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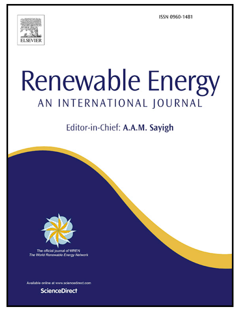

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An improved method for upscaling borehole thermal energy storage using inverse finite element modelling

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Abstract

Dimensioning of large-scale borehole thermal energy storage (BTES) is inherently uncertain due to the natural variability of thermal conductivity and heat capacity in the storage volume. We present an improved method for upscaling a pilot BTES to full scale and apply the method to an operational storage in Brædstrup, Denmark. The procedure utilizes inverse 3D finite element method (FEM) modelling of distributed temperature measurements inside the BTES for inferring the thermal properties of the subsurface. We find that individual geological layers can be distinguished in terms of their heat capacities and thermal conductivities using inverse modelling. The depth integrated estimate of thermal conductivity differs significantly from that obtained from a single thermal response test (TRT) at the site. As such, we find significant scaling effects in terms of the subsurface thermal conductivity distribution which are expected to be further amplified in an expansion of the pilot BTES to full scale. The methodology presented in this paper therefore provides an improved basis for upscaling pilot BTES systems. The operational data and BTES temperature measurements are published with the present paper in the supplementary material.

Keywords: borehole thermal energy storage, numerical modelling, inverse modelling, model validation, thermal conductivity, dimensioning

1. Introduction

Large-scale thermal solar collector arrays are currently being integrated into the district heating networks in Denmark in order to increase the fraction of renewable energy of total heat consumption. Since solar energy production peaks in the summer when heat consumption is low, storage is required for effective balancing of seasonal fluctuations in energy demand and consumption. In addition, the increased production of wind power makes it economically feasible to produce heat by means of heat pumps or electrical boilers when the price of electricity is low, which further increases the need for heat load balancing. In Denmark, district heating networks with large solar collector arrays are typically balanced by a combination of accumulation tanks and hot water pit storage. Currently, the district heating networks in Denmark incorporate more than 80, large-scale solar thermal arrays with either pit or tank storage systems [1].