Predicting Reactive Power Loss in Power Grid High-Voltage Transformers due to Geomagnetic Disturbances: Fusion of Geophysical Observations, CLFA Algorithm and Power Flow Solutions using PSS/e

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The Cascading Linear Filter Algorithm (CLFA; Bonner & Schultz, 2017) projects distant ground level magnetic fields through multistation transfer functions to predict magnetic fields at sites where magnetotelluric (MT) impedance tensors are known, and then projects the predicted magnetic fields through the impedances to determine the ground electric fields due to 3-D electrical resistivity structure. The CLFA method has been demonstrated to provide substantial improvements to predictions of ground level electric fields due to geomagnetic disturbances (GMDs) than earlier methods based on simpler magnetic field models and 1-D ground resistivity structure. Here we apply the CLFA method to the problem of determining the anomalous voltages due to GMDs at high-voltage transmission system power buses by integrating the ground electric fields predicted by CLFA along the path of the transmission lines, and then by using power flow solutions such as PSS/e, we show how distant observations of ground level geomagnetic disturbances may be used to predict the reactive power loss at high-voltage transmission system transformers. Our goal is to work toward a real-time solution, streaming data from USGS and other magnetic observatories, applying the multiple linear filters that constitute the CLFA approach, and then feeding the spatially integrated bus voltages into the power flow model of the transmission network. We have implemented an approach written in Python, and have used the PSS/e Python API for the power flow component. We show examples using the EarthScope MT data set obtained by Oregon State University, comprising over 1000 MT stations currently spanning nearly 2/3rd of the area of the continental US, and by applying data from US and Canadian magnetic observatories, we apply the method to power flow models with thousands of buses. Ultimately, we are working to fuse this geophysical/power engineering approach with data streaming from neutral ground return current and synchrophasor sensors on the power grid, as well as with satellite data of the space weather environment, to provide an advance warning capability to power utilities, providing a probabilistic assessment of risk to specific transformers on the network through a heat map display of components most likely to experience stress due to the predicted GMD.

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