Inclusive Routine of the Soil Surface Energy Balance in COMSOL Multiphysics®

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Abstract

In ground-coupled heat pumps (GCHPs) the coupling between heat pumps and ground occurs by means of ground heat exchangers, that can be installed vertically inside boreholes (BHEs) or horizontally (HGHEs). In the horizontal installation, the heat exchangers are placed in shallow trenches dug few meters deep in soil. Unlike BHEs which benefit from the relatively stable temperature of deep soil, HGHEs use unsteady source/sink energy storage, related to the energy balance at ground surface This is strongly influenced by many environmental factors. The seasonal variation of the soil temperature can lead to unfavorable working conditions and, consequently, to an efficiency reduction. Nevertheless, for long-term operation, it allows to erase the impact of the seasonal energy exploitation and to avoid a ground thermal drift.

For the optimization of GCHPs and designing the ground heat exchangers, commercial CFD codes have been applied widely to carry out long-term simulations under realistic boundary conditions, according to the extreme dynamic coupling exchanger/soil. The numerical approach has critical issues related to the relationship between the energy performance assessed and the energy balance at the soil surface. In some works, the surface heat flux is related to the air temperature, for simplicity. More rigorous methods apply energy balance equations, calibrated by comparison with experimental data.

In the present work, a method to assess the heat balance on the soil surface is developed in relation to the environmental conditions and the soil surface finishing, to study the energy performance of a so-called flat-panel HGHE. The routine is linked to the COMSOL Multiphysics® by means of LiveLink™ to Excel® module. The model solves the heat conduction in unsteady-state in a 2D cross section domain where a flat panel is placed within trenches laid in a wide surrounding soil part. Hourly scale boundary conditions are defined to reproduce the energy requirements at the HGHE.

The simulation is carried out for a whole year and two different soil surface finishing. The boundary condition fixed at the ground surface allows a more precise evaluation of the HGHE performance, even in relation to the ground-surface temperature variation due to the energy exploitation made. The flat-panel shows a good specific heat transfer capacity in comparison

with other widespread HGHEs, and, unlike with BHEs, simulations highlight that long-term subsurface thermal energy build-up or depletion would not be expecting by shallow HGHEs.