Assessing COMSOL Performances on Typical Problems Faced By Turbo-Generator Manufacturers

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Abstract

Multiphysics processes are typically manifesting in the ends of turbo-generators due to the leakage electromagnetic field of stator end windings. Such processes are a compilation of a variety of coupled phenomena with different electromagnetic, thermal, fluid flow and mechanical backgrounds. Electric currents circulation through the metallic frames used for stator core clamping and support, insulation coordination for the stator end winding, or electromagnetic forces acting on the stator end winding involute, are just a few relevant topics of interest for turbo-generator manufacturers. The complexity of 3D geometry describing the frontal end of a generator, mixed with strong electrical and magnetic nonlinearities of materials used, and presence of interfaces delimiting zones with strong contrasts in electromagnetic properties, exposes the finite element modeling effort to challenging numerical analysis tasks. Smart interface and impedance boundary layers for catching skin effect and electric charge build-up on single or double layer electrical surfaces, are mandatory for successfully solving such problems. The presence of such strong electromagnetic contrasts, leads to matrices with a bad condition number. As a consequence, traditional iterative solvers would encounter difficulties in converging in a desired time frame, and therefore shifting towards high performance direct solvers such as MUMPS, would become mandatory. Three different benchmarks were considered to validate numerical results against published experimental and numerical data, available in the technical literature. Several commercial finite element software including COMSOL, were evaluated while choosing these test problems. 1st benchmark is an insulation coordination problem for stator end winding in turbo-generators. For any stator bar leaving the core, a thin semiconductor film is applied on the main insulation. The strongly electrically nonlinear semiconductor tape redistributes conductive and displacement type currents at the bar end, while grading out the electric potential along the surface. Such current redistribution would lead to an electric field reduction along the bar end, while protecting the bar surface against electric discharges. Computed electric potentials were in the expected range while their patterns matched the experimental ones. 2nd benchmark is known as TEAM 7 problem. Induced eddy currents are estimated in a thick aluminum plate with an off-centered hole, asymmetrically positioned in a non-uniform magnetic field produced by an AC current through a race-tracked coil. Both streamlines of magnetic induction and current density computed using COMSOL is shown. An excellent match between numerical COMSOL solution and experimental data reported in [1] was obtained. 3rd benchmark is known as TEAM 21 problem. Two oppositely wound, race-tracked

coils are producing a gradient magnetic field, orthogonal towards a copper screen shielding a magnetically nonlinear iron sheet. Such a scenario would correspond to laminated core end plates used for stator core clamping in turbo-generators. Copper shielding is used by the manufacturer, to screen out the plate against the leakage magnetic field due to the stator end winding. A very good comparison of computed power losses using COMSOL against experimental data reported in [2] was obtained. Such preliminary numerical results indicate that COMSOL is able of handling typical problems, which are daily business for turbo-generator R&D.

Reference

[1] K. Fujiwara, T. Nakata, Results for Benchmark Problem 7 (Asymmetrical Conductor with a Hole), International Journal for Computation and Mathematics in Electrical and Electronic Engineering, Vol. 9, No. 3, pp.137 - 154, 1993.

[2] Z. Cheng et al., Loss Spectrum and Electromagnetic Behavior of Problem 21 Family, IEEE Transactions On Magnetics, Vol. 42, No. 4, pp. 1467 - 1470, 2006.