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Geophysical Electrical Monitoring of Thermal Response Tests for Complementary Thermal Property Estimation

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Thermal Response Tests (TRT) are conducted to determine the equivalent thermal conductivity and, in some cases, the volumetric heat capacity of the subsurface, which are essential for designing low-temperature geothermal systems. During TRTs, heated water is circulated through a ground heat exchanger (GHE), while the temperature variations at the borehole's inlet and outlet are monitored over time (Pasquier et al., 2016). Generally, TRT interpretation yields averaged thermal properties along the entire GHE, overlooking variations in geological materials that can affect heat transfer efficiency. Acquiring detailed thermal and hydraulic property data at varying depths allows for the optimization of GHE design to enhance overall performance. Furthermore, traditional TRTs primarily rely on water temperature measurements, providing limited information into the spatial distribution of temperature changes in the surrounding geological environment.

Geophysical methods, such as electrical resistivity monitoring, can provide complementary measurements using the sensitivity of electrical resistivity to temperature changes. In this study, we investigate the use of geoelectrical monitoring during TRTs to image temperature variations in the geological environment to improve the recovery of localized thermal properties. A geoelectrical cable is placed inside the borehole during the TRT, with an electric current injected through surface and borehole electrodes. Another set of surface and borehole electrodes measures the resulting potential differences. Varying electrode spacing allows to measure apparent resistivity changes at different radial distances from the borehole. This means that electrical measurements are sensitive to temperature changes at various depths in the geological environment and could image heat transfer during the TRT. We conducted two proof-of-concept studies on standing column wells (SCW) in Varennes and Saint-Anne-des-Plaines in Québec, Canada, to test electrical monitoring during a TRT. The SCWs were subjected to heating, bleeding and recovery phases, while time-lapse electrical measurements were taken using a geoelectrical cable installed in the SCWs.

Field data shows a strong correlation between apparent electrical resistivity and temperature variations during heating and recovery cycles. Geoelectrical data is compared with infinite and cylindrical line source models to simulate temperature-induced resistivity changes around the SCW. Preliminary results indicate varying sensitivity of apparent resistivity variations to SCW water temperatures, as well as to the subsurface's thermal conductivity and heat capacity. Building on

these findings, the study aims to derive localized thermal parameters from the geoelectrical data. This approach highlights the potential of geophysical monitoring to enhance the accuracy of thermal characterization in TRTs.

Pasquier, P., Nguyen, A., Eppner, F., Marcotte, D., & Baudron, P. (2016). Standing column wells. *Advances in Ground-Source Heat Pump Systems* (pp. 269–294). Elsevier. http://dx.doi.org/10.1016/B978-0-08-100311-4.00010-8