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3D Finite-element Simulation of Controlled-source EM problems Using Edge and Nodal Interpolation functions

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We deal with the 3D finite-element (FE) solution of the controlled-source electromagnetic (CSEM) problem in a conducting medium. In comparison to the finite-difference and integral equation methods, the finite-element method has been considered more complex to implement. But, in order to properly take advantage of unstructured grids, we used the FE method. The advantage of 3D unstructured meshes composed of tetrahedral elements is that complex geometric structures can be modelled. To separate the galvanic and inductive natures of the EM fields, an A-ϕ decomposition of the electric field is used where A and ϕ are the magnetic vector potential and electric scalar potential respectively. By doing this, a second order partial differential equation (PDE) is obtained consisting of the potential terms and a source term. Upon taking the divergence of the PDE and assuming the *Coulomb gauge condition* a second equation is established. For the source term, an electric line source of current, which can be grounded or form a closed loop, is used. An unstructured tetrahedral grid is used to discretize the domain. The finite-element approximation of the system of equations is done using edge element basis functions for the vector potential and nodal element basis functions for the scalar potential. The Galerkin method is used in which the system of equations is obtained by weighting the residual of the differential equations. All volume and surface integral terms having to do with the interactions of edge and nodal elements are computed numerically. The system of linear equations, consisting of a sparse coefficient matrix, source vector and the unknown solution vector including the real and imaginary parts of the potentials, is formed. Dirichlet boundary conditions for the potentials are applied by setting the vector and scalar weighting functions associated with the edges and nodes on the truncation boundary of the mesh to zero. Iterative solvers from $SPARSKIT$, such as BCG (bi-conjugate gradient) and $BCGSTAB$ (bi-conjugate gradient stabilized) with an incomplete LU preconditioner, are used to solve the system of equations. The performance of the above approach will be compared with a modification in which the *Lorentz gauge condition* is used. Also, the relative contributions to the electric field from the inductive and galvanic terms will be investigated in different situations.