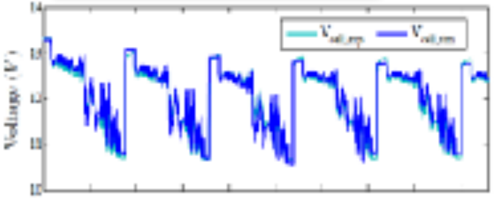
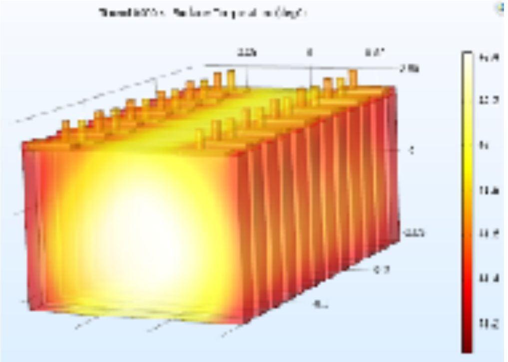
Electro-thermal simulation

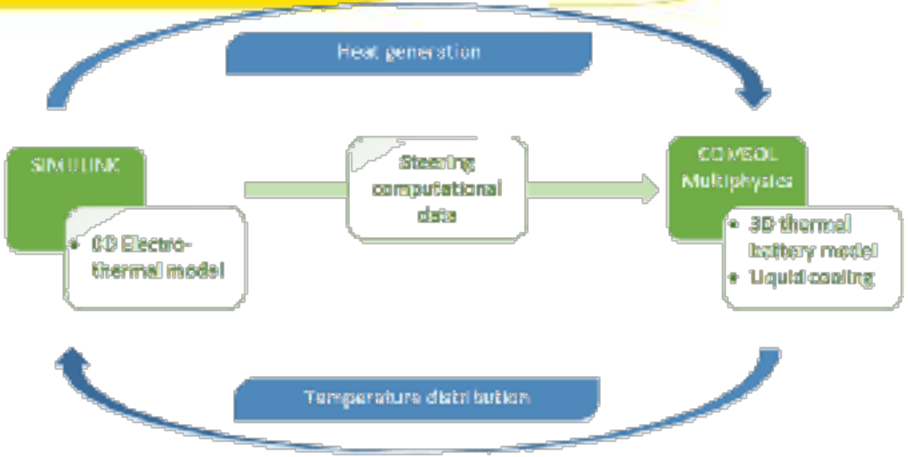


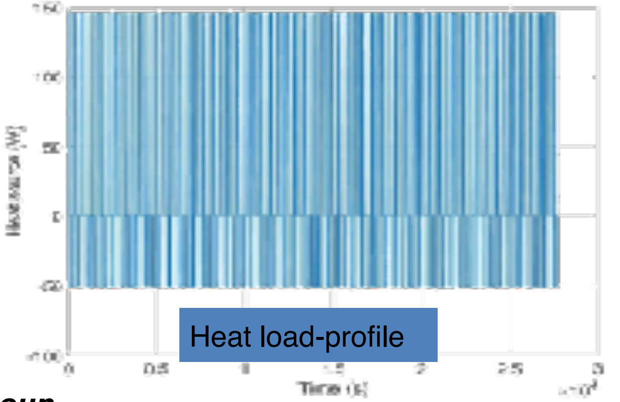


Prototype design and validation

Liquid-cooling - Methodology

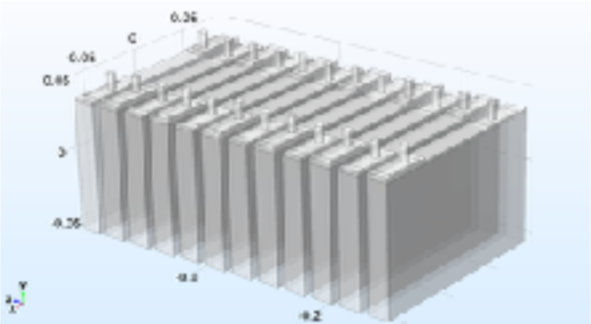
- ***Constraints:***
    - ***Keep the temperature of the whole module below 35 °C;***
    - ***Minimize to the maximum the temperature difference between the cells;***
    - ***The distance between the cells must not exceed 6 mm.***
- ***Methodology:***
    - ***Simulation of the liquid cooling module using a typical load profile for LiCs;***
    - ***Water-fluid temperature starts at 20°C.***

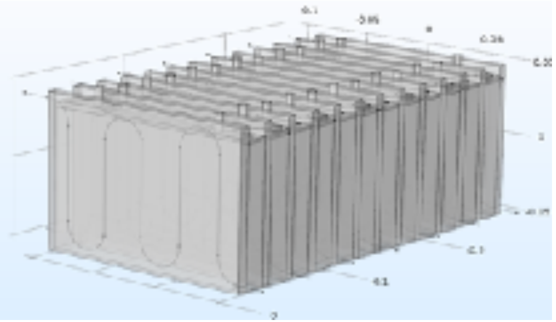


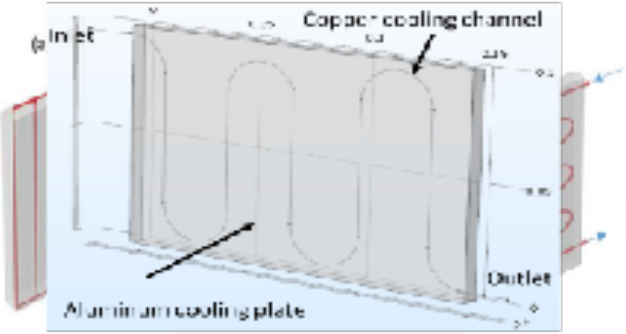


Liquid-cooling - Methodology

- *Simulation phase:*
  - *Starting from natural air-cooling design;*
  - *Testing of four different piping circuits;*
  - *Temperature difference very low;*
  - *Opted for the easiest design;*
  - *Result of the chosen design?*



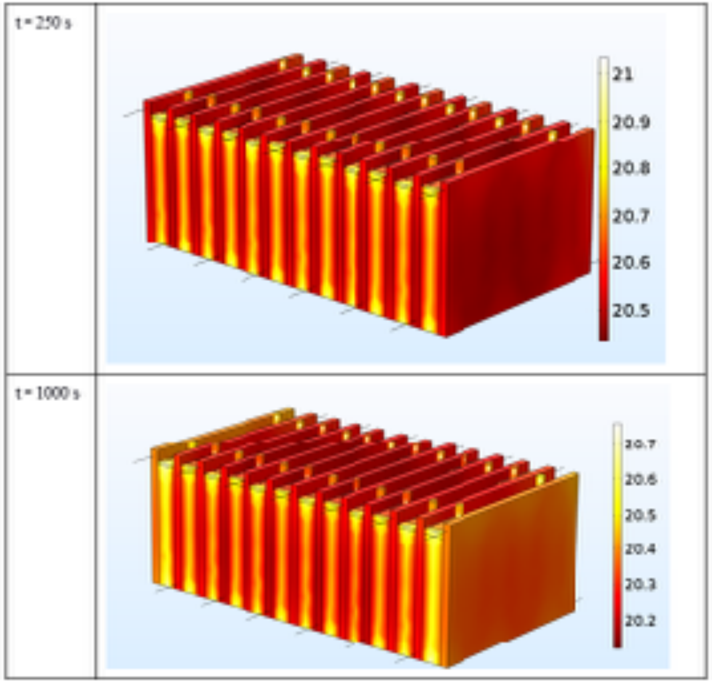


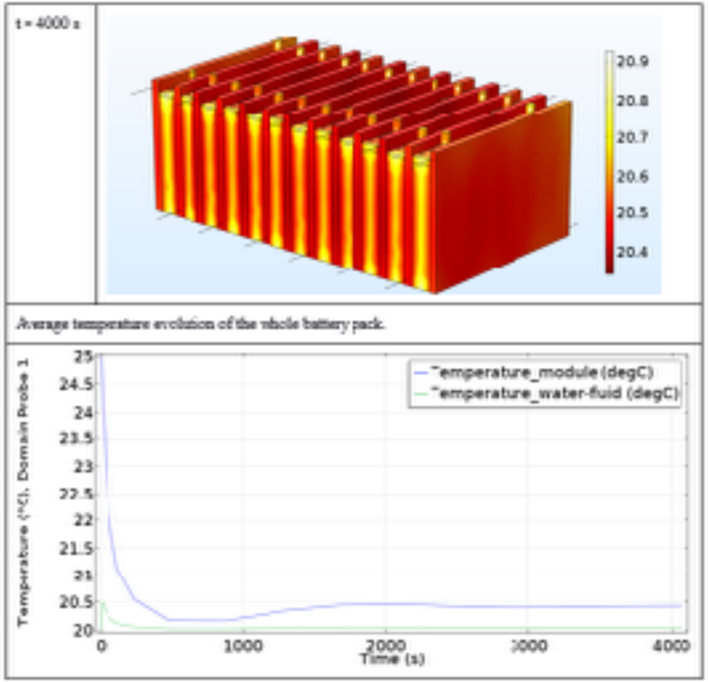


Al-cooling plate

Liquid-cooling - Results

- ***Temperature evolution in average of the LIC module with liquid cooling***
  - ***Temperature is controlled and temperature is uniform;***

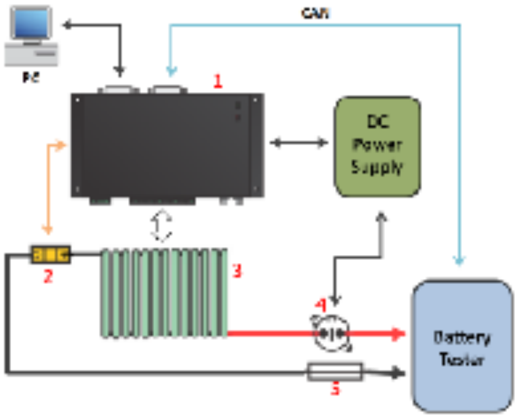




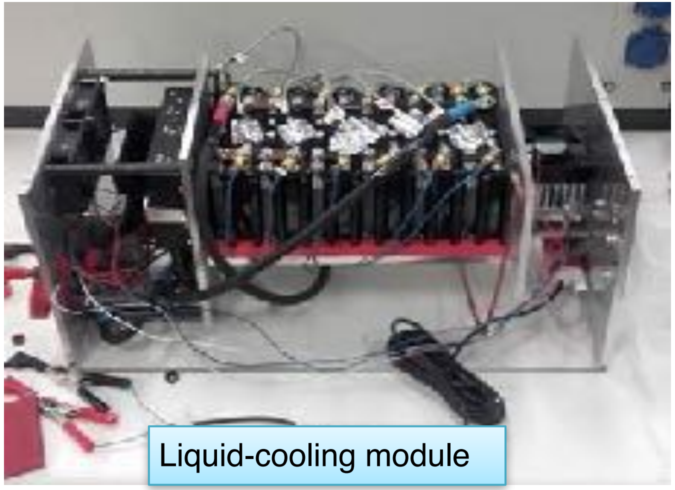
Average temperature evolution of the whole battery pack.

Liquid-cooling - Results

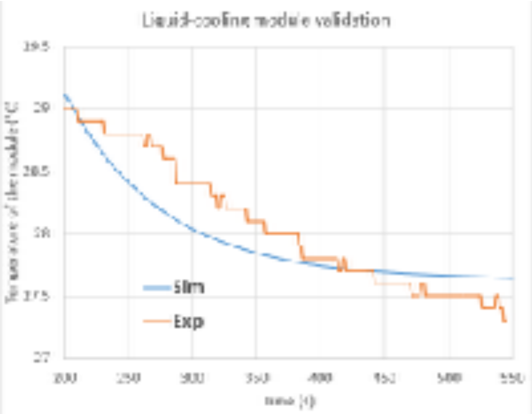
- ***Validation test:***
  - ***Temperature evolution of the liquid cooling LIC module for a current rate of 15 A;***
  - ***Good agreement between the model and the experimental results;***
  - ***Efficient thermal strategy.***



Battery management system



Liquid-cooling module



Validation results

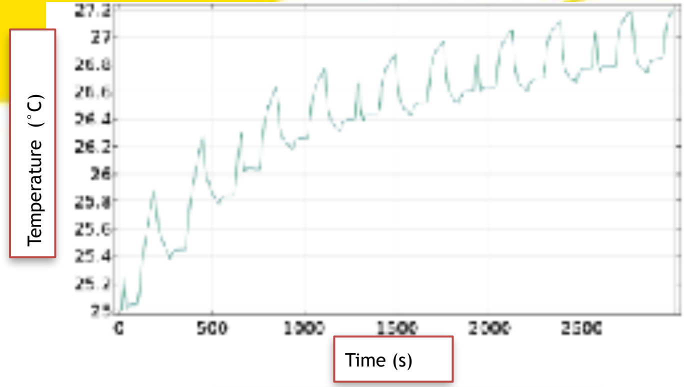
Drawback existing solution

- ***Complex***
- ***Costly***
- ***Heavy***

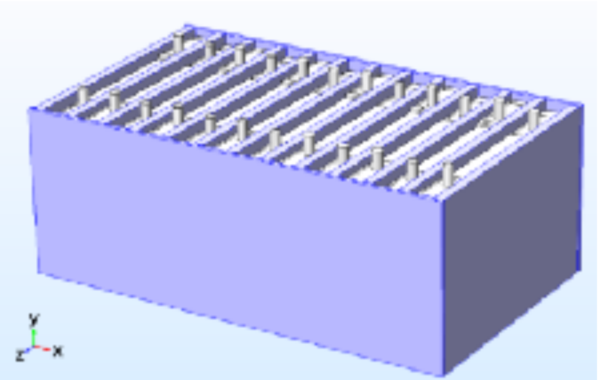
Example of a battery pack

Passive thermal management

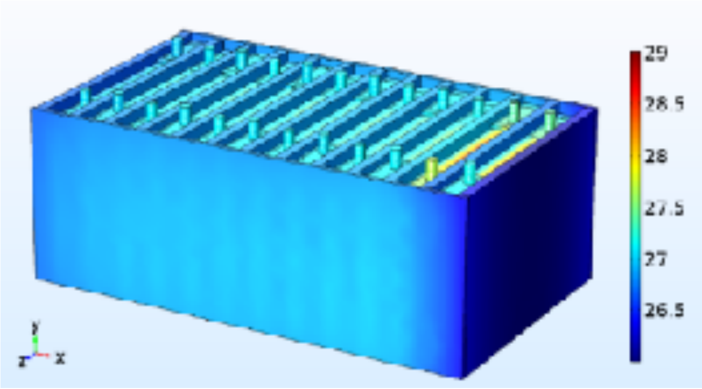
- ***Passive thermal management methodology / results***
  - ***Phase-change material (PCM) in a solid or liquid phase;***
  - ***Absorbs / releases the heat when the system reaches a T;***
  - ***Same load profile and same thickness (6 mm);***
  - ***PCM less efficient but still uniformity is achieved***
  - ***Overall module temperature remains lower than 35°C;***
  - ***Compromise to investigate? Additional cooling system?***



Temperature evolution with PCM (Paraffin+20%Al-foam).



12-LIC module design with PCM - Al (in blue)

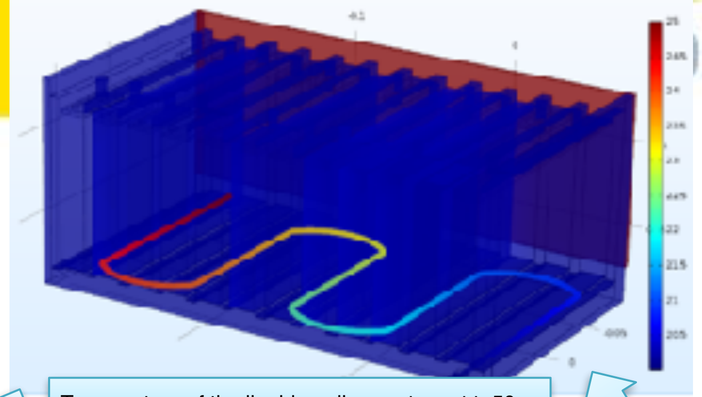


12-LIC module simulation

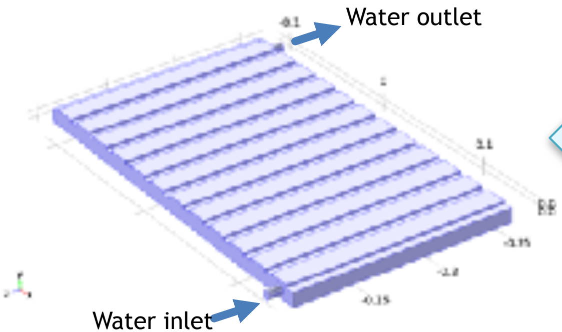
Properties:
- Thermal conductivity:
  - 0.2W/mK at 25°C for PCM
  - 44W/mK with Al
- Heat Capacity:
  - 2800 J/gK at 20°C
  - 2400 J/gK with PCM
- Density:
  - 860 kg / m3.
- Thickness: 6 mm;
- V = 0.0011 m3;
- m = 0.914 kg.

Hybrid thermal management

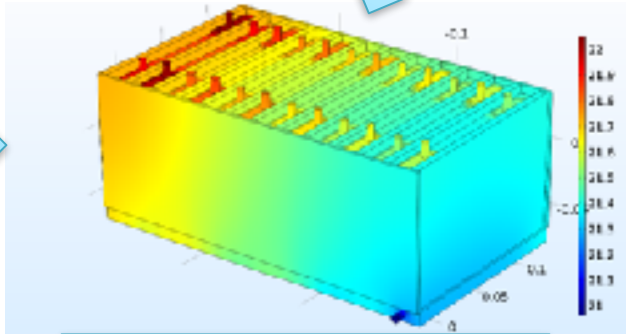
- ***Hybrid thermal management methodology / results***
  - ***Liquid cooling and PCM combined;***
  - ***Al liquid-cooling plate;***
  - ***Same load profile;***
  - ***Temperature dropping to 20°C after 300s;***
  - ***Again compromise to investigate? Weight / cost vs T?***



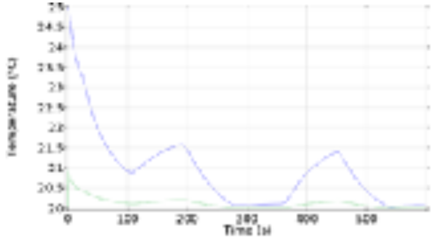
Temperature of the liquid-cooling system at t=50s.



Liquid-cooling plate.



12-LIC module design with PCM (Paraffin+Al-foam) and liquid cooling.



Temperature evolutions: in green PCM and in blue cells

Conclusion & future work

- ***Three thermal management strategies have been investigated***
  - ***Developed 0D-electro-thermal model coupled and a 3D-thermal model have been used;***
  - ***Results with liquid-cooling:***
    - ***The maximum temperature is controlled and temperature is uniform;***
    - ***Due to the high surface contact between the cooling channel and plates;***
    - ***But solution is bulky and complex.***
  - ***Results with PCM:***
    - ***The maximum temperature is higher;***
    - ***It takes less time to reach the hazardous temperatures;***
    - ***Less complex to integrate but investigate the thickness temperature compromise.***
  - ***Results with hybrid combination:***
    - ***The maximum temperature of the module is regulated around the temperature of the fluid, 20°C;***
    - ***Temperature tends to be uniform thanks to the PCM.***

- At the end, several future works.
  - ➢ Concerning the hardware part:
    - ➢ Add a ventilation system at the top of the module to combine air and liquid cooling;
    - ➢ Validate the PCM/ Al design.
  - ➢ Concerning the modelling activities:
    - ➢ Model allows optimizing and sizing the thermal management of the module;
    - ➢ Thermal performances vs cost functions can be conducted to optimize the thermal strategies presented here.

Thank you for your attention