Development of a temperature sensor module for groundwater flow detection in single borehole heat exchanger or water-well

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There are many types of groundwater flow measurements in boreholes, which differ in their underlying measurement principles. The most common methods utilize tracers, heat sources or optical methods and measure the tracer concentration, temperature distribution or particle flow velocity, respectively. All these methods consist of measurements taken in open wells where absent rock changes the natural flow field. Hence, the real groundwater flow is not directly measured, but is obtained after correction of the borehole influence. A method for detecting groundwater flow, which can also be applied when a BHE is installed in the borehole, is the enhanced geothermal response test (EGRT). Classically, thermal response tests (TRT) are used to determine the influence of the underground properties and additional groundwater effect on the effectivity of BHE. While the TRT only provides an effective thermal conductivity for the underground, the EGRT allows a depth resolved vertical distribution of the apparent thermal conductivity near the BHE. Groundwater flow causes high apparent thermal conductivities above the typical thermal conductivities for the respective lithology or above the values measured in the laboratory. In this way, aquifers can be localized and the BHE or BHE field can be characterized more precisely. However, EGRT data cannot be used to determine flow direction and velocity.

The Phd Project aims to develop a new concept for determining the groundwater flow rate and direction using horizontal temperature sensor fiber installed inside a BHE.

This fiber optic based temperature sensor module (FOB-TSM), installed around the BHE into the borehole could permit to detect the temperature field distribution inside and in the direct vicinity of a real BHE. Introducing advective heat transport through groundwater flow causes a distortion in the temperature distribution and hence a difference in temperature with a maximum value in the flow direction. Monitoring the radial temperature distribution on the surface of the borehole heat exchanger could allow determination of the flow direction and the flow strength.

The assumption will be proved by numerical simulations of the heat and mass transport in a 2D plane perpendicular to the BHE using FeFlow and Comsol Multiphysics FEM codes.

The simulation results will serve also to layout the temperature sensor module. Additionally, a FOB-TSM prototype will be mounted in the existing Thermal Cube, available in the Dept of Geoscience lab., consisting in a sandbox device where is it possible of changing the permability conditions of the filling materials and hydraulic heads, in order to verify the concept and validate the FEM models.

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