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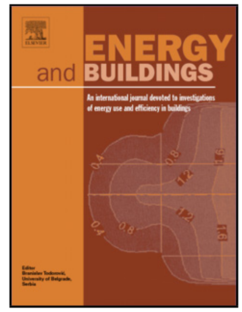

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A New Analytical Model for Short-Term Borehole Heat Exchanger Based on Thermal Resistance Capacity Model

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HighlightsA new simple and accurate analytical model is presented for predicting the thermal behavior of the BHEs in short time periods.

- An Equivalent thermal and resistance network is considered for evaluation of the heat transfer inside the borehole.
- The new presented analytical model gives accurate results in a variety of the thermal properties and the geometric parameters.

1. Introduction

Ground source heat pumps (GSHP) have been gained increasing popularity for the space heating and cooling applications of the residential and commercial buildings due to reduced energy consumption and maintenance costs. Geothermal heat pump systems consist of two parts: the ground heat exchanger and the heat pump unit. The heat exchanger is a system of pipes which is buried in the ground near the building. A fluid -usually water or a mixture of water and antifreeze- circulates through the pipes to extract or dissipate heat from/into the ground. Because of the high efficiency, vertical heat exchangers are the most common types of ground heat exchanger that are used in buildings and are known as Borehole Heat Exchangers (BHEs). In these heat exchangers, fluid passes through U-tube (commonly one or two U-tube) and the borehole is filled with a material called grout.

Accurate modeling of the heat transfer in the boreholes is crucial for the design and simulation of the ground source heat pumps. There have been a number of analytical solutions, numerical methods and the combination of analytical and numerical methods for prediction of the thermal behavior of the BHEs. A number of direct three-dimensional numerical solutions, e.g. finite difference, finite volume and finite element were used to develop a 3D model that can simulate simultaneously the inside of the borehole as well as the overall bore field. Some of the noteworthy numerical methods include the studies of Marcotte and Pasquier [1], Li and Zheng [2], Heidarinejad et al. [3], Nabi and Al-Khoury [4,5] and Rees and He [6]. However, the fully discretized 3D models are more complex than analytical models and need long computational times. These models are not suitable to be implemented in building energy simulation software programs. In contrast, analytical solutions are widely used for the simulation of the heat transfer in the boreholes because of the simplicity and low computational cost.

The first analytical solution is the Ingersoll's line source model (ILS) developed by Ingersoll and Plass [7]. In this solution, the whole borehole is considered as an infinite length line source. Carslaw and Jaeger [8] developed the infinite cylindrical source (ICS) method. The borehole is assumed as an infinite cylinder surrounded by an infinite homogeneous medium in their model. In both the ILS and the ICS models, heat transfer has been considered just in radial direction. Eskilson [9] proposed

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