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Turning Noise into Signal: Utilizing Impressed Pipeline Currents for EM Exploration

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Impressed Current Cathodic Protection (ICCP) systems are extensively used for the protection of central Europe's dense network of oil-, gas- and water pipelines against destruction by electrochemical corrosion. While ICCP systems usually provide protection by injecting a DC current into the pipeline, mandatory pipeline integrity surveys demand a periodical switching of the current. Consequently, the resulting time varying pipe currents induce secondary electric- and magnetic fields in the surrounding earth. While these fields are usually considered to be unwanted cultural noise in electromagnetic exploration, this work aims at utilizing the fields generated by the ICCP system for determining the electrical resistivity of the subsurface. The fundamental period of the switching cycles typically amounts to 15 seconds in Germany and thereby roughly corresponds to periods used in controlled source EM applications (CSEM).
For detailed studies we chose an approximately 30km long pipeline segment near Herford, Germany as a test site. The segment is located close to the southern margin of the Lower Saxony Basin (LSB) and part of a larger gas pipeline composed of multiple segments. The current injected into the pipeline segment originates in a rectified 50Hz AC signal which is periodically switched on and off. In contrast to the usual dipole sources used in CSEM surveys, the current distribution along the pipeline is unknown and expected to be non-uniform due to coating defects that cause current to leak into the surrounding soil. However, an accurate current distribution is needed to model the fields generated by the pipeline source. We measured the magnetic fields at several locations above the pipeline and used Biot-Savarts-Law to estimate the currents decay function. The resulting frequency dependent current distribution shows a current decay away from the injection point as well as a frequency dependent phase shift which is increasing with distance from the injection point.
Electric field data were recorded at 45 stations located in an area of about 60 square kilometers in the vicinity to the pipeline. Additionally, the injected source current was recorded directly at the injection point. Transfer functions between the local electric fields and the injected source current are estimated for frequencies ranging from 0.03Hz to 15Hz using robust time series processing techniques. The resulting transfer functions are inverted for a 3D conductivity model of the subsurface using an elaborate pipeline model. We interpret the model with regards to the local geologic setting, demonstrating the methods capabilities to image the subsurface.