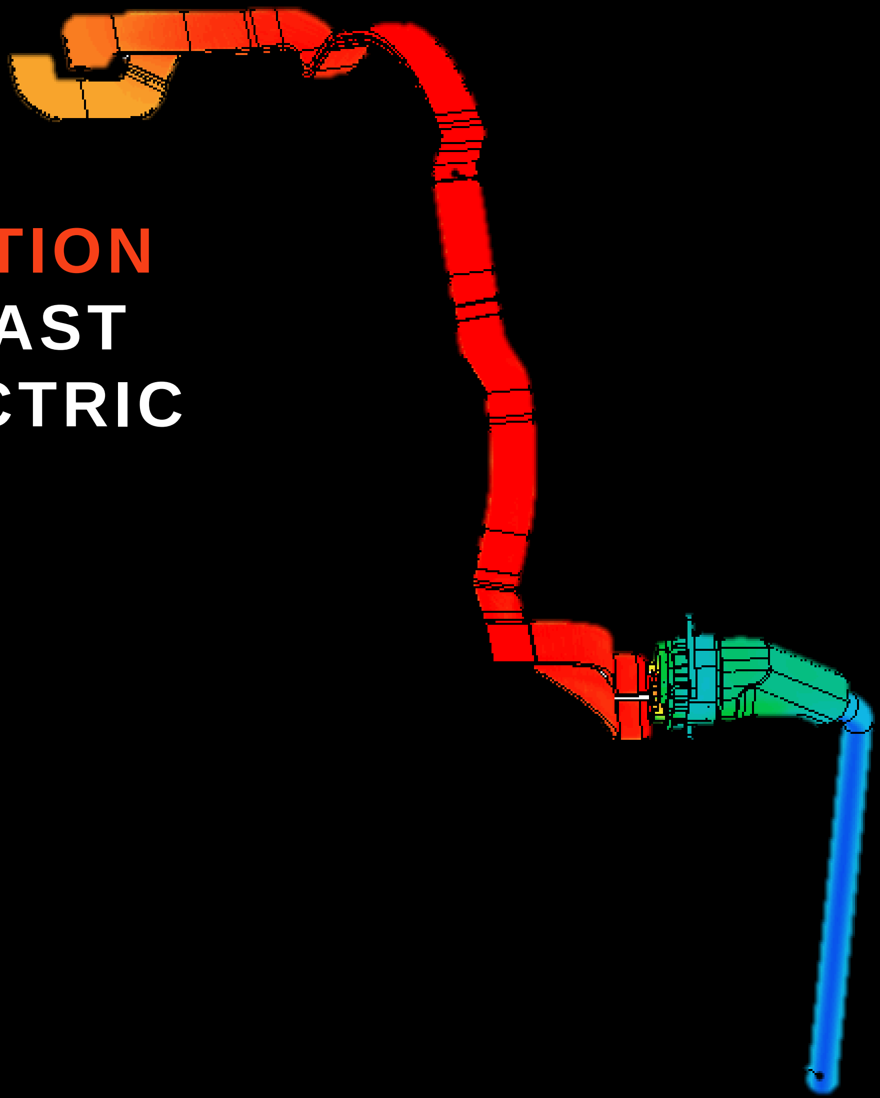
December 3, 2024
Thermal Management Expo

Monika Pieszka
Senior Simulation Expert

CFD AND THERMAL-ELECTRIC SIMULATION METHODOLOGY FOR HIGH-CURRENT FAST CHARGING INFRASTRUCTURE OF ELECTRIC VEHICLES



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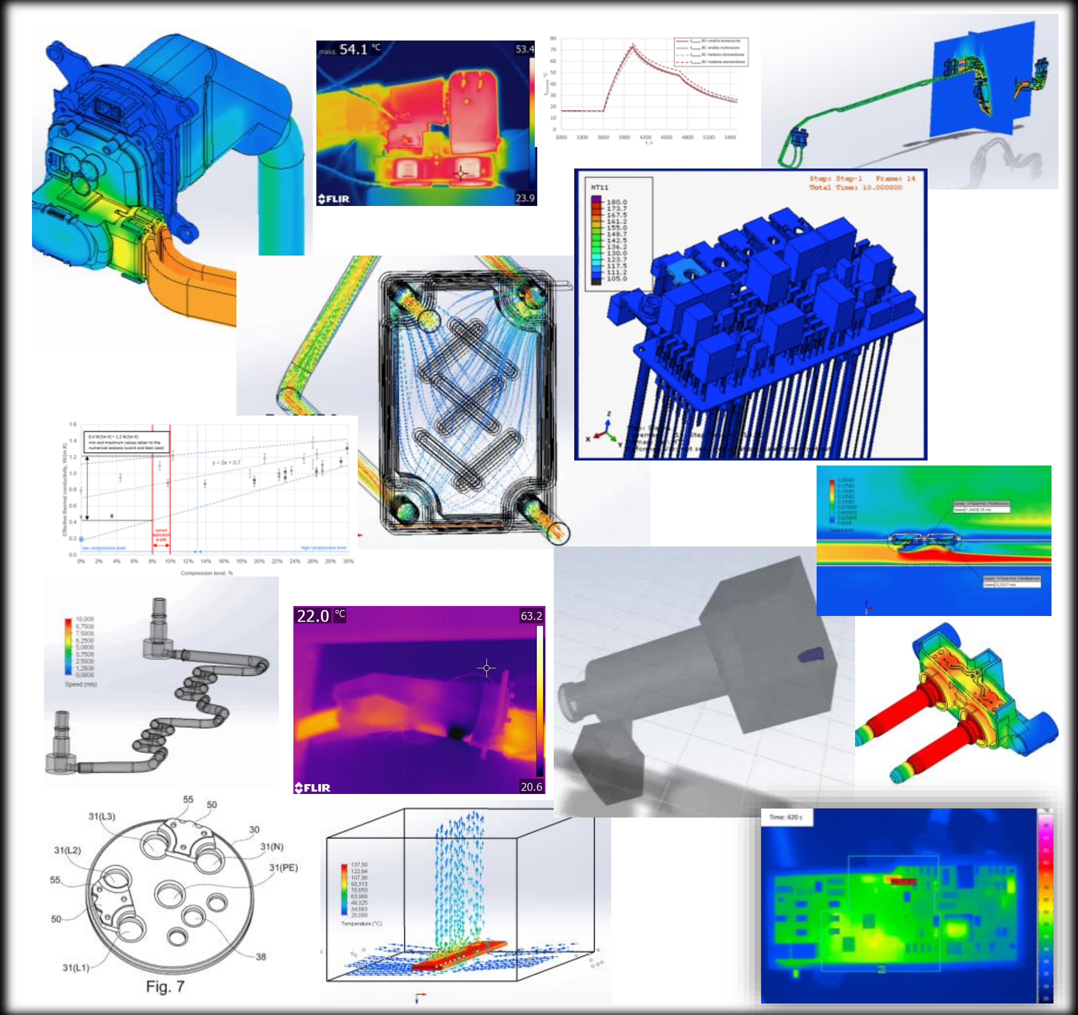
About me



Monika Pieszka

Senior Simulation Expert, Aptiv

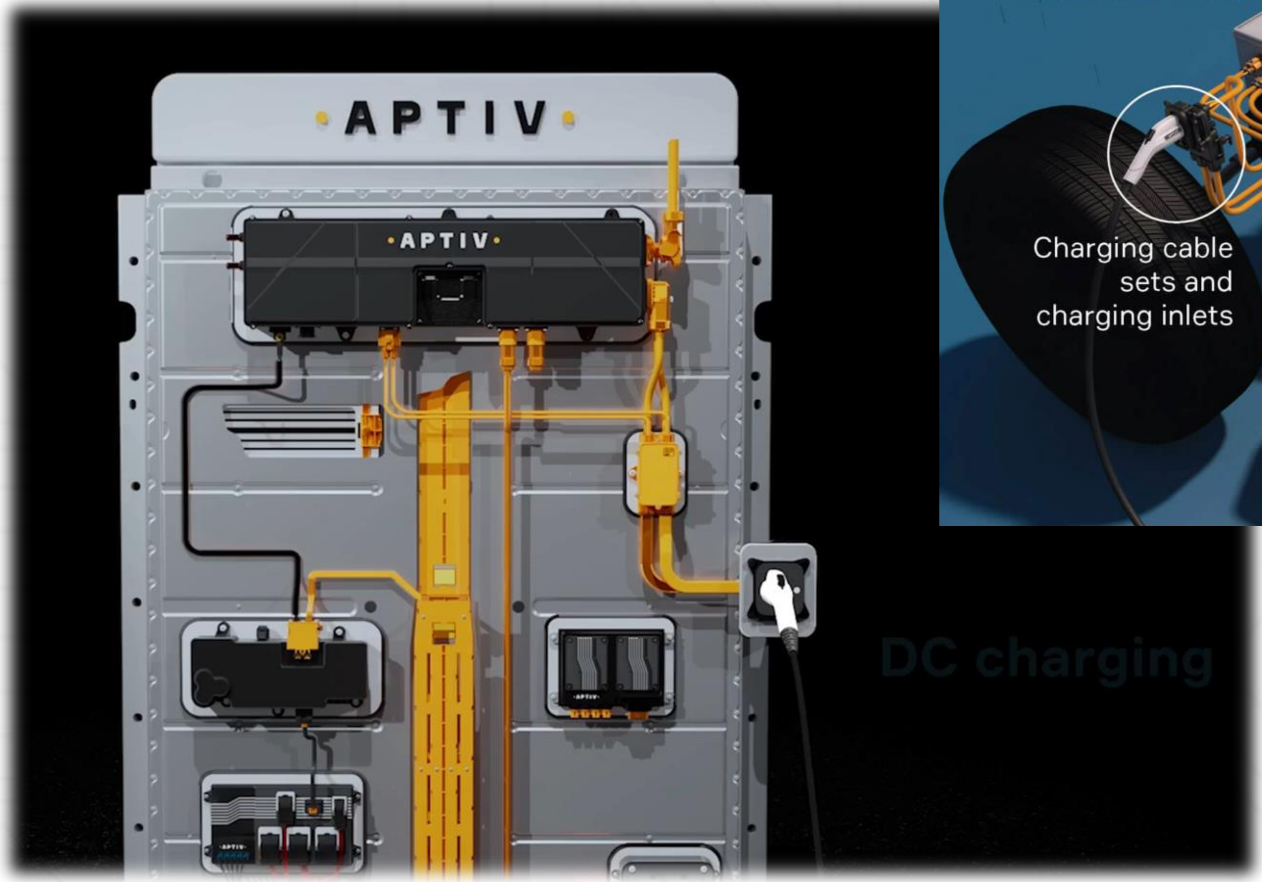
& PhD Candidate, AGH University of Krakow

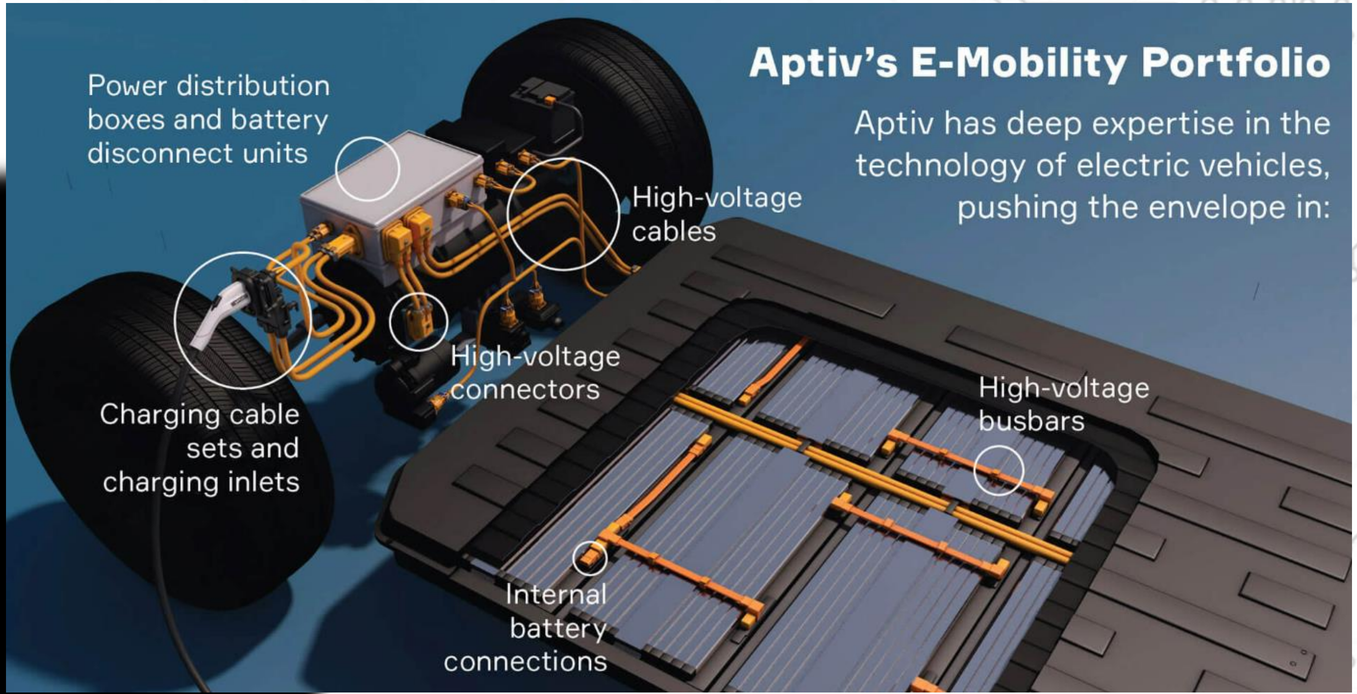
- >6 yrs at Aptiv in the Global Simulation Team
- CFD and thermal simulation, thermal-electric-flow, multiphysics, multiphase
- Vehicle charging architecture (charging inlet, charging coupler, charging harness, battery connection, HV distribution units, associated electronics)
- PhD in progress (material engineering, thermal challenges of EV charging, thermal monitoring systems)

- Simcenter FlothermXT
- Simcenter FloEFD
- Ansys Fluent
- Abaqus/CAE
- Simcenter StarCCM+

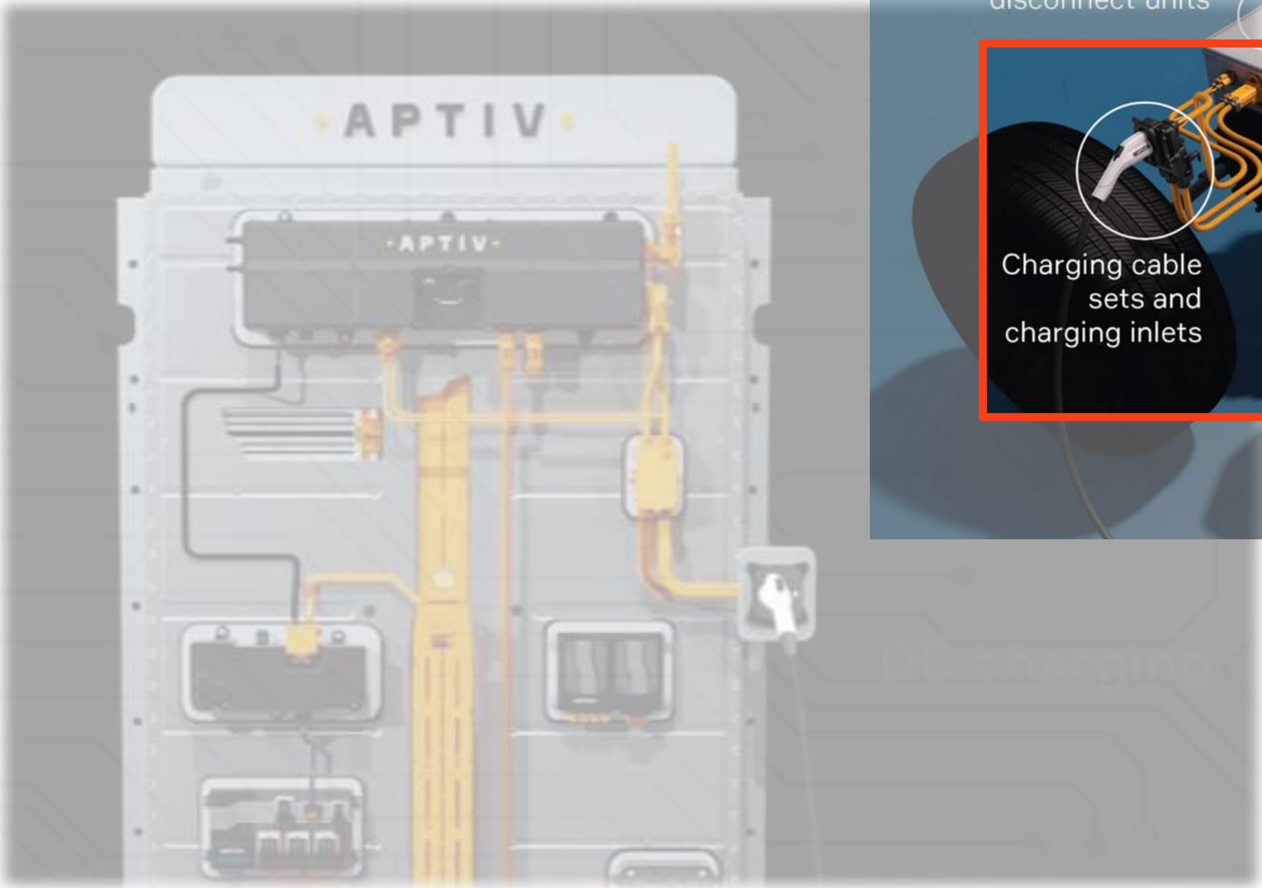
- *M. Pieszka-Łysoń, P. Rutkowski, M. Kawalec, D. Kawalec. 2024. "Determination of Contact Resistance of Thermal Interface Materials Used in Thermal Monitoring Systems of Electric Vehicle Charging Inlets" Materials 17, no. 13: 3103. https://doi.org/10.3390/ma17133103*
- *Patents: https://www.linkedin.com/in/monikapieszka/details/patents/*

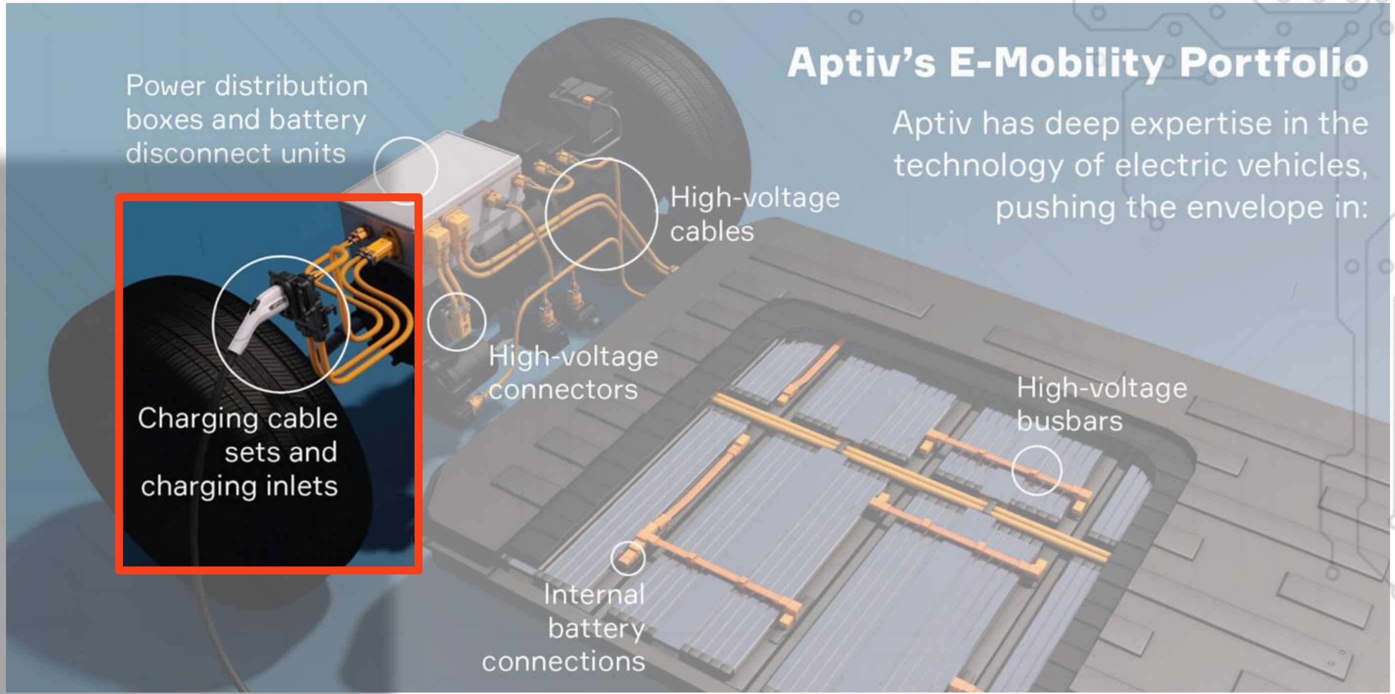
Aptiv Signal and Power Solutions Portfolio





Focus on Charging Infrastructure





- Charging Inlets for OEMs
- Very big influence of a Charging Station
- High-voltage Harness (Cables, Busbars)
- Modelling based on IEC standard
- Calibrations based on Internal Thermal Tests

Simulation methodology

CFD simulations (thermal, electric, flow)

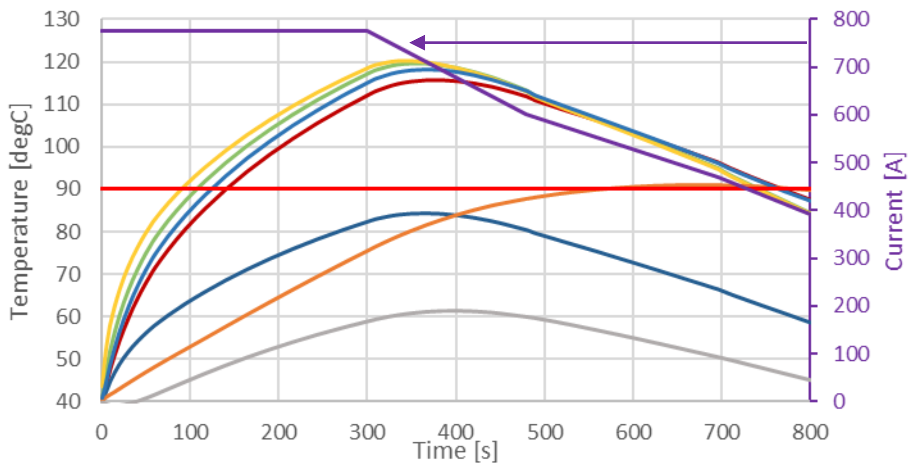
FEM simulations (thermal, electric)

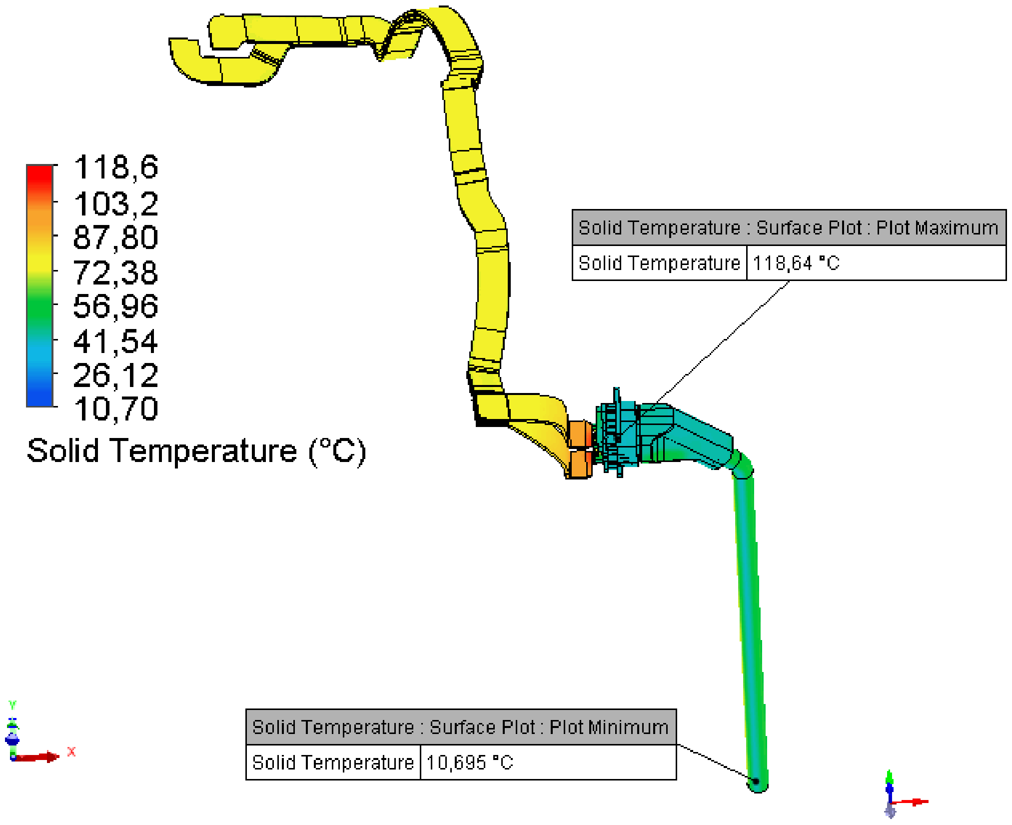
Other high-fidelity CFD simulations (multiphase, multiphysics)

Reduced Order Models (0-1D, RC models, AI/ML models)

CFD thermal-electric simulation

- Thermal and electrical conduction
- Natural or forced convection
- Thermal radiation
- Active cooling
- Unsteady behavior





From the first concept to the validation

Factors influencing thermal behavior

- Ambient temperature
- Electric current load profile

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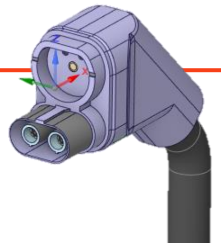

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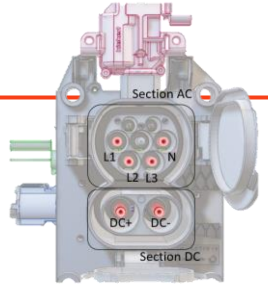

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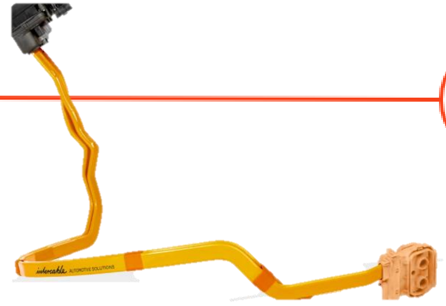

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Charging Station

- Contact resistance
- Cable cross-section and length
- Insulation thermal conductivity
- Interface between conductor and coolant
- Direct/Indirect cooling
- Initial coolant temperature and flow rate
- Cooling unit

Charging Inlet

- Contact resistance
- Cross-section of pin (CCS, NACS, GB/T, CHAdeMO, ChaoJi, Megawat)
- Busbar cross-section
- Thermal monitoring system efficiency

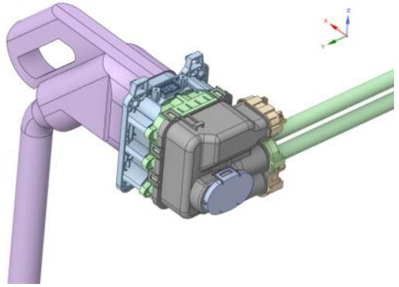
Charging Harness

- Contact resistance
- Cable or busbar cross-section and material
- Insulation thermal conductivity
- Busbar orientation in space
- Passive cooling (or active cooling options)
- Separation between DC+/DC- line

Battery Distribution Unit / Battery connection

- Contact resistance
- High-voltage components heat generation
- Internal busbars cross-sections

Temperature limits



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Charging Coupler

- **50 K temperature rise defined by the IEC standard**
- **Stress relaxation in mechanically working elastic copper alloys at elevated temperature (any elevated temperature)**

Charging Inlet

- **50 K temperature rise defined by the IEC standard**
- **150-175°C silver plating limit depending on passivation**
- **60°C for metallic parts and 85°C for non-metallic parts**

Charging Harness

- **Insulation class, example: C class (3)**
  125°C for 3000 h
  150°C for 240 h
  175°C for 6 h

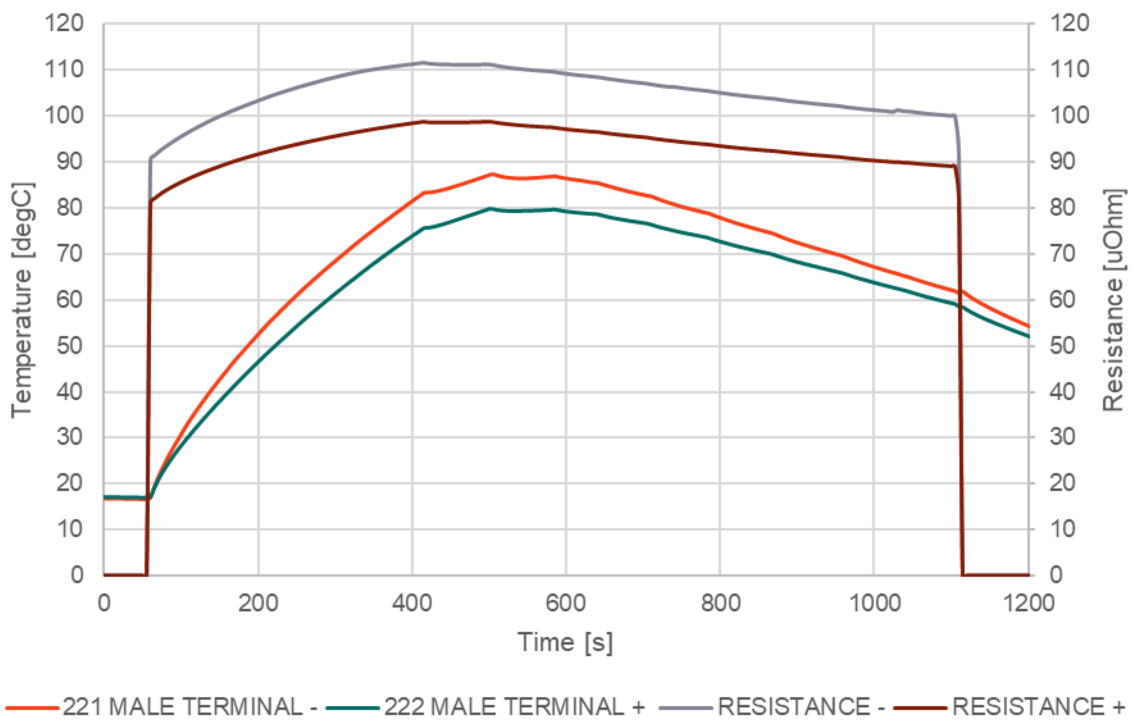
Battery Distribution Unit / Battery connection

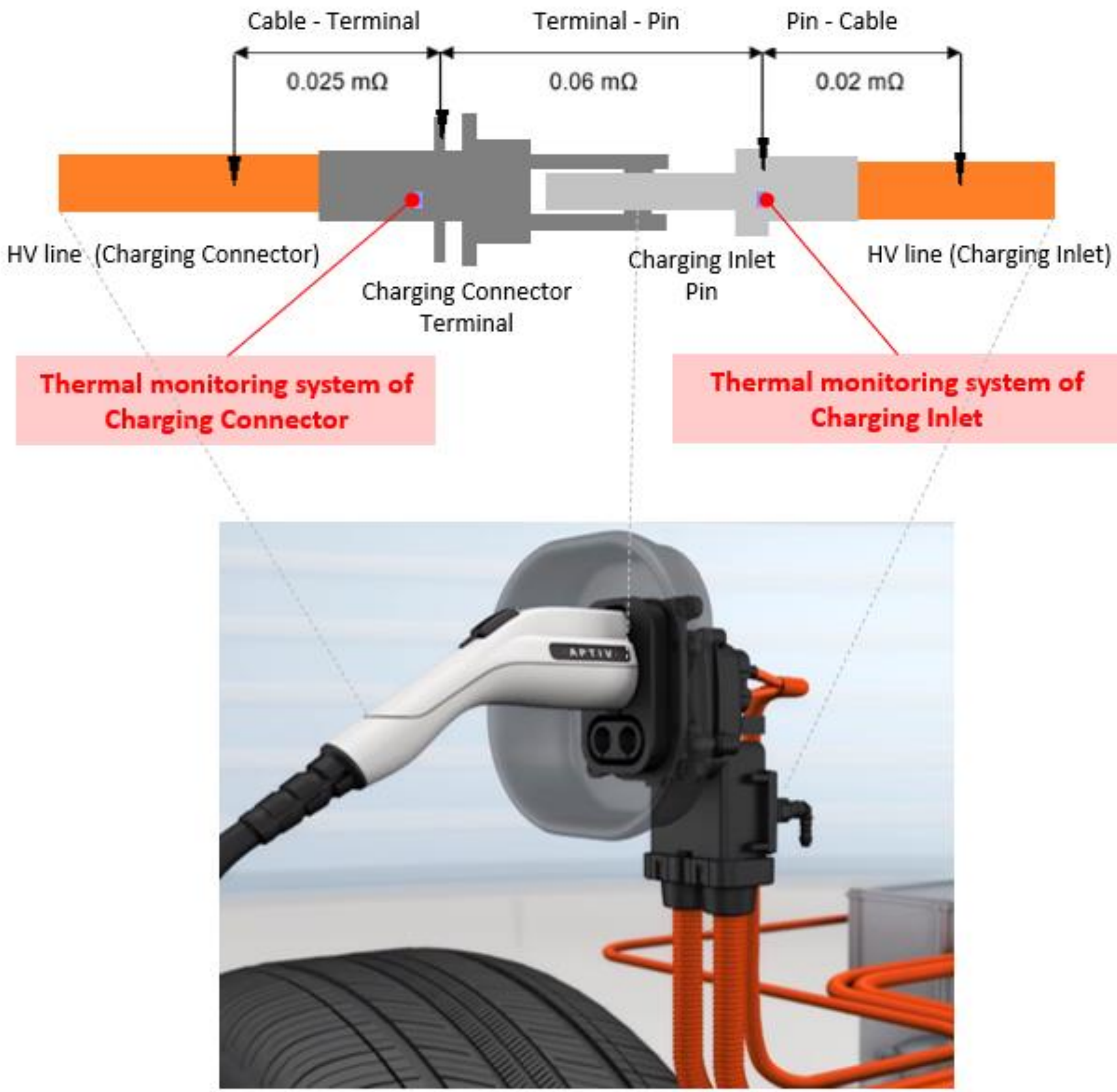
- **150-175°C silver plating limit depending on passivation**

Contact resistance

Very high influence on the results

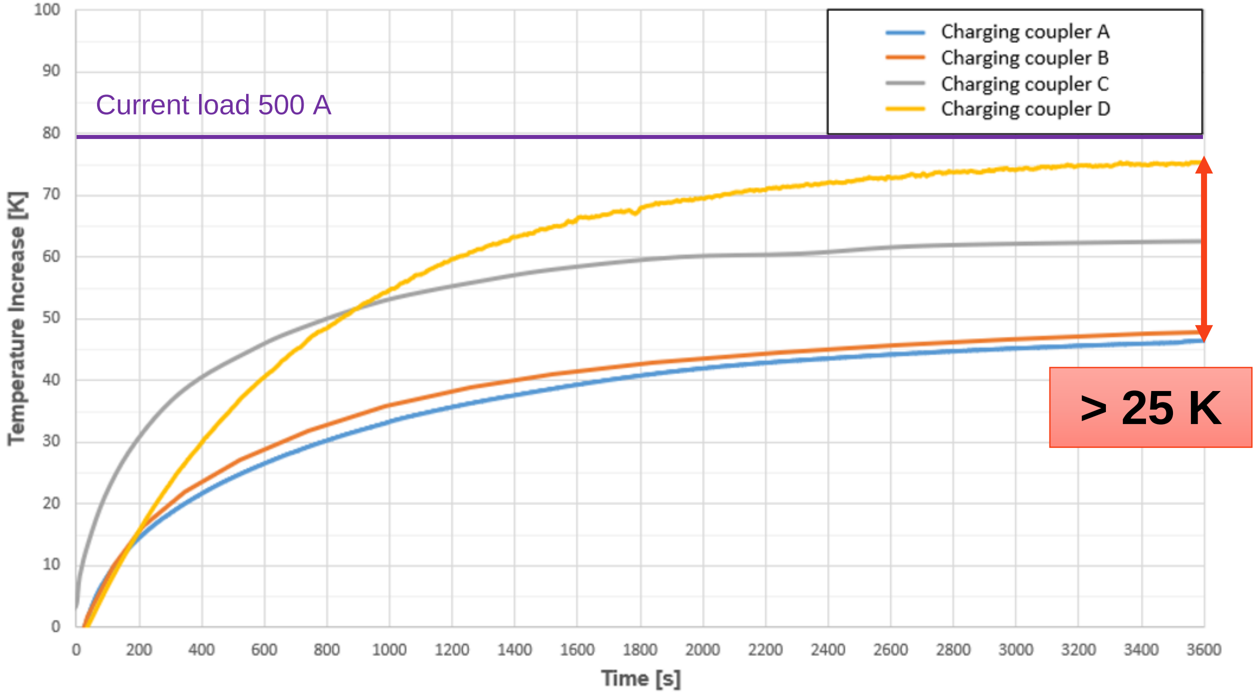
- **Every 10 µΩ can cause 10 K temperature rise!**
- **Pin cross-section is a bottleneck**



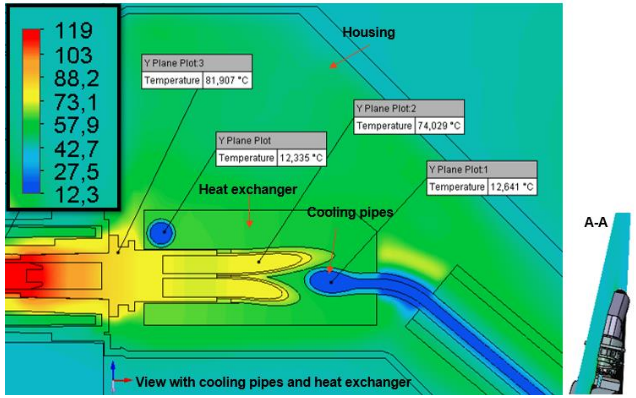


Charging coupler

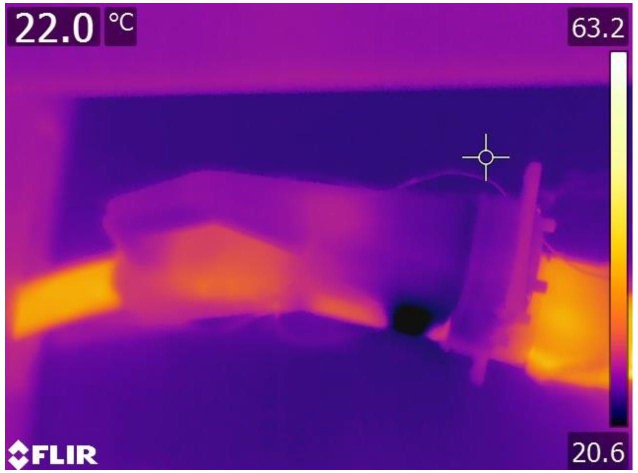
- **Charging coupler type - very high influence on the temperature**
- **Comparison of charging couplers with the same rating:**



Cross section with example temperature contour

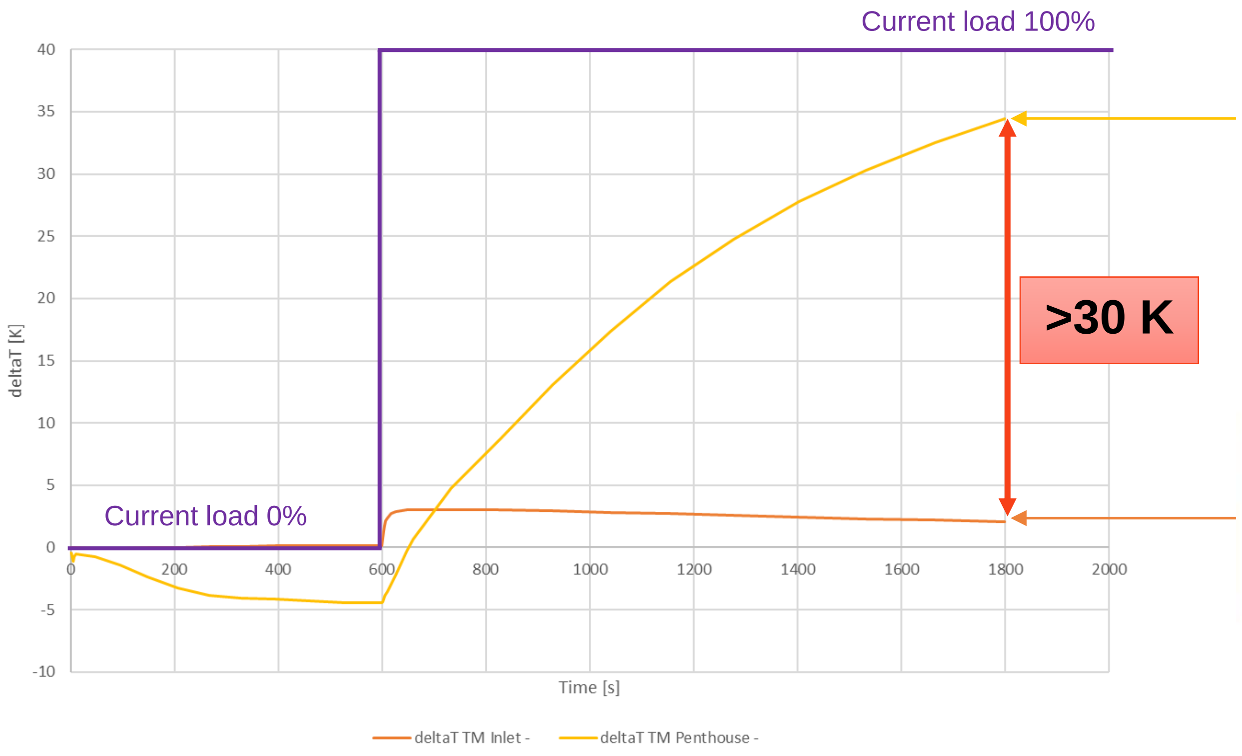


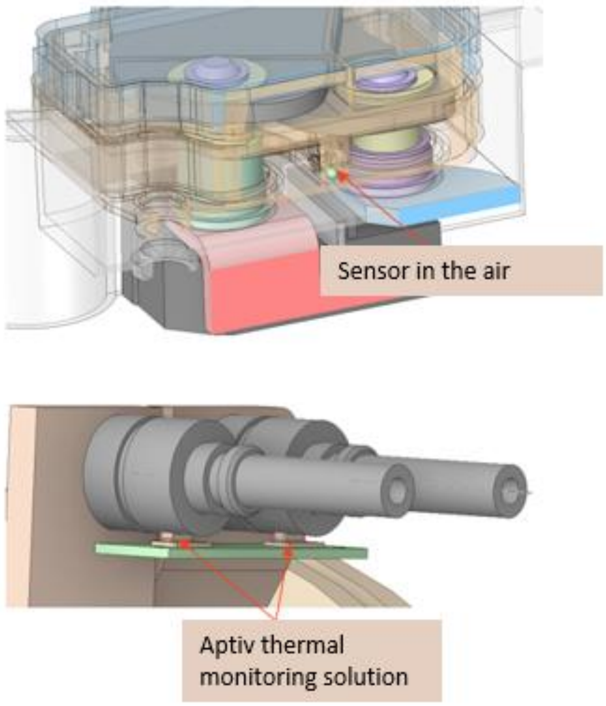
Real measurements using IR camera



Thermal monitoring system

- **Thermal monitoring is responsible for switching off the charging if the permissible temperature is exceeded**
- **High-accuracy thermal monitoring system – cost reduction**





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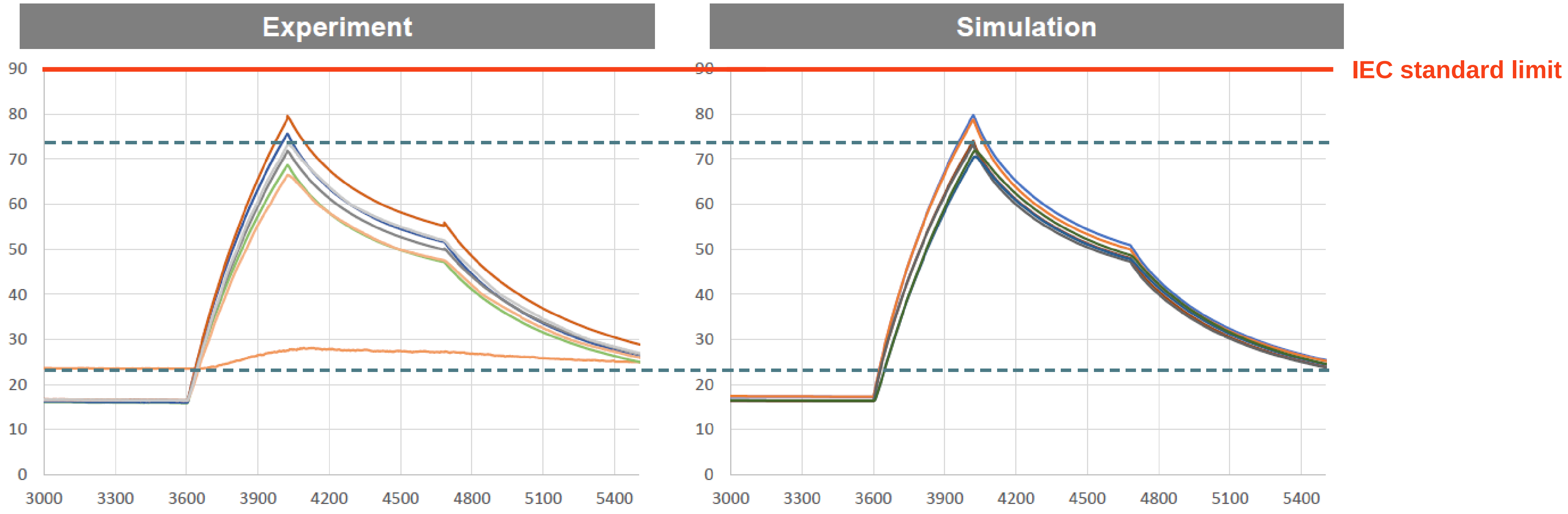
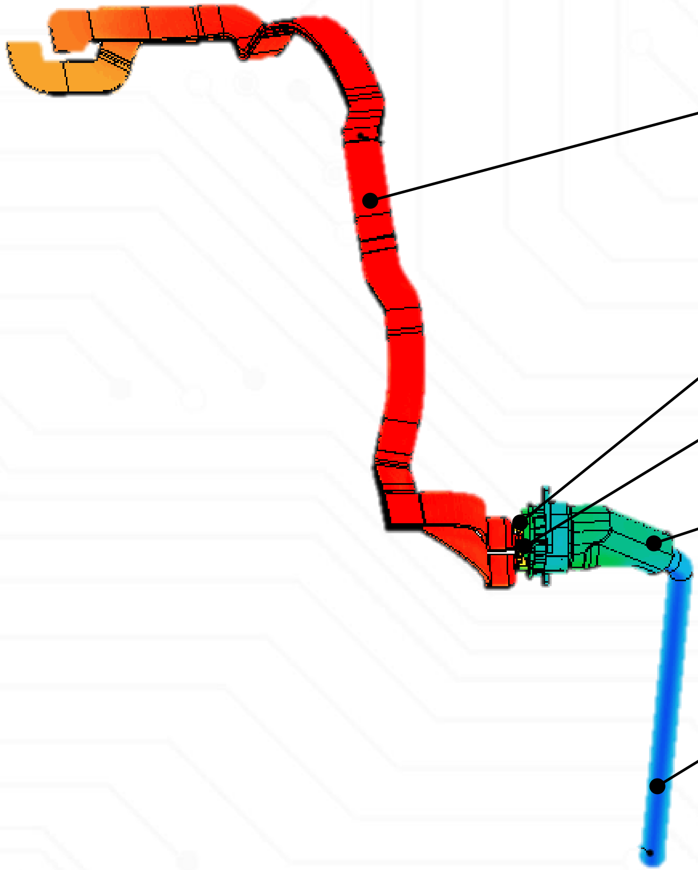
Experimental results

- **Very good accuracy provided that the assumptions are made correctly**
- **Cooperation between: simulation team, product engineering, OEMs, and charging station manufacturers is very important**



Conclusions

Weak points and solutions



- **Inlet harness** → innovative active cooling solutions
- **Inlet pin** → female terminal improvement, compensation by the harness and charging couplers
- **Thermal monitoring accuracy** → the use of high-accuracy thermal monitoring systems prevents false shutdowns
- **Charging Station** → good knowledge about charging coupler allows for better vehicle architecture design
- **Cable and terminals cooling** → direct cooling

High-fidelity thermal-electric-flow simulations help at every stage of the design!

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Thank you.

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