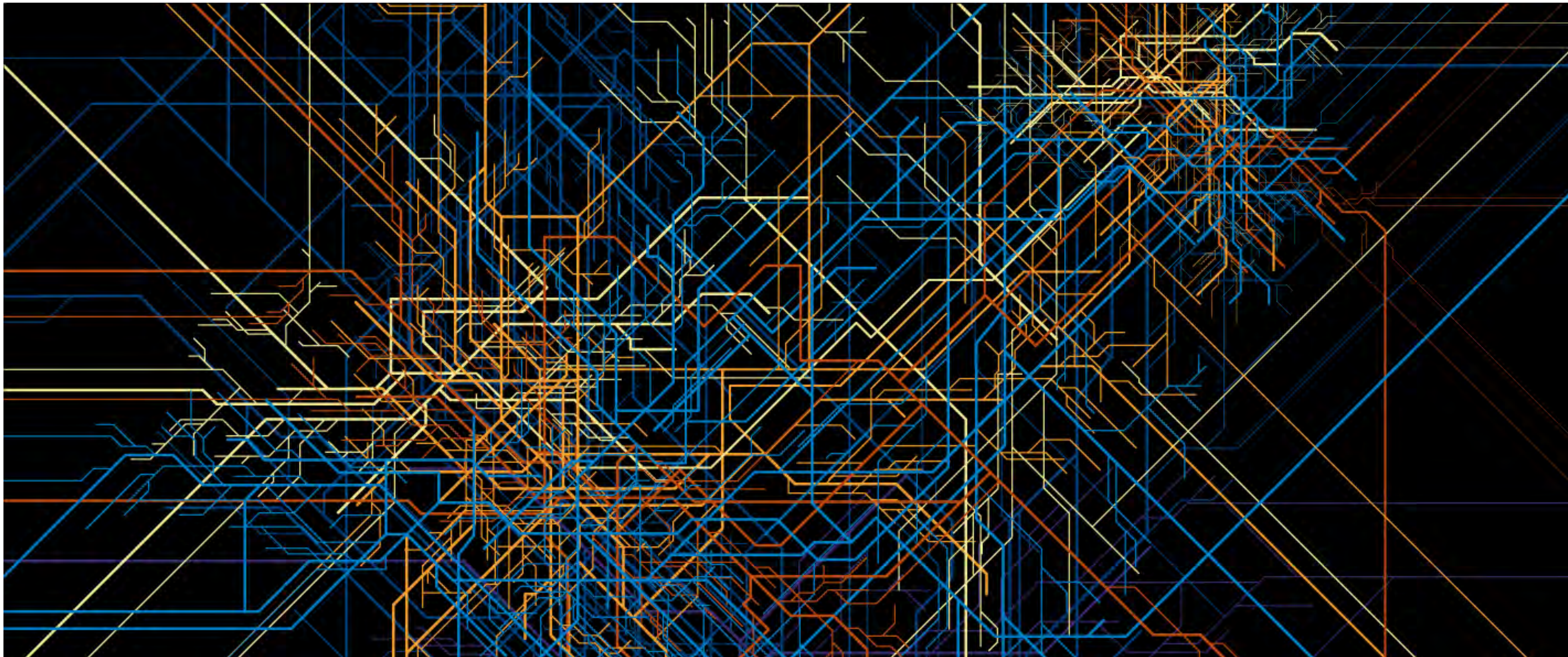


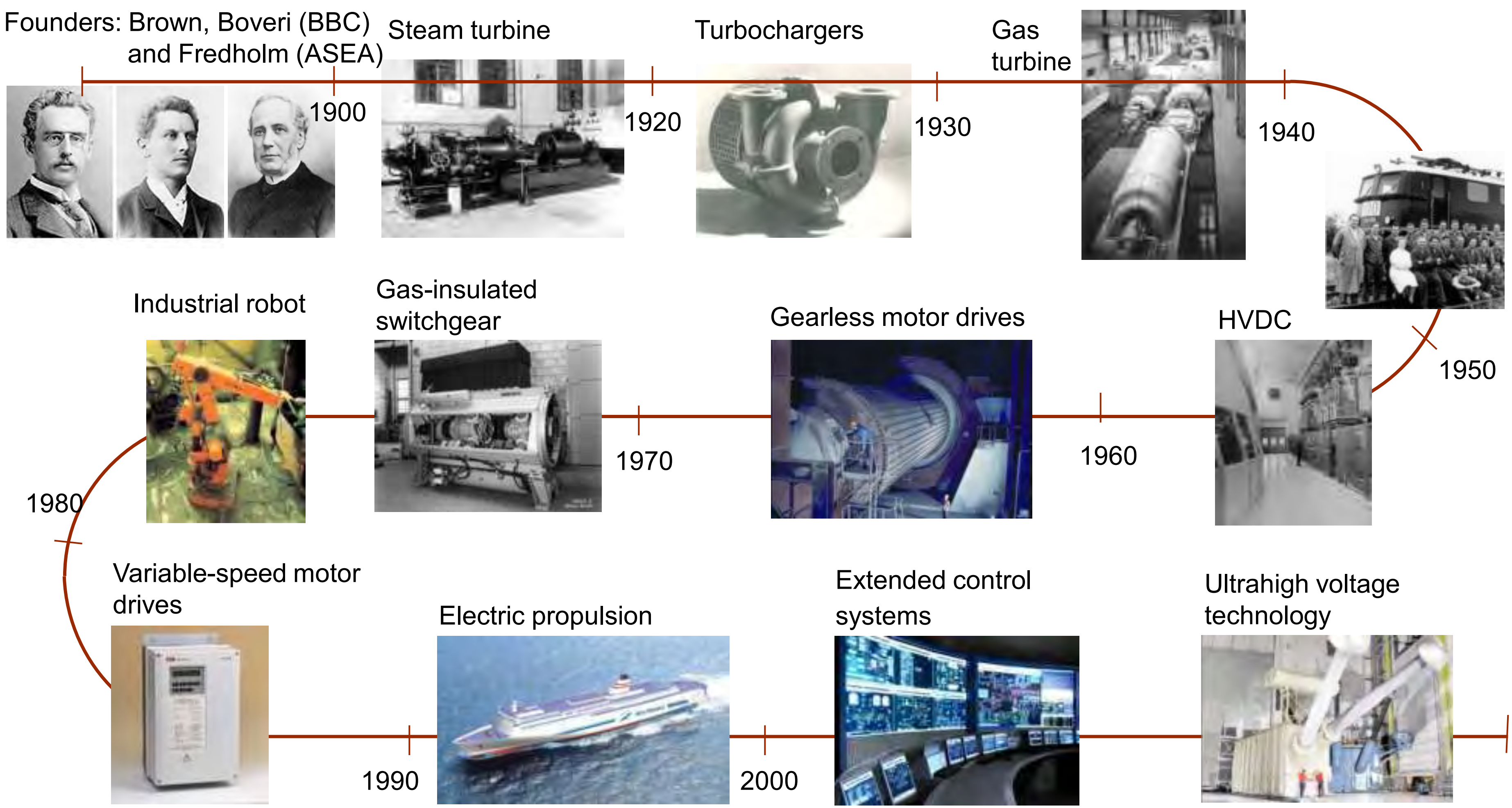
Oliver Fritz, Marlene Ljuslinder and Bernhard Doser

Heat Transfer in High-Voltage Surge Arresters

Comsol Conference, Stuttgart, 2011

Excerpt from the Proceedings of the 2011 COMSOL Conference in Stuttgart

Heat Transfer in High-Voltage Surge Arresters
ABB Technology History



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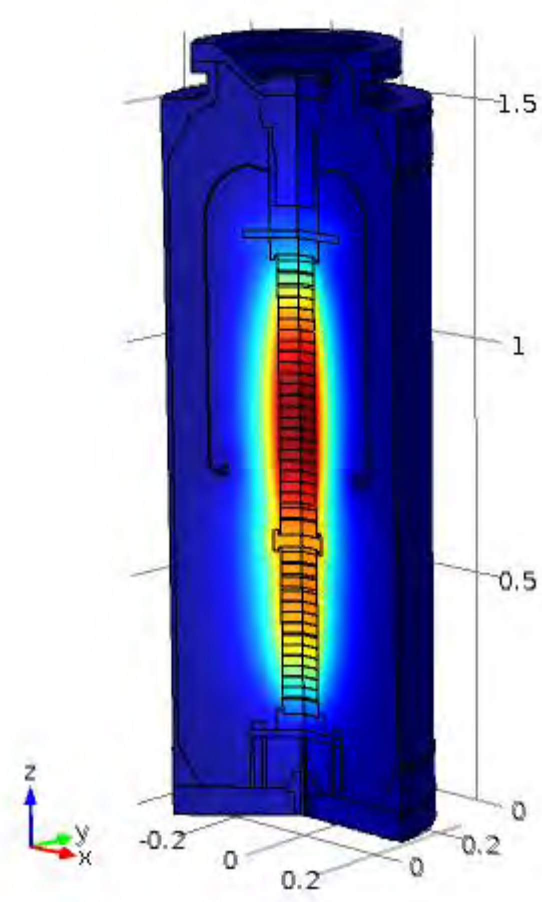
Heat Transfer in High-Voltage Surge Arresters
Introduction

- Modeling and simulation of long-term thermal transport in gas-insulated surge arresters
- Use of experimentally determined non-linear resisitivity characteristics
- Simulation setups that compare to dedicated experiments
- Convergence within reasonable time and with reasonable memory requirements
- Automation through scripts



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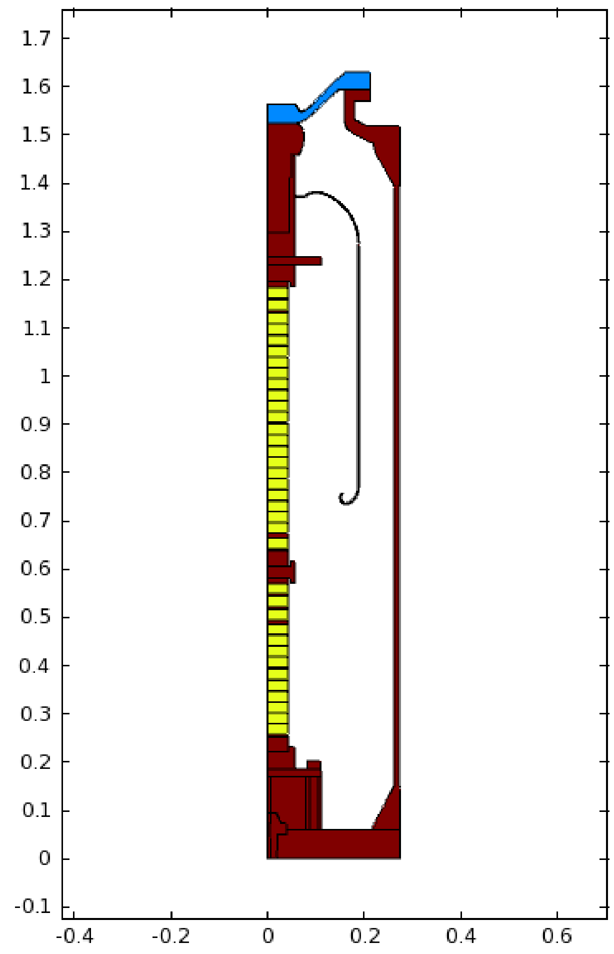
Heat Transfer in High-Voltage Surge Arresters
ABB Product Catalogue

	AZ32A	AZ32G	AZ32M	AZ14	AZ14	AZY14	AZ041
System voltage U_s	≤ 550 kV	≤ 420 kV	≤ 420 kV	≤ 300 kV	≤ 245 kV	≤ 245 kV	≤ 170 kV
Continuous voltage U_c	≤ 374 kV	≤ 317 kV	≤ 317 kV	≤ 211 kV	≤ 174 kV	≤ 174 kV	≤ 154 kV
IEC line discharge class	5	5	5	4	3/4	3/4	3/4
Phases per vessel	1	1	1	1	1	3	3

Heat Transfer in High-Voltage Surge Arresters
Used Simulation Modes

- AC harmonic
  - Applied votage at top contact
  - Ground on lower and outer aluminium casing
- Heat flow in solids
  - All solid parts
  - Convective boundary condition on outer boundary
- Convective flow in SF_6
  - p = 4.5 bar
  - Boussinesq approximation for free convection
- Cylindrical symmetry



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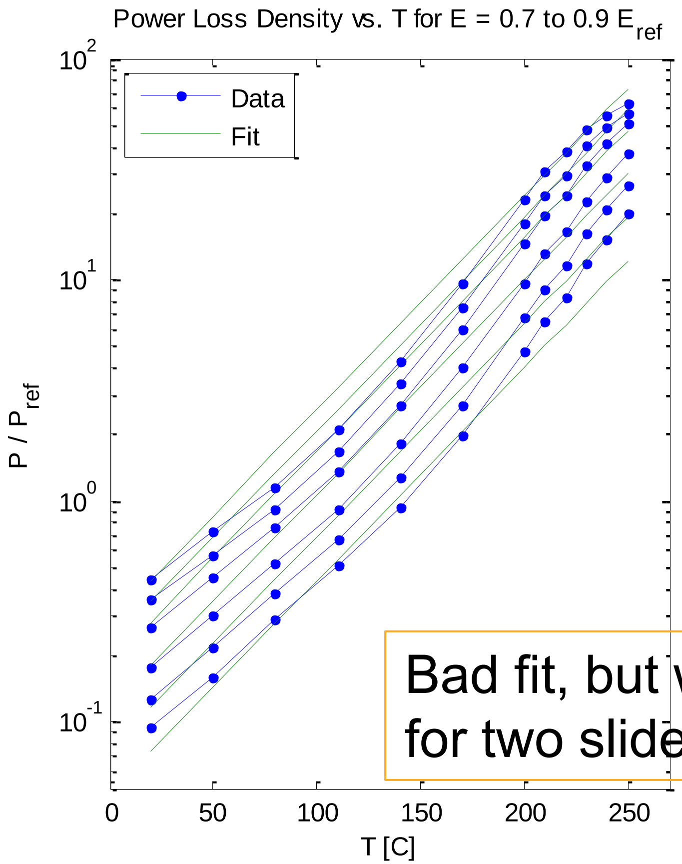
Heat Transfer in High-Voltage Surge Arresters
Power Loss Data



Bad fit, but wait for two slides…

$$\sigma = \sigma_0 \exp(\beta_E E) \exp(\beta_T T) f(E - E_c)$$

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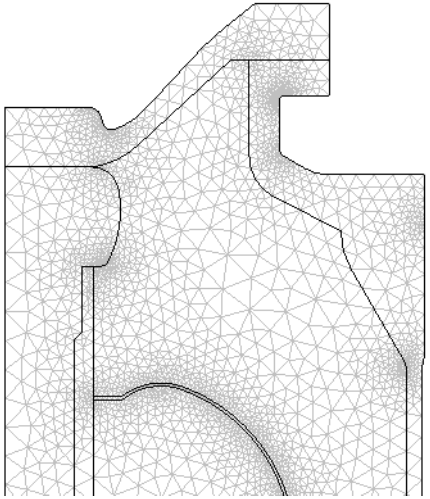
Heat Transfer in High-Voltage Surge Arresters
Modeling and Simulation Strategy (I)

- Imported geometry from 2d CAD drawings
- Small corrections and removal of sharp features
- Automatic meshing with very little manual intervention
- Usually runs on Linux workstations over night
- Started with Comsol 3.5, now at 4.2 with some intermediate refacturing



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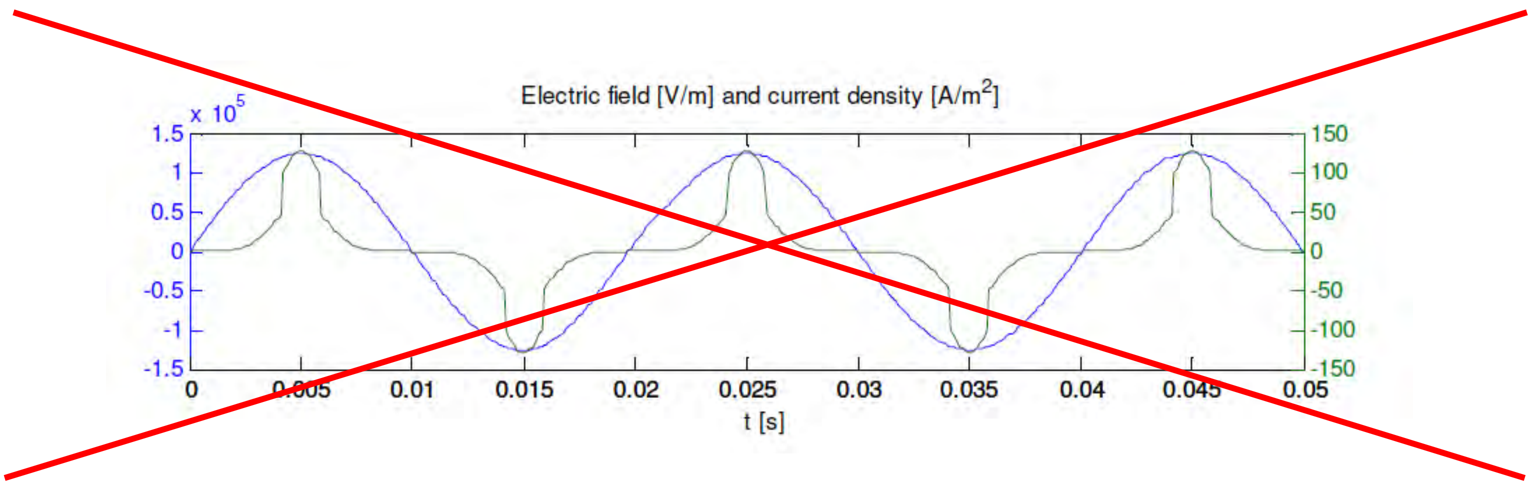
Heat Transfer in High-Voltage Surge Arresters
Modeling and Simulation Strategy (II)

- Fit artificial conductivity that produces identical power loss in AC-harmonic (quasi-static) simulations
- Write function as function sigma(E, T) in material properties
- Understand that this is not the „real“ conductivity, we are NOT doing this:



Heat Transfer in High-Voltage Surge Arresters
Modeling and Simulation Strategy (III)

- Experiments:
  - Constant power input for several hours at 100, 500 and 1‘000 W
  - Measurements of temperature at various points in and outside the arrester
- Simulations:
  - Iterate AC harmonic simulation until total power is correct
  - Calulate heat flow and convection for 10 minutes
  - Re-calculate AC harmonic

```
function U = UofP(model, P, U)

Pi = PofU(model, U);
while abs(Pi-P) > 0.01*P
    dU = 0.01*U;
    dPdU = (PofU(model, U+dU)-Pi)/dU;
    U = U - (Pi-P)/dPdU;
    Pi = PofU(model, U);
end;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function P = PofU(model, U)

model.param.set('U_top', [num2str(U), '[V]']);
model.physics('jh').feature('pot1').set('V0', 'U_top');
model.sol('sol1').runAll;

P = mphglobal(model, 'P_tot');
```

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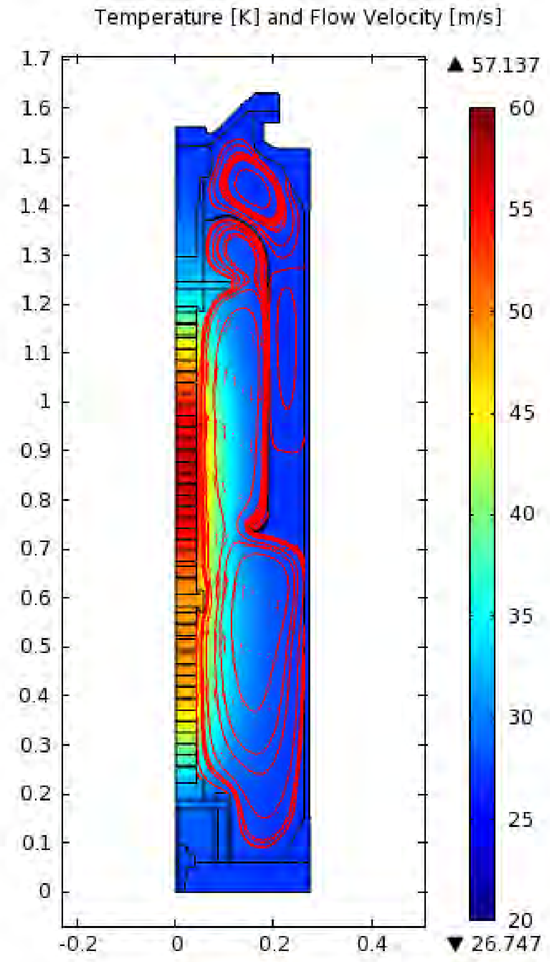
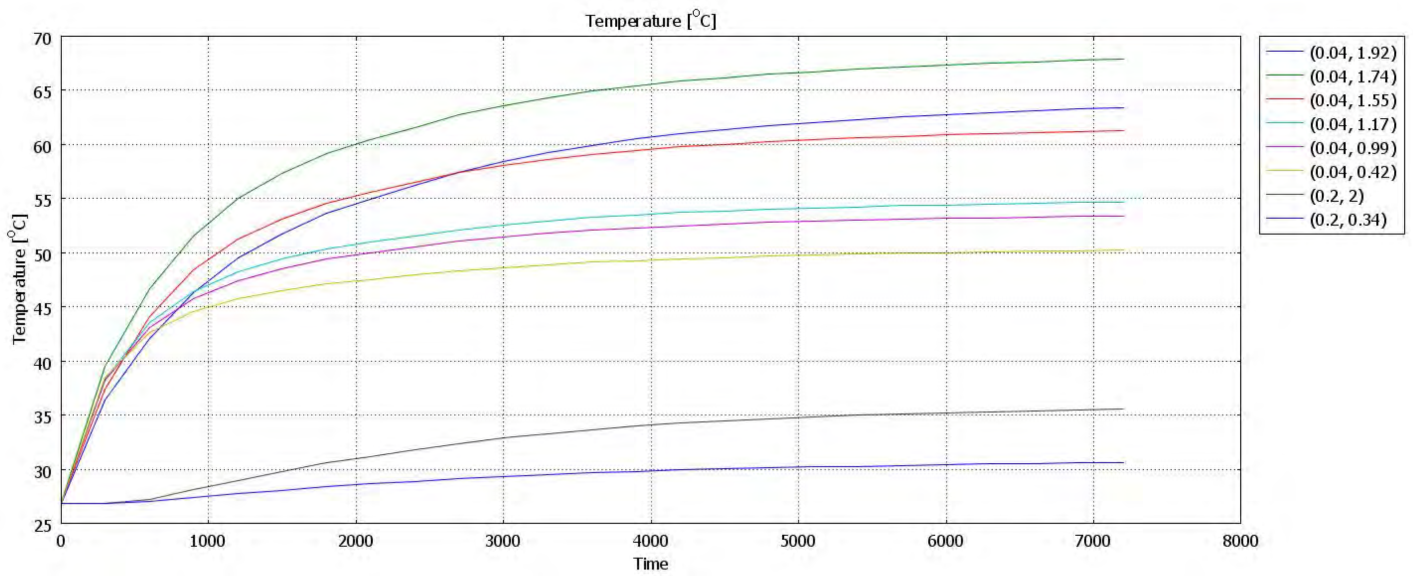
Heat Transfer in High-Voltage Surge Arresters
Results (I)

- Example after 2 hours of simulation time
- Nicely visible non-uniform temperature distribution in varistor blocks
- Expected convective flow pattern in SF_6 volume
- Very accurate reproduction of electric field distortion patterns for various temperatures
- Reproduction of dedicated experiments quite ok



Heat Transfer in High-Voltage Surge Arresters
Results (II)



- Temperature trajectories at various points inside the arrester and on surface
- After two hours almost at steady state
- Final temperature obviously determined strongly by convective cooling on outer surface

Heat Transfer in High-Voltage Surge Arresters
Conclusions

- A rough fit is ok, as long as you know what you want to calculate and adapt your simulation strategy
- A „commodity“ mesh for CFD is fine for all used simulation modes, but probably wastes some simulation time
- The fully automatic „power-controller“ via extrusion variables or an additional algebraic equation did not really prove robust when compared to the hand-written solution

- Results are fine and allow for selected design studies
- Currently 3d neither necessary nor realistic

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