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 evaluate geomagnetically induced currents (GICs) flowing in the Japanese power grid during severe space weather by using several methods. First, the three-dimensional distribution of the geomagnetically induced electric field (GIE) was calculated by using the 3D 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. To simulate a time evolution of magnetic storms, the sheet current with its intensity inferred from the ground magnetic disturbance for famous magnetic storms is imposed. We compared the calculated GICs with the observed ones at substations around Tokyo, and found a certain agreement when the uneven distribution of GIE is incorporated with the simulation. The simulation result shows that GIE exhibits localized, uneven distribution that can be attributed to charge accumulation due to the inhomogeneous conductivity 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 inhomogeneous ground conductivity on GIC appears to depend on a combination of the location of substations and the direction of the source current. Second, we assume conductivity anomaly simulating a plate boundary to test the effect of large-scale underground structure on GICs. We find that these structures may strongly enhance GIC just above them. Finally, we derive transfer functions between the GIC observation at 4 substations in Japan and geomagnetic field recorded at the Kakioka station. The transfer functions are not always applicable for Japanese GIC. We will discuss the validity of the assumption of uniform ground and influence of the time variation of earthing resistance of substations.

