MODELING OF ELECTROMAGNETIC FIELD IN 3D GEOLOGIC ENVIRONMENT OF MARINE OIL ANG GAS FIELD

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Dependence of electric conductivity on depth expressed in terms of function $\sigma(z)$ is a characteristic feature of sea water. This paper examines computational methods based on vector finite element method for the frequency domain electric field with functional realizations of dependence of sea water electric conductivity on depth. Numerical experiments on different frequencies for 3D geologic environment of marine oil and gas field were made.

The behavior of a time-harmonic electromagnetic field is described by the system of the Maxwell equations. Let the field $\vec{\mathbf{E}}$ depends on time $\vec{\mathbf{E}}(x,t) = \vec{\mathbf{E}}(x)e^{i\omega t}$, where i is the imaginary unit ($i^2 = -1$), $\omega = 2\pi f$, f is the frequency.

Reduce the system of the Maxwell equations to a second order equation in the complex-valued vector field $\vec{\mathbf{E}}$ and obtain Helmholtz equation:

$$rot(\mu^{-1} rot\vec{\mathbf{E}}) + k^2\vec{\mathbf{E}} = -i\omega\vec{\mathbf{J}}^{real},$$

where $\vec{\mathbf{E}} = \vec{\mathbf{E}}^{real} + i\vec{\mathbf{E}}^{im}$, $k^2 = i\omega\sigma(z) - \omega^2\epsilon$ is the wave number, $\sigma(z)$ is electroconductivity, μ is magnetic permeability, ϵ is the dielectric permittivity.

If the dependence $\sigma(z)$ takes place, conservation law seems like:

$$\frac{\partial\sigma(z)}{\partial z}\vec{\mathbf{E}}_z + \sigma(z)\left(\frac{\partial\vec{\mathbf{E}}_x}{\partial x} + \frac{\partial\vec{\mathbf{E}}_y}{\partial y} + \frac{\partial\vec{\mathbf{E}}_z}{\partial z}\right) + i\omega\epsilon\left(\frac{\partial\vec{\mathbf{E}}_x}{\partial x} + \frac{\partial\vec{\mathbf{E}}_y}{\partial y} + \frac{\partial\vec{\mathbf{E}}_z}{\partial z}\right) = 0$$

Relative to the real components $\vec{\mathbf{E}}^{real}, \vec{\mathbf{E}}^{im}$, arrive at the following linear system:

$$\begin{pmatrix} \mu^{-1} rotrotI - \epsilon\omega^2 I & -\sigma(z)\omega I \\ \sigma(z)\omega I & \mu^{-1} rotrotI - \epsilon\omega^2 I \end{pmatrix} \begin{pmatrix} \vec{\mathbf{E}}^{real} \\ \vec{\mathbf{E}}^{im} \end{pmatrix} = \begin{pmatrix} 0 \\ -\omega\vec{\mathbf{J}}^{real} \end{pmatrix} \qquad (1)$$

Introduce the following spaces $H(rot,\Omega) = \left\{\vec{u} \mid \vec{u} \in (L^2(\Omega))^3, rot\vec{u} \in (L^2(\Omega))^3\right\}$, $H^0(rot,\Omega) = \{\vec{u} \mid \vec{u} \in H(rot,\Omega), \vec{u} \times \vec{n} = 0\}$. Scalar multiply (1) by basis function V from the same space. With the help of a Green formula, obtain discontinuous matrix-vector system of equations with non-symmetrical matrix.

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