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Optimal placement of capacitive electrodes in a borehole for monitoring purposes in geothermal applications

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SUMMARY

Monitoring temperature changes in geothermal applications is crucial to ensure sustainable heat production and storage operations. This work focuses on a geothermal project situated on the campus of Delft University of Technology in the Netherlands. In connection to deep low-enthalpy geothermal reservoir exploration, an aquifer thermal energy storage system for the purpose of seasonal shallow heat storage is planned. To enable monitoring changes in the electrical resistivity distribution due to heat injection and extraction operations in the shallow subsurface, a new 480 m deep borehole will be equipped with an electrode setup. Measuring the vertical component of the electric field in the borehole using a frequency-domain surface-to-borehole controlled-source electromagnetic setup is particular effective for monitoring reservoir changes. Due to corrosion effects, conventional electrodes have rather limited lifespans, which may not be sufficient for the multi-decade operational plan for this geothermal application.
We use a new approach integrating capacitive electrodes in composite borehole casings. Tests in shallow boreholes have shown comparable results to standard electrodes. Integrating the capacitive sensors in the composite borehole casing is rather time- and cost-intense requiring pre-drilling installation and specially designed electronics. Therefore, we want to optimise the electrode placement along the borehole trajectory. We simulate vertical electric fields at closely spaced receivers along the borehole trajectory for different subsurface scenarios originating from resistivity changes introduced by injecting and extracting hot fluids. Applying the Ramer–Douglas–Peucker algorithm, we determine which electrode locations and combinations are optimal to record resulting variations in the vertical electric field component. The proposed methodology for optimal electrode placement is promising to improve monitoring efficiency in geothermal applications, ensuring sustainable and effective operation over extended periods.

Keywords: optimisation, capacitive electrodes, controlled-source electromagnetics, geothermal applications, vertical electric fields