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Electrodynamical analysis of a high voltage surge arrester

extracted from
Electromechanical simulations of high voltage equipment

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EB Rebosio – Gruppo Bonomi

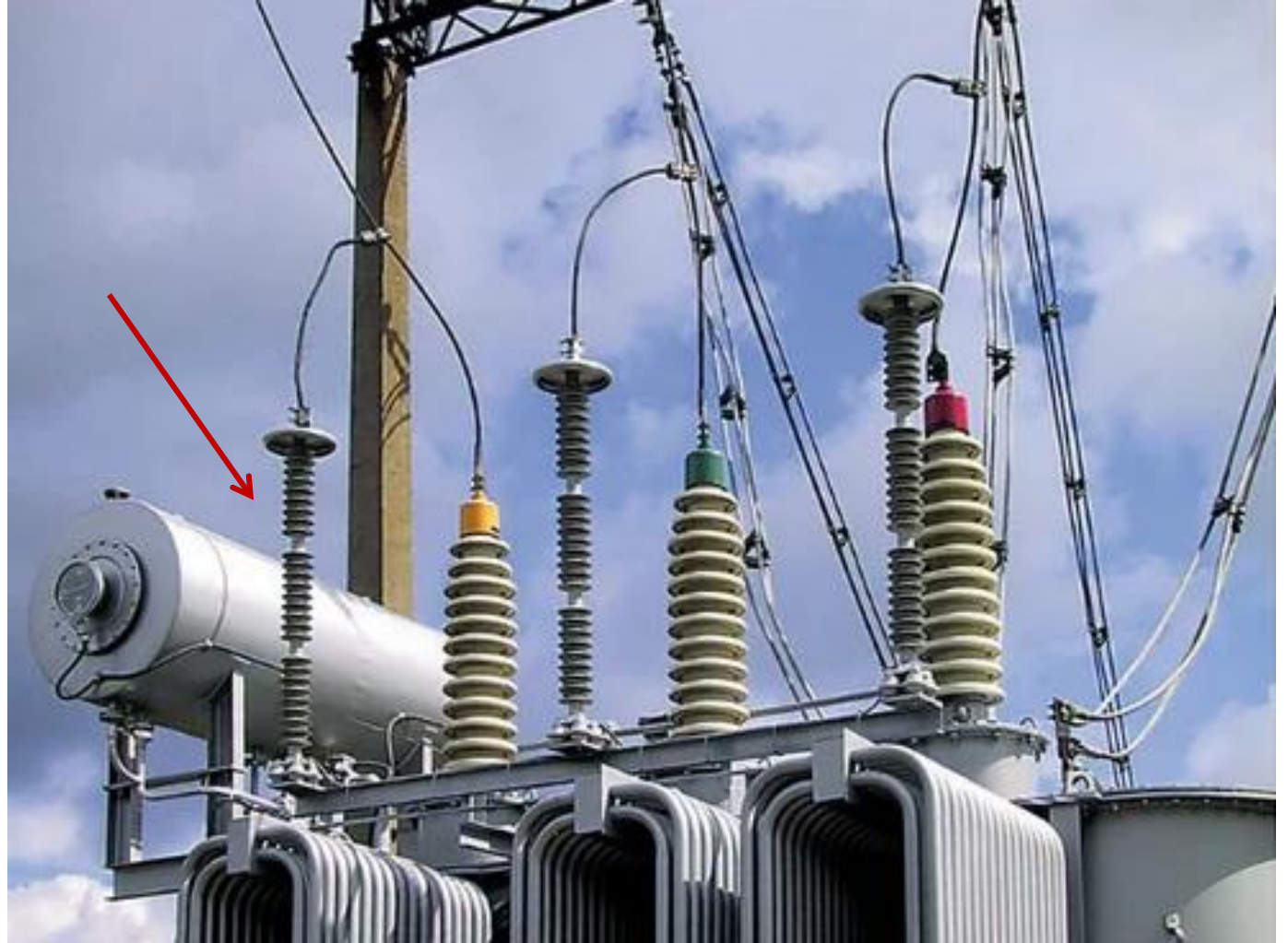
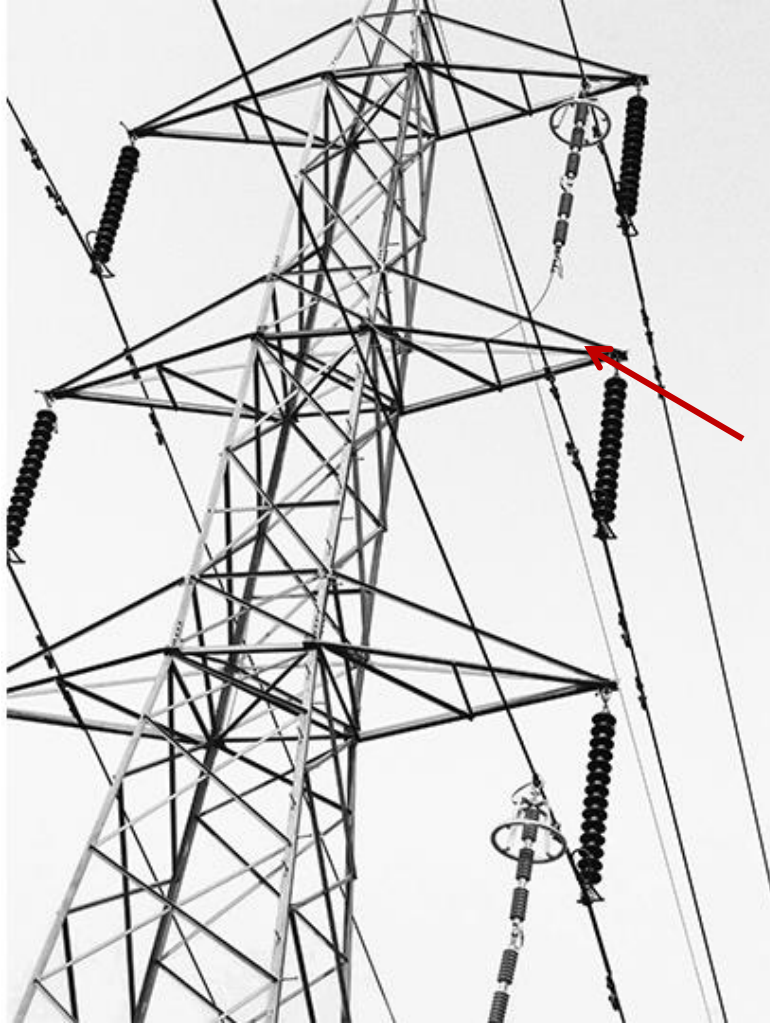
Introduction

The Problem

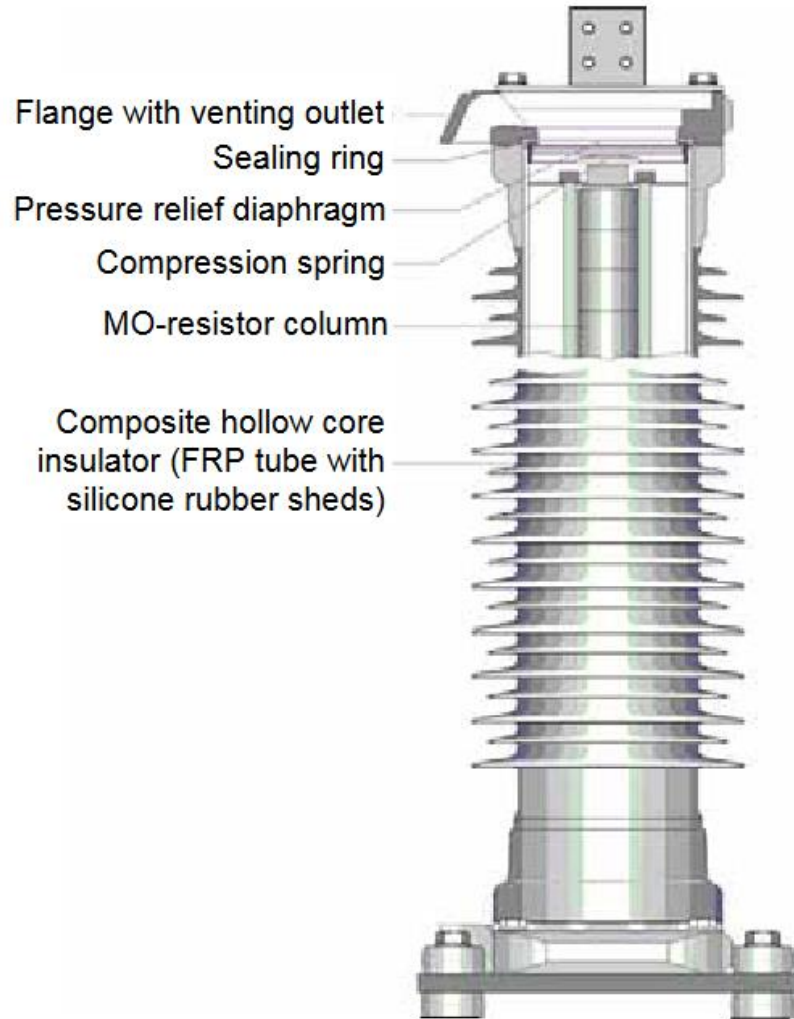


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Surge Arresters



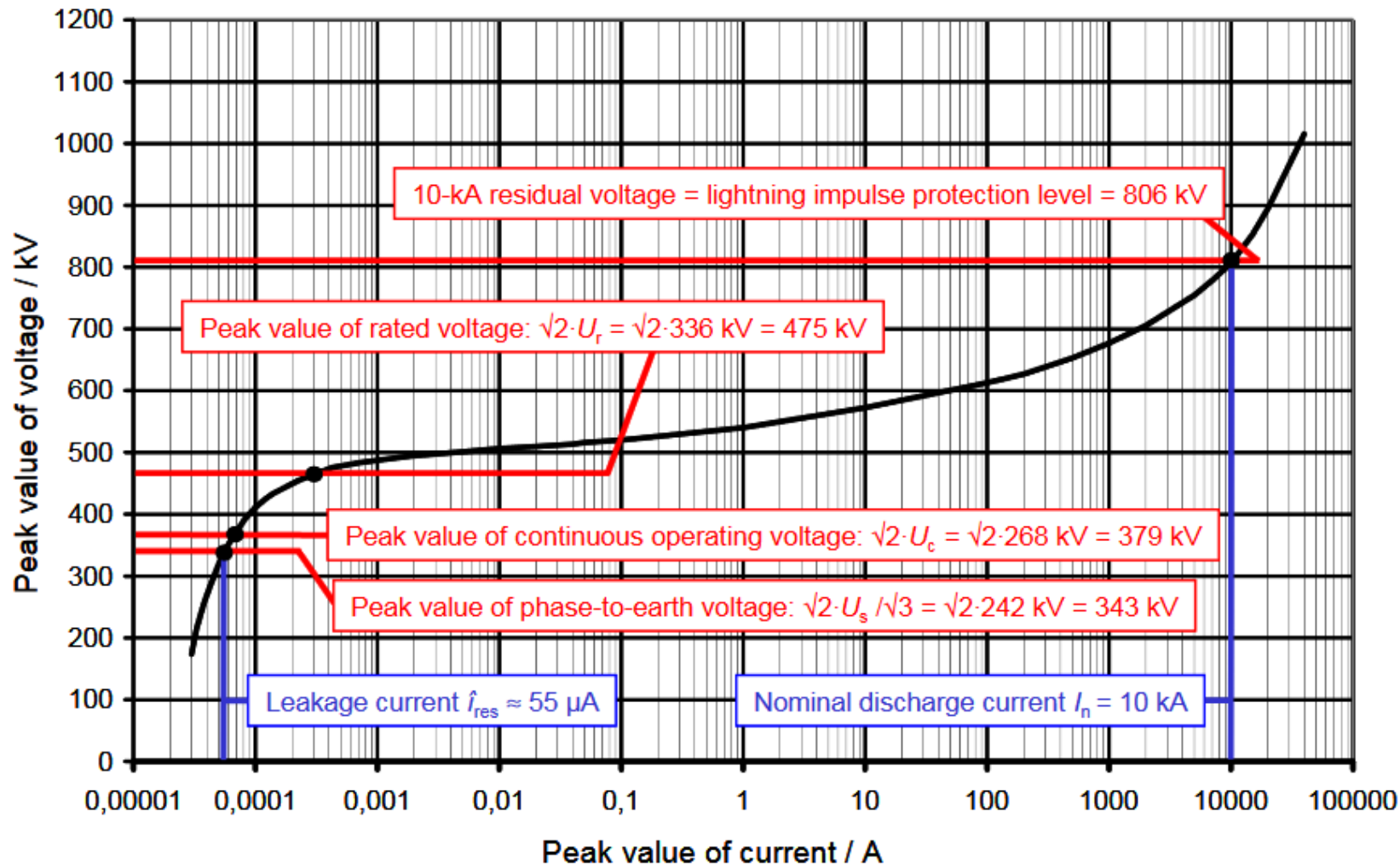
Structure



Doped Metal Oxide Tab Resistors

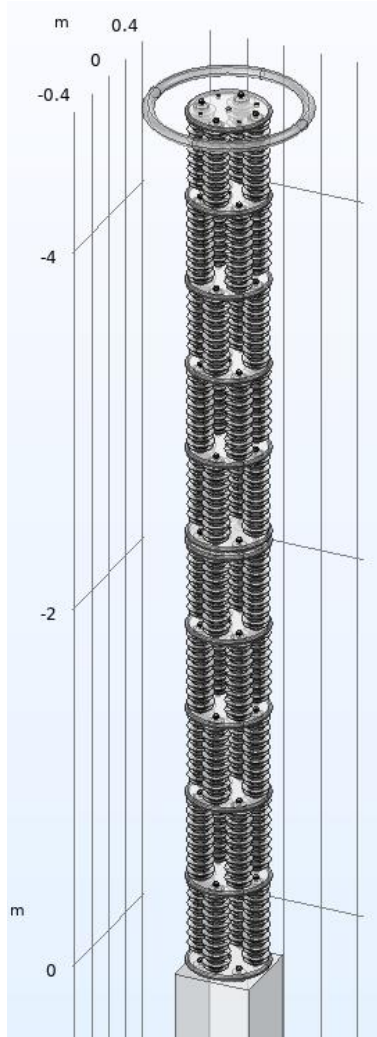


Zinc Oxide Properties



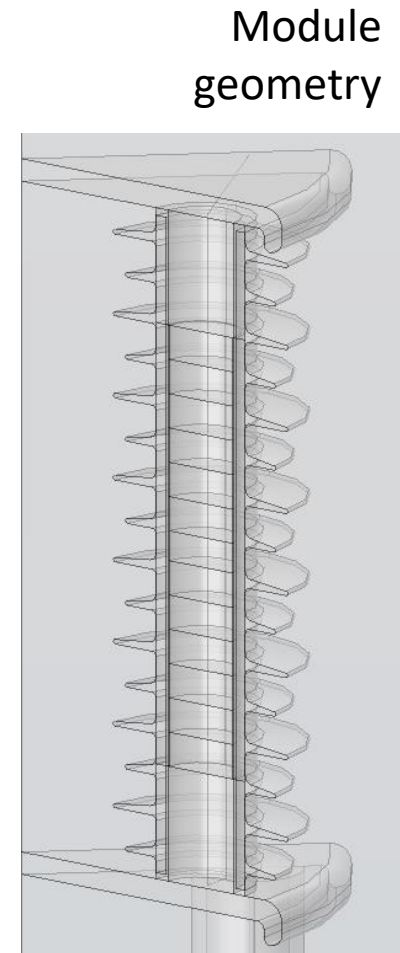
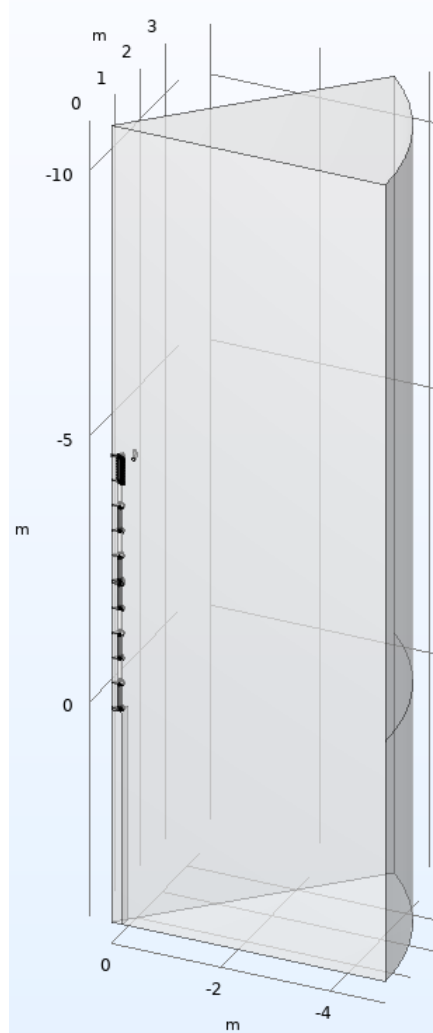
Highly non linear resistivity, acting almost as an open circuit for low voltages, switching to a high conductivity at higher voltages.

The Project



Multistage surge arrester tower for a nominal 420 kV line.
Composed by 40 modules (4 per floor, 10 floors)

Space modelled profiting from sector symmetry



Methods and use of COMSOL Multiphysics

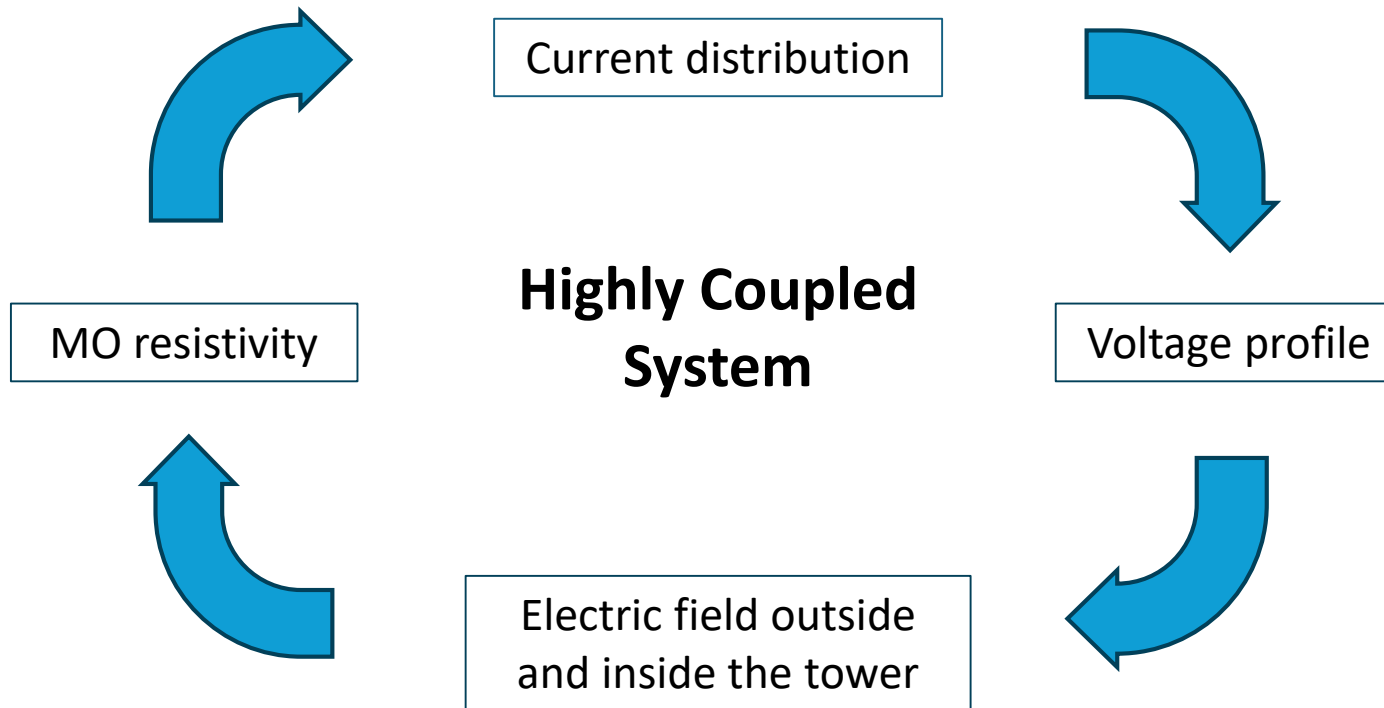
How COMSOL AC-DC Module can help

Evaluation of the electric field

1. Inside the Metal Oxide tabs:
Prevent excessive stress and premature ageing
2. At the surface:
Prevent corona activity, tracking, and erosion of the silicone housing



Complication



Setup

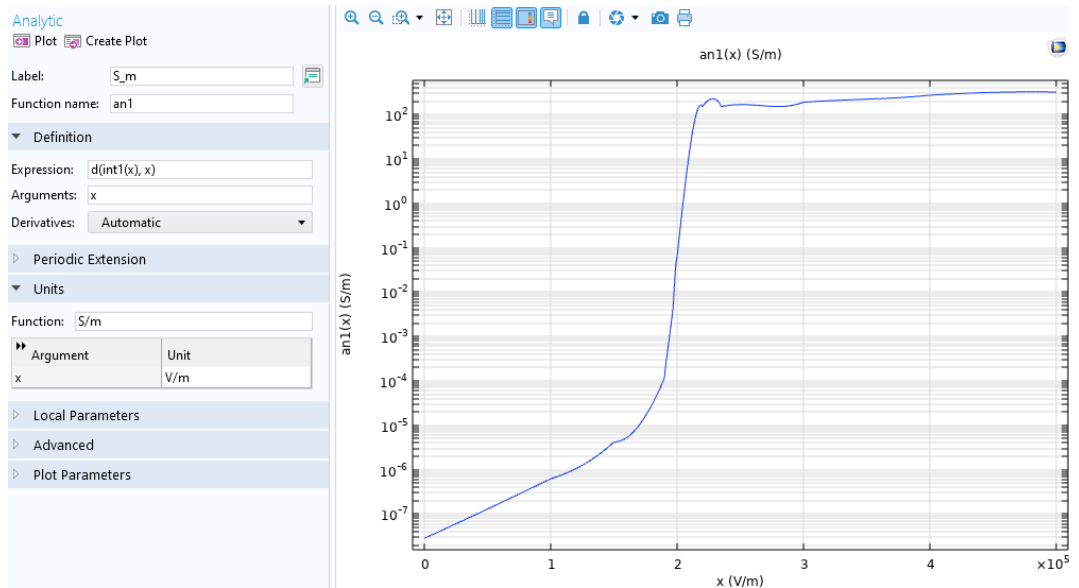
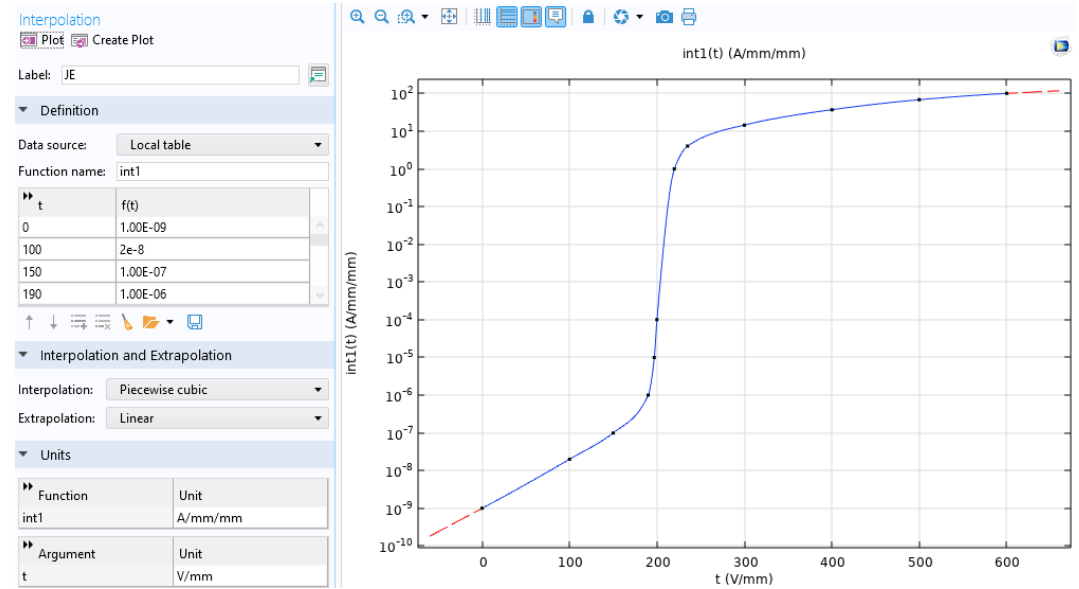
Voltage-current characteristic of a tab with particular size from supplier.



Size independent electric field-current density input to COMSOL.



Electric field-Conductivity material property obtained taking a derivative.



Other Settings

Material	Permittivity [#]	Conductivity [S/m]
Air	1	10^{-18}
Alluminium	1	10^6 *
Silicone Gum	3.5	10^{-12}
Epoxy Fiber Glass	4.5	10^{-15}
ZnO	830	an1(root.comp 1.ec.normE)

* Can be reduced by a couple of orders of magnitude to improve convergency without impacting on the result (unstable current loops are sometimes observed)

- Electric Currents (ec)
 - Current Conservation 1
 - Electric Insulation 1
 - Initial Values 1
 - Ground 1
 - Electric Potential 1
 - Symmetry Plane 1
 - Mesh 1
 - Size
 - Edge 1
 - Edge 2
 - Edge 3
 - Mapped 1
 - Free Quad 1
 - Study 1
 - Step 1: Time Dependent
 - Solver Configurations
 - Solution 2 (sol2)
 - Compile Equations: Time D
 - Dependent Variables 1
 - Time-Dependent Solver 1
 - Direct
 - Advanced
 - Fully Coupled 1**
 - Iterative 1

Fully Coupled

Compute to Selected = Compute

Label: Fully Coupled 1

General

Linear solver: Direct

Method and Termination

Nonlinear method: Automatic highly nonlinear (Newton)

Initial damping factor: 1E-4

Minimum damping factor: 1E-8

Restriction for step-size update: 10

Restriction for step-size increase: 1

Use recovery damping factor: Automatic

Recovery damping factor: 0.75

Termination technique: Tolerance

Maximum number of iterations: 4

Tolerance factor: 1

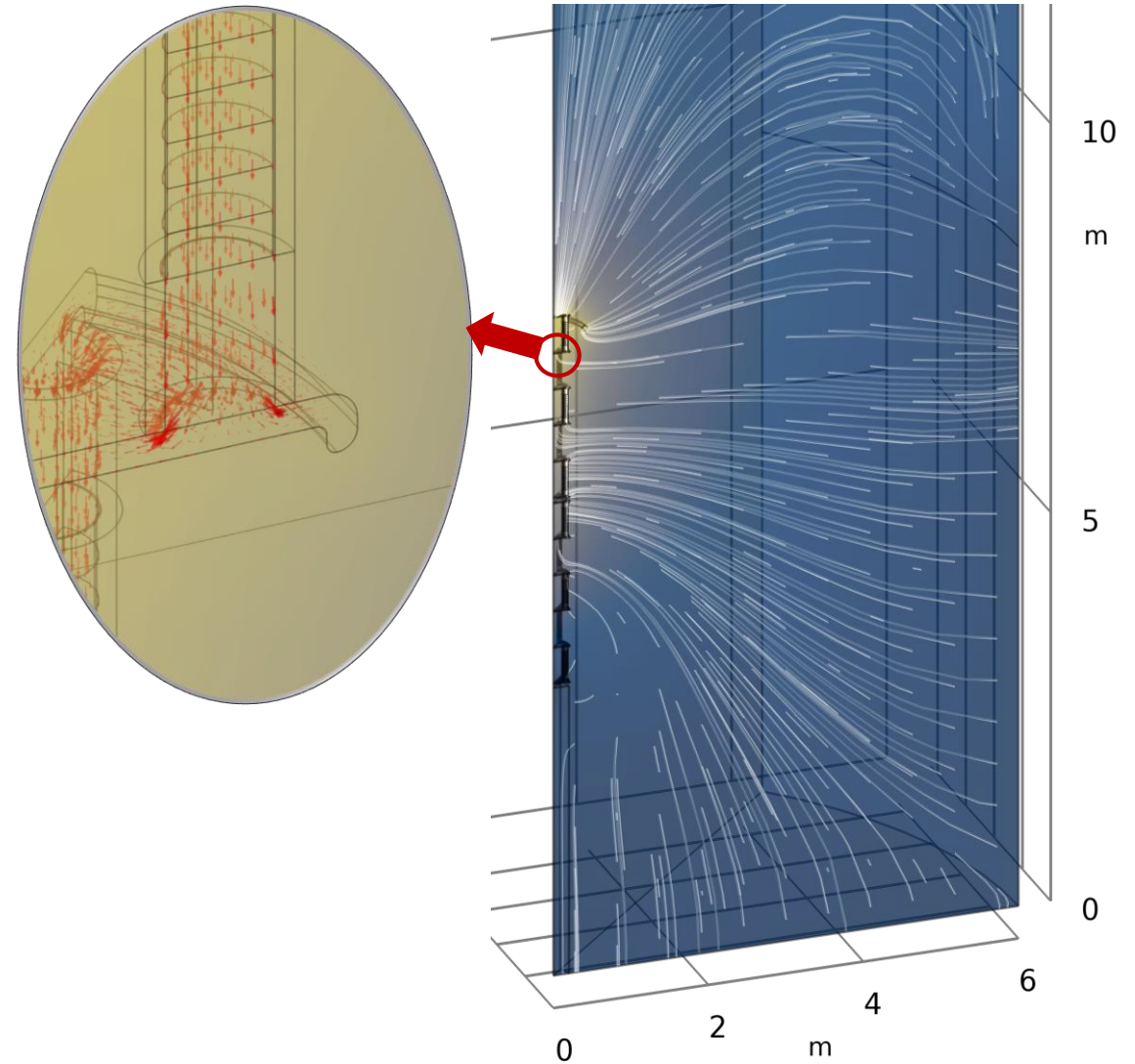
Termination criterion: Solution

Obtained Results

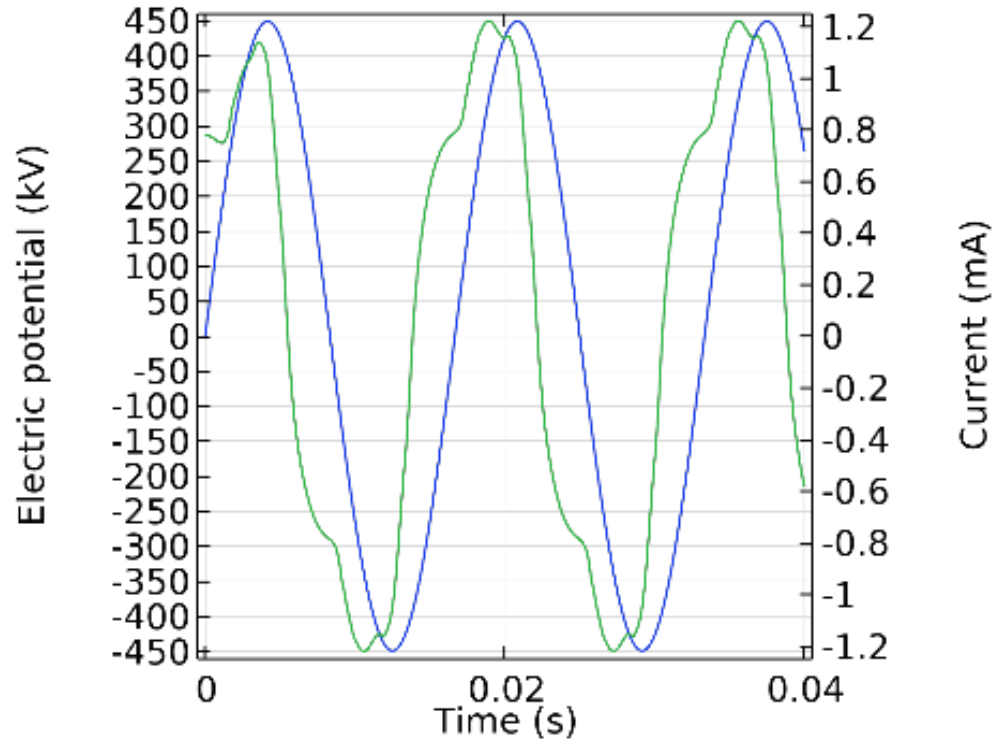
Overview

Check of:

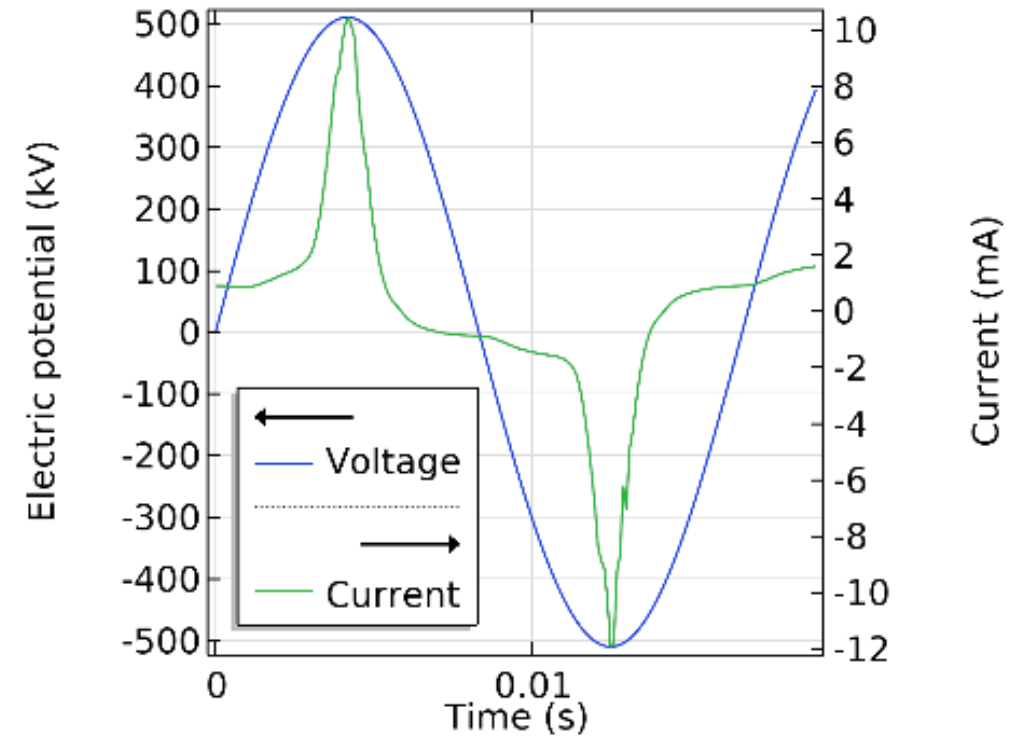
- Voltage distribution (blue to yellow)
- Electric field lines (white lines)
- Current density along the tower (red arrows)



Time dependent current and voltage



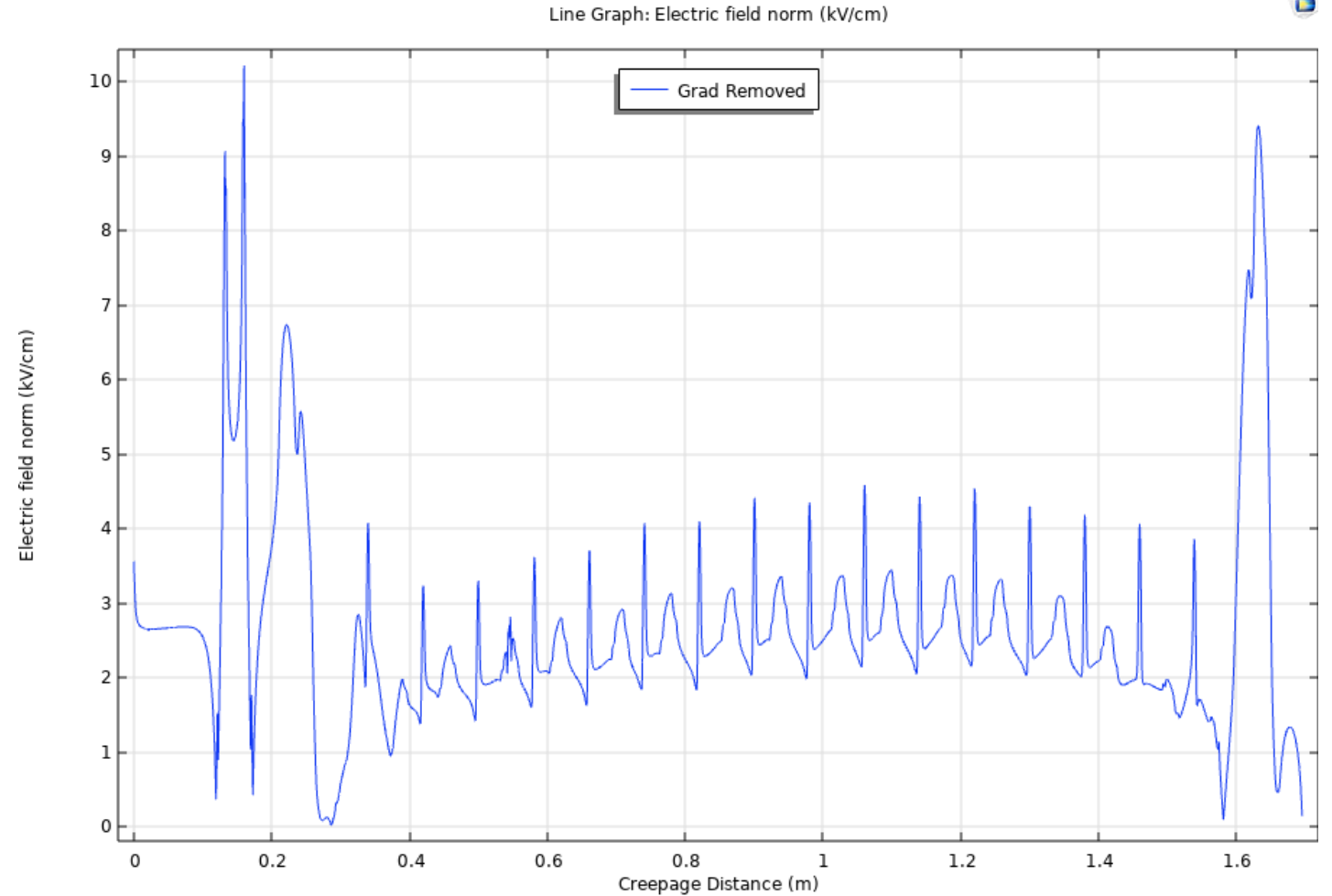
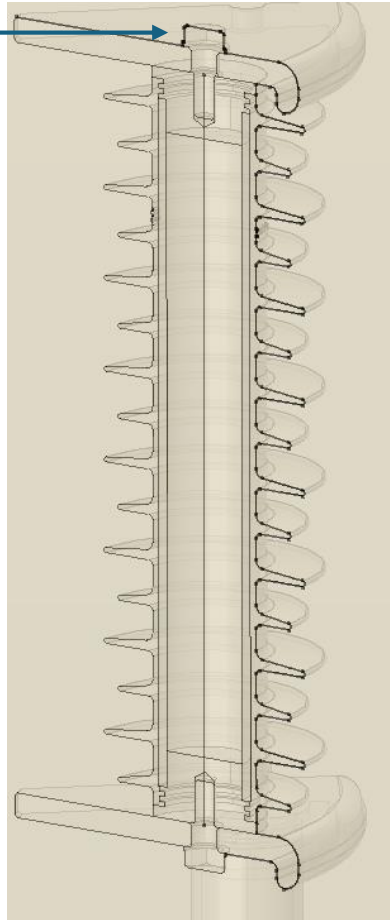
Slightly below activation voltage:
strong capacitive component.



Slightly above activation voltage:
strong resistive component.

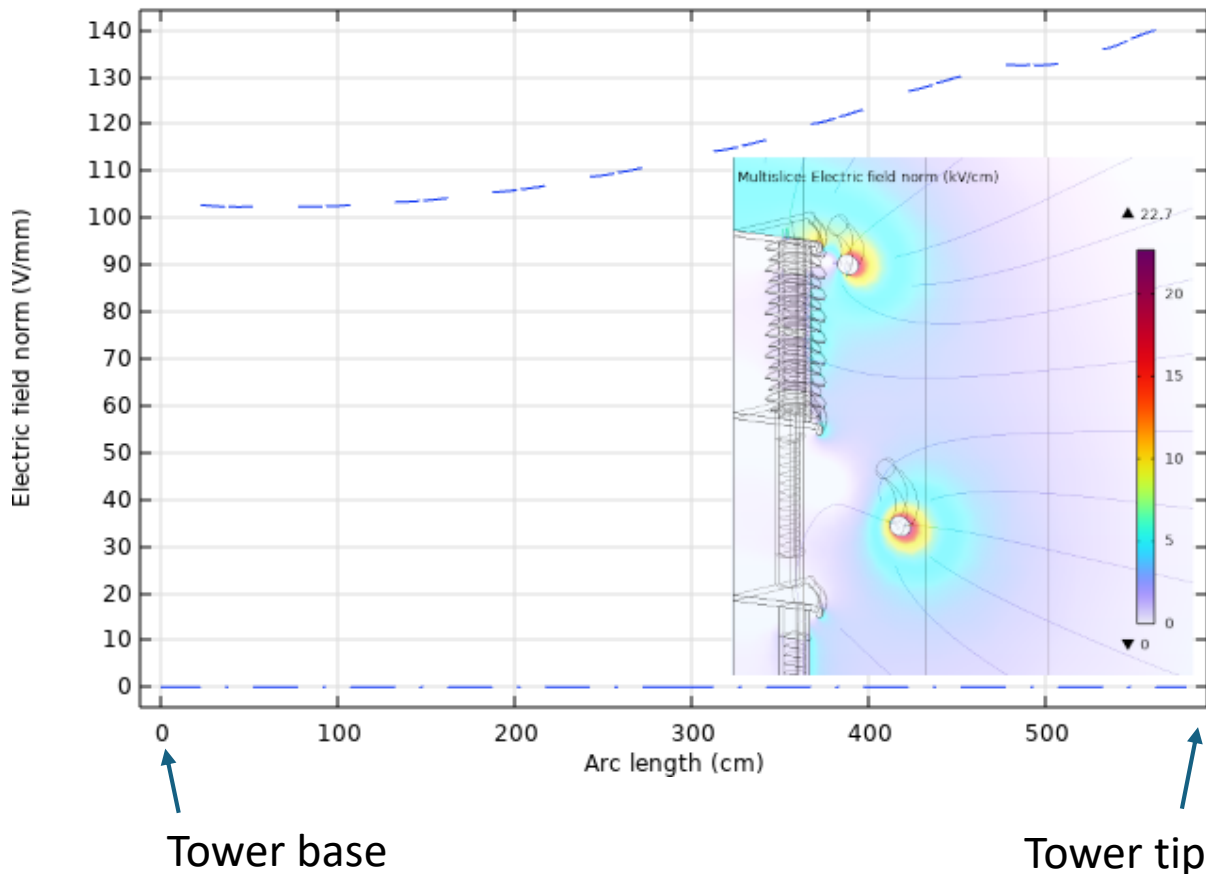
Field at the surface

Field magnitude plotted along a line running 0.5mm from the external surface

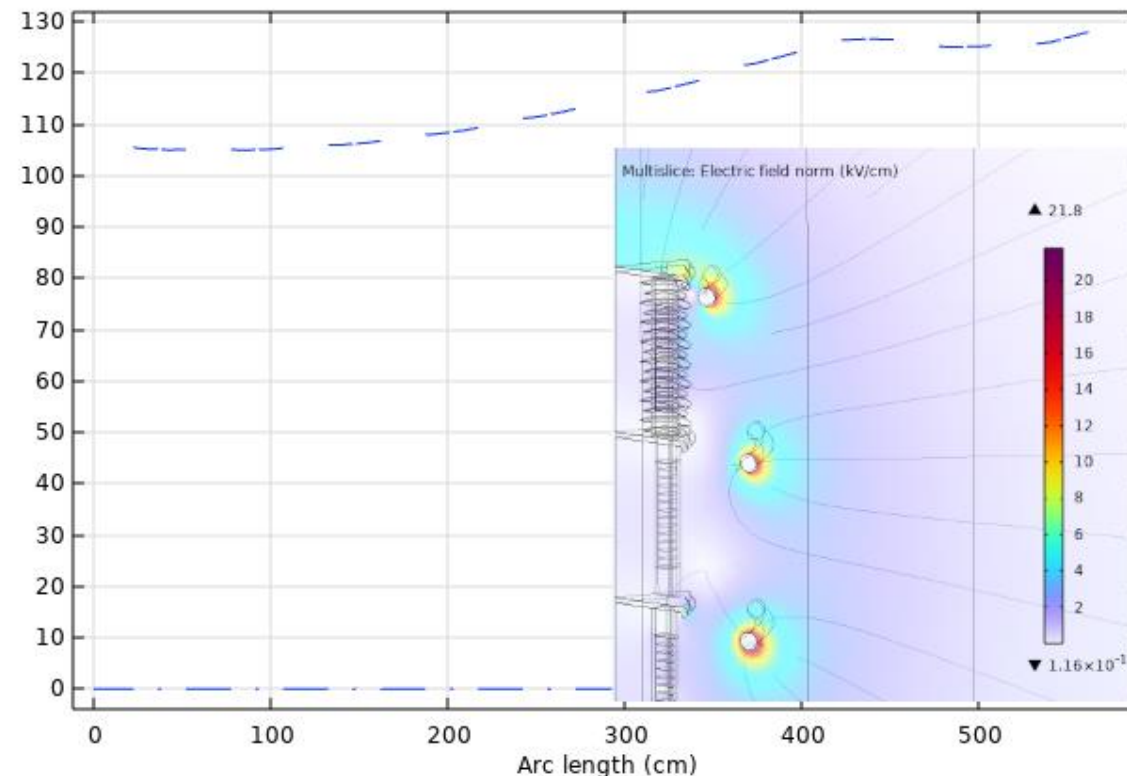


Electric field in the tabs along the tower

Line Graph: Electric field norm (V/mm)



Line Graph: Electric field norm (V/mm)



Design of shielding devices (grading rings) to keep the field within 130 V/mm

Conclusions

The study performed with COMSOL AC-DC Module allowed to characterize the **electrical behavior** of a surge arrester tower, establishing a design for **protective devices** (grading rings).

The completion of the study required a time transient analysis considering the **field dependent conductivity** of the metal oxide core.

In addition to the inspection of the field distribution, it was possible to investigate the **current density distribution** along the tower and to reproduce the **transition** from capacitive to resistive mode above the threshold voltage.



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Thank you
for your attention