Toward self-monitoring cable systems in the field based on digital twins backed by COMSOL® simulations

Digitalization in the cable business

Dr. Romeo Bianchetti

LEONI

Our Vision:

Passion for intelligent energy and data solutions.

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Wiring Systems Division

Service and product portfolio

Wiring systems and their specific components such as harnesses including electromechanical and electronic components

Low voltage wiring systems

Harnesses and modules for power and data distribution in various types of vehicles as well as individual subsystems

Data solutions

Cable systems and solutions for data management in vehicles

Services

Use of comprehensive system expertise in design, optimisation and validation of modern vehicle architectures

High voltage solutions

High voltage harnesses and power distribution units for electromobility as well as solutions for the distribution of data and power in high voltage battery system

Energy solutions

Electromechanical and electronic systems for vehicle power distribution

Wire & Cable Solutions Division

Portfolio and markets

› Wire & Cable Solutions

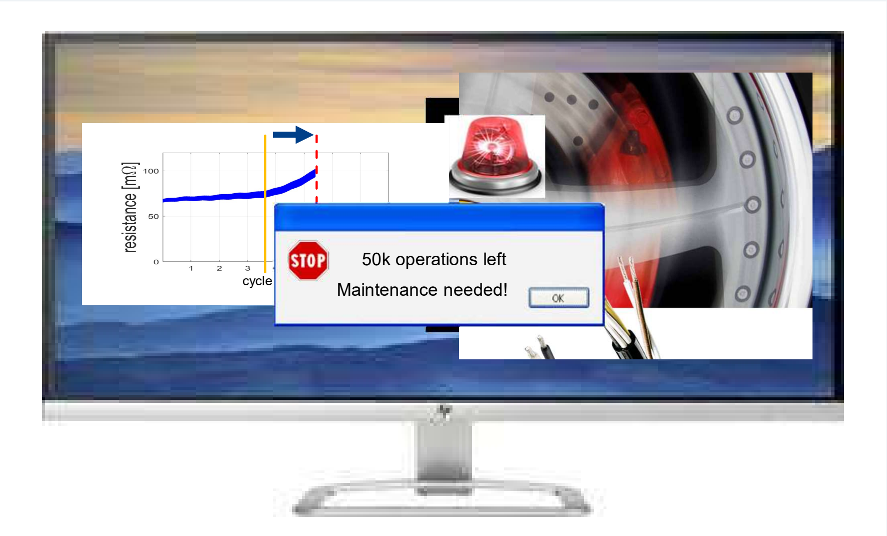
The WIRE & CABLE SOLUTIONS DIVISION (WCS) is a leading manufacturer of wire and cable systems, which is undergoing a digital transformation to successively become a solutions provider for safe and intelligent power transmission and data management systems.

The division's portfolio includes wires, strands and optical fibers, standardised cables, special cables and fully assembled systems as well as related services.

Markets of the Wire & Cable Solutions Division

CoE - Digital Functional Simulations

Base technology for digital solutions and data-driven business models

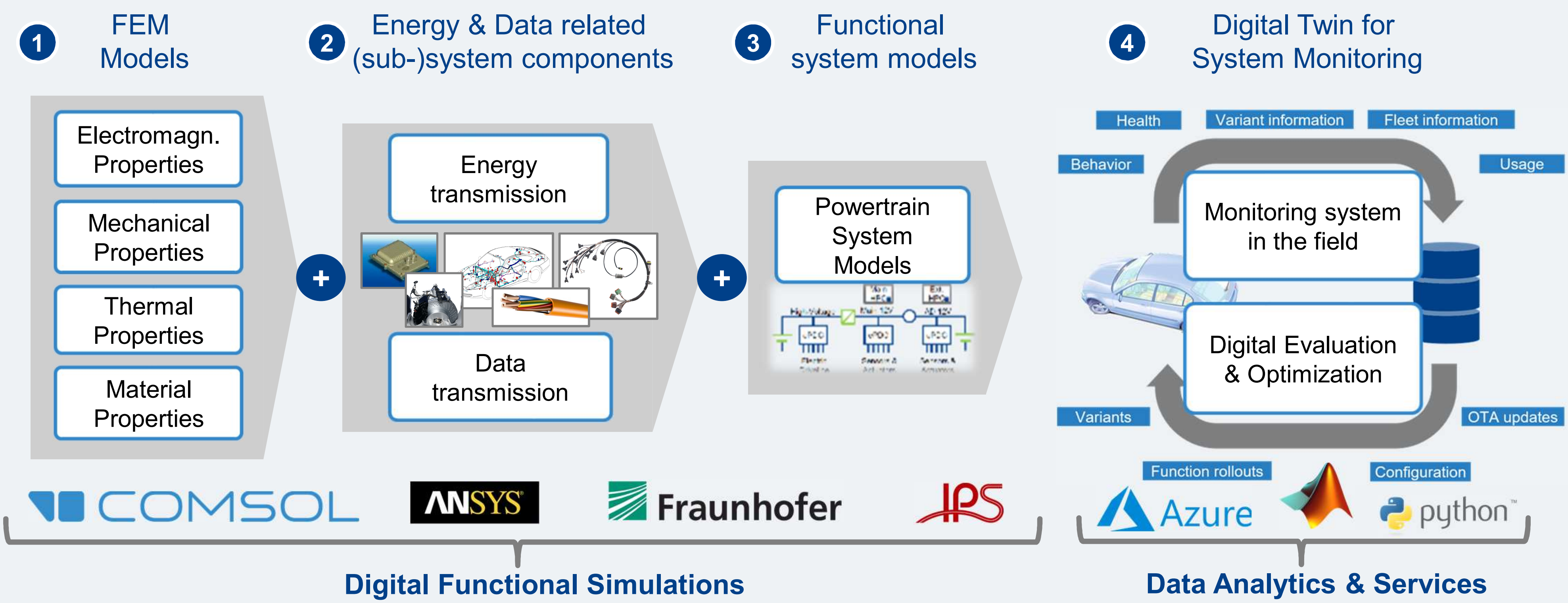


digital twins

- **condition monitoring**
- **predictive maintenance**
- **reduction of time-to-market**
- **model-based engineering**

Our digital competencies for intelligent solutions

Technology approach, scope, tools and partners



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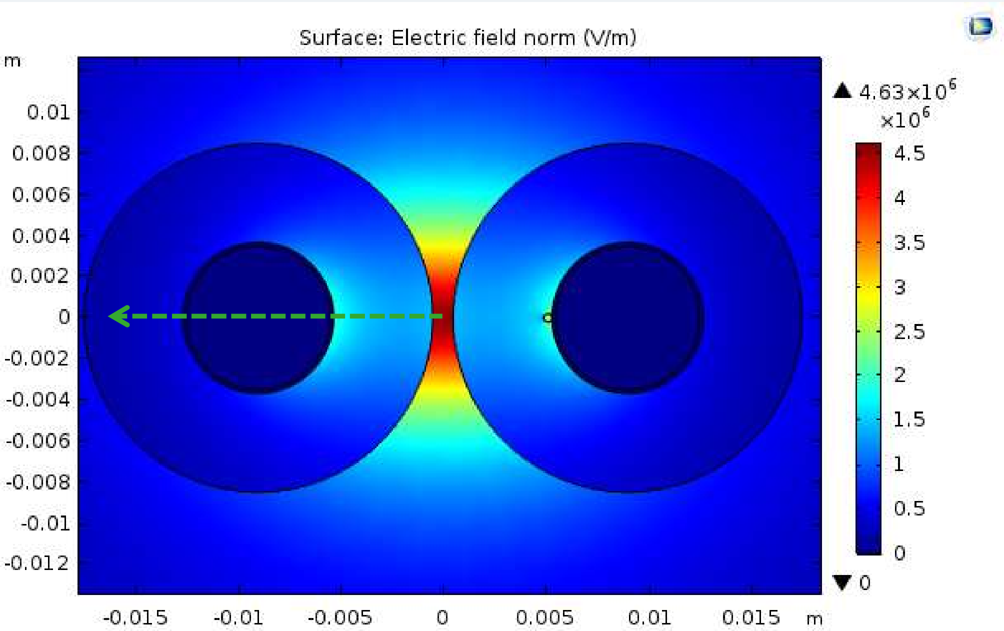
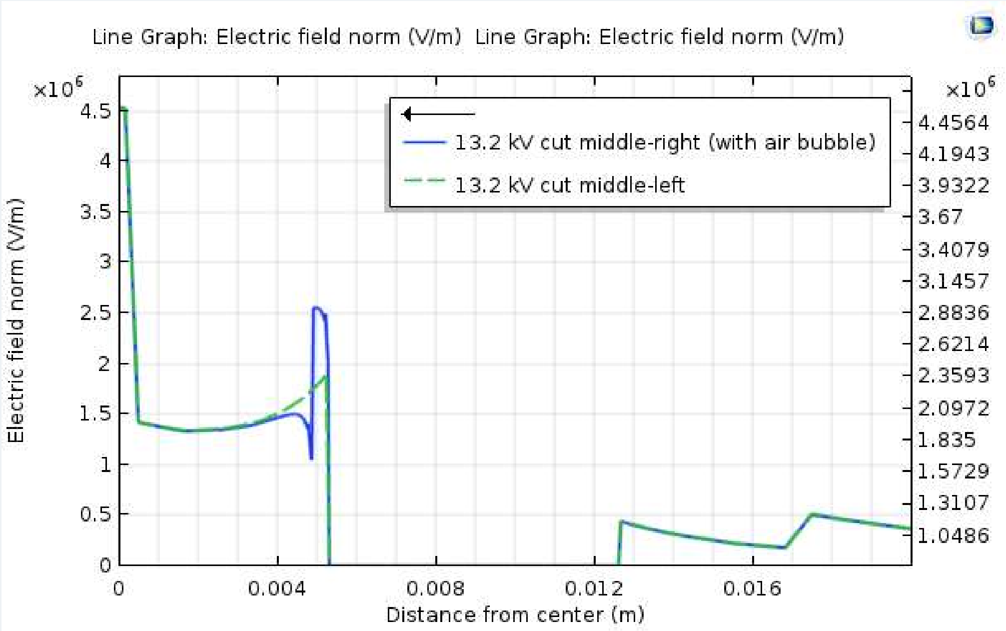
Medium voltage cable simulation

Electro magnetic simulation of 2 parallel cables in 2D

› Electric field norm for a 13.2kV configuration



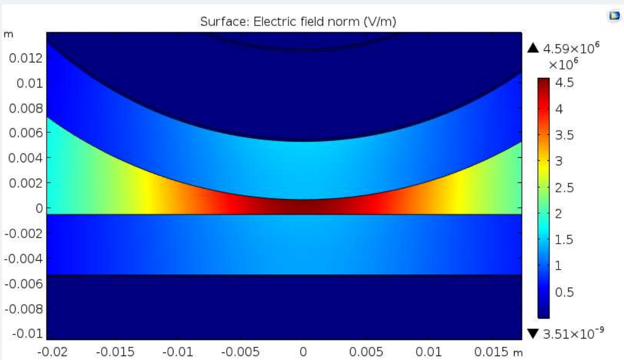


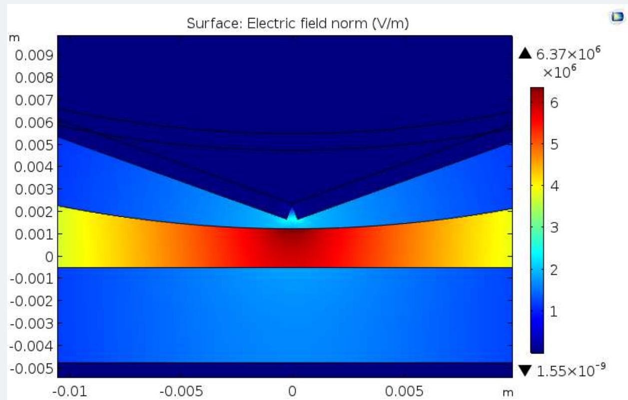
› Dielectric strength in air: $3 \cdot 10^6$ V/m
› Dielectric strength in silicone: $25 \cdot 10^6$ V/m

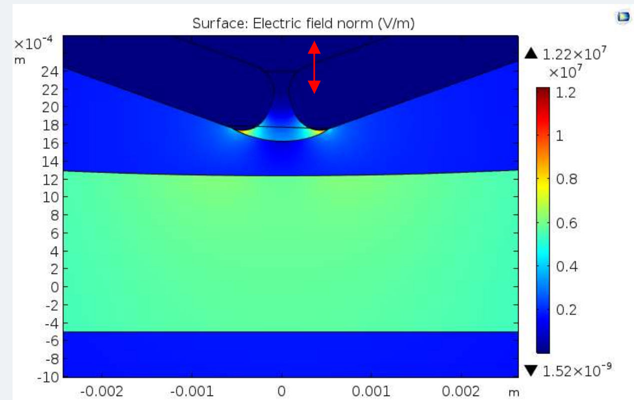
} Partial discharge could occur in air

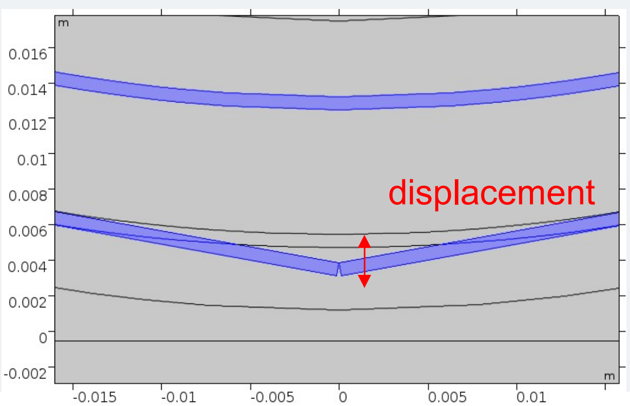
Medium voltage cable simulation

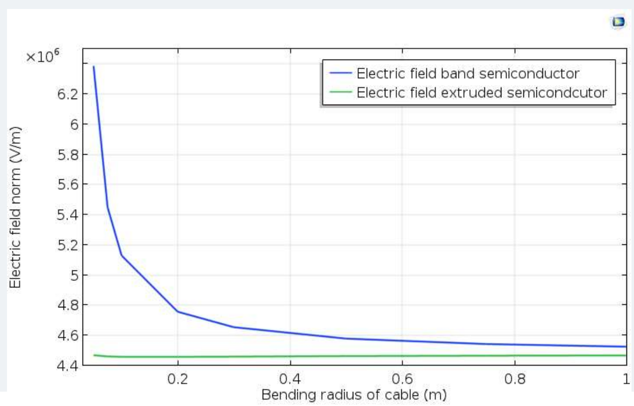
Various configurations and comparisons, AC and DC Configurations

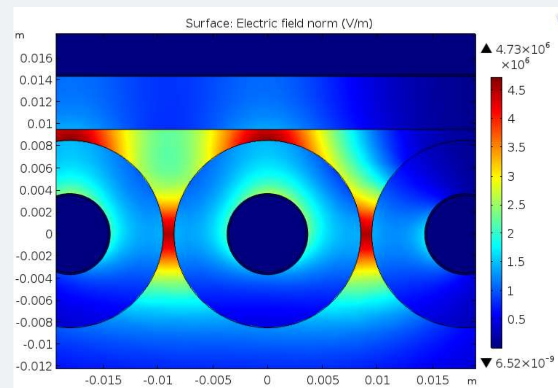












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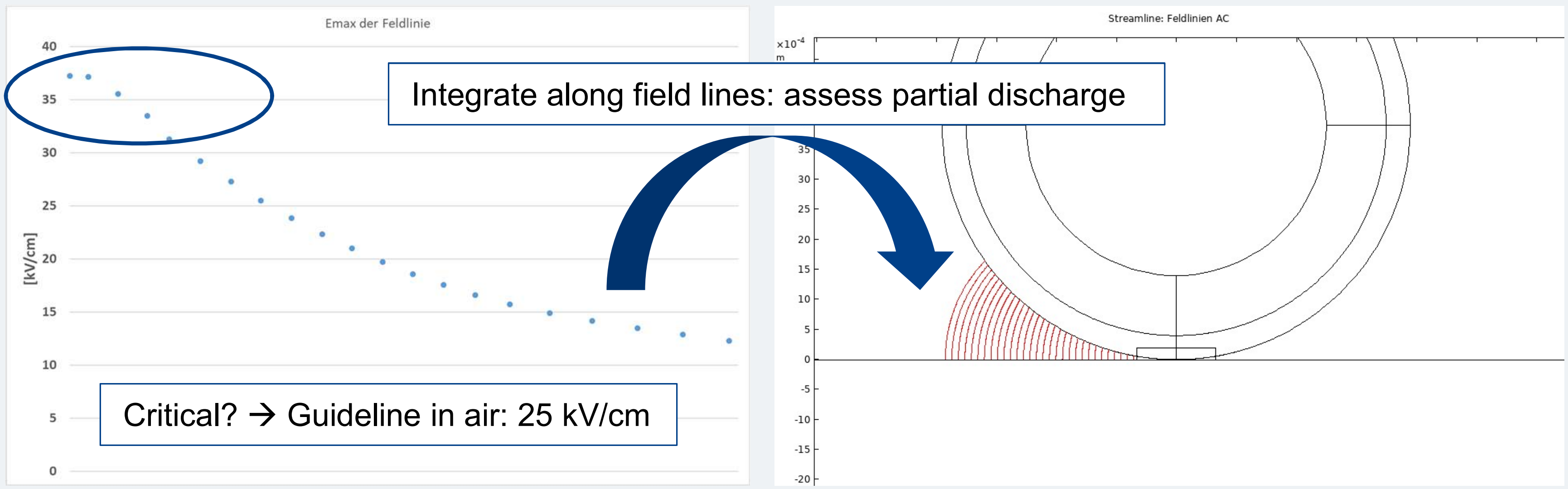
[Public]

Field strength is not enough, need stringent failure criteria

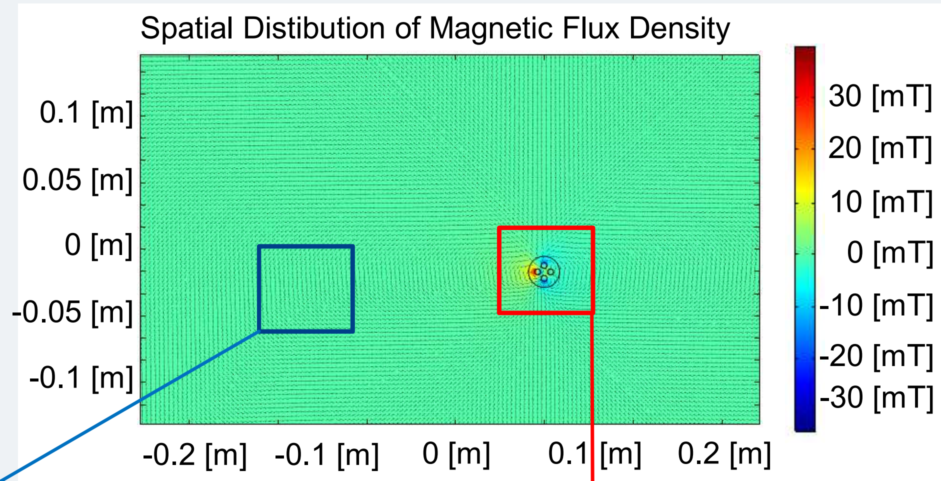
Assess and predict failures

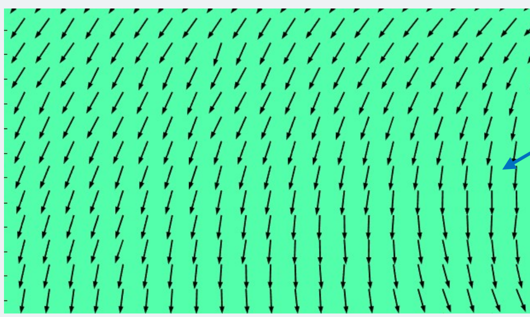


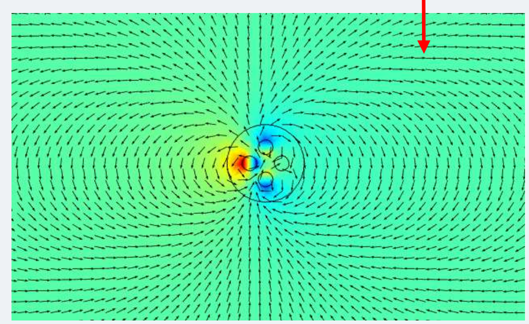
- Streamer criterion: ~4.6 kV (AC) and ~2.3 kV (DC)
- Townsend mechanism: ~3.5 kV (AC) and ~1.7 kV (DC)
- Parameters? Validation? Need Data!

Magnetic fields around high current twisted cables

A simple case to solve? In the near field, convergence in the far field is not trivial.







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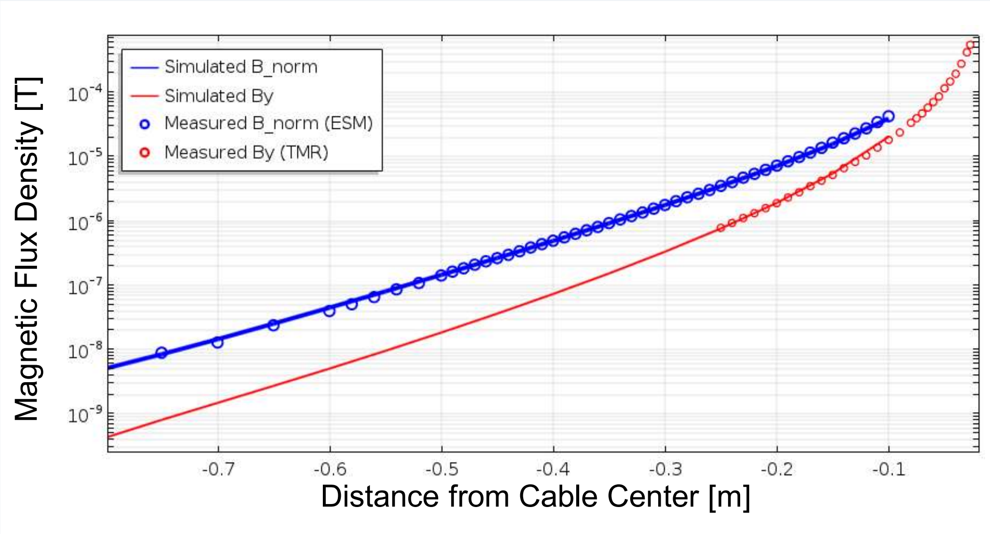
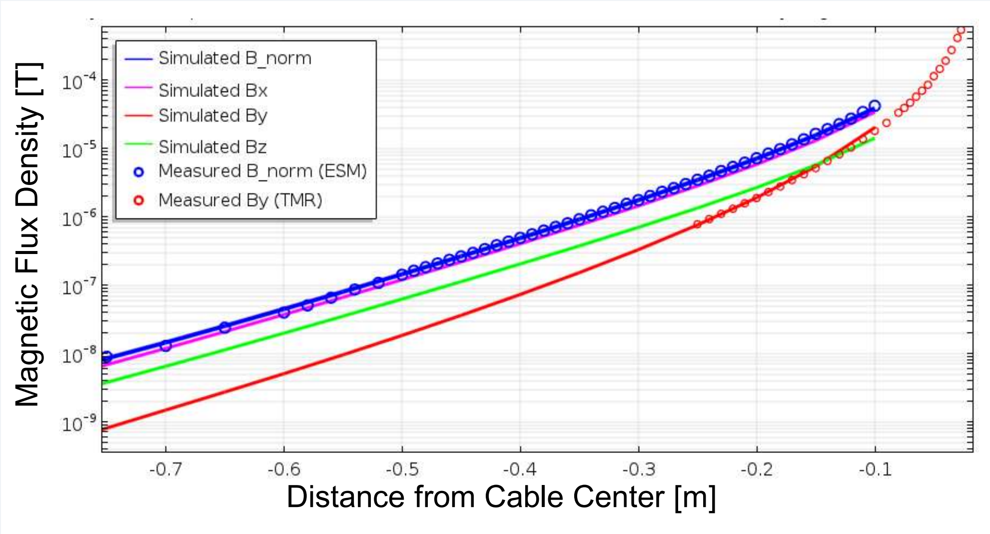
Magnetic fields around high current twisted cables

A simple case to solve? Only if you manually integrate Biot–Savart

Comparison between measurements (done at NTB by Prof. A Weitnauer) and simulation using $$\boldsymbol{B}(\boldsymbol{r}) = \frac{\mu_0}{4\pi}\int_C \frac{I\, d\boldsymbol{l} \times \boldsymbol{r}'}{|\boldsymbol{r}'|^3}$$





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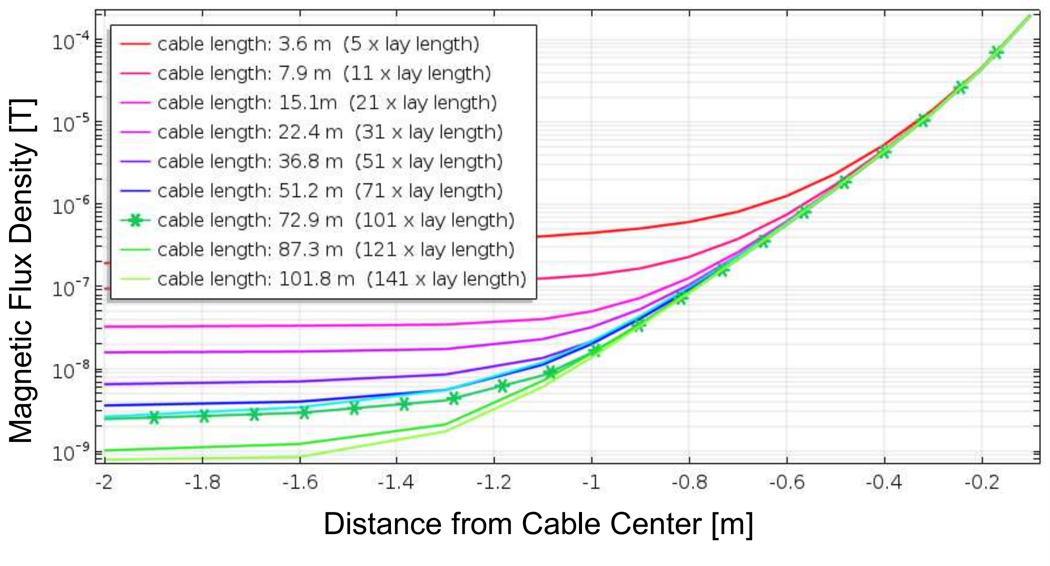
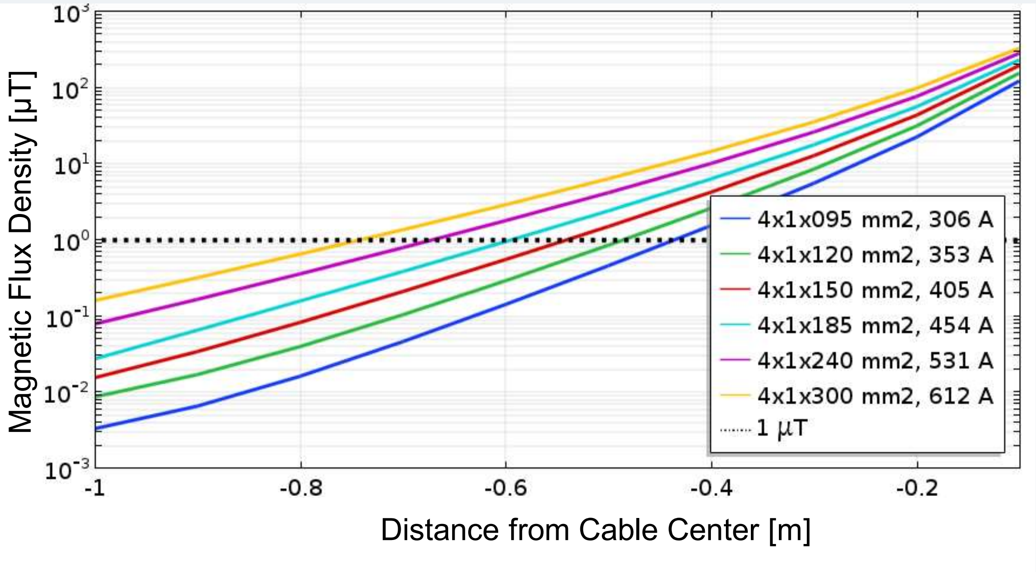
Magnetic fields around high current twisted cables

Scaling and parameter sensitivity

Cable length dependence of magnetic field



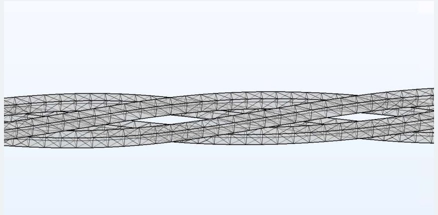
Simulation of TRAFO-FLEX line of LEONI Studer AG



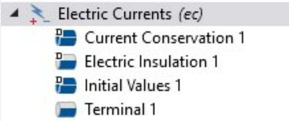
Magnetic fields around high current twisted cables

Design settings

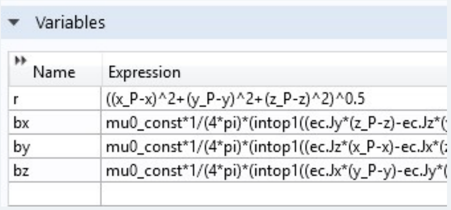
Geometry: Twisted conductors, no airbox



Solve just for the electric field



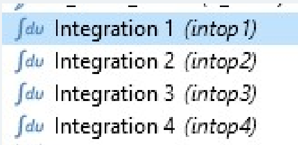
Biot–Savart as explicit variable



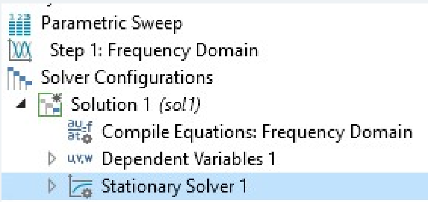
Variables

Name	Expression
r	((x_P-x)^2+(y_P-y)^2+(z_P-z)^2)^0.5
bx	mu0_const*1/(4*pi)*(intop1((ec.Jy*(z_P-z)-ec.Jz*(
by	mu0_const*1/(4*pi)*(intop1((ec.Jz*(x_P-x)-ec.Jx*(:
bz	mu0_const*1/(4*pi)*(intop1((ec.Jx*(y_P-y)-ec.Jy*(

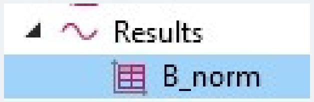
Define a parameter sweep and a set of integrals



Direct solution in one step on tiny mesh

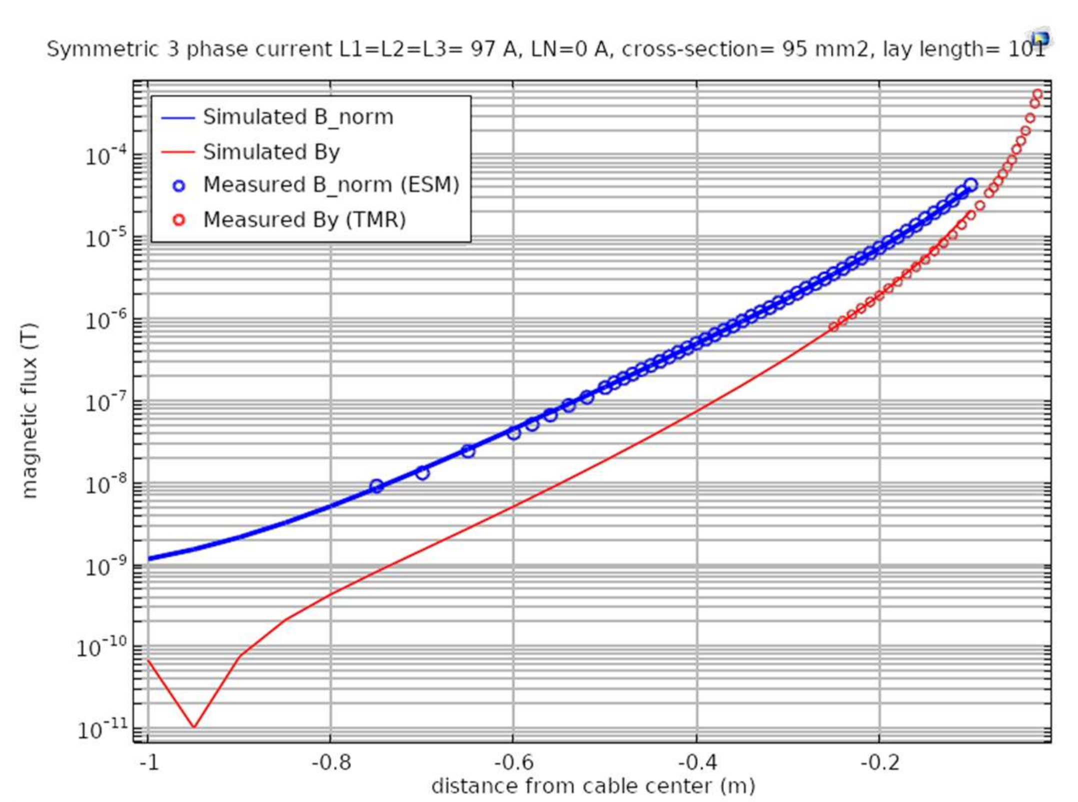


Postprocess, plot and export the results



Magnetic fields around high current twisted cables

Design settings



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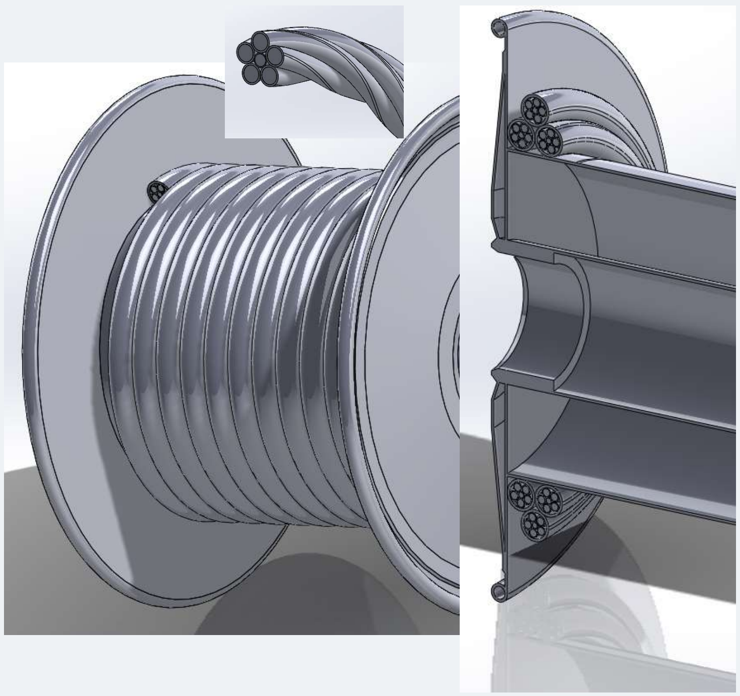
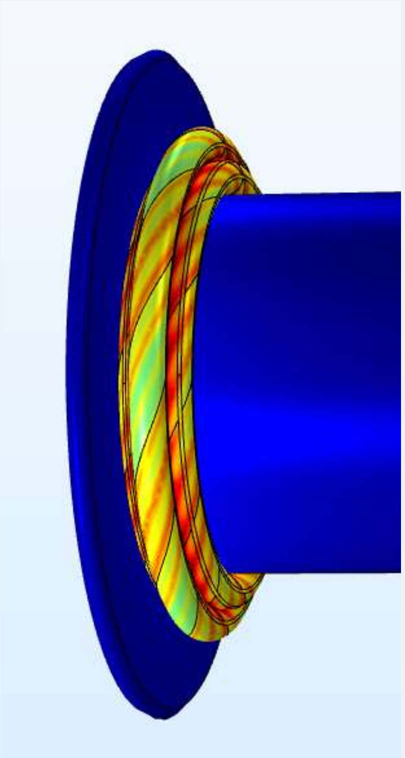
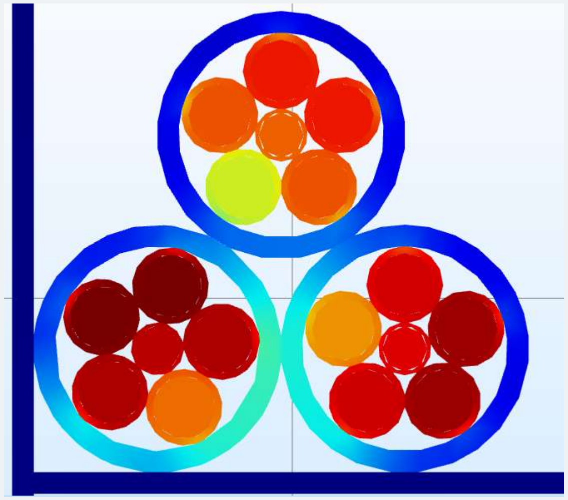
Simulating the impact of the environment on cable systems

Setting up a drummed cable (HPC DC)

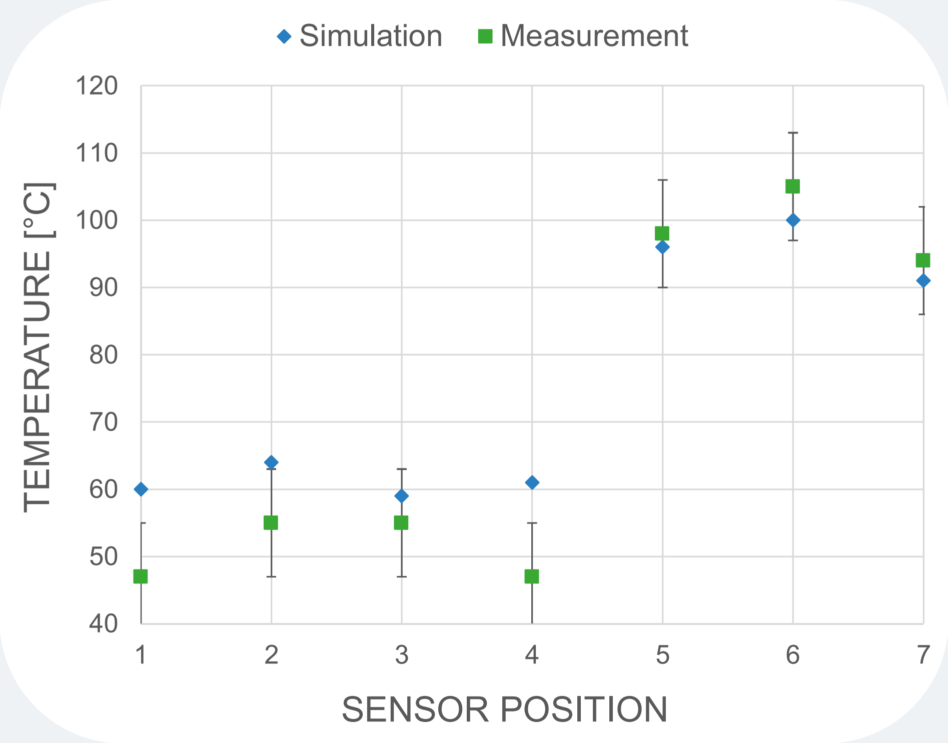


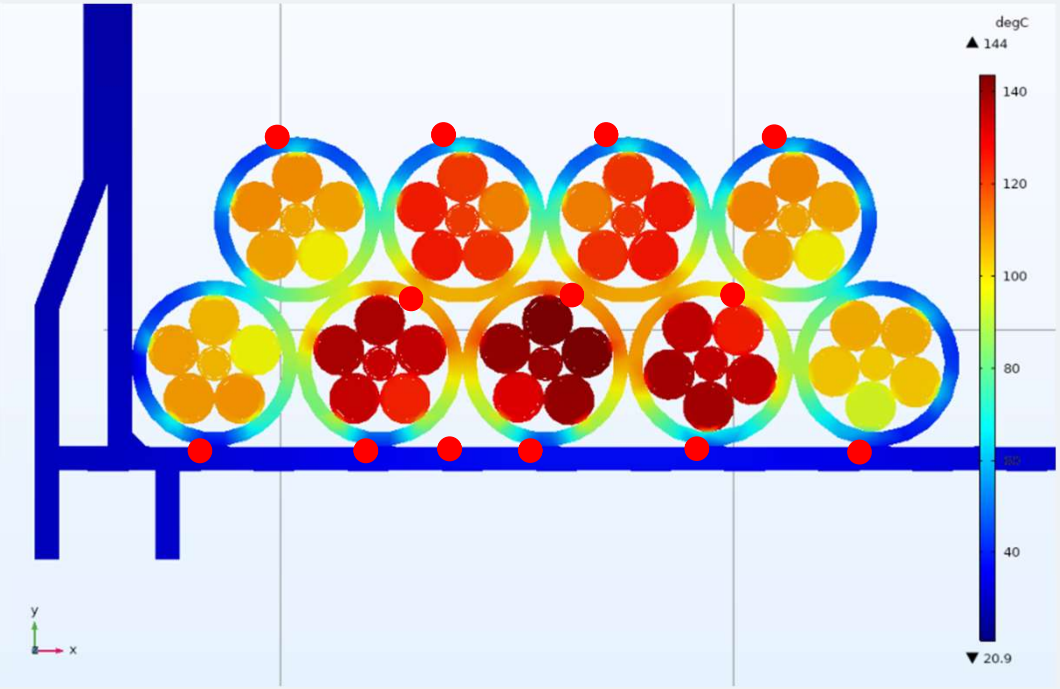




Simulating the impact of the environment on cable systems

Validating a drummed cable





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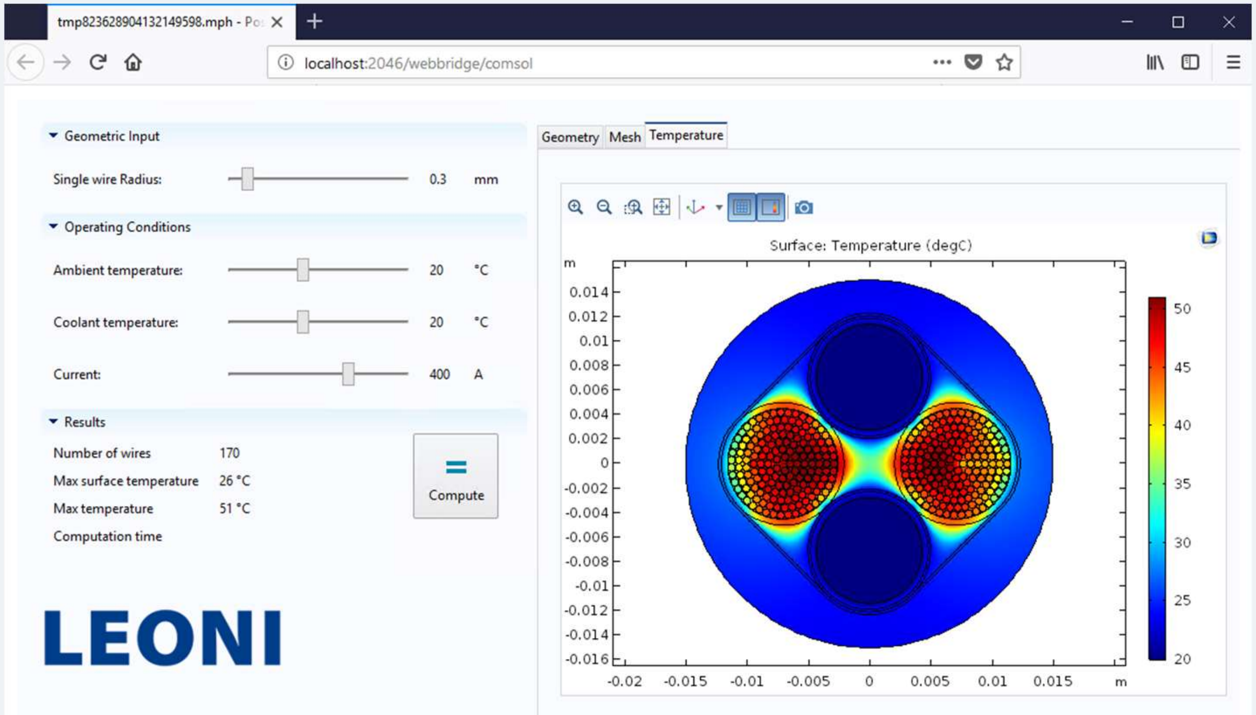
Simulating the impact of the environment on cable systems

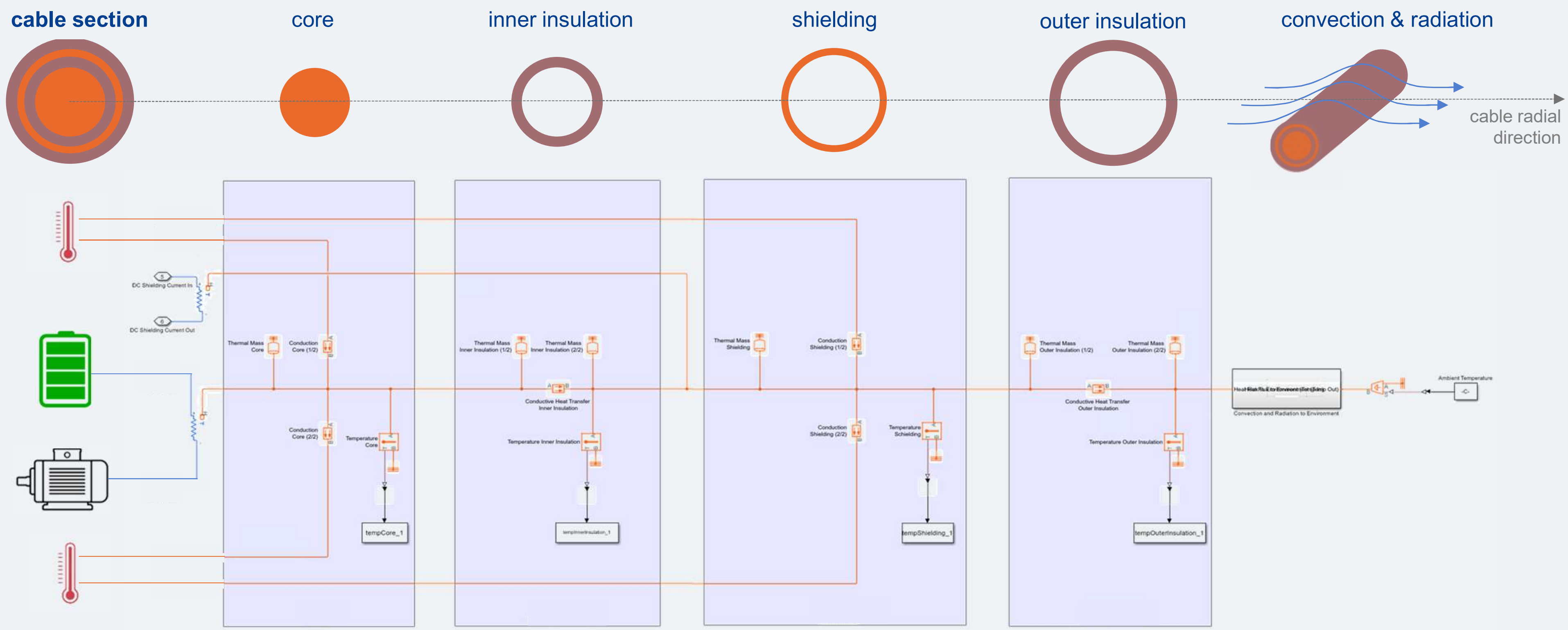
Reduce complex multiphysics simulations to simple app

- Executable without licenses and limitations
- Easy to share across units
- Show case for sales
- Support for product development



Sub-System Simulations – Thermal Network Modelling

Description of thermal properties of a cable using the thermal network approach



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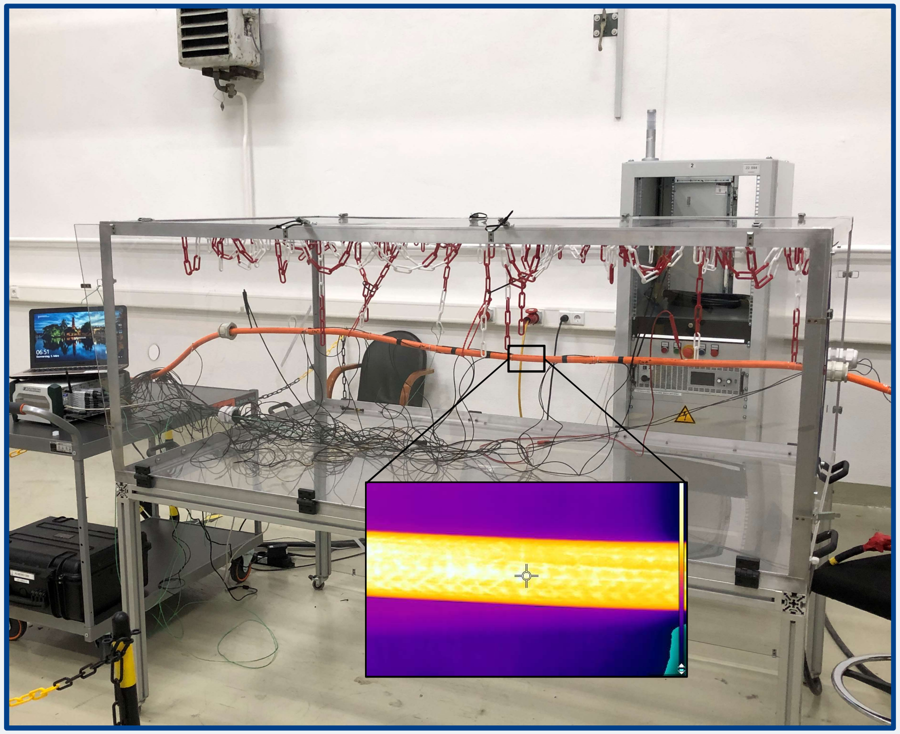
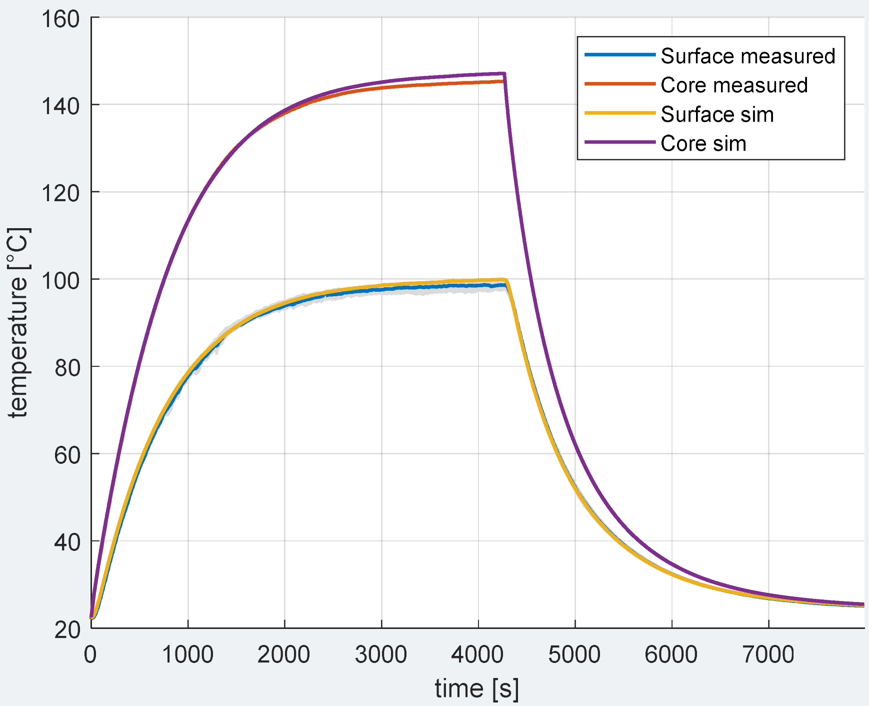
Sub-System Simulations – Thermal Network Modelling

Validation – Electric thermal cable model

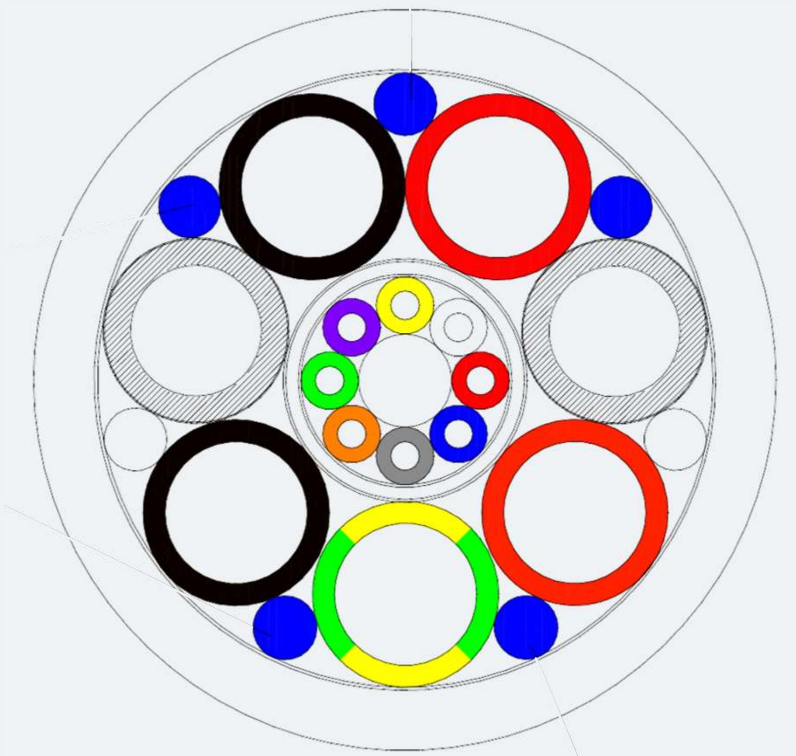




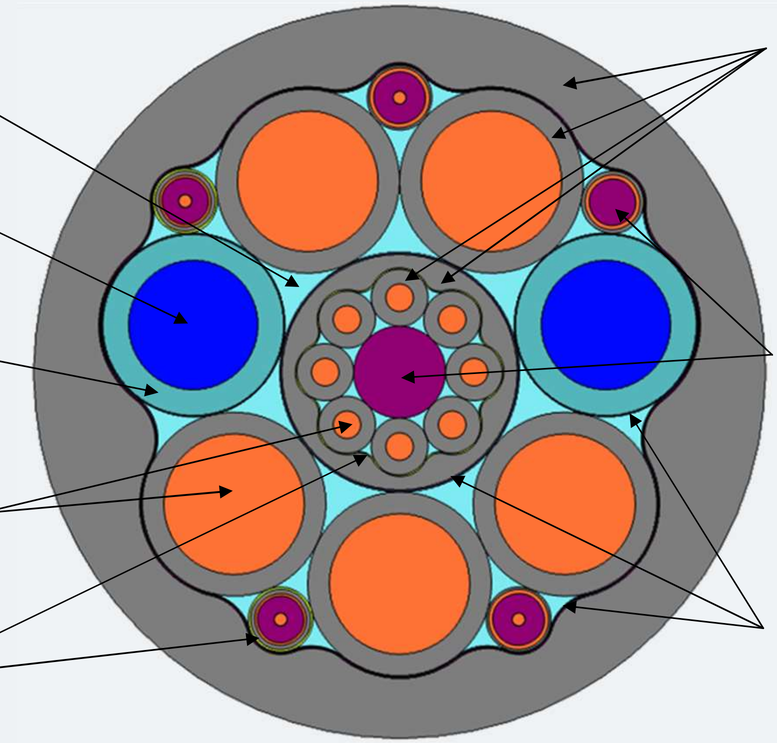
What happens for more complex systems?

A water-cooled high performance DC Automotive charging cable

Drawing



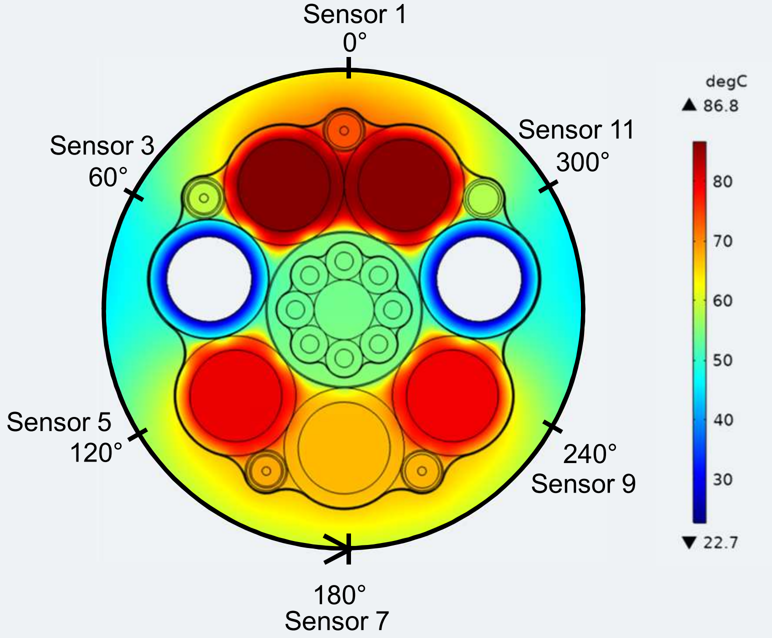
Model

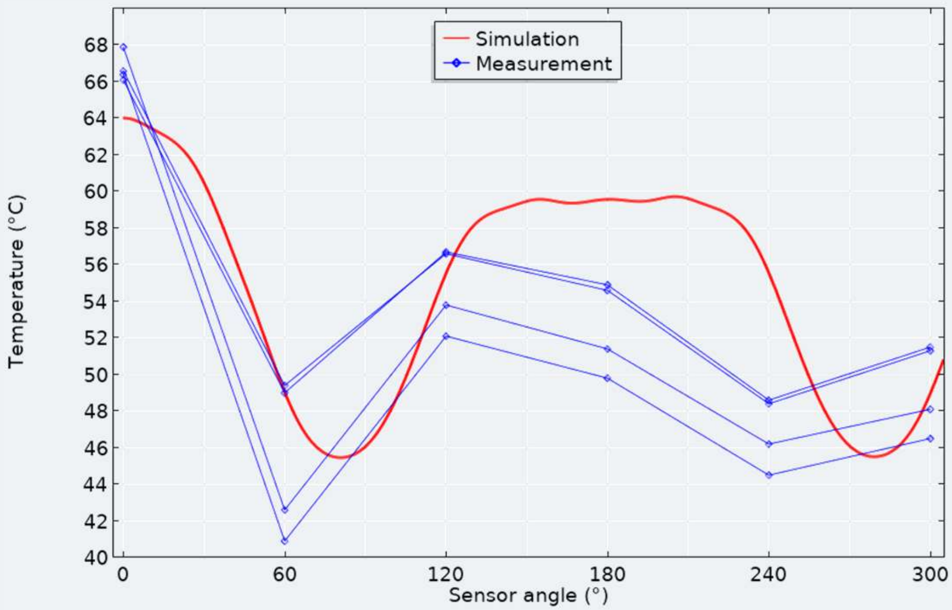


Simulation validation

Comparison with experimental data at **500A**

- FEM Simulation compared to measurements
- Adapt copper material properties to correct filling factor using measured electrical resistance per meter
- Important uncertainties in thermal conductivity and c_p of polymers → fit inside bounds





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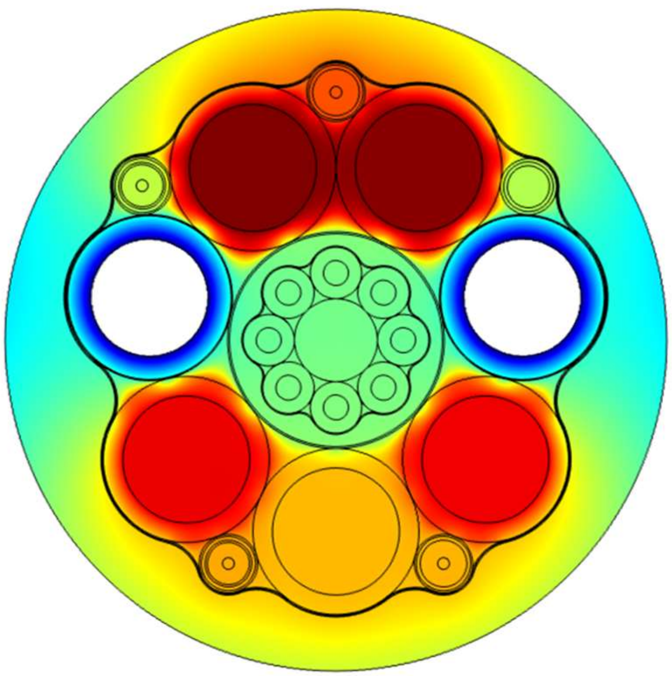
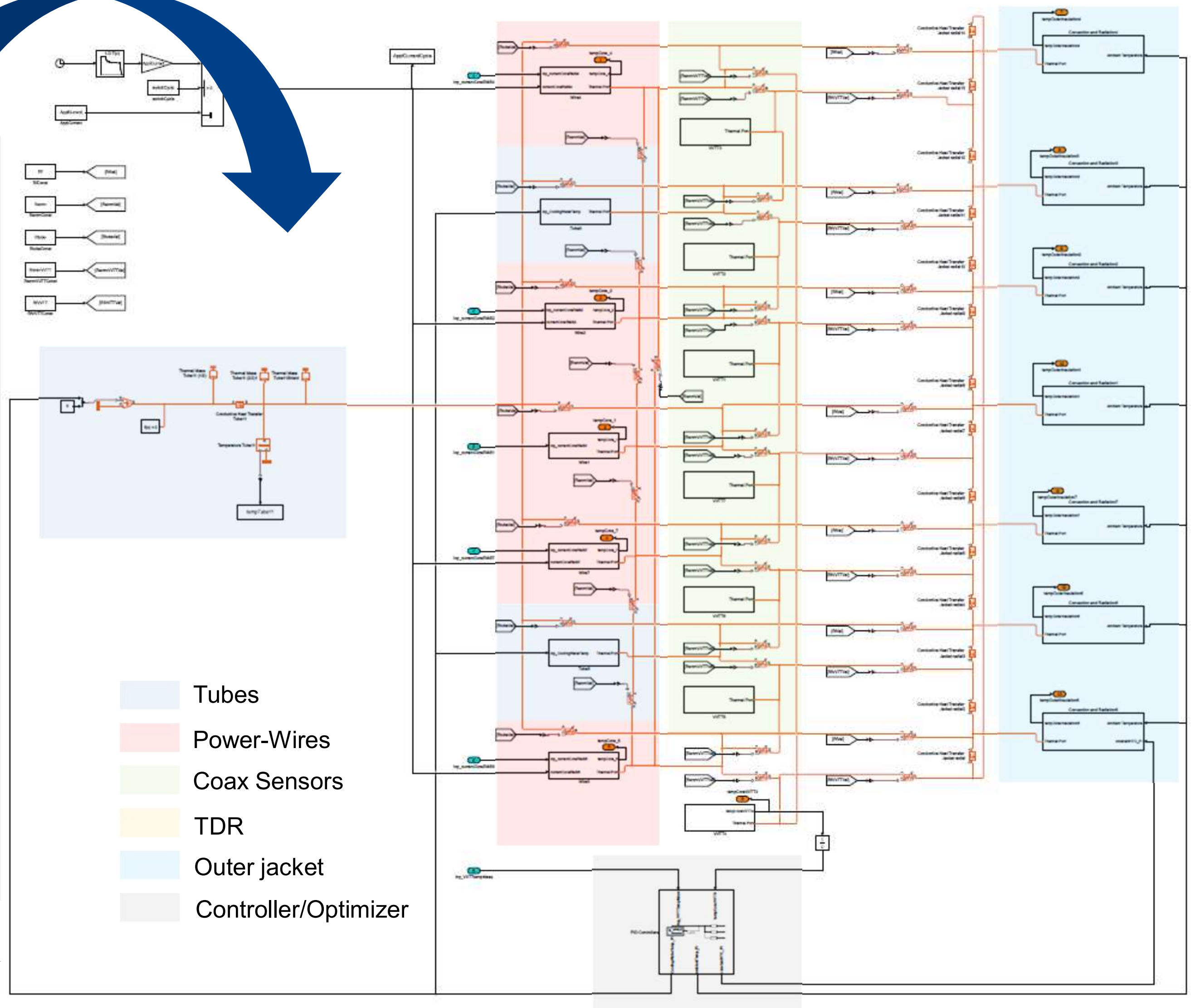
Thermal network

Increasing complexity

FEM simulation

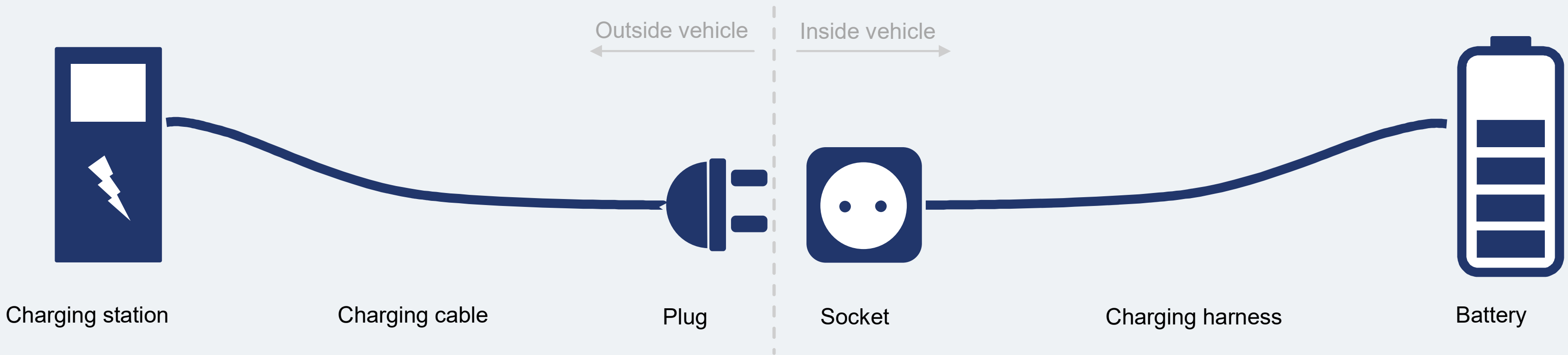


Thermal network



Simulation capabilities

Electro-thermal systems: an example

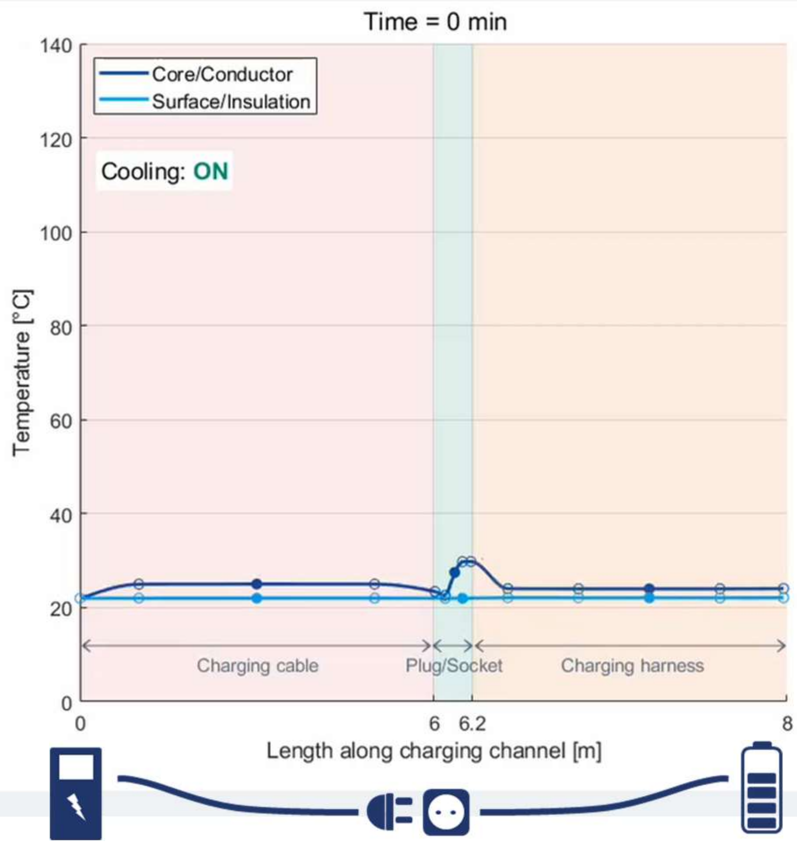


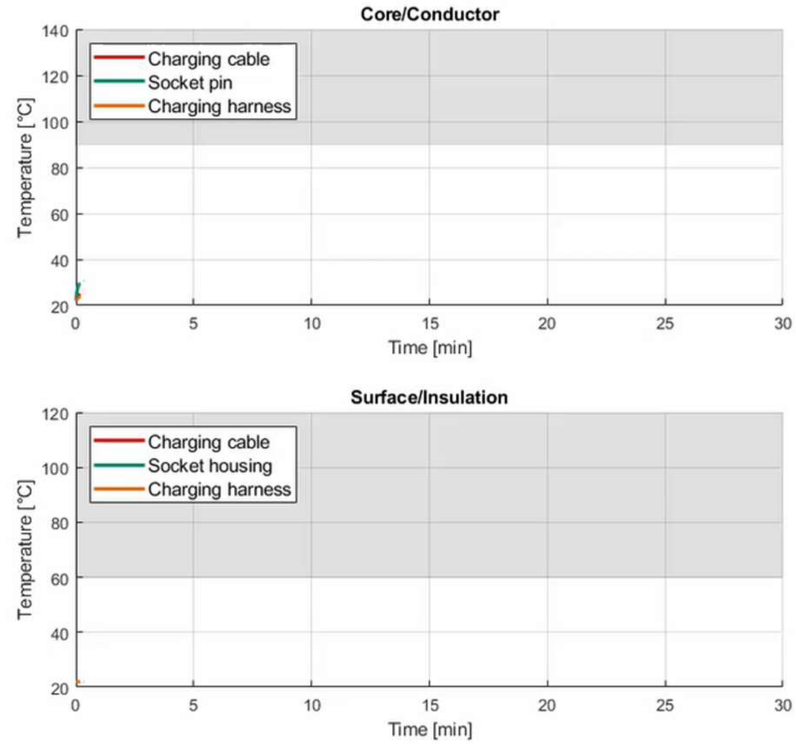
- Modeling of charge cycle components and interaction within system
- Coupling of electrical power flow and resulting thermal heating of components and cables
- Optimize system design and enable condition monitoring and predictive maintenance

Digital functional system simulation

Example: Intelligent charging column

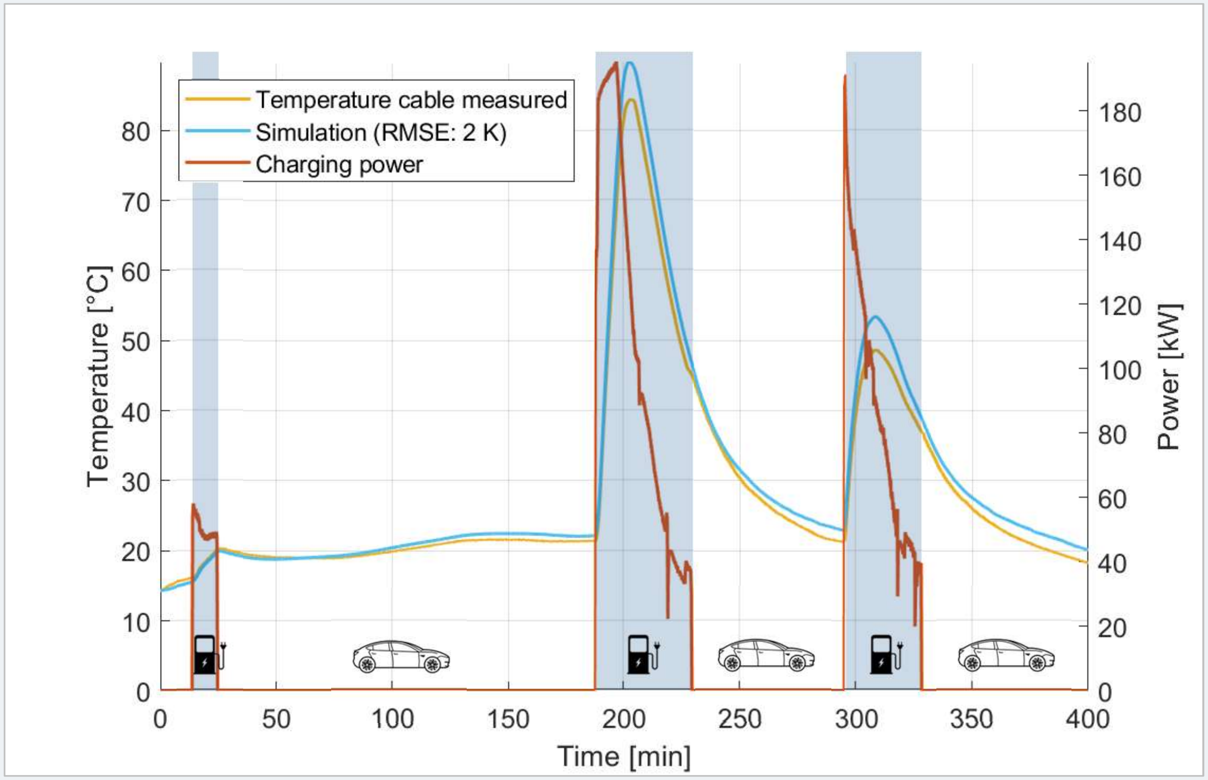
- 500A
- 400V
- 200kW
- Cooling
- 100kWh
- 30 min





LEONiQ TechCar: Digital twin for charging cable set

Simulating sub system of charging cable set towards temperature development



Simulation of charging channel

- Simulation results show matching transient behaviour during charging and following cool down period: Ø RMSE 1.4 K
- Model computes transient "3D" temperature distribution of charging cable
- Real-time capable simulation model
- Transfer of LEONI electric thermal cable model from laboratory setup into application

Ideal areas for application

Use cases for intelligent cables and functional simulations

Integration of intelligent cables into:

- **Systems with high safety demands**
- **Complex systems with high maintenance demands (high downtime costs)**
- **Systems transparency in high performance applications**

Application of functional simulations in:

- **Complex development projects**
- **Lifetime prediction with LEONiQ**

Your contact

Dr. Romeo Bianchetti

› Team Lead Digital Twins

› Address Hohlstrasse 190
8004 Zürich

› Phone +41 79 626 38 00
› E-mail romeo.bianchetti@leoni.com

www.leoni.com