Modelling and monitoring thermal response of the ground in borehole fields

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Academic Dissertation which, with due permission of the KTH Royal Institute of Technology, is submitted for public defence for the Degree of Doctor of Philosophy on Friday the 23rd February 2018, at 10:00 a.m. in Sal D2, KTH, Lindstedtsvägen 5, Stockholm.
Abstract

This Ph.D. dissertation aimed at developing tools for the evaluation of ground response in borehole fields connected in parallel through modelling and monitoring studies.

A total heat flow and a uniform borehole wall temperature condition equal in all boreholes have often been accepted when mathematically modelling the response of vertical ground heat exchangers connected in parallel. The first objective of this thesis was the development of a numerical model in which the ground controls the temperature response at the borehole wall, instead of imposing heat flow or temperature conditions at this interface. The unavoidable fluid-to-borehole wall thermal resistance and the variation of the heat flux distribution along the borehole depth violates the assumption of uniform temperature at the borehole wall. This aspect, which is often disregarded, was taken into account in this model. The results obtained from the numerical simulations are believed to come closer to reality and can be used as a reference for other approaches.

When bore field sizing, the worst ground load conditions are usually assumed to occur after several years of operation, but these may occur during the first year of operation. The second objective of this work was the development of a general sizing methodology that calculates the total required bore field length for each arbitrary month during the lifetime of the installations. The methodology was also used to investigate to what extent the borehole spacing can be reduced without increasing the total required bore field length when the ground load condition is thermally quasibalanced.

The ground source heat pump community still lacks detailed and accurately measured long-term data for validation of modelling tools. In order to partially contribute to filling this gap, the last part of this Ph.D. study focused on state of the art monitoring activities. The main goal of this part is to provide a comprehensive description of the ground thermal loads and response measurements at a large bore field, that is being monitored from the beginning of its operation. Unique data sets, showing the thermal loads and ground thermal response during extraction and injection, along with measurement error analyses are reported in the thesis.

Keywords

ground temperature response, borehole heat exchanger, modelling, monitoring, sizing

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