How Nexans Increases the Cost-Effectiveness of Cable Assets Using Multiphysics Simulation

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Presentation outline

- Nexans core business: power & communication cables and accessories
- Why Nexans uses multiphysics simulation
- Virtual prototyping of cables and accessories
  - Improving time-to-market of research and development projects
- Dynamic cable rating methodology
  - Improving cost-effectiveness of cable installations thanks to dynamic multiphysics simulations
- Perspectives in cable multiphysics simulation

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Nexans: electric cables and accessories

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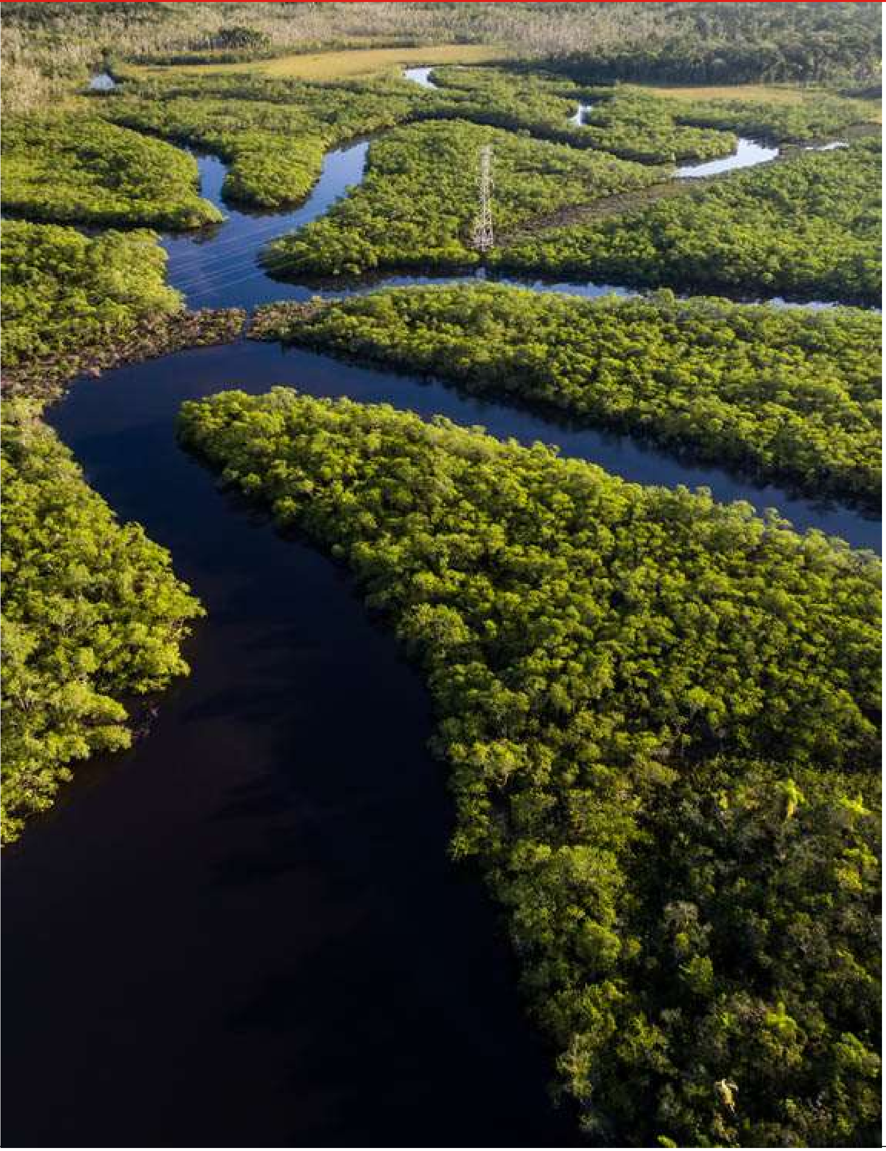

Nexans global footprint

Headquarters in **Paris**

Serving customers on **all continents**

Industrial footprint **in 34 countries** and commercial activities **worldwide**

26,000 employees

Sales in 2017 of **6.4 billion Euros**

Serving key markets

HIGH VOLTAGE & PROJECTS

Support customers from the beginning (design phases) to the end (system management) in finding the right cable system solution to address their efficiency and reliability challenges.

INDUSTRY & SOLUTIONS

Support OEMs and industrial infrastructure projects in customizing their cabling and connectivity solutions addressing their electrification, digitalization and automation challenges.

TELECOM & DATA

Help customers to easily deploy optical fiber infrastructure with “plug-and-play” cable, connectivity and solutions.

BUILDING & TERRITORIES

Provide reliable cabling and smarter energy solutions to support buildings and territories to become more efficient, livable and sustainable.

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Nexans in everyday life

Transportation: ~1km of cable per passenger

5,000 km
CRUISE SHIP

650 km
ADVANCED CIVIL AIRCRAFT

200 km
DATA CENTER

1,750 km
OFFSHORE WIND FARM

450 km
MINE

Examples of **lengths of power and data cables** in each unit

30 km
1,500 SQ. M. BUILDING

1,500 km
OFFSHORE PLATFORM

300 km
HIGH-SPEED TRAIN

5 km
CAR

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Nexans: an innovative cable manufacturer

More distance with lower losses for offshore grids and farms

HVDC submarine cables go deeper - 1300m deep with 525kV MI Joints

HVDC underground extruded cables - qualified at 320kV

Higher capacity within less space for Urban Grids

Superconductive systems in Germany and USA

A new project in Chicago Grid

Smart charging solutions for electric vehicles

Partnership with G2mobility

Decrease cost to serve for renewable energy in Wind

Copper replacement by Aluminum

Harnesses with connectors

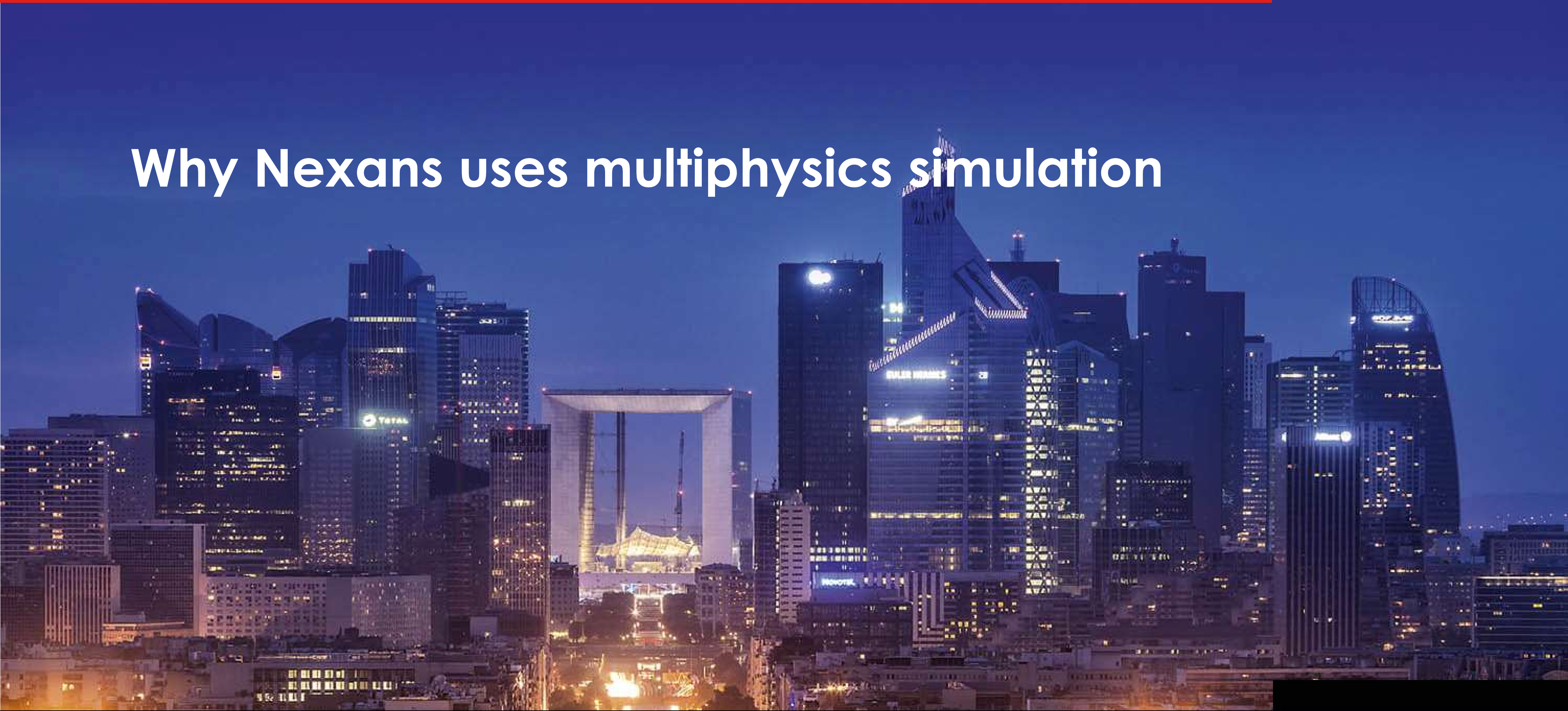
High performance operation at -65°C for Oil & Gas platforms

New materials with high mechanical resistance at low temperature

Improved safety with Fire retardant cables for buildings and tunnels

Regulation compliance, e.g. CPR in Europe

Why Nexans uses multiphysics simulation



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Cable installation design implies multiple physics

HEAT TRANSFER

Maximum operating temperature of cables and accessories, related to their **lifetime**

Limitation **in environment temperature increase** due to cables

Electro-magnetism

Electric and magnetic fields generate **losses**.

Voltage drop in conductors can be a bottleneck

Limited magnetic and electric fields must be emitted to the environment

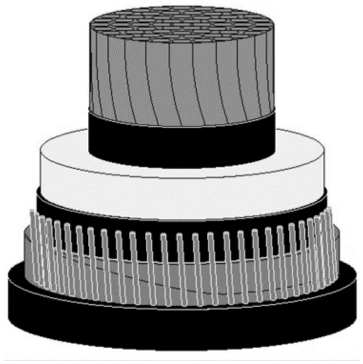
Fluid dynamics

Heat is often dissipated in the environment by **natural or forced convection**

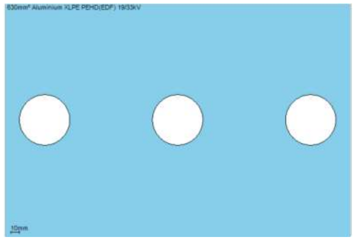
Heat can also be transferred through **fluids or gases** (air, water, oil, SF6)

Environment plays a major role in cable sizing

33kV 630mm² aluminum cable

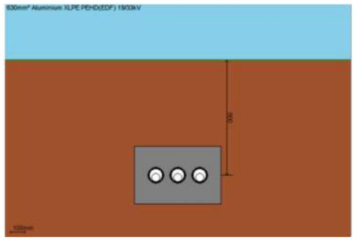


Installed in free air



1099 A
(62.9 MVA)

Installed in buried ducts



528 A
(30.2 MVA)

⇒ **Power transmission capacity is not an intrinsic parameter of power cables**

⇒ **Accurate understanding and modeling of cable environment is required**

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Analytical models exist describing several phenomena to be described

Heat transfer

- Thermal resistances of cable layers, and of the external components
- Mutual heating of cables, cable lines crossings
- External heat source

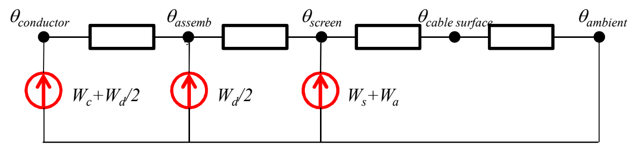
Magnetic and electric fields

- Skin and proximity effects
- Induced currents and voltages in screens and armors
- Inductances
- Magnetic losses
- Dielectric losses

Fluid dynamics

- Convection correlations depending on installation
- Equivalent thermal conductivities for narrow spaces

⇒ Most of these analytical formulas can be found in cable calculation standards (e.g. IEC standards)



$$I = \sqrt{\frac{\Delta\theta - W_d\left(0.5T_1 + n(T_2+T_3+T_4)\right)}{RT_1 + nR(1+\lambda_1)T_2 + nR(1+\lambda_1+\lambda_2)(T_3+T_4)}}$$

⇒ These standards are rather complex, errors can be made due to misinterpretations

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We like using COMSOL® as a complement to standards

- More versatile, avoiding tedious detailed reading and interpretation of standards

  IEC provides cables sizing standards counting ~20 documents for a total of ~500 pages

  A FE model can be used numerous times with minor adaptations (parameter change)

⇒ Less room for errors

- Complex problems can be solved with less approximations

⇒ Less conservatism leading solutions optimized one step further

- Complex design methodologies can be brought to all using applications

⇒ And now standalone executables with COMSOL® 5.4!

- It takes time and expertise to setup models, but it saves time by avoiding trial-and-error processes

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Virtual prototyping

Improved time-to-market of cables and accessories

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Magnetic-thermal design of a submarine cable plug
Simplification of geometry

Thermal problem: cable and connector have a maximum operating temperature

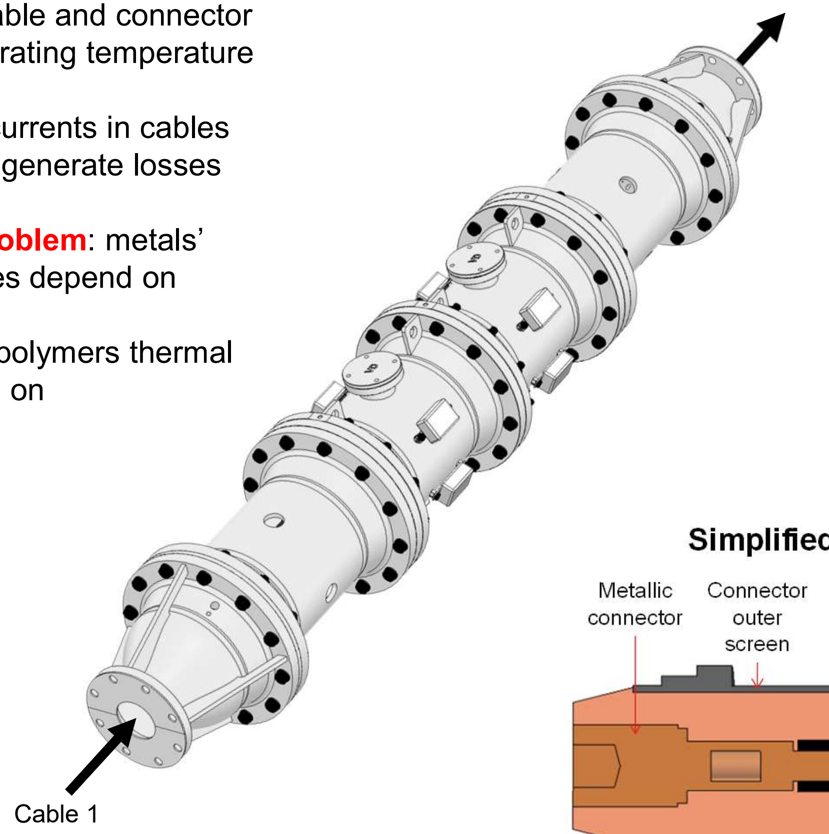
\+

Magnetic problem: currents in cables and induced currents generate losses

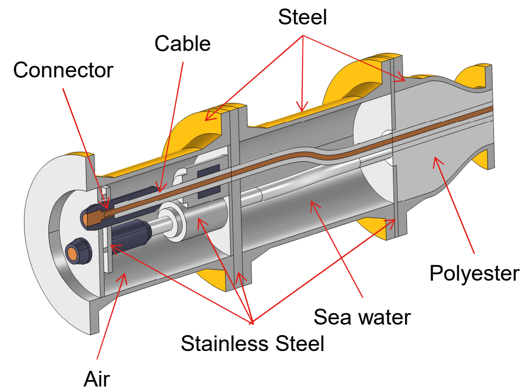
=

Strongly coupled problem: metals' electrical conductivities depend on temperature

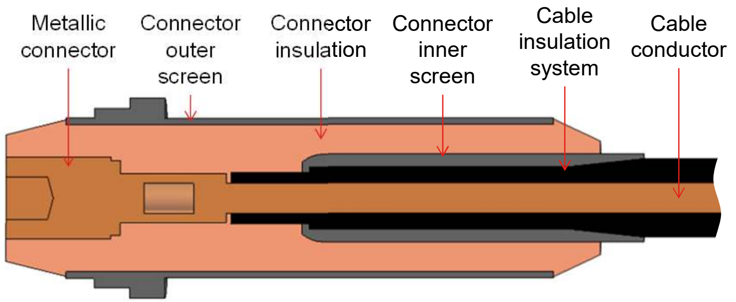
Nonlinear problem: polymers thermal conductivities depend on temperature



Halved and simplified plug geometry



Simplified connector geometry



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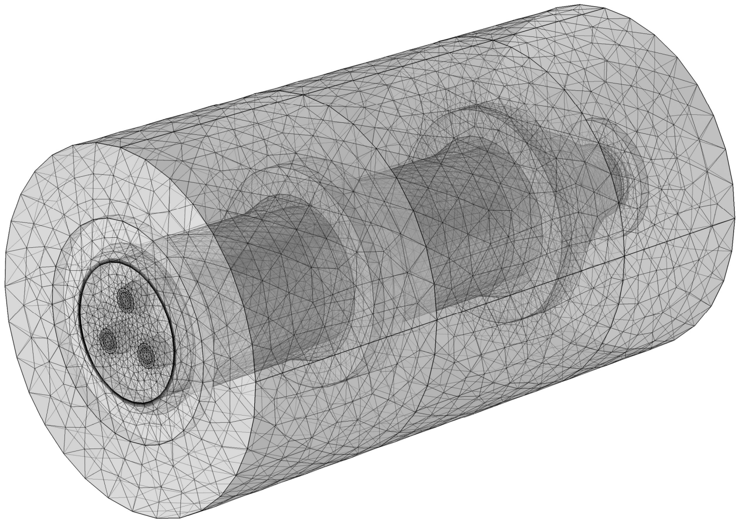
Magnetic-thermal design of a submarine cable plug

Mesh and boundary conditions



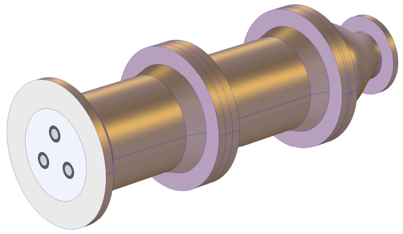
Boundary layer meshing
(skin and proximity magnetic effects)

⇒ 4.7 Mdof for the magnetic part

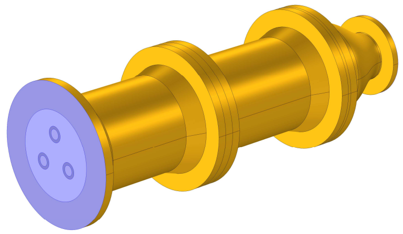
⇒ 1.6 Mdof for the heat transfer part

2-layers thermally thick layer to model coating & marine growth

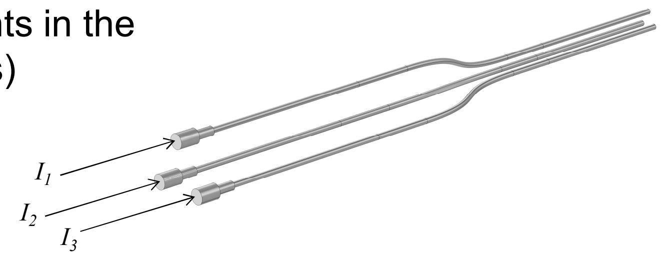
Water temperature on external face



Thermal insulation on lateral faces



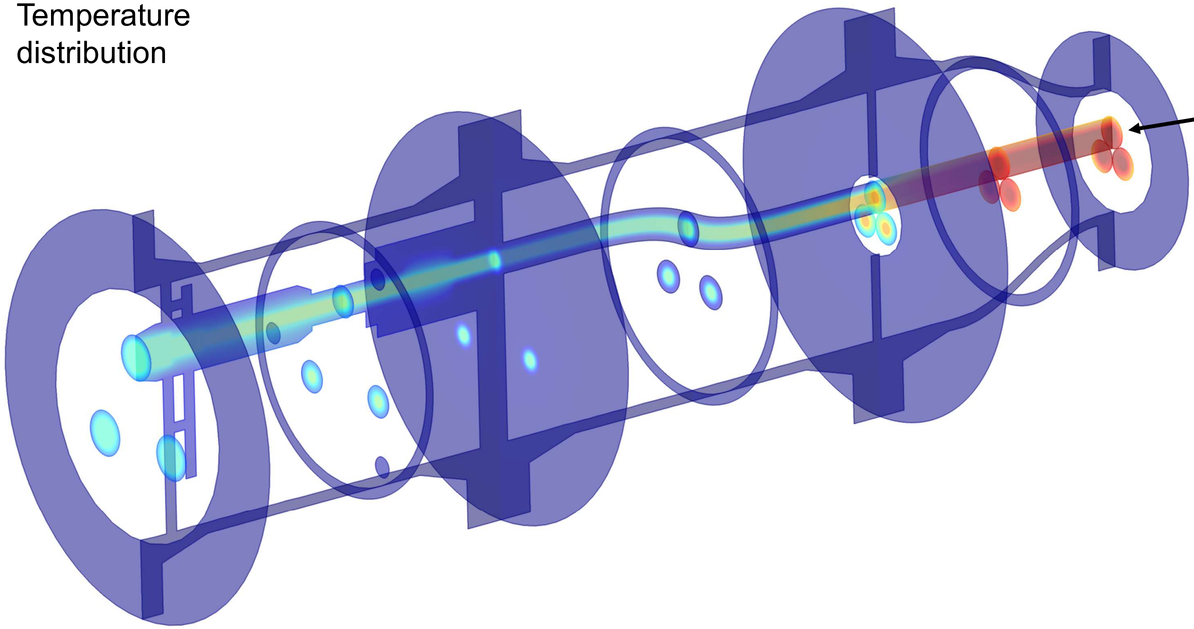
Perfectly balanced currents in the conductors (coil domains)



Magnetic-thermal design of a submarine cable plug

Temperature result

Temperature
distribution



Overheating problem identified

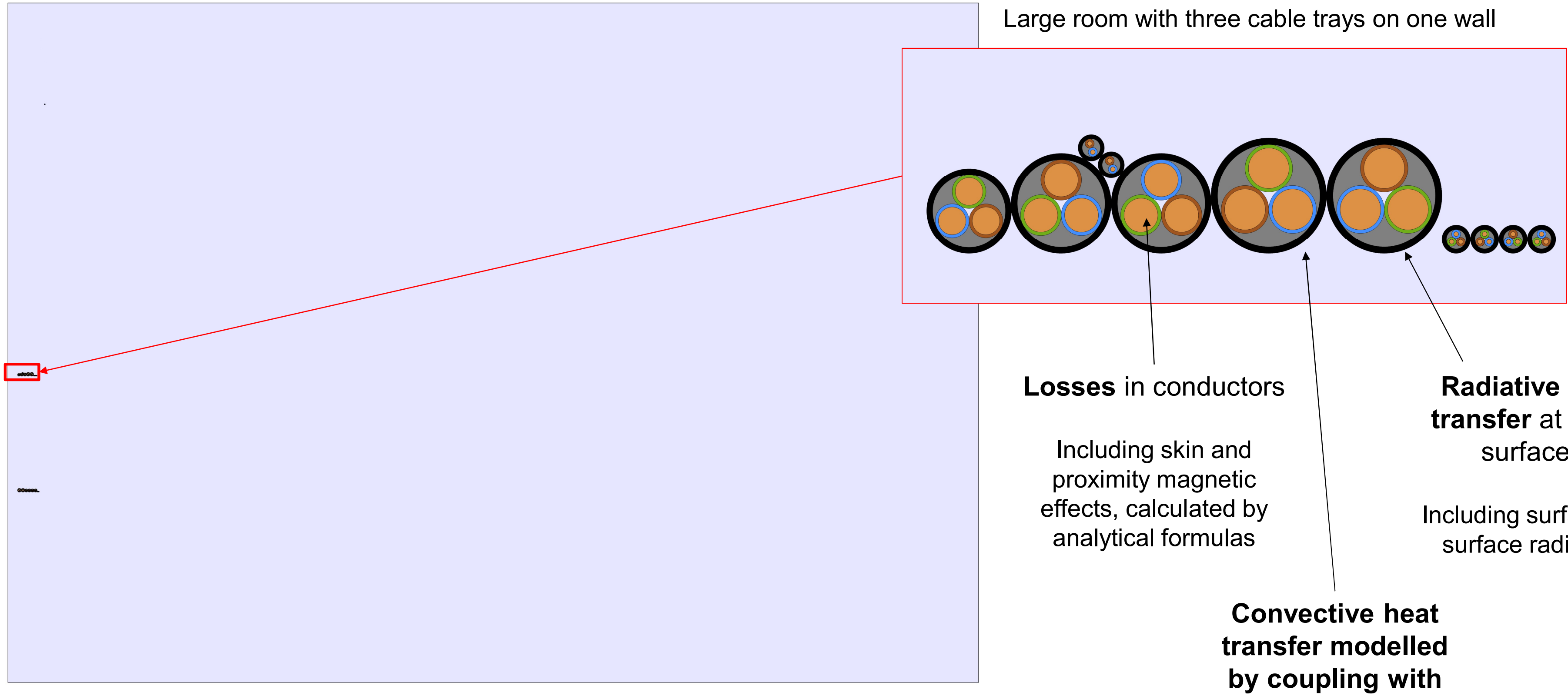
⇩

Decision not to manufacture a prototype, a **redesign phase** is required first

Thermal-CFD model for cable installation design

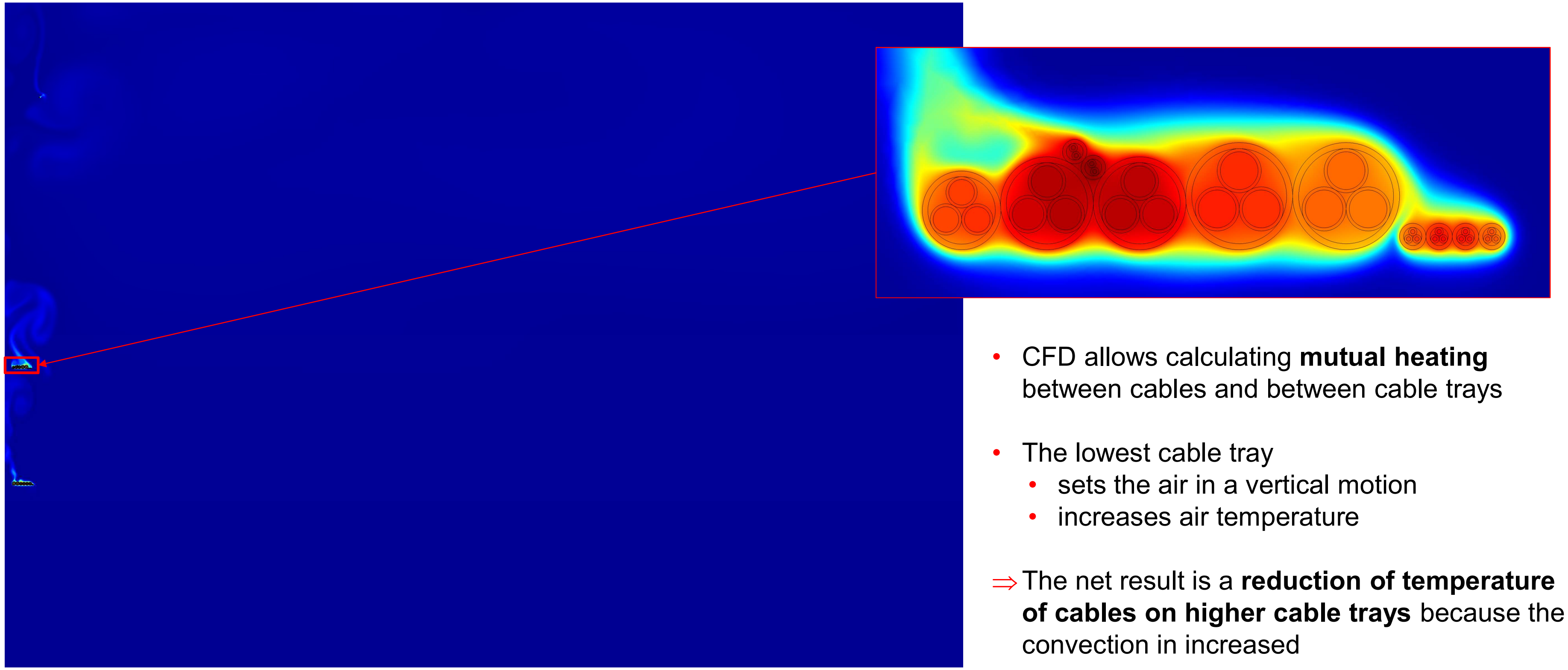
Objective: choose proper conductor cross-sections to ensure proper operation and required lifetime

Large room with three cable trays on one wall



Thermal-CFD model for cable installation design

Calculation result: cables operating temperatures



- CFD allows calculating **mutual heating** between cables and between cable trays
- The lowest cable tray
  - sets the air in a vertical motion
  - increases air temperature

⇒ The net result is a **reduction of temperature of cables on higher cable trays** because the convection in increased

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Dynamic cable rating

Improved cost-effectiveness thanks to dynamic analyses

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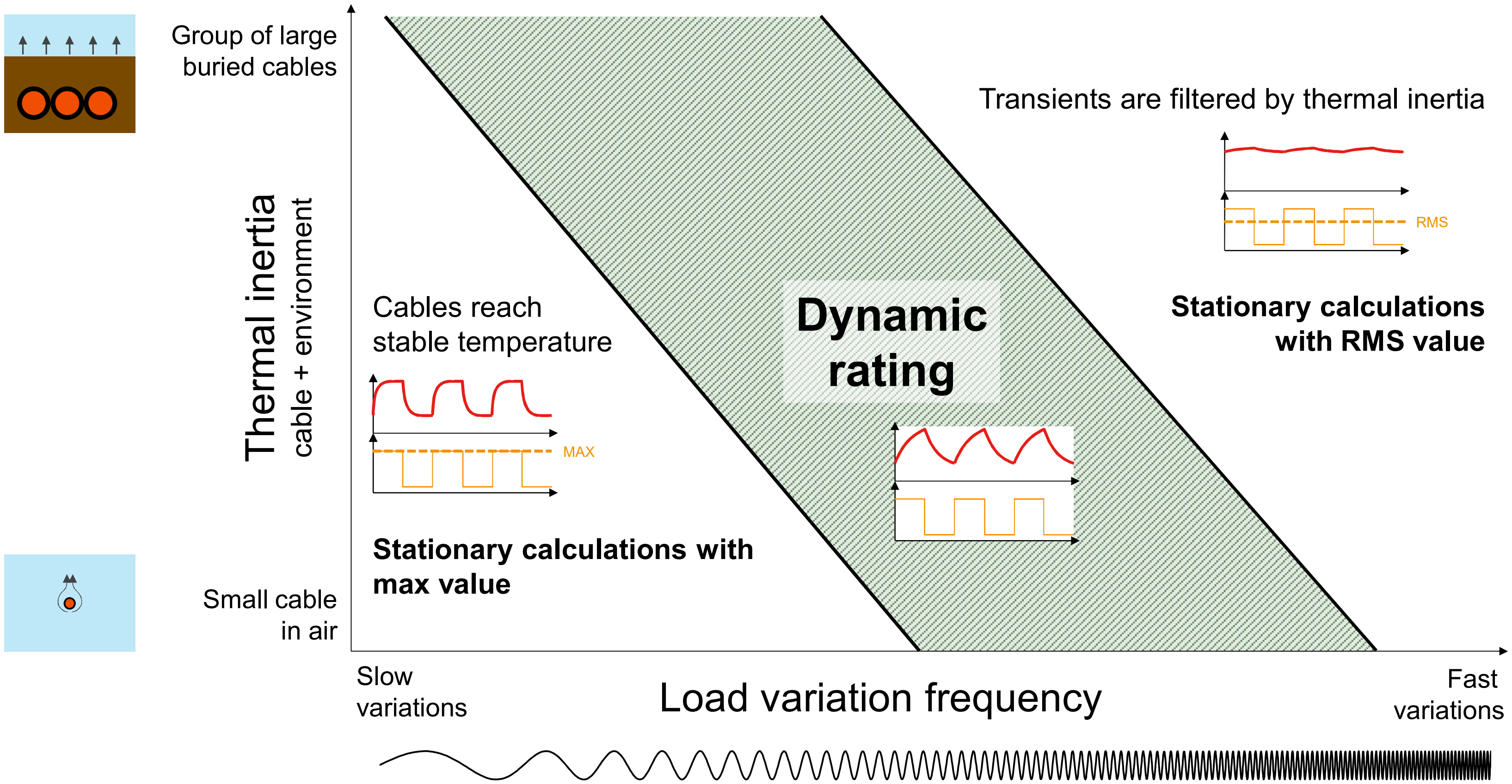
Principle of dynamic cable rating: Benefit from both load changes and thermal inertia



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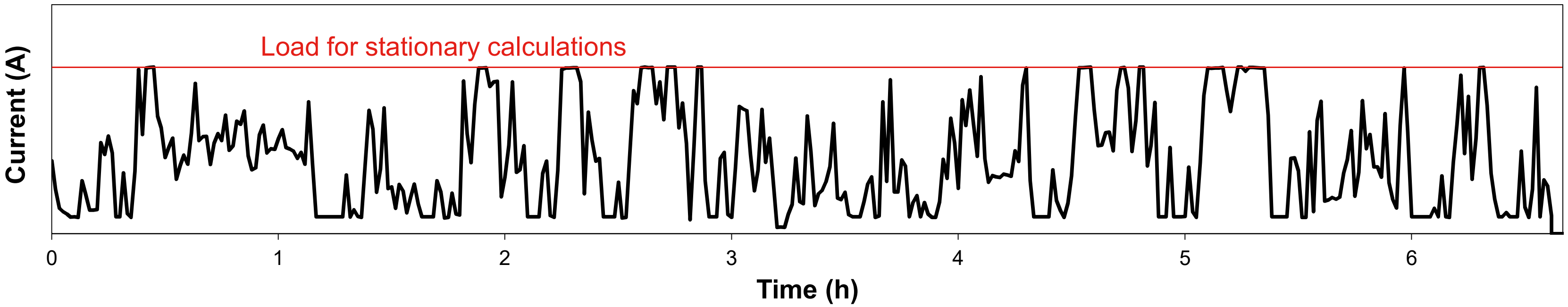
Cables dynamic rating: example of train motor cables



Three options for choosing proper cables

Calculation using EN standard

COMSOL simulation, stationary

COMSOL simulation, time-dependent

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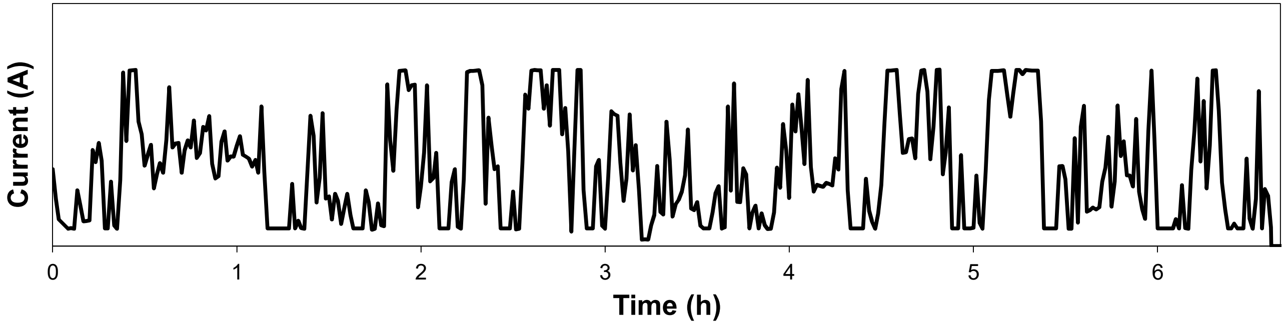
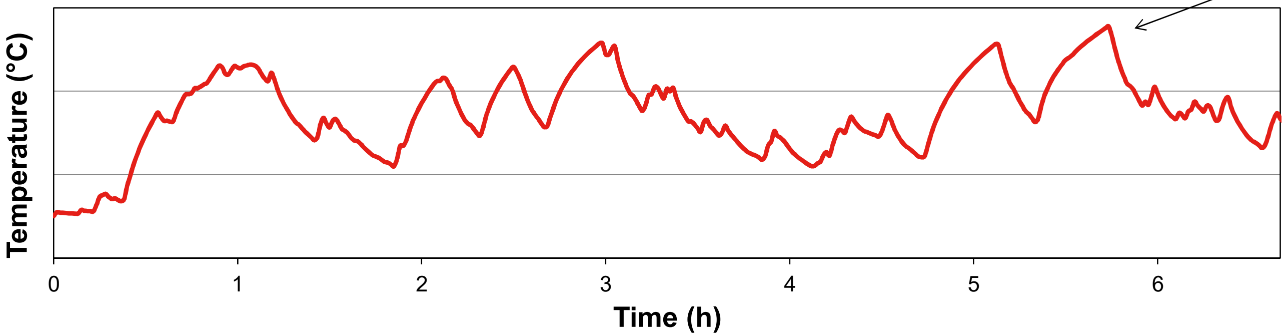
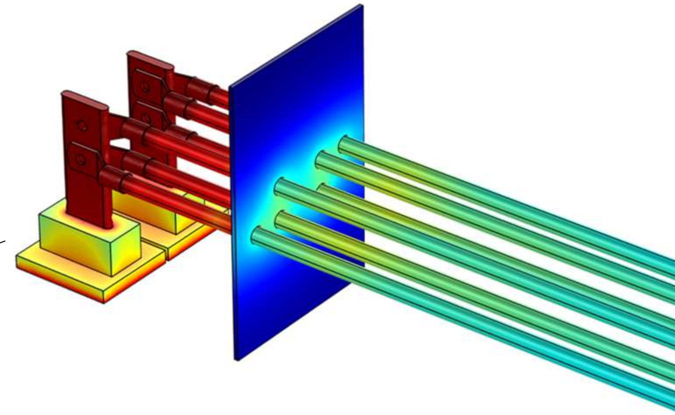
Cables dynamic rating: example of train motor cables

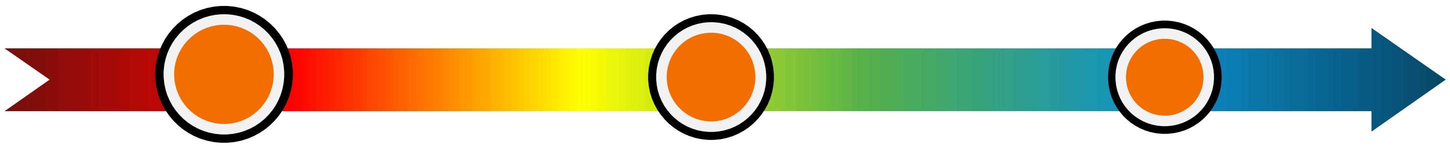






Cables dynamic rating: example of train motor cables

Calculation using standard | **COMSOL simulation, stationary** | **COMSOL simulation, time-dependent**



300 mm² copper conductor | **240 mm² copper conductor** | **185 mm² copper conductor**

Size reduced by 17%

Weight reduced by 40%

Cable cost reduced by 39%

Many systems now benefit from dynamic rating methodology: battery cables, electrical vehicle cables, rolling stock traction cables, wind turbine cables, etc.

Perspectives for cable multiphysics simulations

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What cable multiphysics simulation brings to cable installation design

- Complementary to standards for complex installations and loads
- Faster time-to-market and cheaper development of new cables and accessories
- Safe cable installations preventing overheating phenomena
  Hazardous in the worst case and detrimental for cables lifetime for the least
- Cost-optimized cable installations: best bang for the buck!
  Optimize the cost of cables and cable installations
- BUT despite some markets have been using numerical simulation for all their designs for decades, others still require a change in mindset regarding simulation

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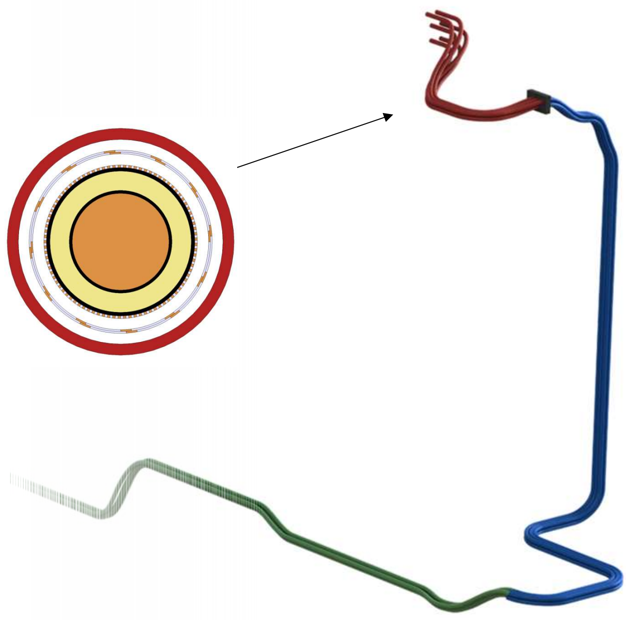
There is still model development work

- Simulation of cables installations with large "form factor"
  - Long cables but small thickness layers
  - Cables conductors are excellent heat conductors
  - Longitudinal heat flows allow reducing temperature in hot spots

- Predicting long-term thermo-electrical ageing of cable materials
  - Related to diffusion mechanisms and chemical reactions in polymers
  - Strong coupling with temperatures cycles seen by cables

- Large size models with multiple physics are still challenging
  - 3D + magnetic field + heat transfer + CFD

- Dense matrices when surface-to-surface radiation is used in large models



⇒ Thanks to **COMSOL technical assistance** and **Simtec**, key member of the COMSOL Certified Consultant Program in France, for their support in model development

⇒ We wish to continue with **other fruitful collaborations**

SIMTEC

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Thank you!

Adrien Charmetant

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