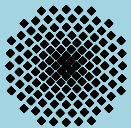


Analysis of a Three-Phase Transformer using COMSOL Multiphysics and a Virtual Reality Environment

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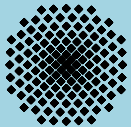
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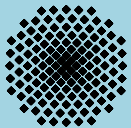
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- Introduction
- Numerical model
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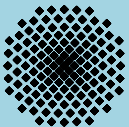
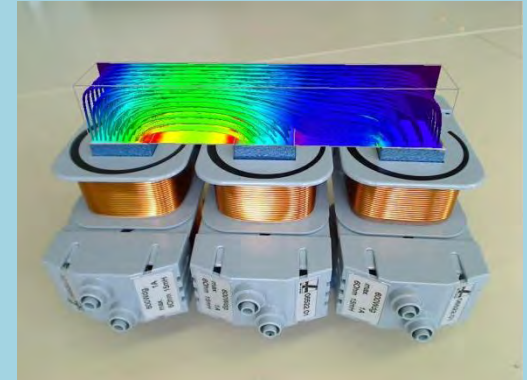
Introduction

- Three-dimensional electromagnetic field problems
- FEM analysis using COMSOL Multiphysics
- Expressive and vivid post-processing
- Collaborative visualization tool HLRS COVISE
- Interactive data exchange via LiveLink for MATLAB and COM
- Extensive analysis of results in MATLAB and COVISE
- Visualization with virtual reality technique



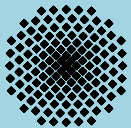
Numerical model

- Separable three-phase transformer
- Iron core with non-linear magnetic material properties
- Computation of magnetic flux density
- Time-harmonic electric currents in three coils
- Phase between two coils $\frac{2}{3}\pi$
- Iron core made of thin insulated sheets
⇒ very small eddy currents



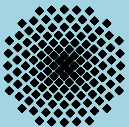
Numerical model

- AC/DC module of COMSOL Multiphysics
- Three-dimensional model
- Magnetic field formulation based on magnetic vector potential
- Stationary solver (no eddy currents)
- Parameter sweep for initial phase of the coil currents
- Parameterized geometrical model
- Constant volume current density in the coils
- Boundary condition of air domain: $\mathbf{n} \times \mathbf{A} = \mathbf{0}$



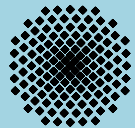
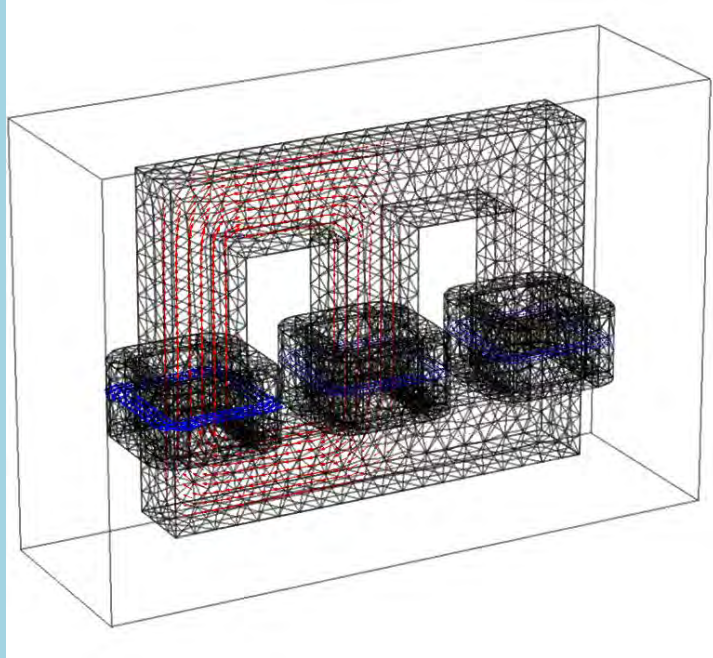
Numerical model

- Finite element mesh with 41784 tetrahedrons
- Linear system of equations with 266334 unknowns
- 33 parameter steps
- 3 or 4 non-linear iteration steps (first parameter: 7)
- Memory requirements: 1.2 GB
- Computation time: 130 minutes



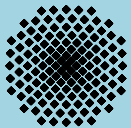
Post-processing

- Visualization of the magnetic flux density



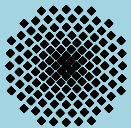
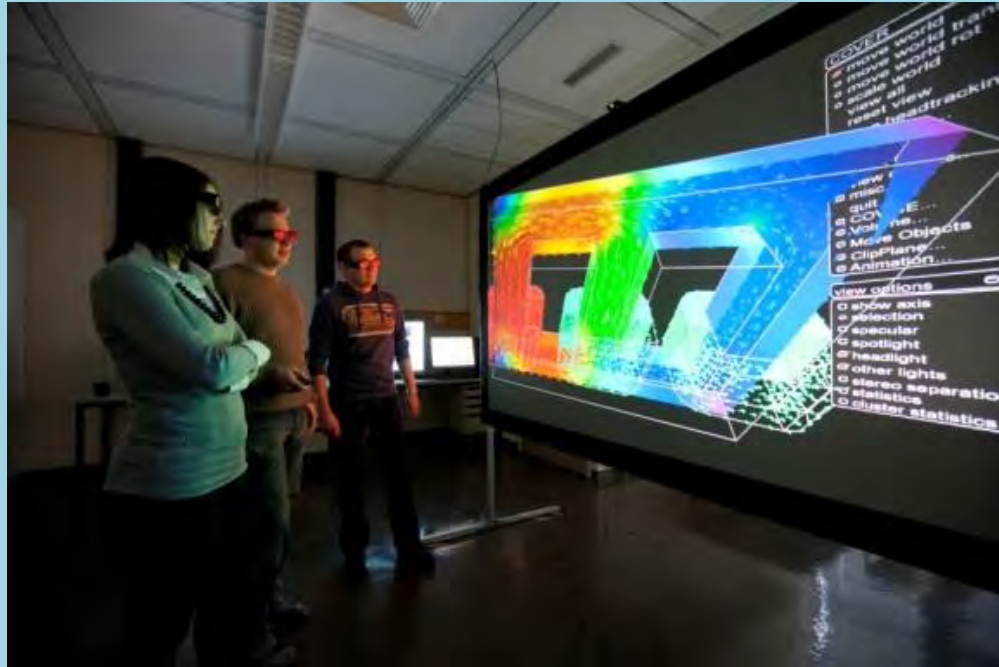
Post-processing

- Interactive coupling of HLRS COVISE and COMSOL Multiphysics via MATLAB and LiveLink for MATLAB
- All features of COMSOL Multiphysics accessible in MATLAB
- Access to MATLAB via COM interface
- Computation of post-processing data on demand
- Evaluation of data in MATLAB and COVISE
- Visualization of data and rendering in COVISE
- Three-dimensional display of rendered objects



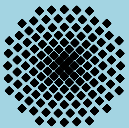
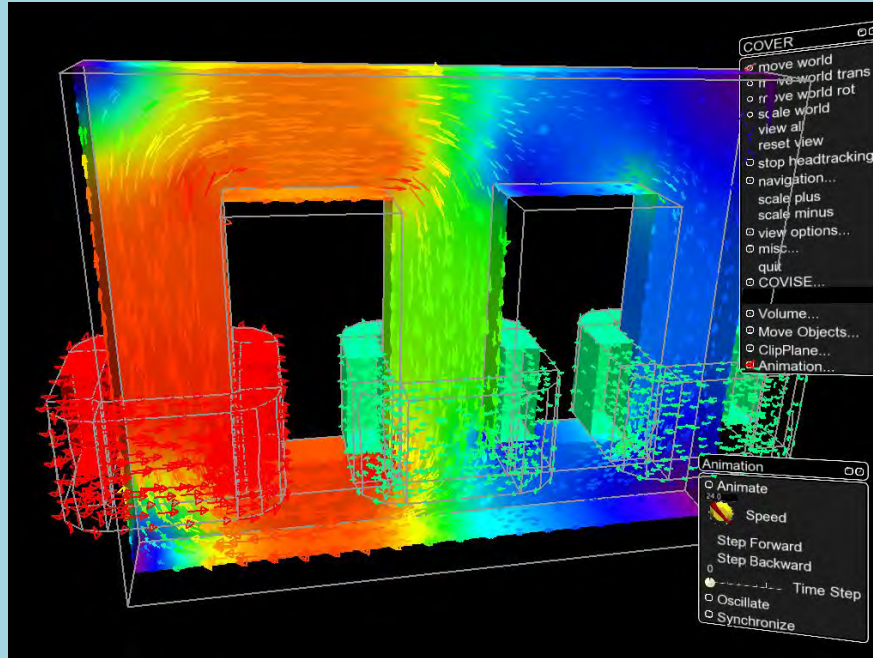
Post-processing

- Powerwall



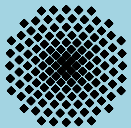
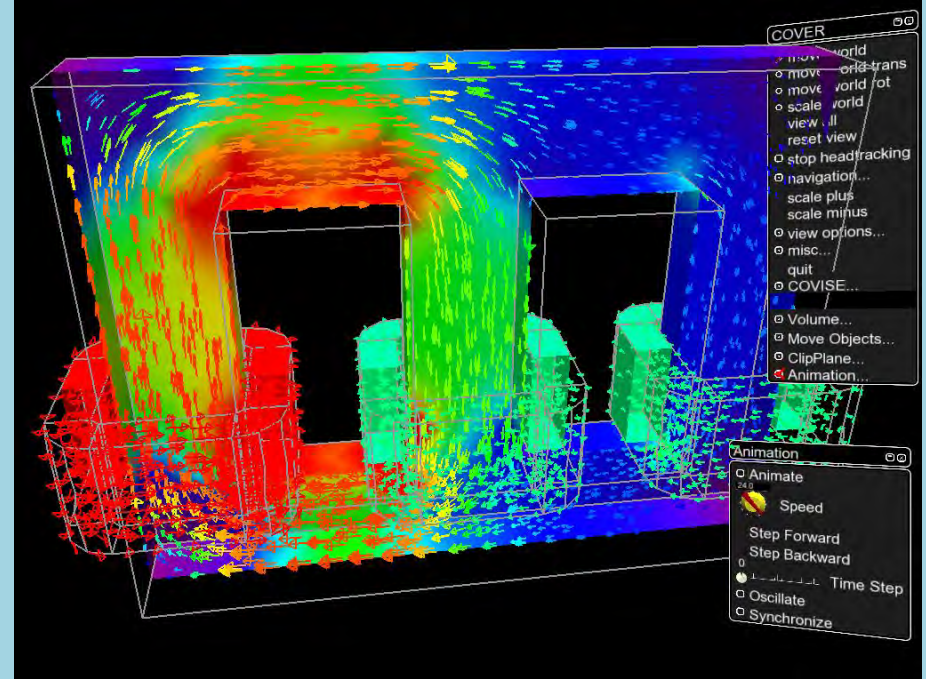
Post-processing

- Magnetic flux density inside the iron core of the transformer



Post-processing

- Magnetic flux density of nonlinear computation and difference to a linear model



Conclusions

- Efficient computation of the magnetic field of a transformer
- Post-processing in HLRS COVISE with virtual reality
- Coupling of COVISE and COMSOL via MATLAB
- Powerful API of COMSOL in MATLAB
- Suitability of COMSOL for scientific applications, research projects, and teaching at universities

