Time domain simulation of geomagnetically induced current (GIC) flowing in 500 kV power grid in Japan including a three-dimensional ground inhomogeneity

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We performed time domain simulation of geomagnetically induced currents (GICs) flowing in the Japanese 500 kV power grid. The three-dimensional distribution of the geomagnetically induced electric field (GIE) was calculated by using the finite-difference time-domain (FDTD) method with a three-dimensional electrical conductivity model constructed from a global relief model and a global map of sediment thickness. First, we imposed a uniform sheet current at 100 km altitude with a sinusoidal perturbation to illuminate the influence of the structured ground conductivity. The simulation result shows that GIE exhibits localized, uneven distribution that can be attributed to charge accumulation due to the inhomogeneity below the Earth's surface. The charge accumulation becomes large when the conductivity gradient vector is parallel, or anti-parallel to the incident electric field. For given GIE, we calculated the GICs flowing in a simplified 500 kV power grid network in Japan. The influence of the structured ground conductance on GIC appears to depend on a combination of the location of substations and the direction of the source current. Uneven distribution of the power grid system gives rise to intensification of the GICs flowing in remote areas where substations/power plants are distributed sparsely. Secondly, we imposed the equivalent sheet current inferred from the ground magnetic disturbance for the magnetic storm of 27 May 2017 as a source current of the FDTD simulation. The calculated GIC agrees well with the observations at substations around Tokyo when the uneven distribution of GIE is incorporated with the simulation.

