Computation of quasi-static electromagnetic fields with respect to coupled problems

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Abstract— Static electromagnetic fields can be described by partial differential equations of the Poisson type, and in the slow time-varying case, the quasi-static field problem, by the diffusion equation. The most standard and common approach to solve such problems is the finite element method (FEM). Various physical effects such as ferromagnetic saturation and hysteresis, eddy currents and motional effects can be considered in the single problem type. In reality field effects are coupled. Various mechanisms of couplings are possible to describe the overall problem. Roughly but in general it can be distinguished between four different coupling mechanisms to solve a problem:

- geometrically
- physically
- solution method
- coupled in time

Applying this classification, different approaches and strategies to solve the overall problem are possible. The particular problem class, coupled field types, recommend a different solution strategy such as the coupling of different numerical models, FEM coupled with equivalent thermal circuits, weak/full numerical coupling on matrix level and others. The coupling mechanism can be classified by the boundary conditions, the coupling interface equations, the properties of circuit parameters and/or the source terms.

Looking to the basic equations, typical engineering problems considering coupled fields will be discussed. As examples, the warming up of three phase high voltage energy cables and the thermal/magnetically coupled problem of an induction machine will be studied. In the first problem type three individual 2D problems have to be defined, electro-static, magneto-static, static thermal. Every problem is computed on its own FEM discretisation and coupled with the other field solutions by projection methods, to obtain the static overall solution of the temperature distribution. In the second example, a FEM model is coupled with an equivalent thermal circuit model. Of course, in this example the electrical circuit equations are coupled with the FEM model as well.

References

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