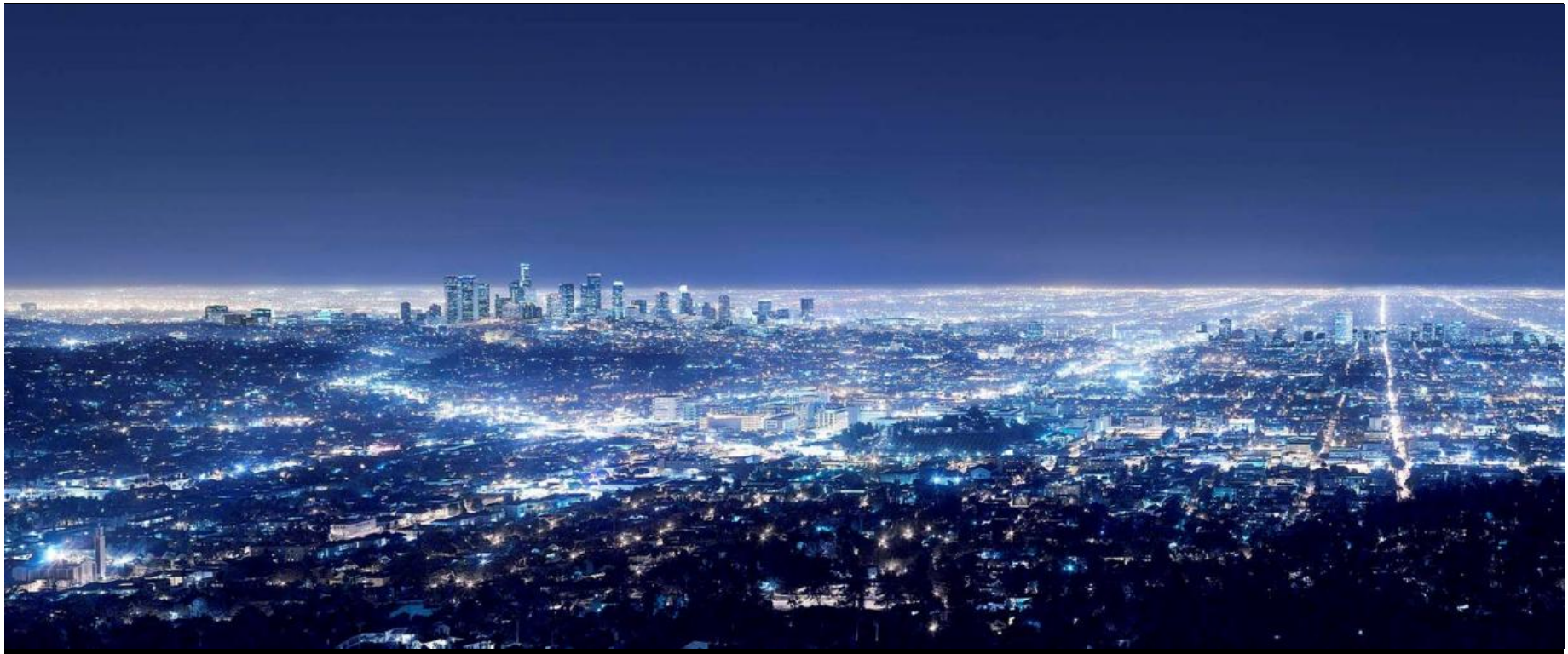


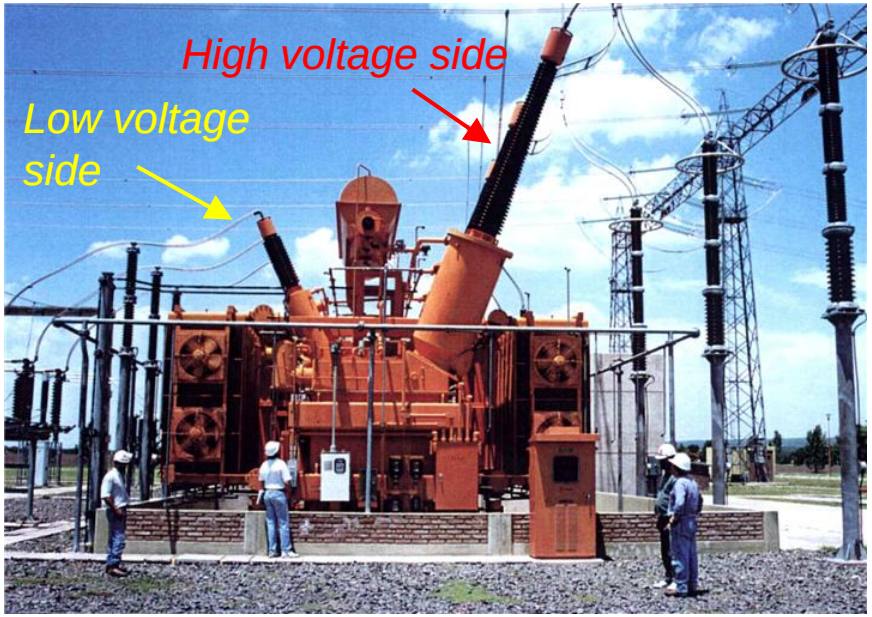
Göran Eriksson, ABB Corporate Research, Västerås, Sweden

Coupled Electric/Thermal/Fluid Analysis of High Voltage Bushing

COMSOL CONFERENCE EUROPE 2012

Excerpt from the Proceedings of the 2012 COMSOL Conference in Milan

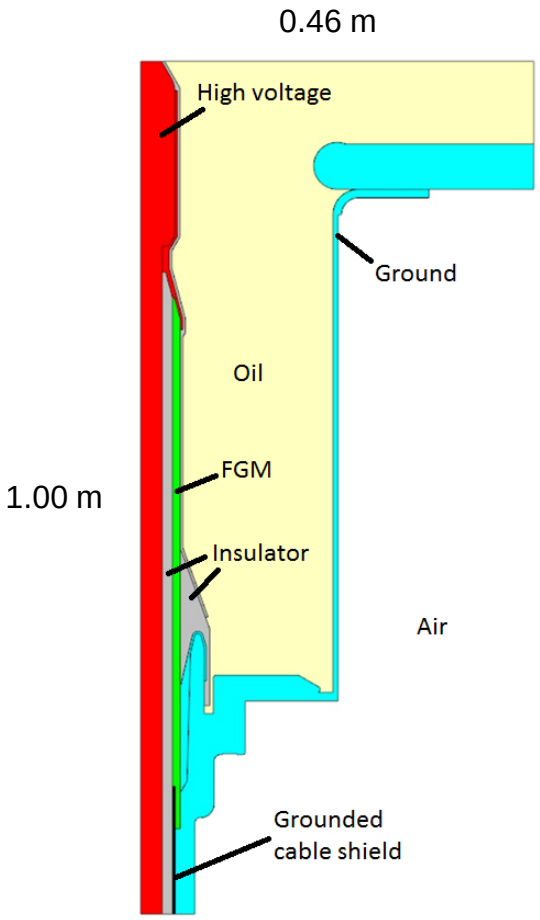
High Voltage Bushings



A large power transformer

- Modern power transmission systems operate at high voltage to reduce resistive loss due to large line currents
- On the low voltage side of a transformer the current is high
- A bushing prevents a flashover from a high voltage conductor penetrating a grounded wall
- Electric stress due to high voltage and/or thermal stress due to current-generated resistive heating must be kept under control

An Oil-Cooled DC Bushing to be Studied

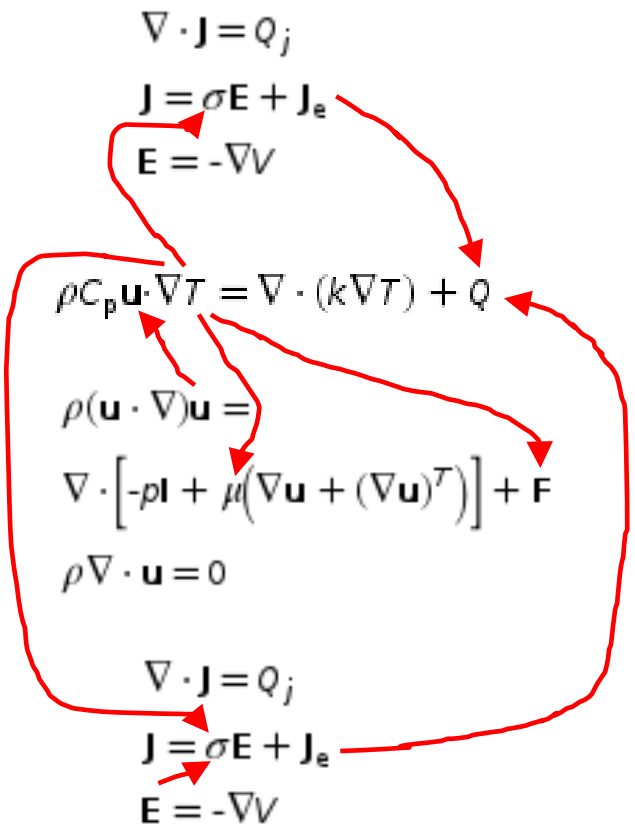


Axisymmetric model of a bushing

- Unconventional DC bushing mounted on the bottom side of an oil-filled container
- Field stress is reduced using a Field Grading Material (FGM) having a field dependent conductivity
- The oil acts both as a cooling liquid and an electrical insulator
- An optimal design is sought for that minimizes size, weight and cost while keeping electric field strength and temperature at acceptable levels

A Strongly Coupled Multiphysics Problem

1. Current distribution in the conductor is computed using the *Electric Currents* interface
2. Temperature is solved for in the *Heat Transfer* interface
3. Oil flow velocity is computed by the *Laminar Flow* interface
4. The overall electric field and leakage current distributions are found using a second *Electric Currents* interface node



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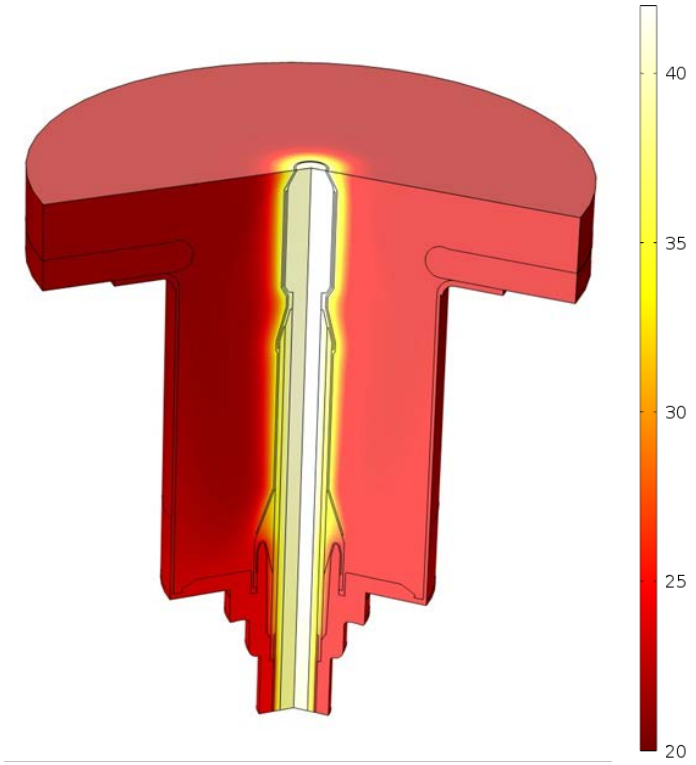
Solution

Resistive heating power density (W/m³) in the current-carrying inner conductor



3D representation of the temperature distribution

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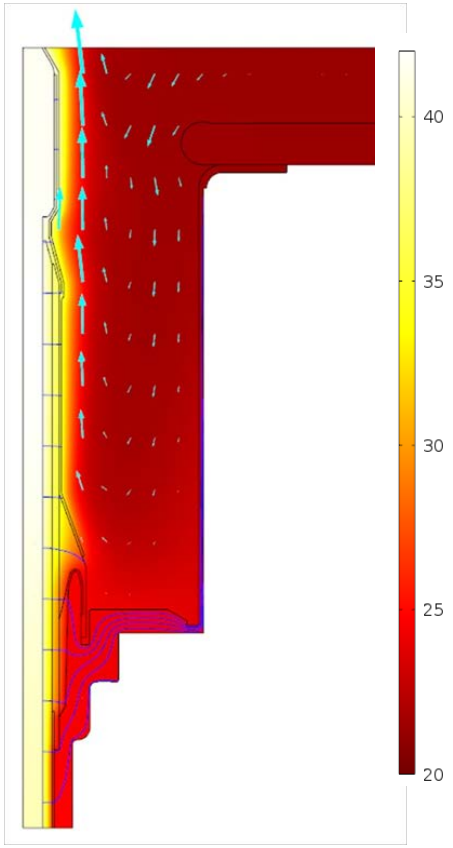
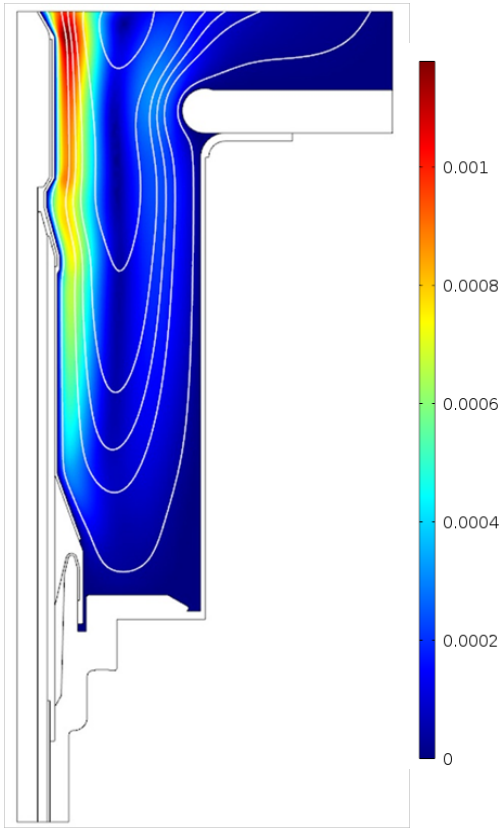
Solution



2D representation of temperature distribution. Arrows and streamlines denote heat flow

Open boundary



Oil flow streamlines and color coded velocity amplitude

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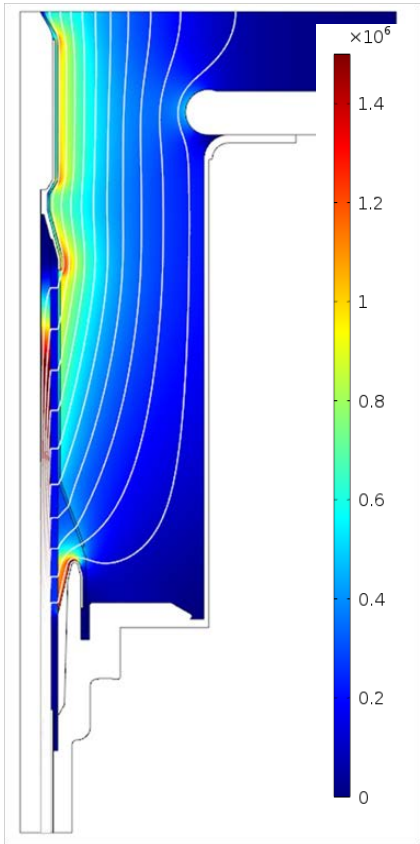
Solution

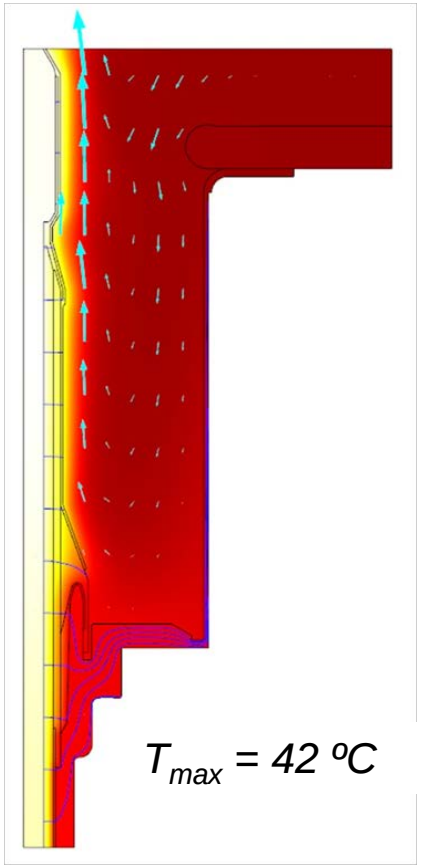


Color coded electric field strength and equipotential curves

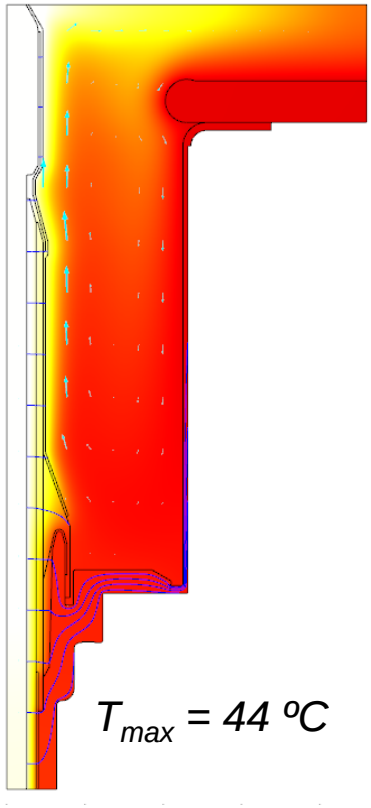
- Note the high field stress occuring in some very localized regions
- Without the use of FGM these hot spots would cause partial discharges and thermal ageing, eventually leading to electrical breakdown
- Even with FGM applied very careful geometry design optimization is needed

Temperature for Different Boundary Conditions

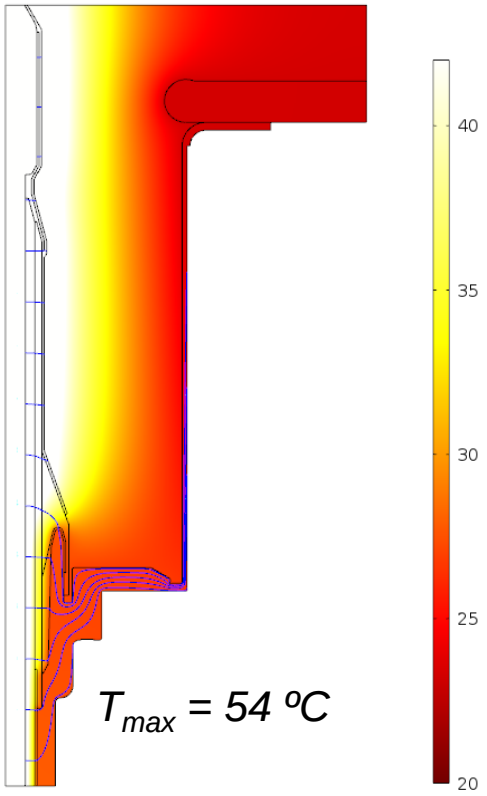
Closed boundary



Original model



No heat and oil flow across the upper boundary



Zero oil flow velocity **u**

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Conclusions

- It has become possible to simulate and predict the electric and thermal stresses in a high voltage bushing
- Transient simulations can also be carried out
- The results are consistent with measurements and test results
- Such computations have become a crucial part of the design optimization
- In a case similar to that shown here, the size of the bushing could be reduced by 30% thanks to the simulations