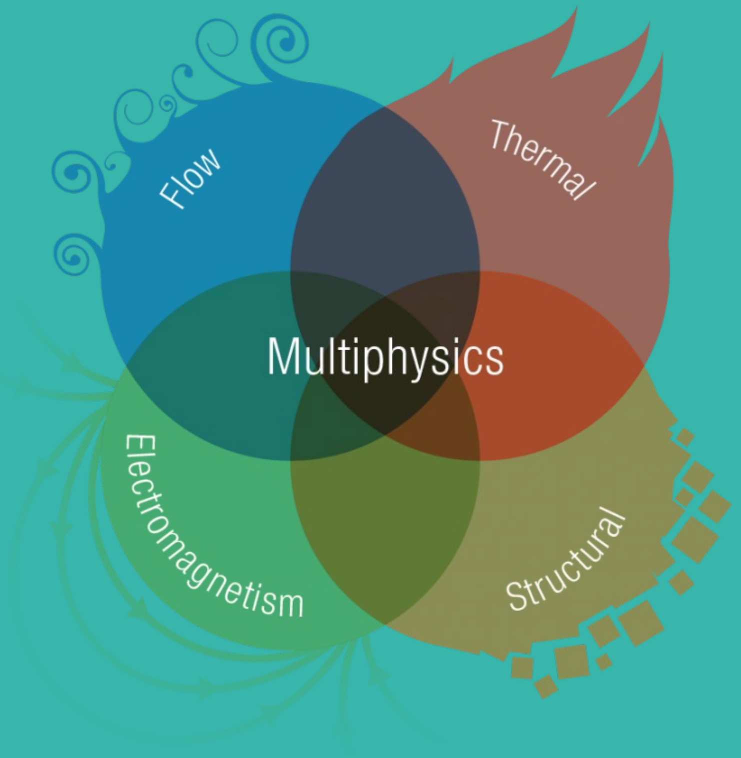

Magnetic shielding of an electrical substation

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COMSOL CONFERENCE 2023

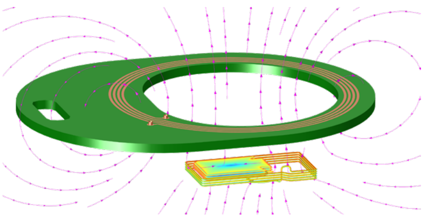
DEMCON | MULTIPHYSICS

Introduction

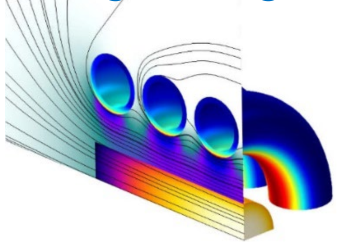
- Demcon group:
  - Engineering group, Netherlands
  - +1000 employees
  - Product and one-off development

- **Demcon Multiphysics**:
  - Physics consultancy division
  - 20 employees
  - Active in flow, thermal, electromagnetism, structural, etc.

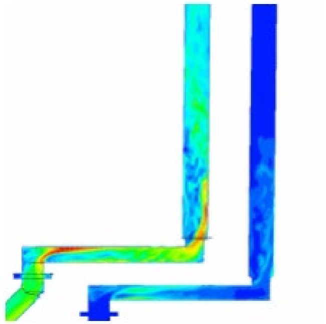
Electromagnetics



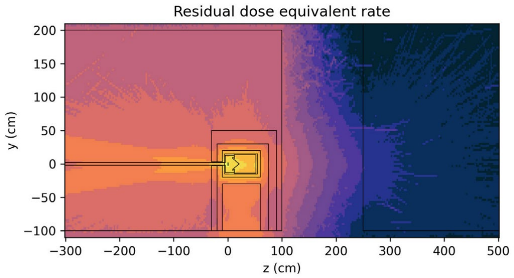
Thermal engineering



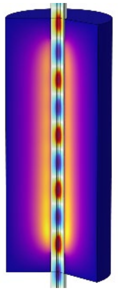
Fluid flows



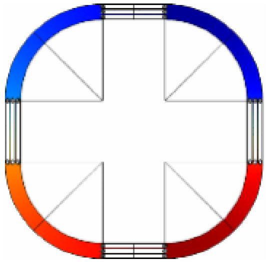
Nuclear physics



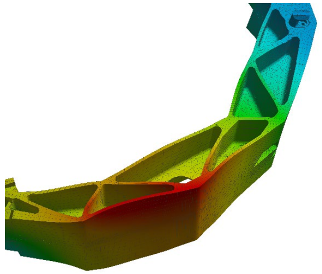
Plasma physics



Acoustics and



Structural mechanics

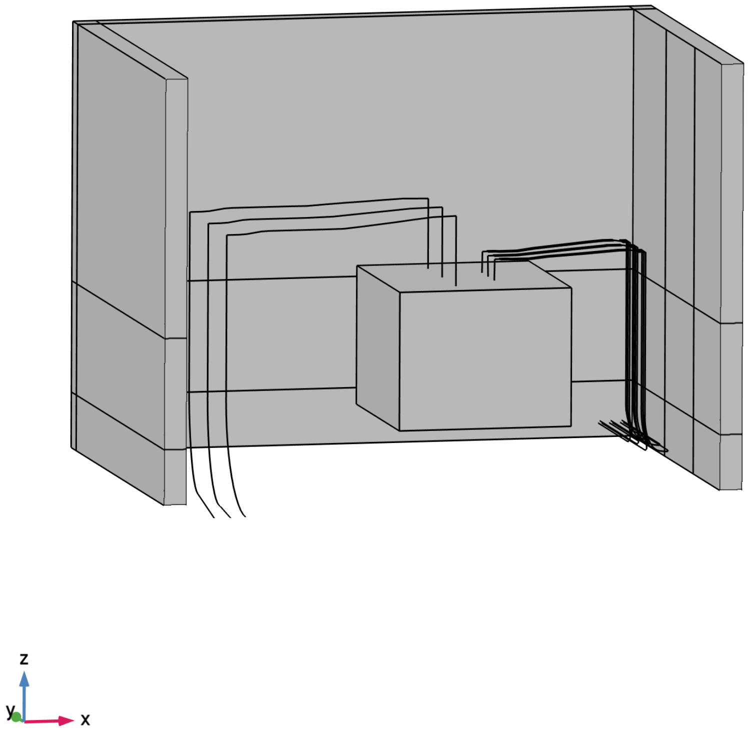


Experiments

Multiphysics engineer

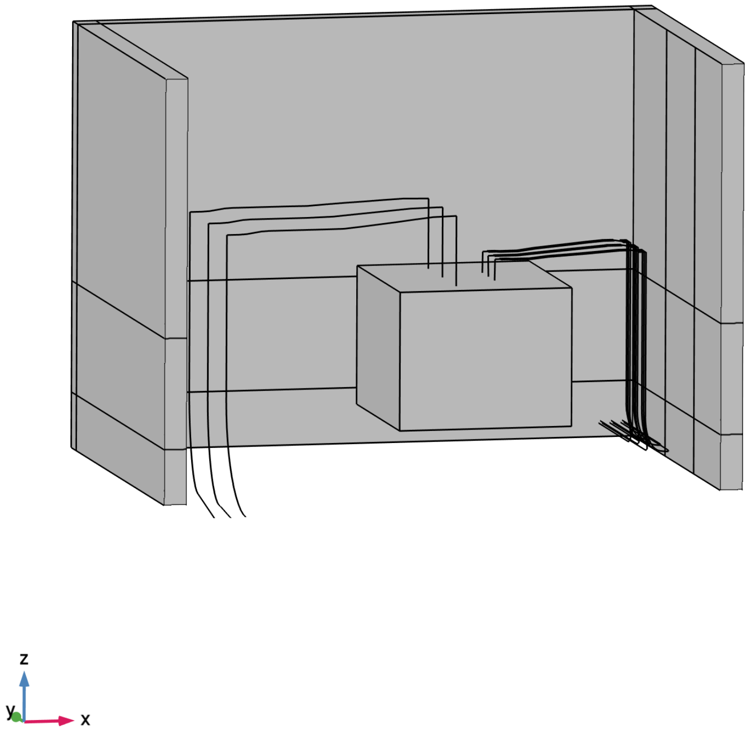
Introduction

- In electrical substations current is transformed to a lower voltage
- Large currents in cables in substations generate magnetic fields
- Exposure limit 100 µT at 50 Hz
- **Goal: Simulate magnetic shielding to stay below the exposure limit outside the substation**
- Focus will be on a consistent and convenient method to compute current paths



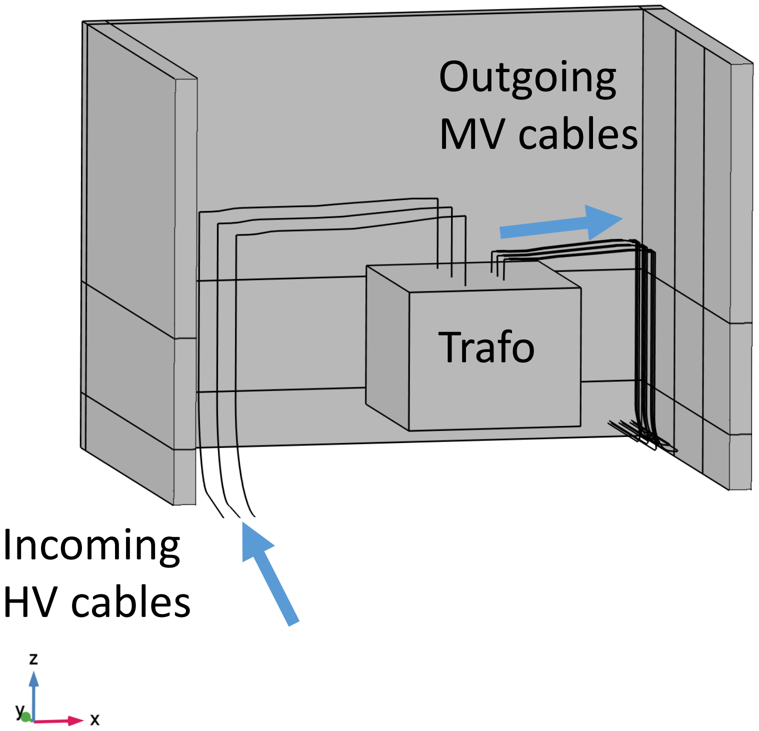
Approach

- Setup geometry
- Calculate the current distribution along the cables using the Edge PDE interface
- Use current distribution as input for the Edge Current feature in the Magnetic Fields interface
- Compute the magnetic fields
- Design magnetic shielding



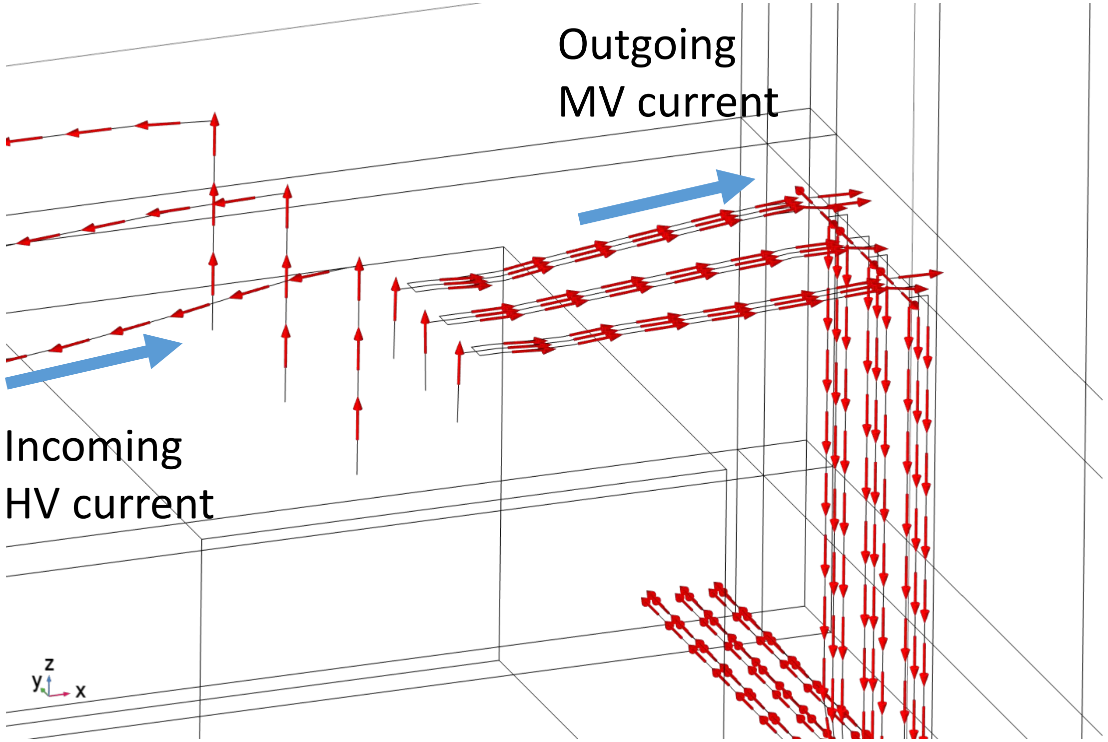
Geometry overview

- Of the substation we include the:
  - Walls
  - Transformer
- The electrical cables are represented by line segments
- On one side of the transformer, we have incoming high voltage (HV) cables
- On the other side, there are outgoing medium voltage (MV) cables



Calculate current distribution

- To use the Edge Current feature in the Magnetic Fields interface, each line segment needs a specified current
- Tedious and error-prone because of:
  - Sign usage due to arbitrary edge direction
  - Junctions, where current paths split or merge
- Here the current direction of the HV current is opposite to the direction of the edge

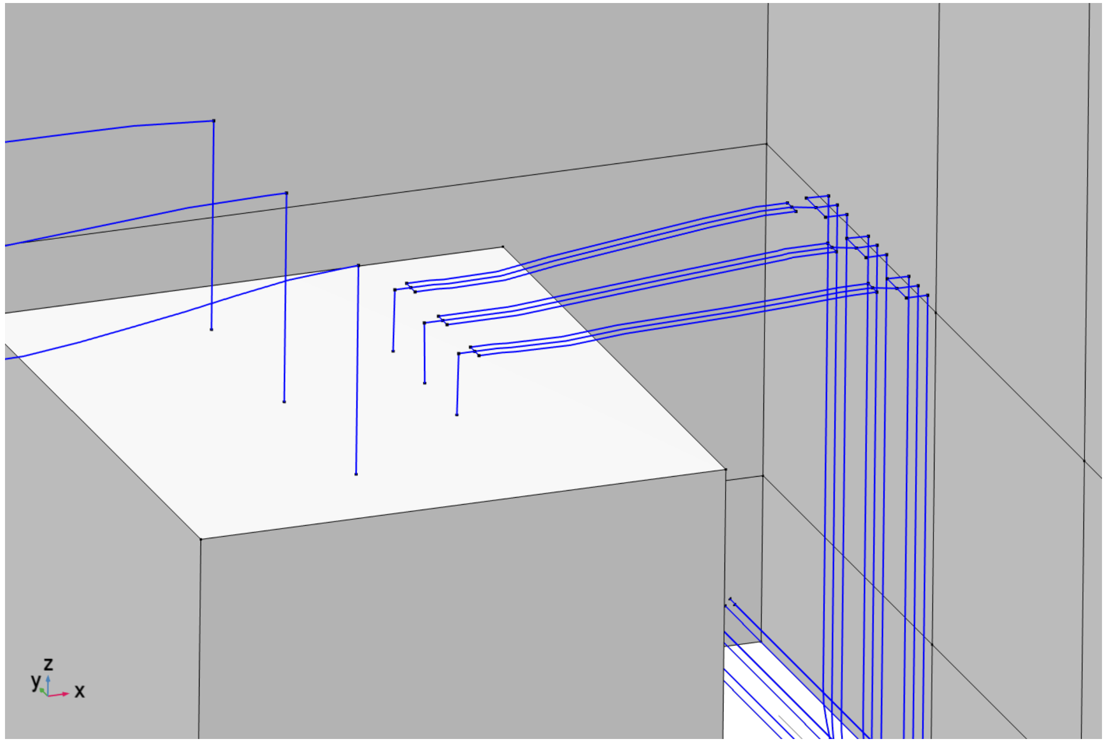


Laplace equation

- Use the Edge PDE interface to impose a Laplace equation on the cables

$$\nabla_T^2 u = 0$$

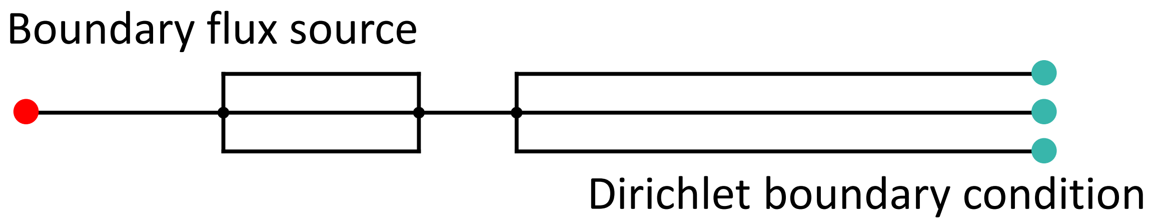
- Here u plays the role of a scalar potential
- Its gradient (a flux) $\Gamma = -\nabla_T u$ is the current
- Automatic current conservation
- Assumption: All cables have the same resistance per unit length



Laplace equation – boundary conditions

- On one end we set a boundary flux source equal to the input RMS current
- On the other end of the current path, we set a Dirichlet boundary condition $u = 0$
- This is indicated schematically for the current path on the right
- The obtained RMS current distribution I_{comp} is used as input using the Edge current feature

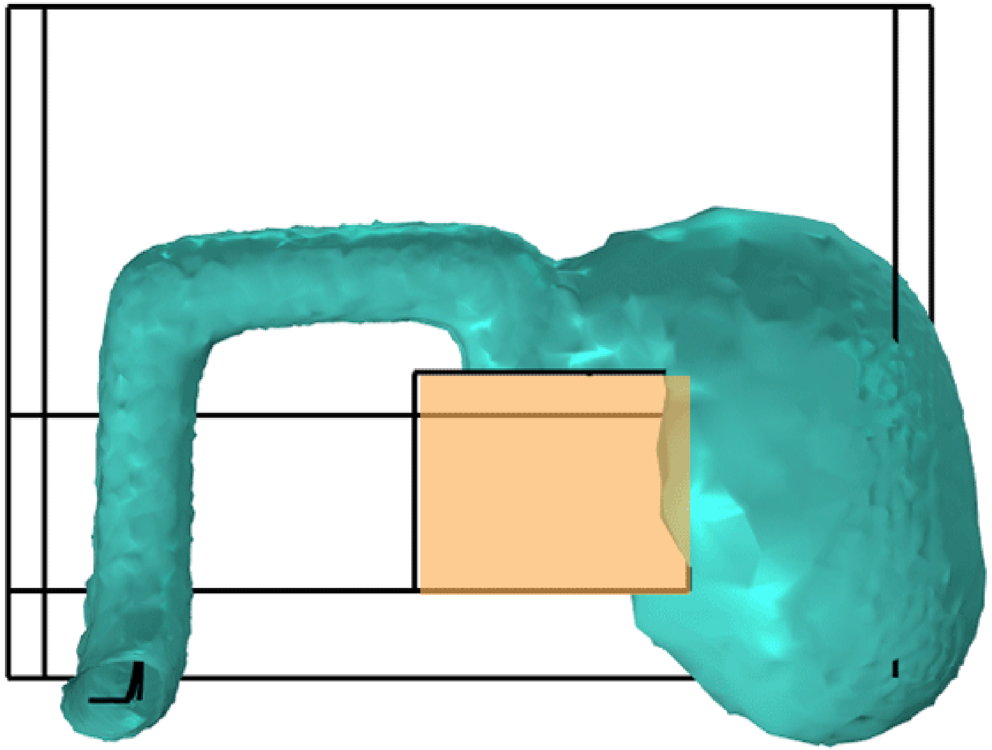
$$I = \sqrt{2} I_{\mathrm{comp}} e^{i\phi}$$



Magnetic field calculation

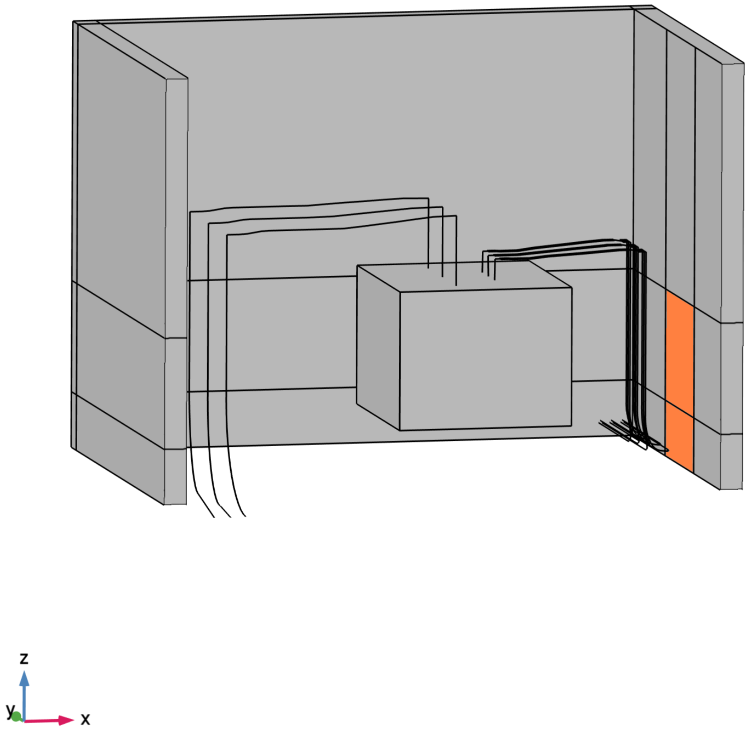
- We compute the magnetic fields using the Magnetic Fields interface
- This interface computes induction currents, which is relevant for the magnetic shielding
- The transformer is excluded via a magnetic insulation condition on its surface
- The 100 µT contour of the B-field extends outside of the walls of the substation

BEFORE



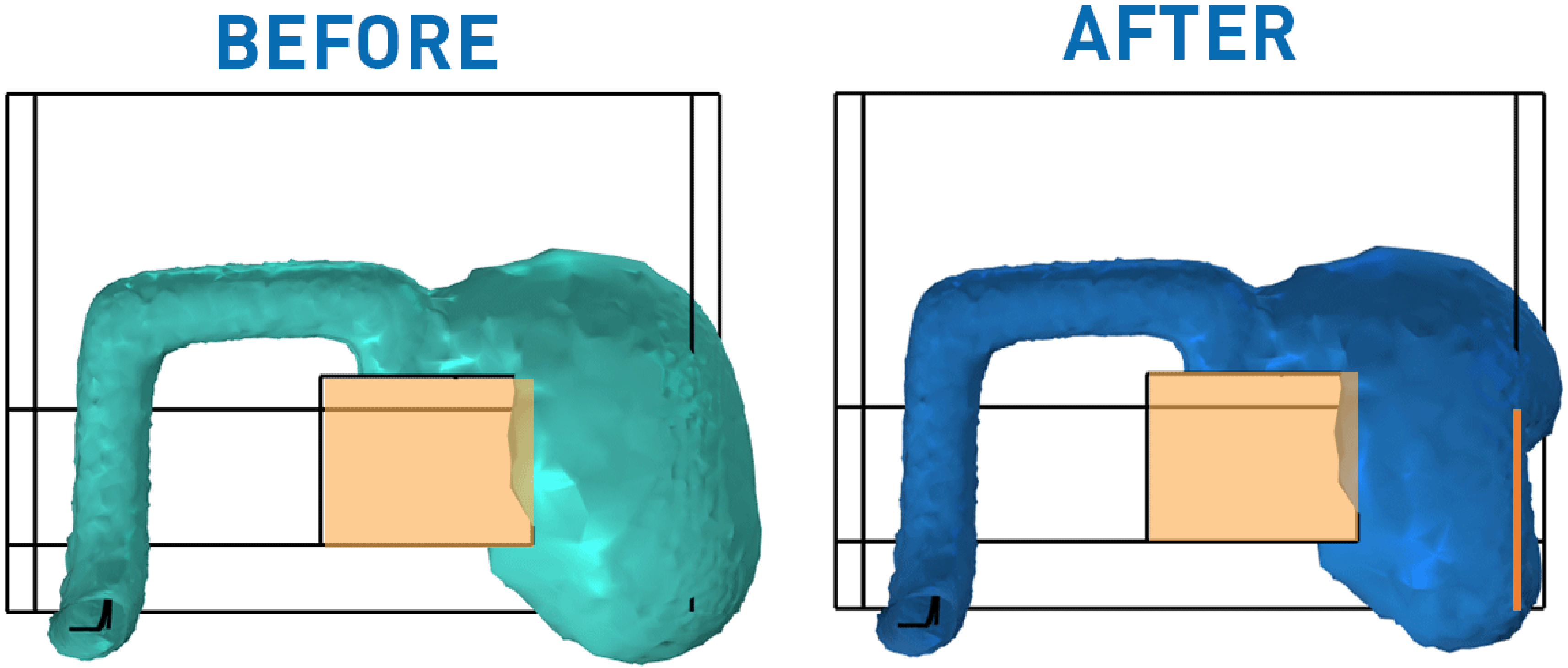
Magnetic shielding design

- We apply shielding to the orange part of the inner wall
- The shielding consists of aluminium sheets, based on its high conductivity
- We model the effect of the shielding via a transition boundary condition
- The dimensions were varied to determine the amount of material required



Magnetic shielding effect

- With the magnetic shielding in place, the 100 µT contour becomes mostly confined to the interior of the substation, apart from a small region that is inaccessible due to its height



Summary

- We designed and simulated magnetic shielding to reduce the magnetic field outside the substation below the 100 μT limit
- To impose the correct edge currents on all line segments, we implemented a Laplace equation on the line segments
- This is a consistent and convenient method to compute current paths that helps us a lot in our modelling work

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Shielding mechanism

- The magnetic field of the substation induces eddy currents in the shielding
- The magnetic fields created by these eddy currents are opposed to the magnetic field of the substation
- This reduces the magnetic field outside the substation