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Fast Computation of Nonlinear 3D FE Analysis for Electrical Machines

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Nowadays, 3D FE simulation on electrical machines is essential, but it requires huge computational resources. Alternate solutions consist in using analytical models such as permeance network method. However, they should be validated with 3D FE models. In this paper, an approach to reduce CPU time is presented. It is based on a convenient choice of the mesh topology and the convergence criterion for a nonlinear resolution.

To illustrate this approach, a claw pole synchronous machine (CPSM), shown in figure (1), is a good candidate for 3D simulation. Various commercial 3D FE softwares are available, but in many cases the geometry is derived from a CAD import. The use of a free FE software such as the mesh tool Gmsh (C. Geuzaine and J.-F. Remacle, "Gmsh: a three-dimensional finite element mesh generator with built-in pre- and post-processing facilities", in Int. J. Numer. Meth. Engng, vol 79, pp. 1309-1331, 2009), and the solver GetDP (P. Dular et al, "A general environment for the treatment of discrete problems and its application to the finite element method", in IEEE Trans. Magn., vol 54, pp 3395-3398, 1998) is an alternative solution to avoid CAD and to test different mesh topologies and convergence criterion.

A magnetic vector potential ($\mathbf{a} - v$) formulation is adopted as it is well adapted to take into account end-windings, even if the number of DOF is high. Different combinations of standard mesh elements (tetrahedron - hexahedron) can be tested in different domains of the machine (stator, air-gap, rotor). Different convergence criteria related to physical local and global quantities (co-energy, flux, torque, reluctivity, ...) can also be chosen to stop the iterative resolution. The figure (2) shows the CPU time for a set of adopted mesh topologies and convergence criteria. It can be seen that the CPU time can be very different depending on the mesh topologies and convergence criteria. Generally, the convergence criteria corresponding to global quantities (energy, coenergy, ...) are more suitable for a reduced time.

For the considered machine, the case of hexahedron mesh in the stator and in the rotor, and tetrahedron in the air-gap (Config #2) with a convergence criterion on the stator flux seems to be the best configuration. The CPU time is divided by 12, compared to a standard solution (only tetrahedrons and convergence criterion based on the residual of the system).

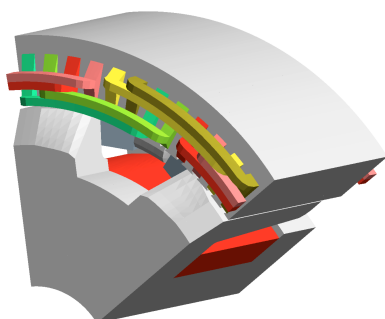


Figure 1: CPSM modelling

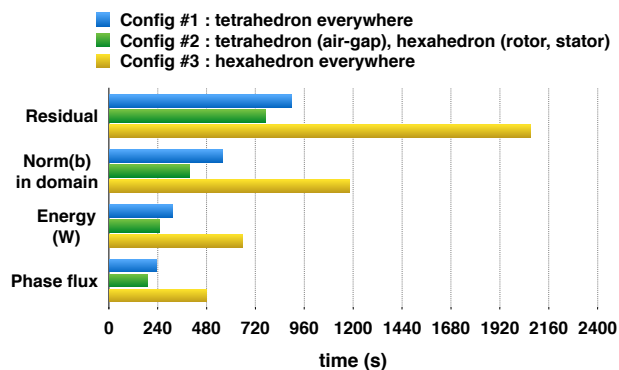


Figure 2: Time according to the convergence criterion