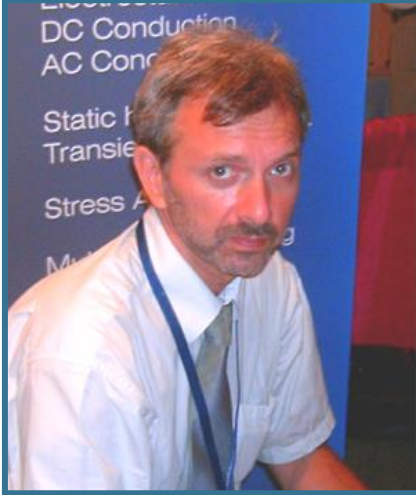




# AC conduction simulation with QuickField



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# QuickField Analysis Options

|  |  |
|--|--|
| <b>Magnetic analysis suite</b>         | Magnetostatics                                   |
|  | AC Magnetics                                     |
|  | Transient Magnetic                               |
| <b>Electric analysis suite</b>         | Electrostatics (2D,3D) and DC Conduction (2D,3D) |
|  | AC Conduction                                    |
|  | Transient Electric field                         |
| <b>Thermostructural analysis suite</b> | Steady-State Heat transfer (2D,3D)               |
|  | Transient Heat transfer                          |
|  | Stress analysis                                  |



# QuickField Analysis Options

|  |  |
|--|--|
| <b>Magnetic analysis suite</b>         | Magnetostatics                                   |
|  | AC Magnetics                                     |
|  | Transient Magnetic                               |
| <b>Electric analysis suite</b>         | Electrostatics (2D,3D) and DC Conduction (2D,3D) |
|  | <b>AC Conduction</b>                             |
|  | Transient Electric field                         |
| <b>Thermostructural analysis suite</b> | Steady-State Heat transfer (2D,3D)               |
|  | Transient Heat transfer                          |
|  | Stress analysis                                  |



# Electrostatics vs. DC Conduction vs. AC Conduction

In electric problems there is only electric field.  
Magnetic field is ignored, there is no eddy current

| Electrostatics             | DC Conduction             | AC Conduction                                      |
|----------------------------|---------------------------|--|
| Electric permittivity      | Electrical conductivity   | Electric permittivity and electrical conductivity. |
| No currents. No heat loss. | Only conductivity current | Conductivity current, displacement current.        |

Electric Permittivity

$\epsilon_x =$

$\epsilon_y =$

Anisotropic

Electric Charge Density

$\rho =$

Electrical Conductivity

$\sigma_x =$   (S/m)

$\sigma_y =$

Anisotropic

Depends on Temperature

Temperature:

Electric Permittivity

$\epsilon_x =$

$\epsilon_y =$

Electrical Conductivity

$\sigma_x =$   (S/m)

$\sigma_y =$



# QuickField AC vs. Transient

**Electric Permittivity** **AC**

$\epsilon_x =$

$\epsilon_y =$

---

**Electrical Conductivity**

$\sigma_x =$   (S/m)

$\sigma_y =$

Specify phasor magnitude and phase

Voltage:  $U = U_0$

$U_0 =$   (V)

$\varphi =$   (deg)

**Electric Permittivity** **Transient**

Nonlinear Permittivity

Anisotropic Permittivity

---

**Electrical Conductivity**

Nonlinear Conductivity

Anisotropic Conductivity

---

**Coordinates**

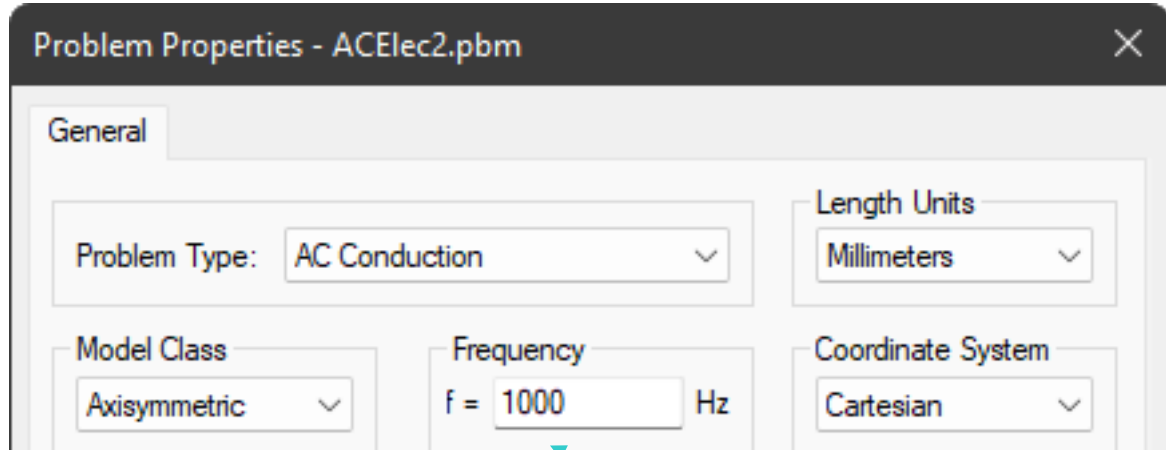
Cartesian

Polar

Voltage:  $U = U_0$  **Specify formula of time**

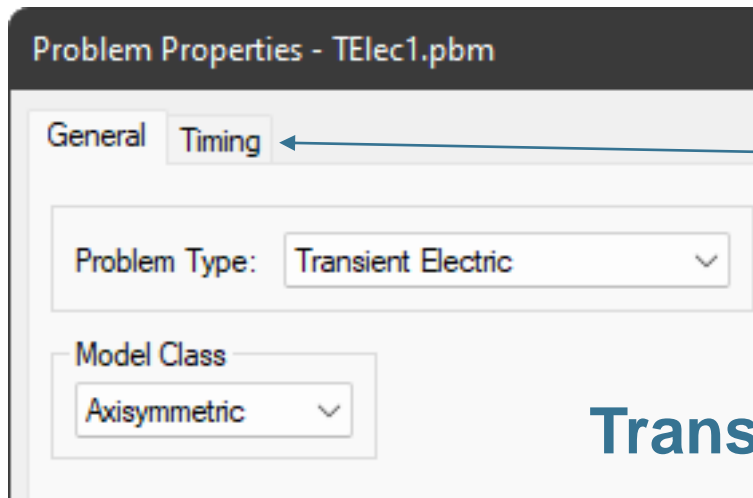
$U_0 =$   (V)

# QuickField AC vs. Transient



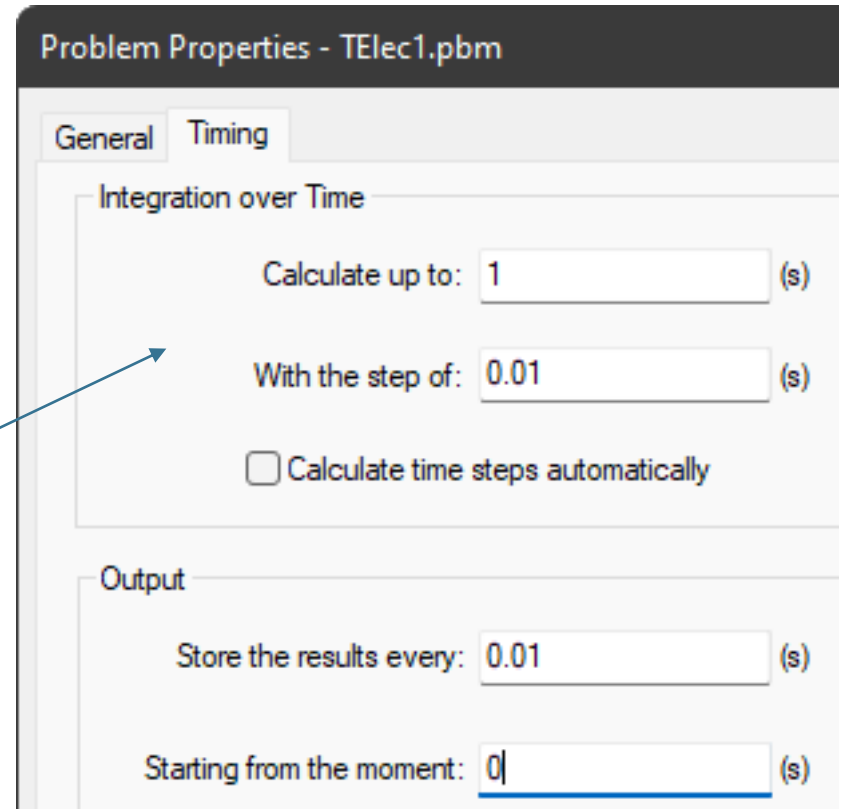
AC

Specify frequency value



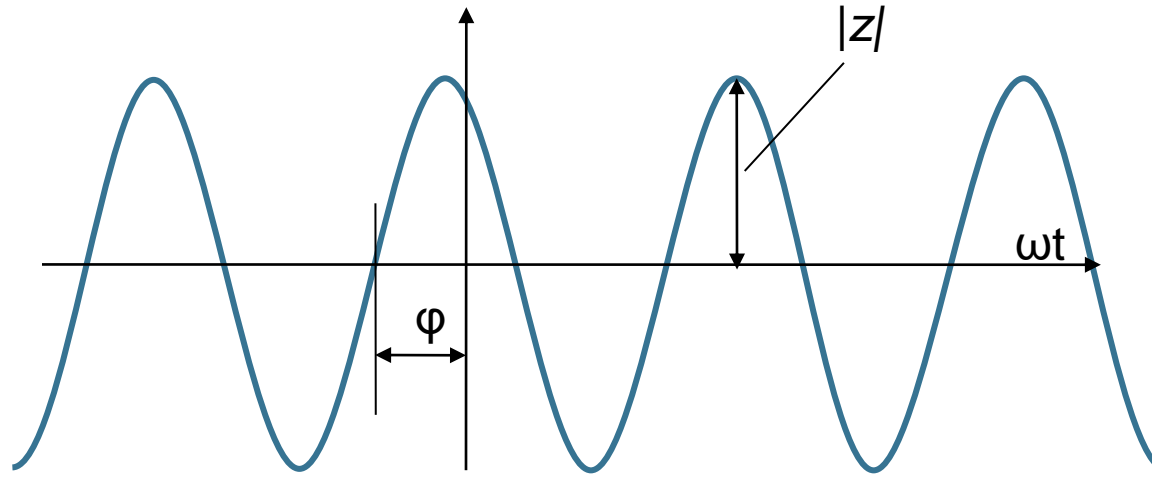
Transient

Specify integration time step and final time





# QuickField AC vs. Transient



## AC

Field components are considered to be time-harmonic, vary with time as  $z = z_0 \cdot \cos(\omega t + \varphi_z)$ , and presented as complex values with real and imaginary parts.

- Complex Values
  - |Z| Flux Function  $\Phi = 0.00010681$  Wb
  - |Z| Voltage  $V = 0.2128$  V
  - |Z| Current Density  $j_{total} = 1924400$  A/m<sup>2</sup>
  - $\varphi = 115.06^\circ$

## Transient

Field sources and boundary conditions can be defined by time-dependent formulae (including time-harmonic), and the transient solution is obtained by time integration using time steps.

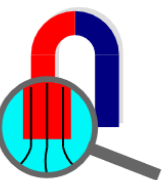
Postprocessing TEMa

Time: Set the time for the displayed results

$\int ds$  0.25

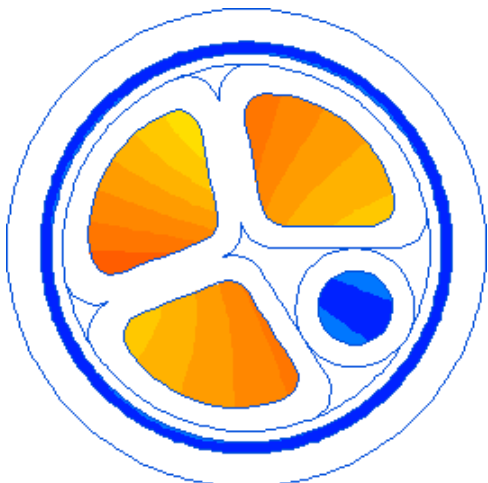
Values

- Current Density  $j_{total} = -1508400$  A/m<sup>2</sup>



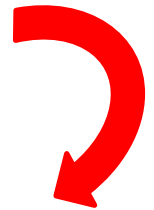
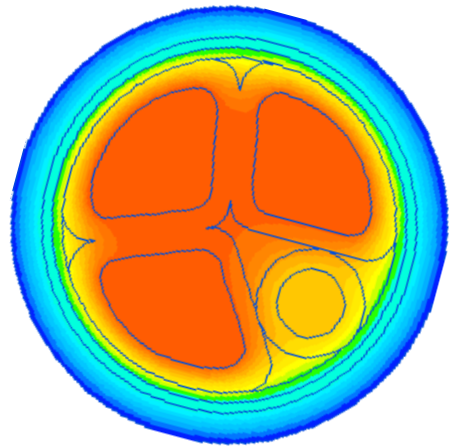
# MultiPhysics (2D)

Electromagnetic fields



Losses  
→

Temperature field

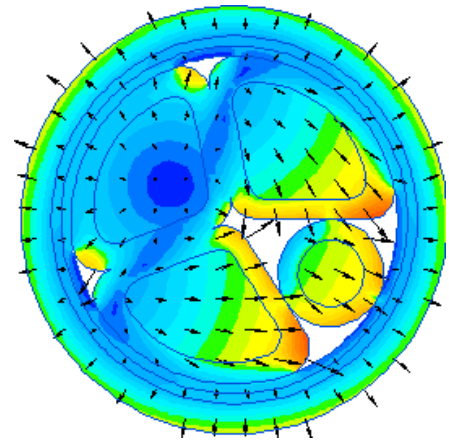


Temperature field import



Magnetic state import

Forces  
→



Thermal Stresses  
←

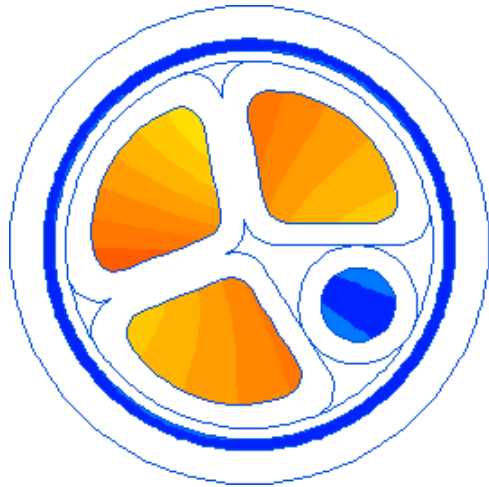
Stresses & Deformations





# MultiPhysics (2D)

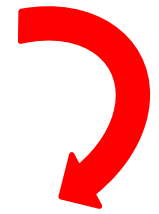
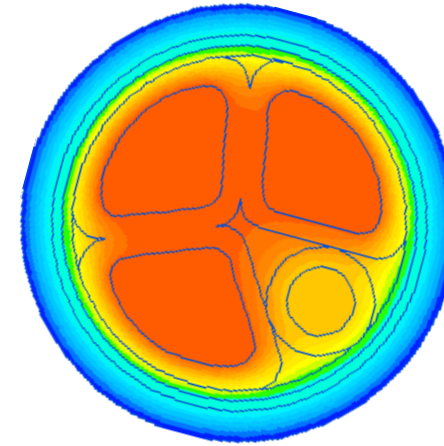
Electromagnetic fields



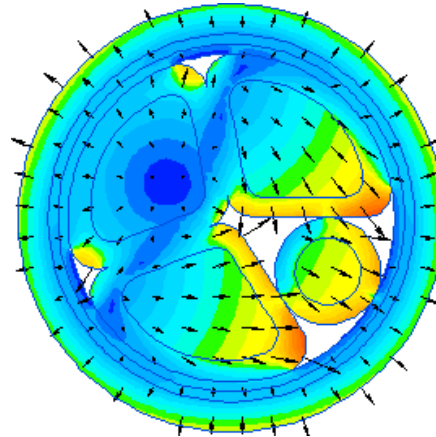
**Joule Losses**



Temperature field



**Temperature field import**



**Thermal Stresses**

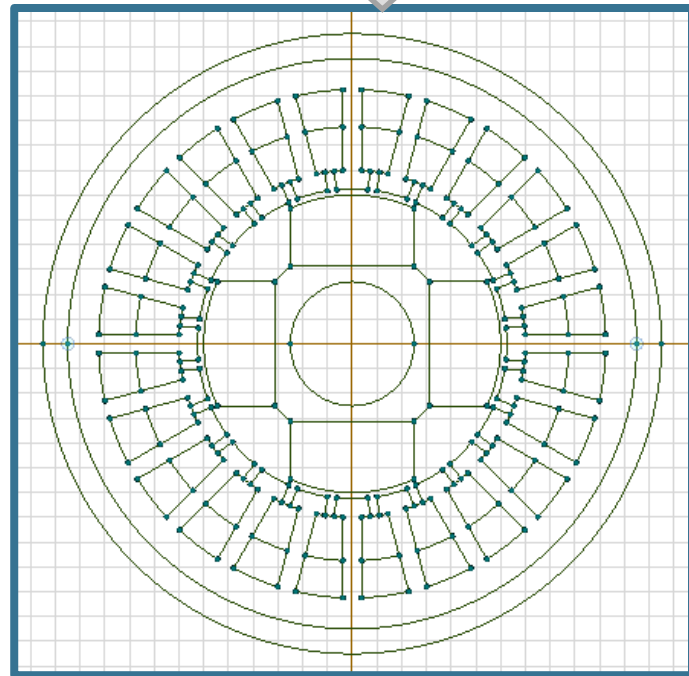


**Stresses & Deformations**

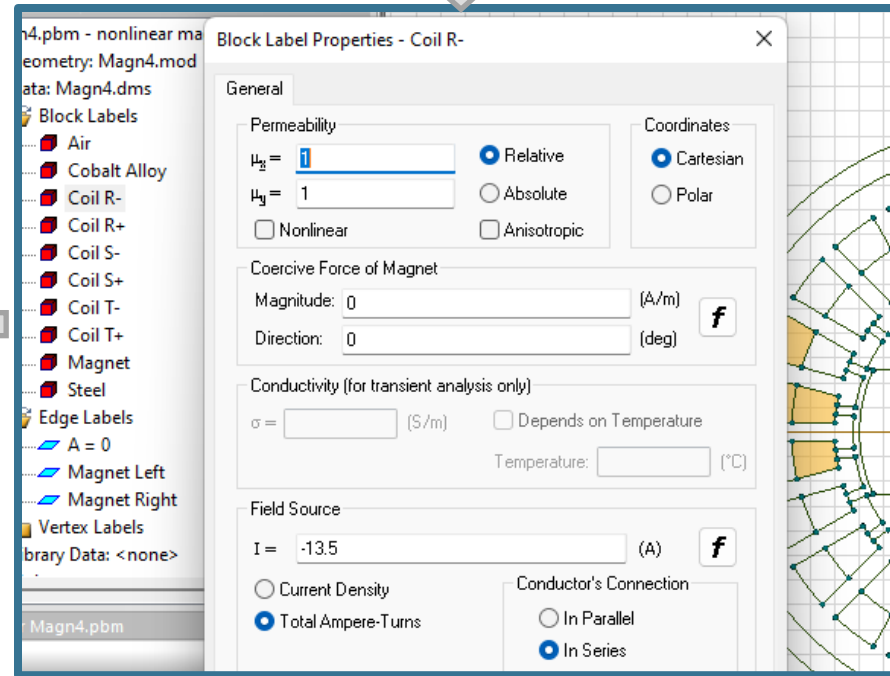


# QuickField Workflow

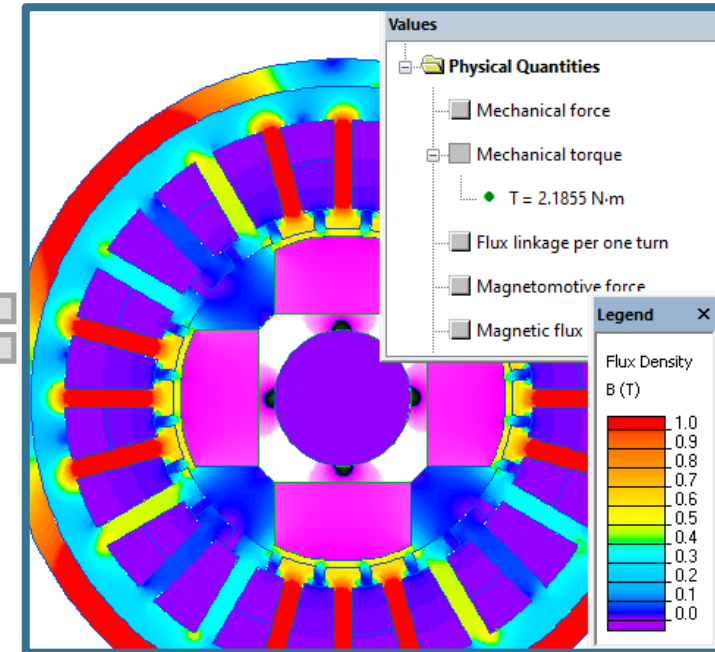
**Problem setup**



**Model editor**

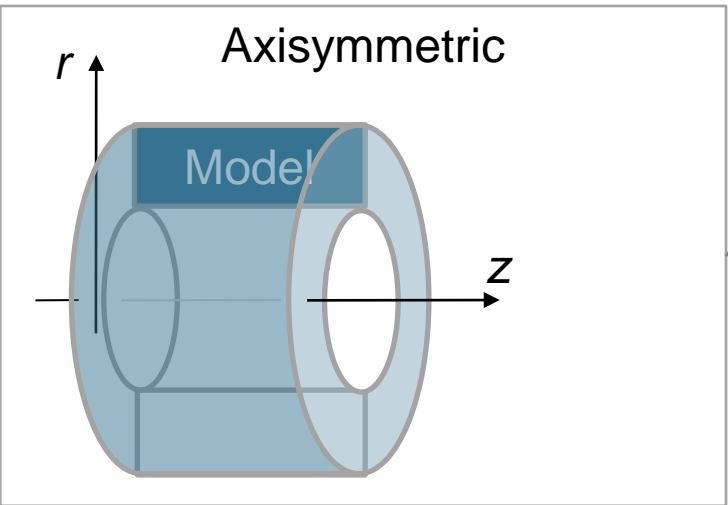
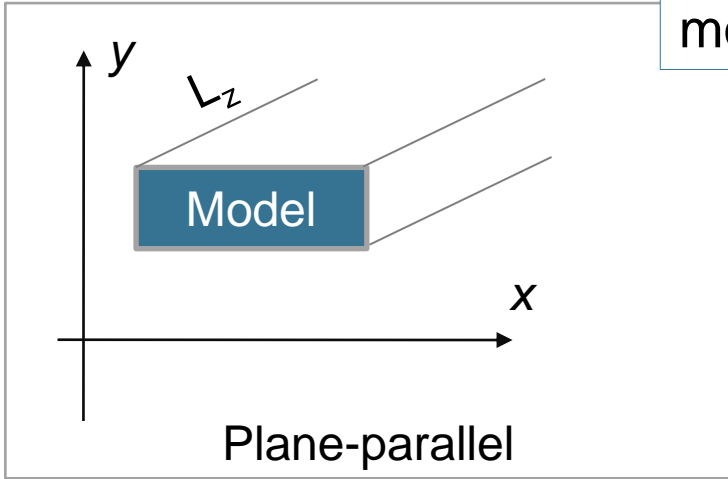
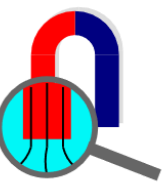


**Material physical properties,  
field sources and  
boundary conditions**



**Results analysis**

# QuickField AC Conduction. Problem setup



2. Choose model class

1. Choose problem type: AC conduction

3. Enter frequency value

Problem Properties - dielectric\_loss.pbm

General

Problem Type: AC Conduction

Length Units: Millimeters

Model Class: Plane-parallel (selected), Plane-parallel, Axisymmetric

Frequency: f = 100000 Hz

Coordinate System: Cartesian

Precision: Non

Files

Geometry: Dielectric\_loss.mod

Data: Dielectric\_loss.dec

Library Data:

Location: D:\temp\ac\_cond\dielectric\_loss\student

OK Cancel Help



# QuickField AC Conduction. Label properties

Block

Edge

Vertex

Block Label Properties - dielectric

General

Electric Permittivity

$\epsilon_x =$    Relative  
 $\epsilon_y =$    Absolute

Electrical Conductivity

$\sigma_x =$    $\sigma_y =$   (S/m)

Coordinates

Cartesian  Polar

Anisotropic

OK Cancel Help

Edge Label Properties - U+

General

Voltage:  $U = U_0$   
 $U_0 =$   (V)  
 $\varphi =$   (deg)

Normal Current Density:  $j_n = j$  ( $\Delta j_n = j$ )  
 $j =$   (A/m<sup>2</sup>)  
 $\varphi =$   (deg)

Floating Conductor (Equal Voltage)

Even Periodic:  $U_1 = U_2$   
 Odd Periodic:  $U_1 = -U_2$

OK Cancel Help

Vertex Label Properties - Source

General

Voltage:  $U = U_0$   
 $U_0 =$   (V)  
 $\varphi =$   (deg)

External Current  
 $I =$   (A)  
 $\varphi =$   (deg)

OK Cancel Help



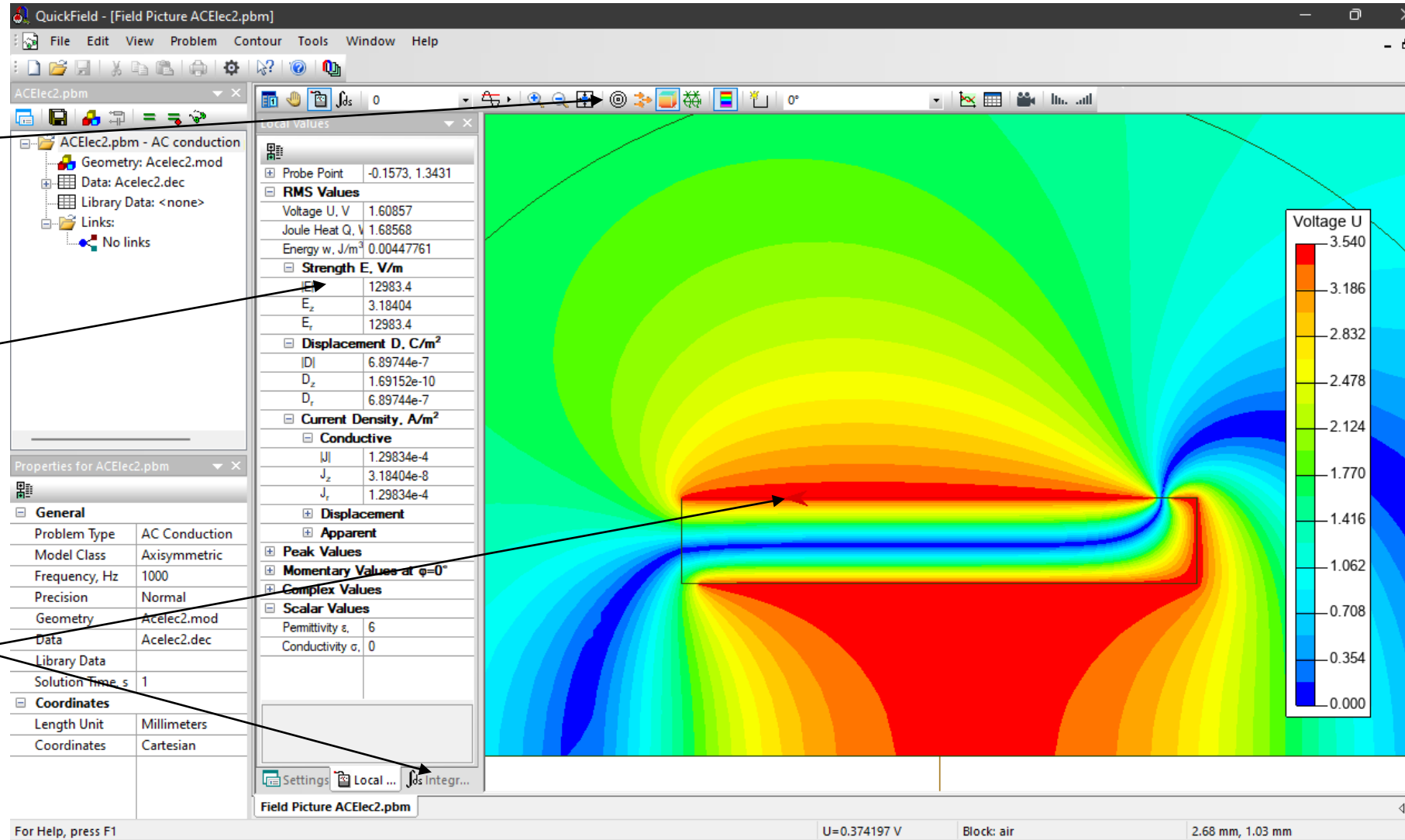
# QuickField AC Conduction. Results

Results analysis is the most complicated part, having more options. Generally, the following types of result analysis are available:

Field maps showing the space distribution of different field parameters

Field parameters in arbitrary point

Contour analysis, including field parameters distribution and integral calculations





# QuickField AC Conduction. Results

## Field maps

**Field Picture Properties**

Phase for Momentary Values:  deg

**Field Lines**

Snapshot at given phase Interval:  V

Snapshot at phase + 90°

**Vector Plot**

Snapshot at given phase

Snapshot at phase + 90°

Cell:  mm

Scale:

Strength E  
Displacement D  
Current Density  $j_{active}$   
Current Density  $j_{reactive}$   
Current Density  $j_{apparent}$

**Zone Plot**

Momentary Value

Color Map of:  RMS Value  Peak Value

Color Grades:

Maximum:  V

Minimum:  V

Strength E  
Strength  $E_x$   
Strength  $E_y$   
Displacement D  
Displacement  $D_x$   
Displacement  $D_y$   
Current Density  $j_{active}$

Show Mesh

OK  
Apply  
Cancel  
Help  
Suggest

## Local field data

**Local Values**

- Coordinates
- RMS Values
- Average Values
  - Active Power  $Q_{active} = 4646.4 \text{ W/m}^3$
  - Reactive Power  $Q_{reactive} = 1.819e-12 \text{ W/m}^3$
  - Apparent Power  $Q_{apparent} = 4646.4 \text{ W/m}^3$
- Peak Values
- Momentary Values at phase  $\phi$
- Complex Values
  - $|Z|$  Voltage  $U = 202.23 \text{ V}$
  - $|Z|$  Current Density  $j_{active,x} = 0.029868 \text{ A/m}^2$
  - $|Z|$  Current Density  $j_{active,y} = 1.007e-10 \text{ A/m}^2$
  - $|Z|$  Current Density  $j_{reactive,x} = 3.981 \text{ A/m}^2$
  - $|Z|$  Current Density  $j_{reactive,y} = 1.3422e-8 \text{ A/m}^2$
- Scalar Values
  - Conductivity  $\sigma = 9.6e-8 \text{ S/m}$
  - Permittivity  $\epsilon = 2.3$

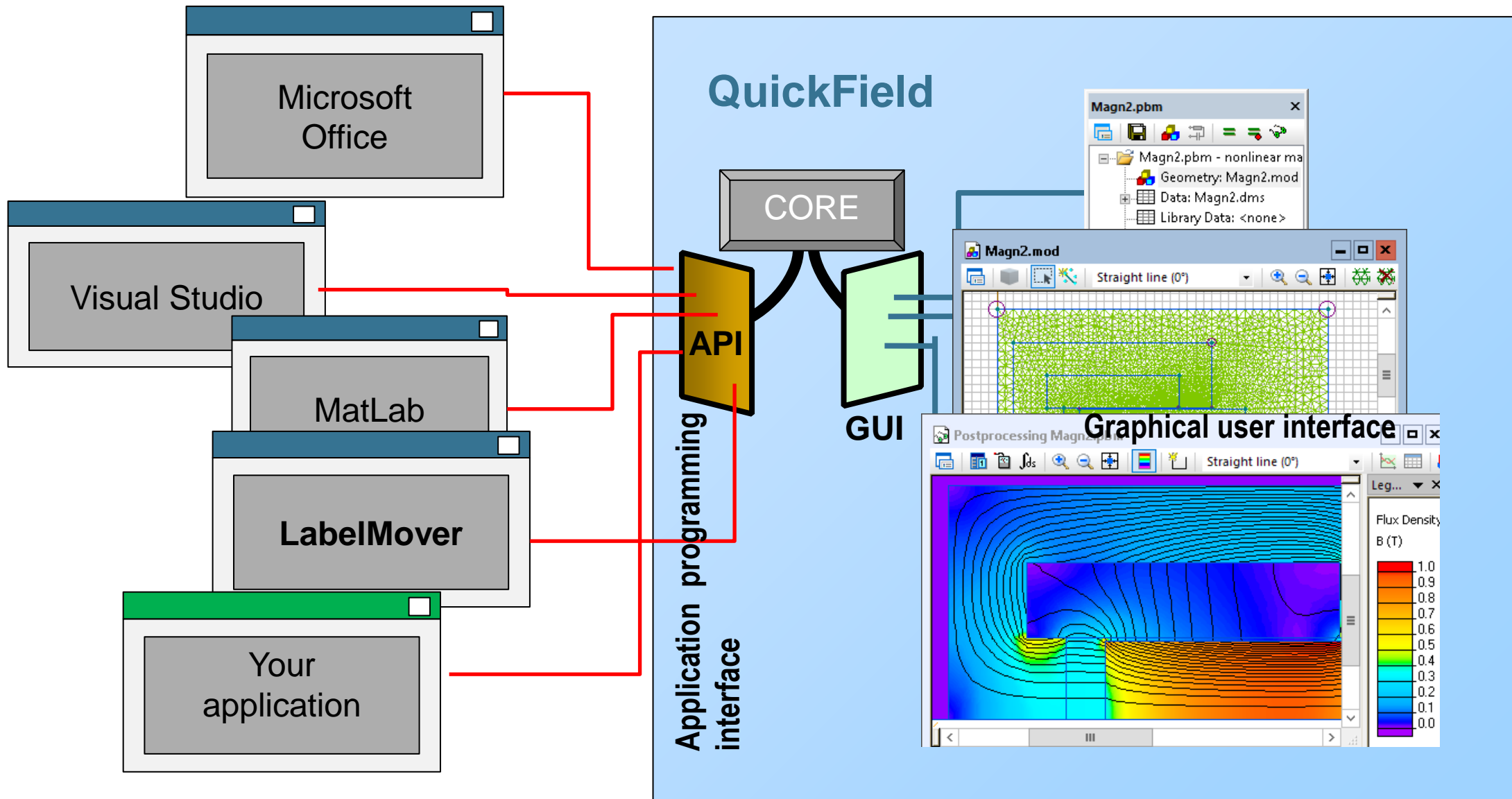
## Integrals

**Physical Quantities**

- Electric charge
- Active current through a given surface
- Reactive current through a given surface
  - $|Z| I_{Reactive} = 0.0003981 \text{ A}$
  - $\phi = -90^\circ$
  - $\text{Re}(I_{Reactive}) = -3.4685e-15 \text{ A}$
  - $\text{Im}(I_{Reactive}) = -0.0003981 \text{ A}$
  - Momentary Value =  $-3.4685e-15 \text{ A}$
- Apparent current through a given surface
- Active power produced in a volume
- Reactive power produced in a volume
- Apparent power produced in a volume
- Mechanical force
- Mechanical torque
- Electric field energy
- Surface energy



# QuickField API



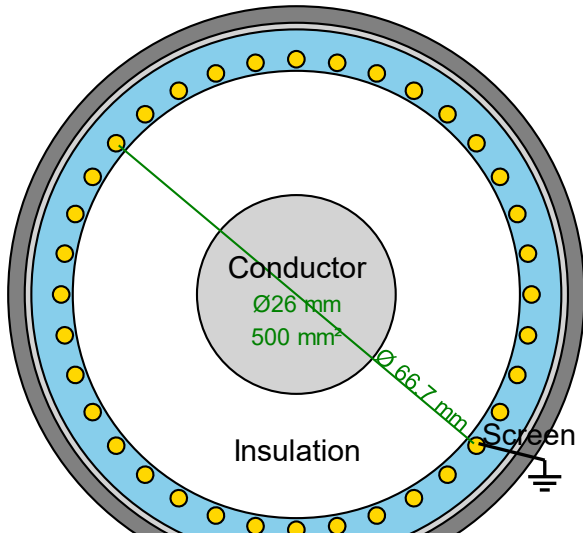


# QuickField Difference

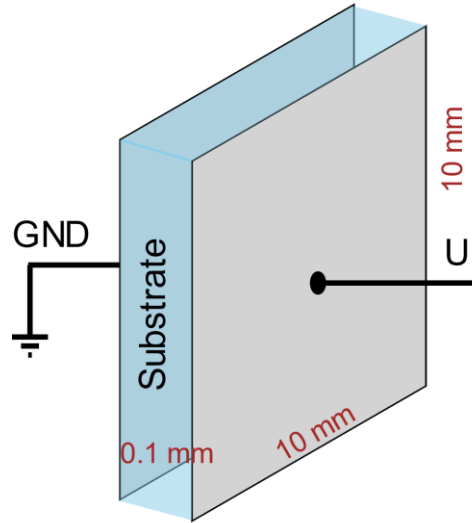




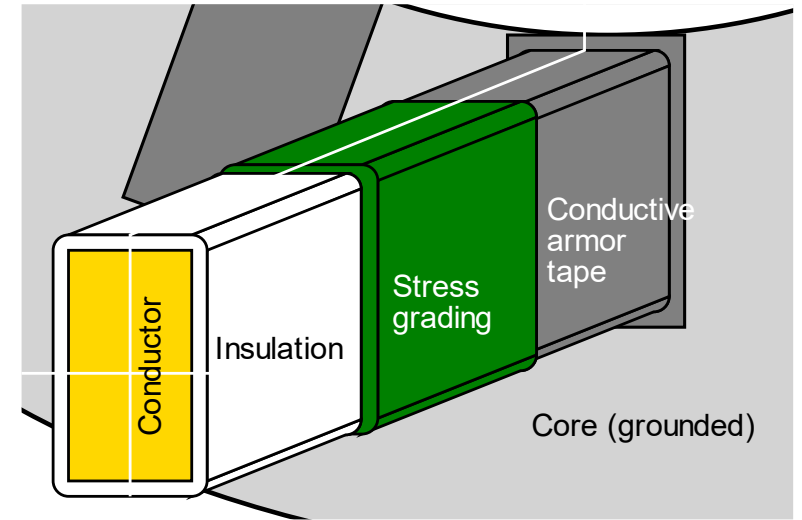
# AC conduction simulation with QuickField



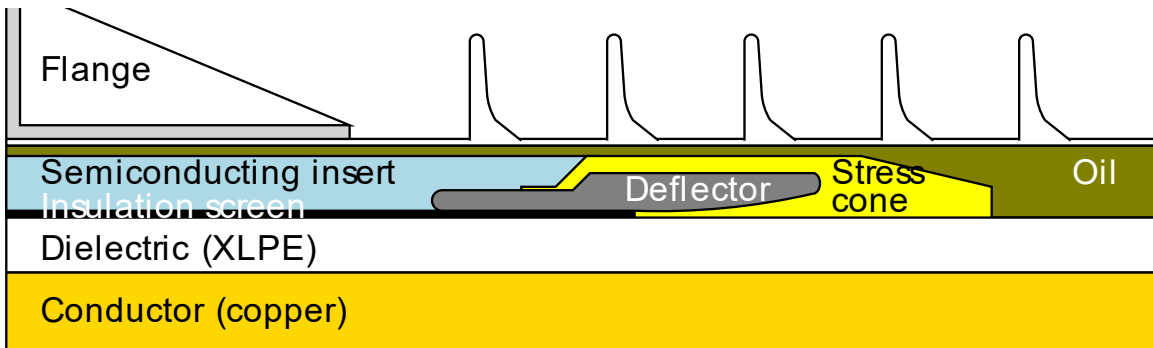
Dielectric loss in cable



Plane capacitor dielectric loss



Core-end insulation electric stress



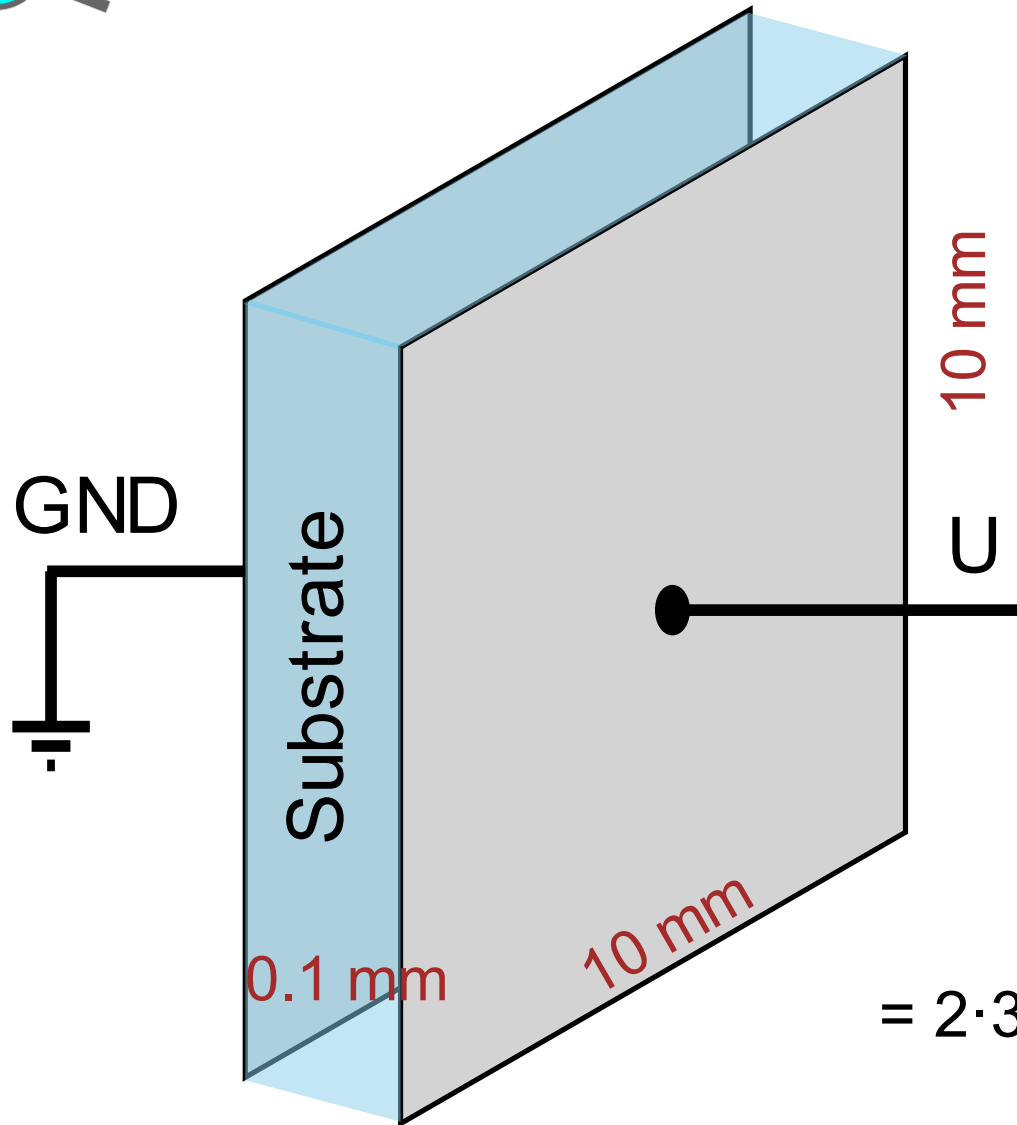
Cable termination to oil filled bushing



Dielectric heating



# Plane capacitor dielectric loss



## Problem specification:

Relative permittivity of substrate  $\epsilon = 10$

Voltage  $U = 5$  V, frequency  $f = 1$  MHz

Loss tangent  $\tan(\delta) = 0.01$

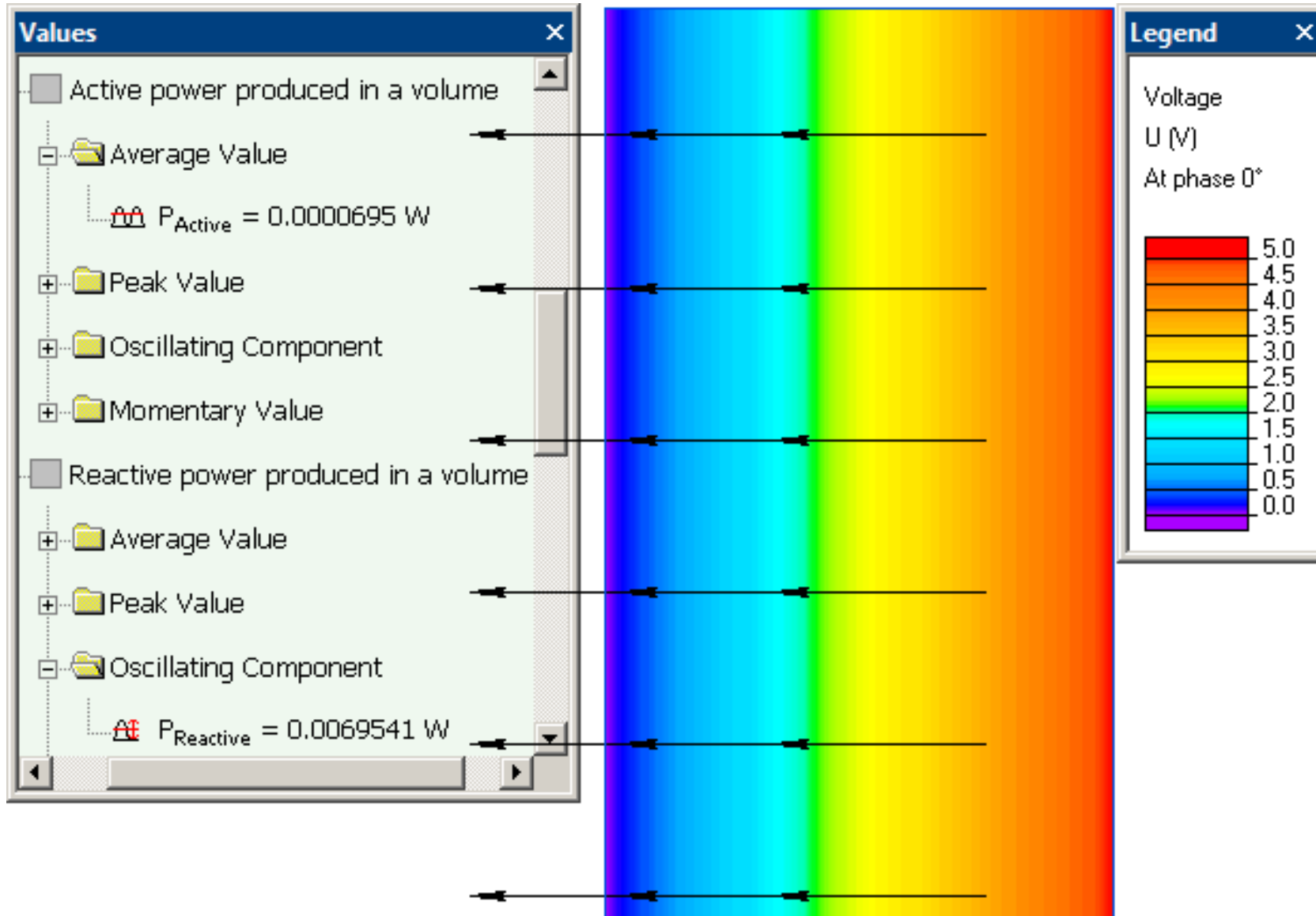
## Task:

Calculate dielectric loss in the substrate.

$$\begin{aligned} \text{Apparent conductivity} \\ g &= 2\pi f \cdot \epsilon \cdot \epsilon_0 \cdot \tan(\delta) = \\ &= 2 \cdot 3.142 \cdot 10^6 \cdot 10 \cdot (8.854 \cdot 10^{-12}) \cdot 0.01 = 5.56 \cdot 10^{-6} \text{ S/m.} \end{aligned}$$

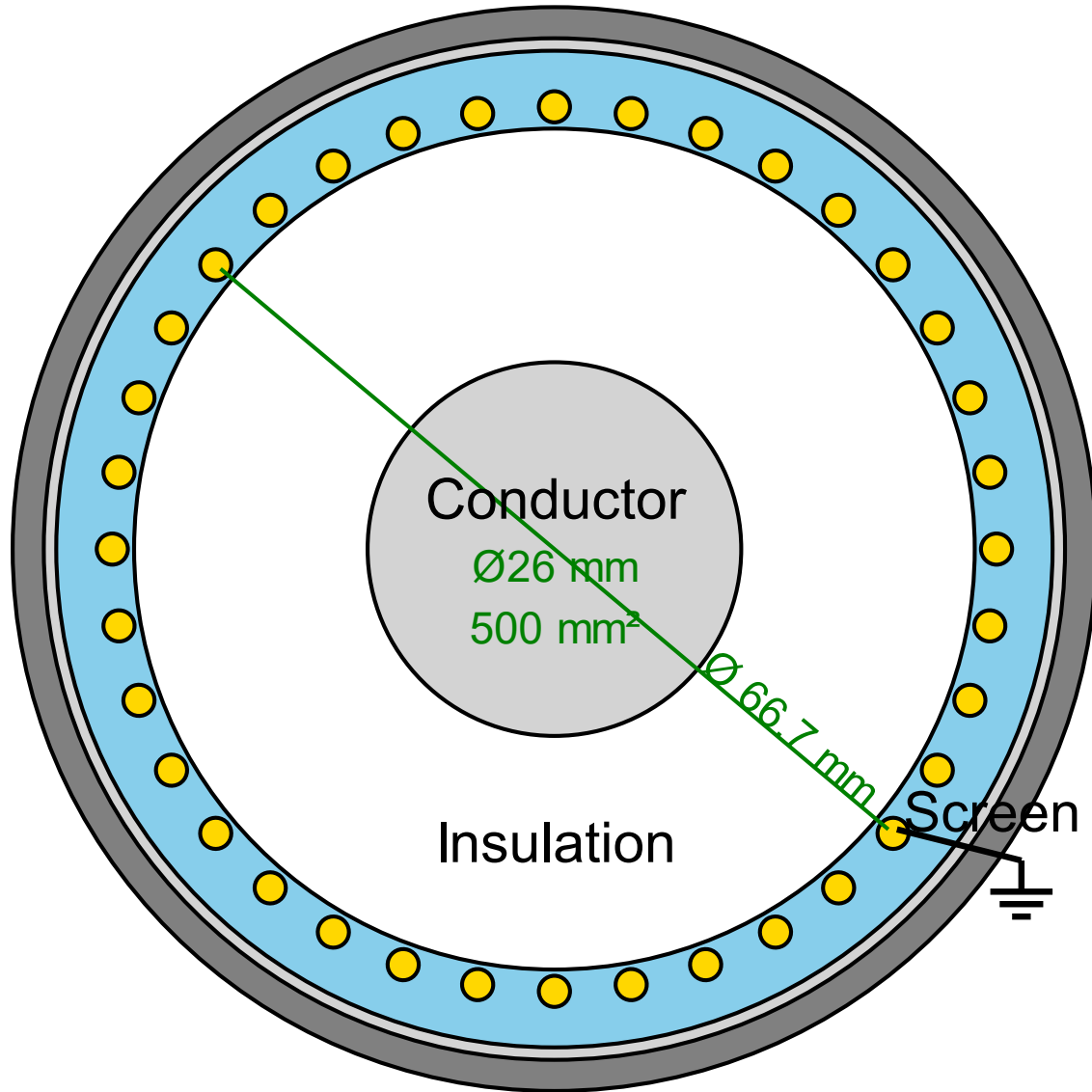


# Plane capacitor dielectric loss





# Dielectric loss in cable



## Problem specification:

Voltage  $U = 132 \text{ kV}$  (r.m.s.), frequency  $f = 50 \text{ Hz}$ .  
XLPE permittivity 2.5, loss tangent  $\tan(\delta) = 0.001$

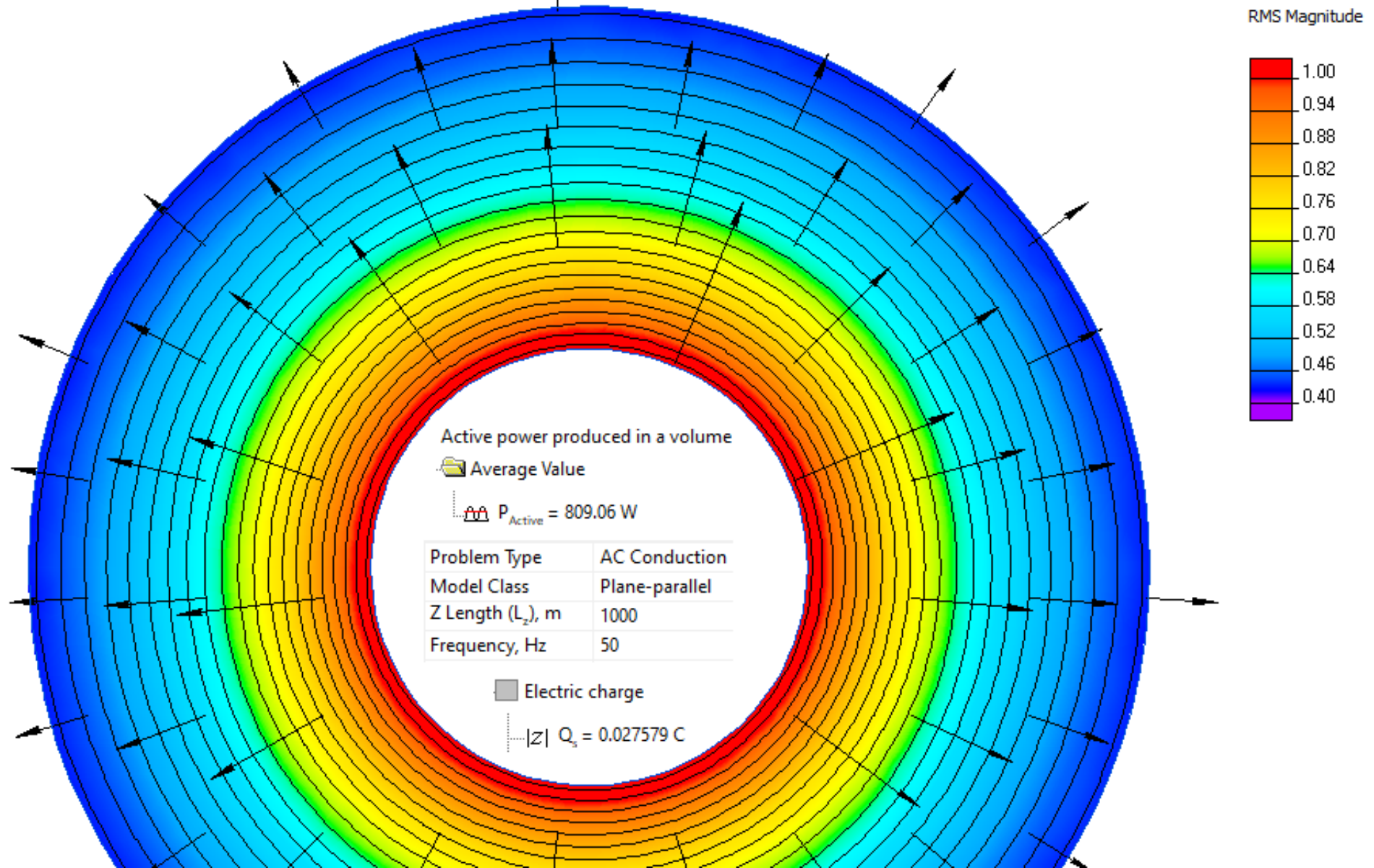
## Task:

Calculate the capacitance and dielectric losses

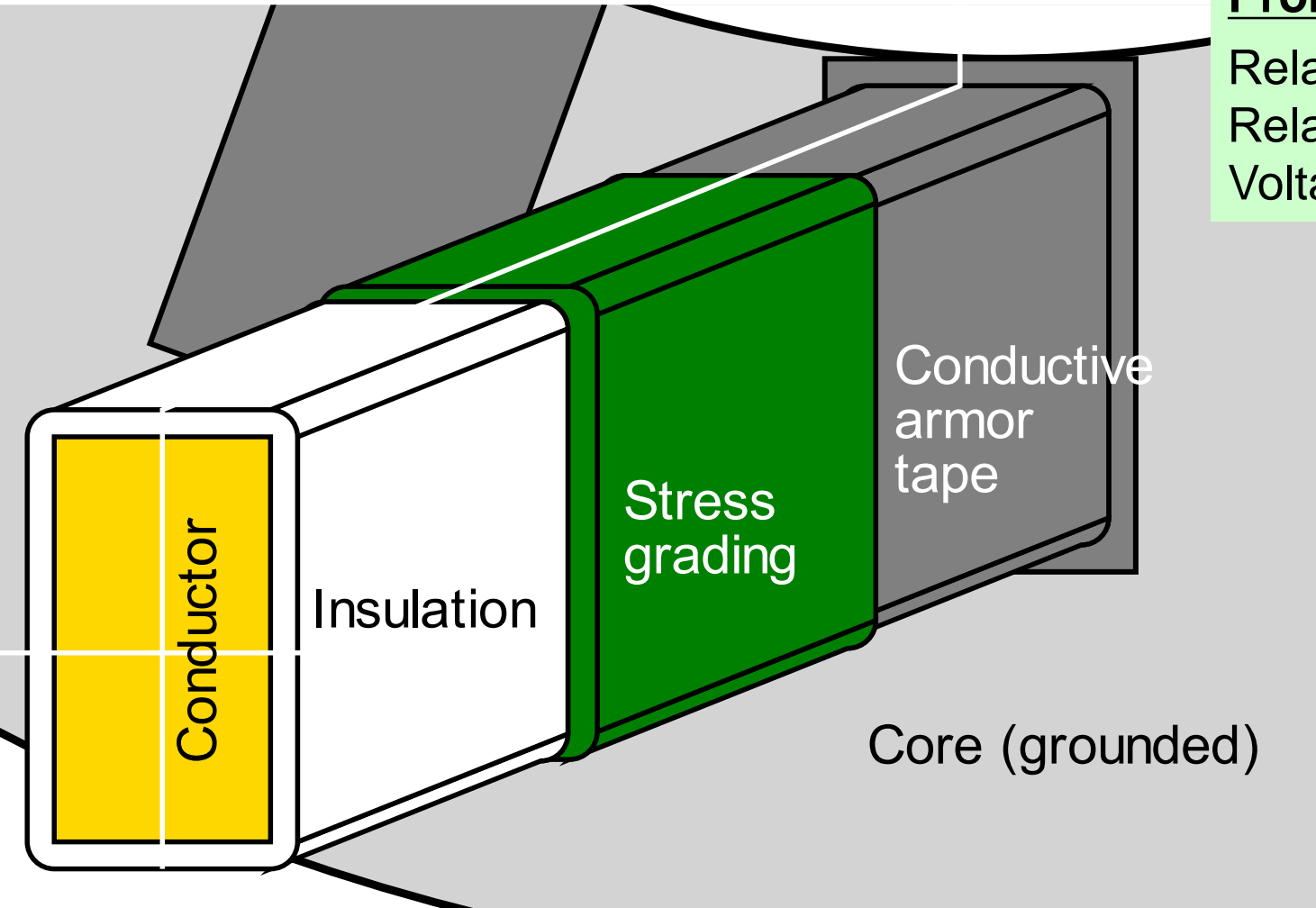
$$\begin{aligned} \text{Apparent conductivity } \sigma &= 2\pi f \cdot \epsilon \cdot \epsilon_0 \cdot \tan(\delta) = \\ &= 2 \cdot 3.142 \cdot 50 \cdot 2.5 \cdot 8.854 \text{e-}12 \cdot 0.001 = \\ &= 6.95 \text{ pS/m.} \end{aligned}$$



# Dielectric loss in cable



# Core-end insulation electric stress



## Problem specification:

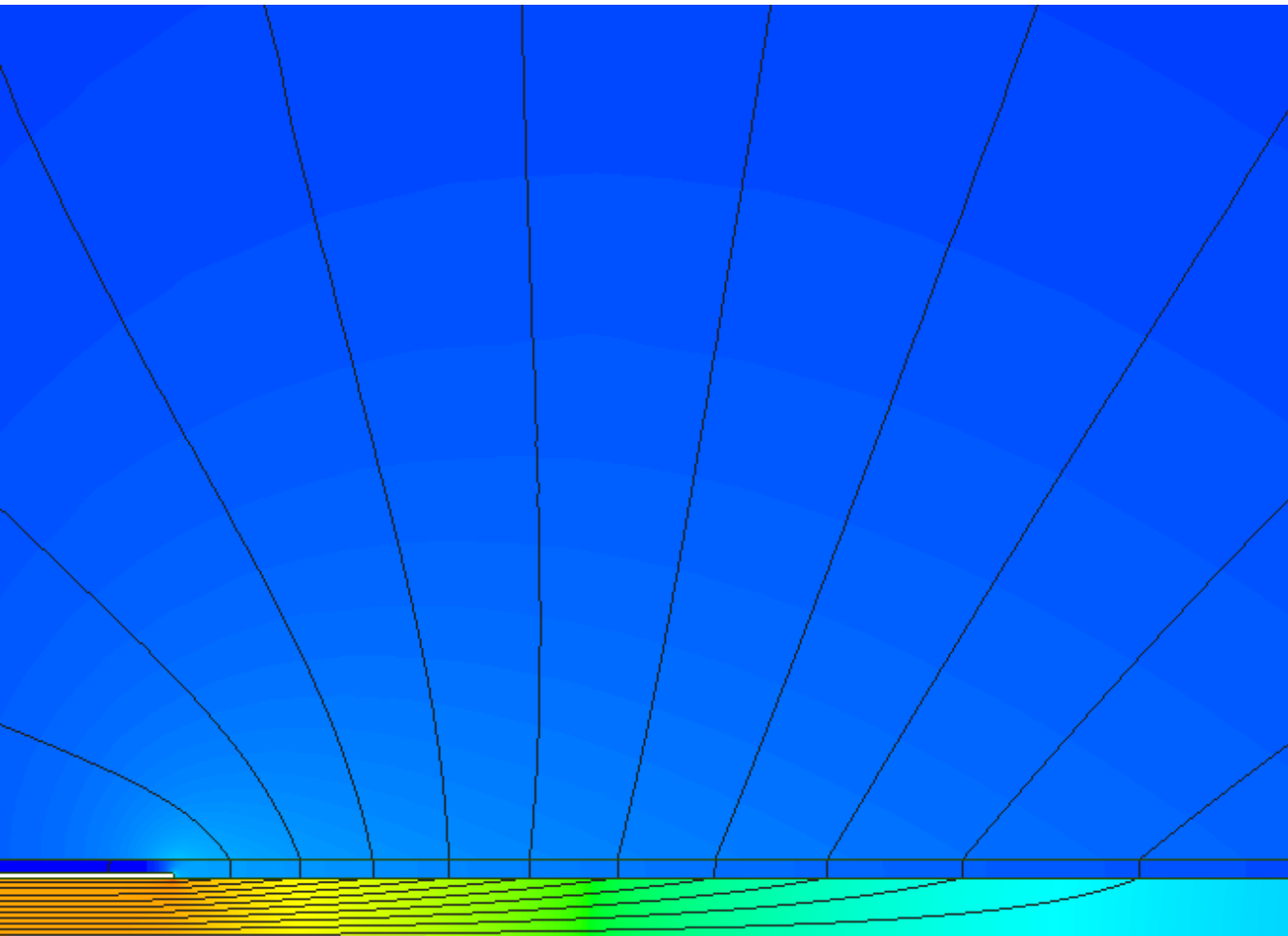
Relative permittivity of stress grading paint  $\epsilon = 4$ ,  
Relative permittivity of insulation  $\epsilon = 3$   
Voltage  $U_f = 15$  kV (r.m.s.), frequency  $f = 50$  Hz.

## Task:

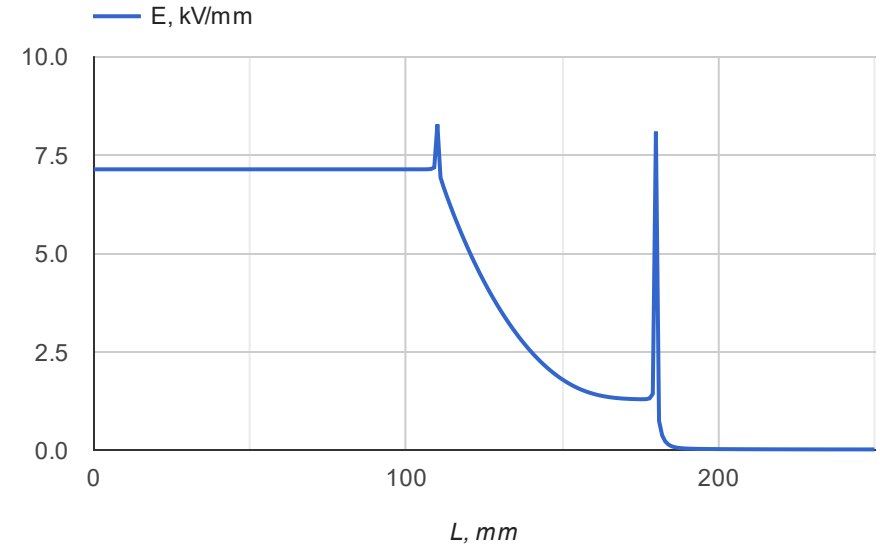
Calculate the electric field stress distribution



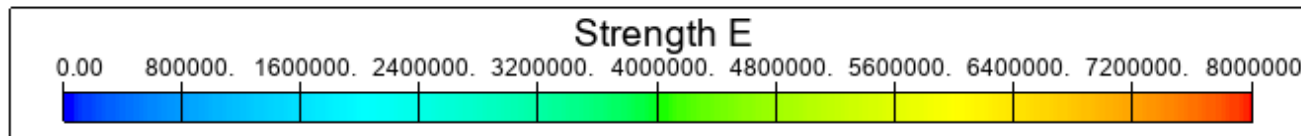
# Core-end insulation electric stress



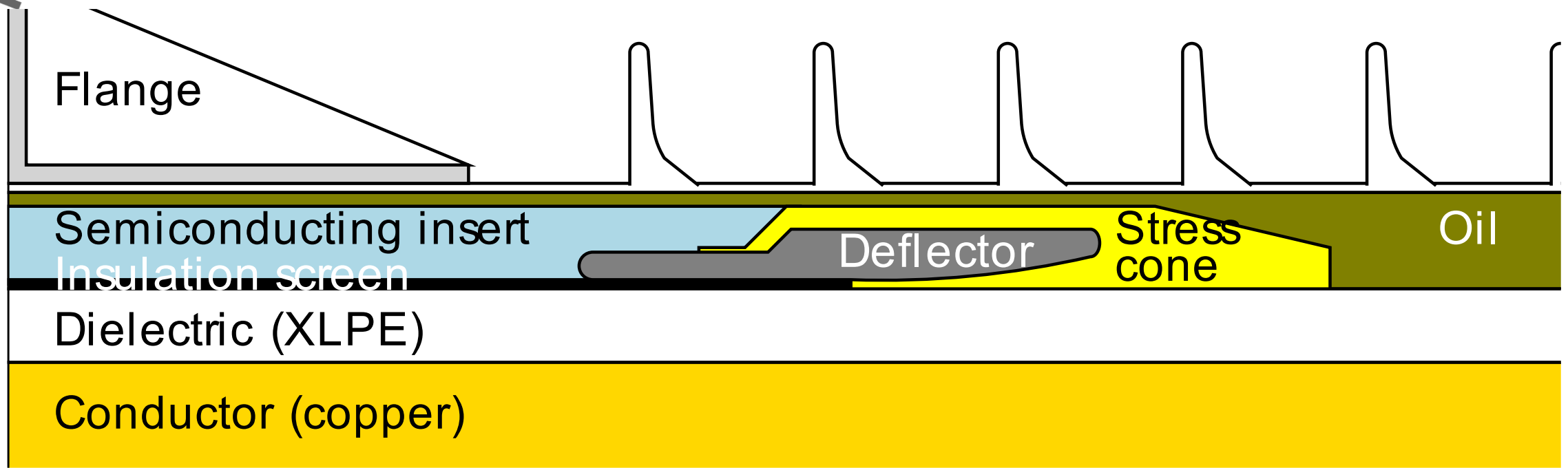
Electric field intensity plot along the insulation surface



|                        |                |
|------------------------|----------------|
| Problem Type           | AC Conduction  |
| Model Class            | Plane-parallel |
| Z Length ( $L_z$ ), mm | 1000           |
| Frequency, Hz          | 50             |



# Cable termination to oil filled bushing



## Problem specification:

Voltage  $U = 64$  kV (r.m.s.), frequency  $f = 50$  Hz.

Relative permittivity of media: oil 12,  
insulator 2.3, stress cone 22, deflector 2.5.

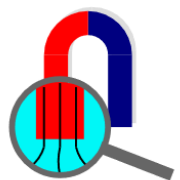
Deflector electrical conductivity 0.0002 S/m.

## Task:

Calculate the  
electric field  
stress  
distribution

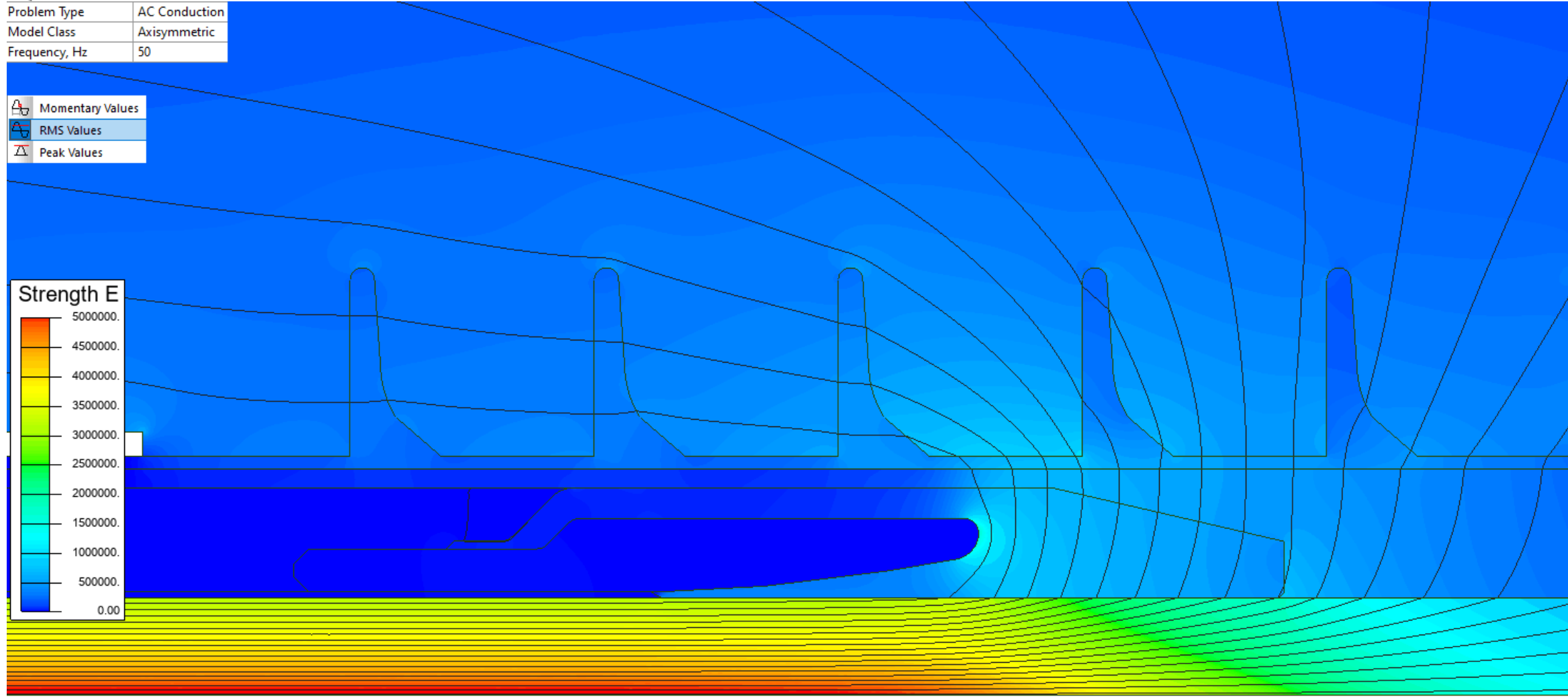
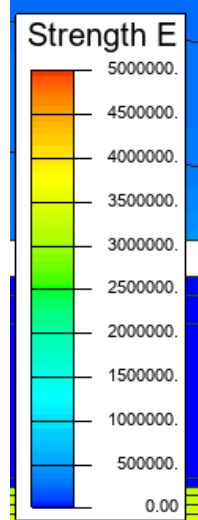


# Cable termination to oil filled bushing



|               |               |
|---------------|---------------|
| Problem Type  | AC Conduction |
| Model Class   | Axisymmetric  |
| Frequency, Hz | 50            |

- Momentary Values
- RMS Values
- Peak Values



Voltage:  $U = U_0$

$U_0 = 64000 \cdot \text{sqrt}(2)$  (V)

$\varphi = 0$  (deg)

# Dielectric heating

## Problem specification:

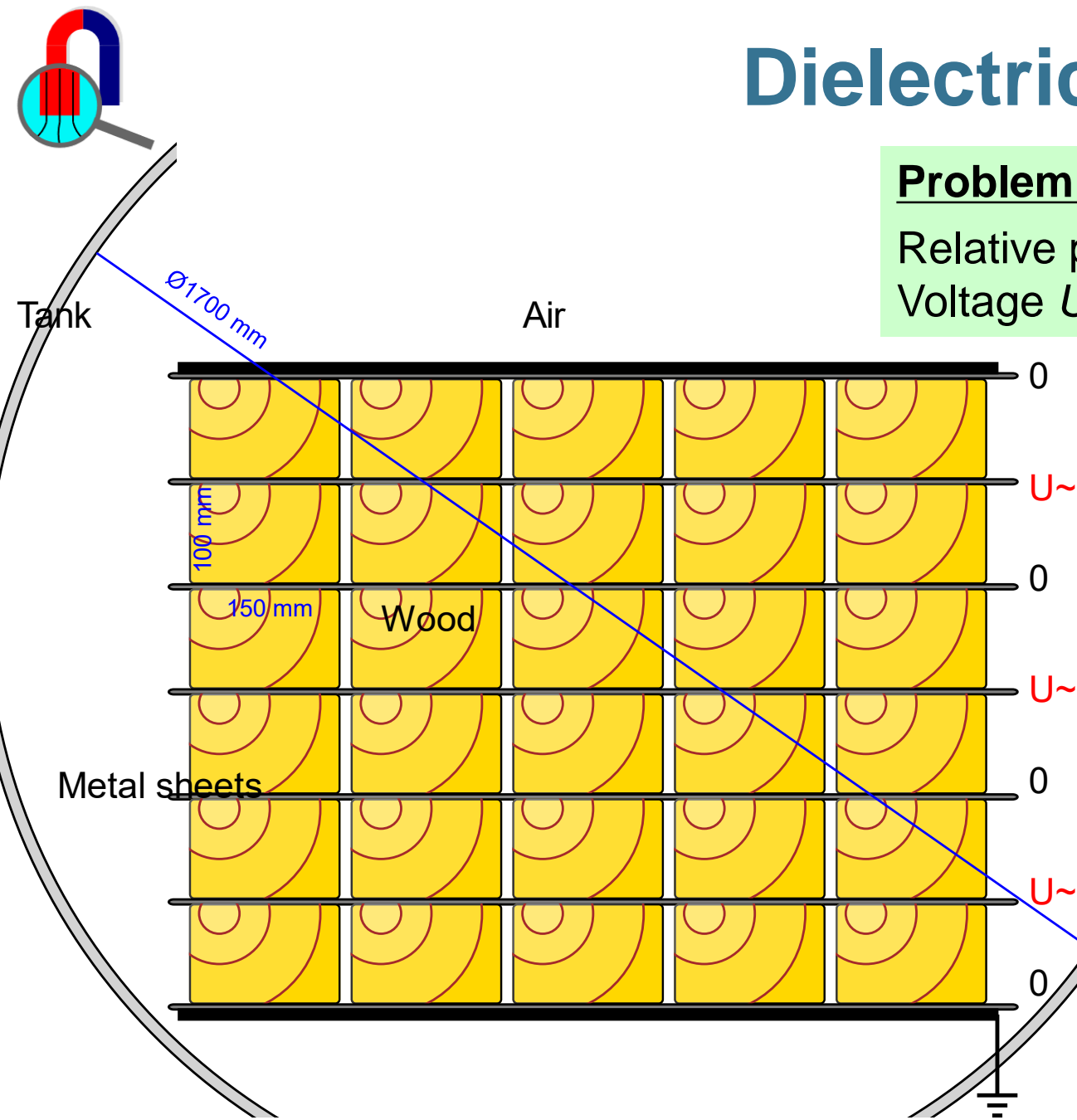
Relative permittivity of wood  $\epsilon = 2$ , loss tangent  $\tan(\delta) = 0.1$   
Voltage  $U_{\sim} = 1$  kV, frequency  $f = 6.87$  MHz

## Task:

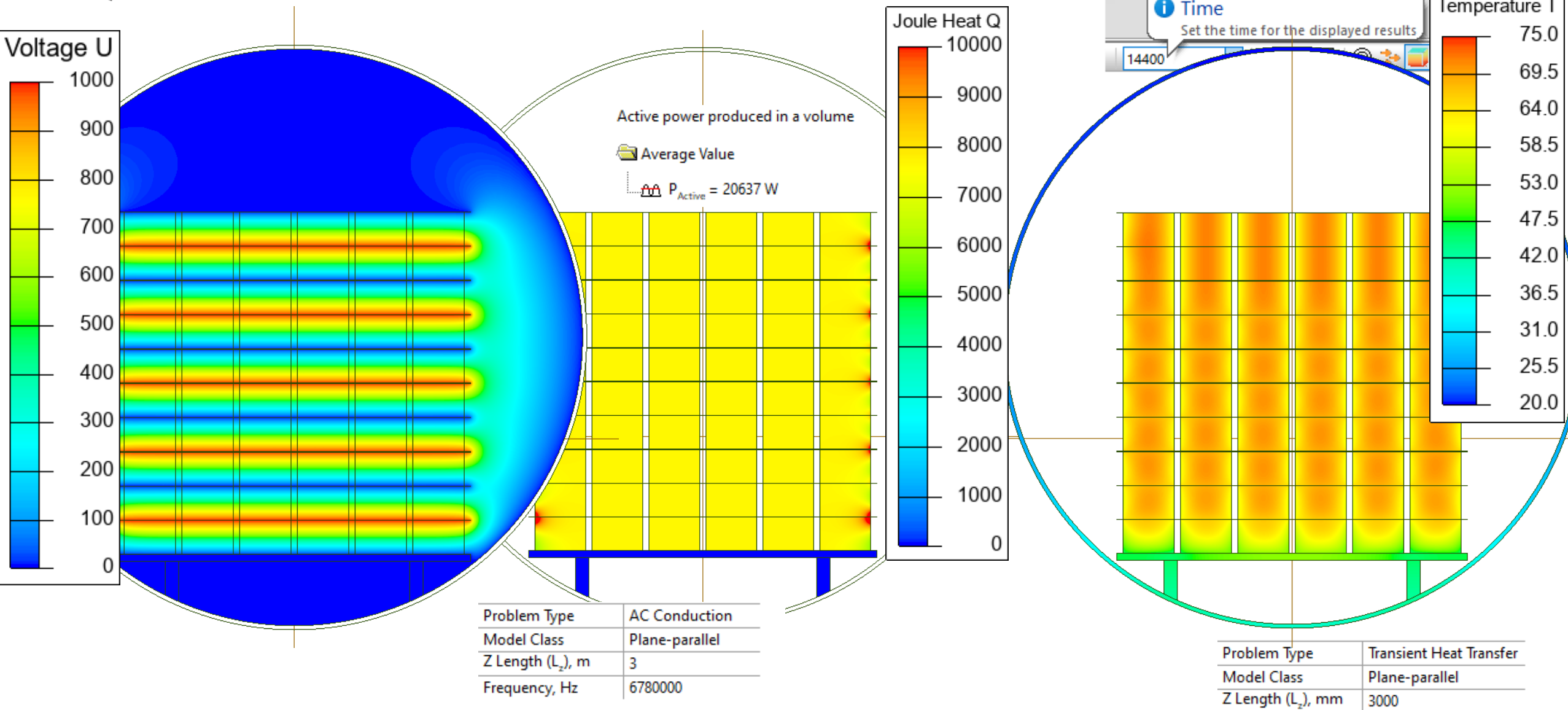
Calculate temperature rise in the wood.

Apparent conductivity

$$\begin{aligned}\sigma &= 2\pi f \cdot \epsilon \cdot \epsilon_0 \cdot \tan(\delta) = \\ &= 2 \cdot 3.142 \cdot (6.87 \cdot 10^6) \cdot 2 \cdot (8.854 \cdot 10^{-12}) \cdot 0.1 = \\ &= 76.4 \text{ uS/m}\end{aligned}$$



# Dielectric heating





**This recording is over**

**More recordings and simulation  
examples at  
[www.quickfield.com](http://www.quickfield.com)**

Your feedback is welcome: [support@quickfield.com](mailto:support@quickfield.com)