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Poster
During geomagnetic disturbances, quasi-direct (DC) currents are induced along electric power transmission lines and flow from the bulk power grid into the ground through transformer windings. This can result in operational difficulties as the transformers enter an abnormal condition called half-cycle saturation, which increases reactive power demand on the grid, generates abnormal harmonics in the current and voltage waveforms, and can cause heating in and around the transformers. Assessing the impact of a geomagnetic storm on the operations of an electric power grid requires knowledge of the geoelectric field at the Earth's surface, a phenomenon that in turn is caused by the interaction of the time varying geomagnetic field and the conductivity properties of the solid Earth in the footprint of the power grid.

One approach for estimating the geoelectric field at the surface has been to combine information from ground-based magnetic observatories with magnetotelluric (MT) impedance tensors as derived from MT surveys, to generate a near-real-time estimate of the ground-level geoelectric field over contiguous United States (CONUS), as has been done in the joint NOAA-USGS Geoelectric Field Maps 3D empirical operational data product [https://www.swpc.noaa.gov/products/geoelectric-field-models-1-minute]. The local magnetic field time series between the magnetic observatories is estimated using the method of spherical elementary currents (SECS) [Rigler et al., 2019 and references therein]. The MT impedances are time-stationary, frequency-domain transfer functions that relate the time variations in Earth's geoelectric field to time variations in Earth's geomagnetic field. These data reflect the local and regional electrical conductivity of the Earth and allow for accurate estimation of ground-level geoelectric field. Since 2006, continuous MT surveying of CONUS was supported through the National Science Foundation's (NSF's) USArray and the NASA, then US Geological Survey's (USGS) USMTArray projects. These efforts have provided a quasi-regular 70km grid of long-period (10-10,000 sec) MT impedance observations covering most of CONUS.

The empirical tensors are also used by the MT community to obtain three-dimensional (3D) electrical conductivity models of various regions in CONUS. We collected these regional models in a coherent 3D electrical conductivity compilation for the entire CONUS, covering depths up to 250 km [Kelbert et al, 2019; Murphy et al, 2023]. We then developed a spherical-coordinate variant of ModEM 3D [Kelbert et al., 2014], a parallelized Fortran MT modeling and inversion code and employed that for high-resolution continental-scale forward modeling of MT impedances to create a gridded national impedance map, as detailed in the USGS Geomagnetism Program Research Plan [Love et al., 2020]. We compute and analyze the gridded MT impedances modeled at 0.1-degree resolution, and predicted at the Earth's surface at a range of frequencies for our composite CONUS 3D electrical conductivity model.

In this work, we compare ground measurements with simulated geomagnetic fields produced by the SECS model, simulated electric fields generated using 3D empirical MT impedances, and simulated electric fields generated using MT impedances derived from a high-resolution 3D earth conductivity model inverted from empirical MT impedances. We select geomagnetically disturbed time periods and compare the model outputs with electric field and magnetic field measurements that were obtained from surveys carried out during those disturbances.

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