Model study of the thermal storage system by FEHM code

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Abstract

The use of low-temperature geothermal resources is important from the viewpoint of global warming. To evaluate various underground designs using low-temperature geothermal resources, we estimate parameters of a typical underground system using the 2-well model. By changing the parameters of the system, six different heat extraction scenarios were studied. Out of the six cases, one scenario is recommended because of its small energy loss.

Keywords: thermal storage system, model study, Open system, FEHM

Introduction

From the viewpoint of global warming, the use of natural energy (Solar, Wind and Biomass etc.) has been reviewed. One of the more common natural energy sources is low-temperature geothermal resources. Applications of low-temperature geothermal resources include direct use of ground water and GHP (Geothermal Heat Pump) systems etc.
In order to examine an underground design using low-temperature geothermal resources, a model study was performed. Parameters for the study included well distance, flow rate, and the depth of well. To evaluate the sensitivity of these parameters, the basic data for the underground design is provided.

Modeling

Underground system using low-temperature geothermal resources are divided two types. One is used the circulated water through the pipe (Closed system), Other is direct use of ground water (Open system). Aiming to estimate parameters of underground system (well distance, flow rate, the depth of well and layout of well e.g.), we think the one of open system as shown in Figure 1. In this system, is constant flow rate is pumped in the injection well, and the same flow rate is recovered from the production well. Injection and production wells are located in lattice.

To estimate the performance of this system, we develop the 2-well model as shown in Figure 2. This model is a one-unit of the system. The size of this 2-well model is $25\sqrt{2}$m x $25\sqrt{2}$m x 50m. As grid is divided into 15 gridblocks in the horizontal direction, and 33 gridblocks in the vertical direction, the number of nodes is 8704.

As the drilling length is very important to design the underground system (NEDO, 1995), well length depth was set at the relatively shallow depth of 36m for the 2-well system. Water level of the model was set at 6m; thus the unsaturated zone is 0m to 6 m. The model's properties are based on the survey of the Tokyo area and are given in Table 1. Simulation code is FEHM (Finite Element Heat and Mass transfer) code (Zyvoloski et. al, 1997). This code was developed at Los Alamos National Laboratory. In the FEHM code, the conservation equations of heat and mass in a porous media are solved using the control volume finite element method.

Results

To estimate the characteristics of system, this 2-well model was run at some condition as shown in Table 2. To simulate the heating and cooling conditions, the inlet temperature was held constant at 5 ^{o}C for one half year, then changed to a temperature of 25 ^{o}C for the rest of the year. Total simulation time was 10 years; the initial temperature of this model was 17.5 ^{o}C. History of temperature between injection and production wells is shown in Figure 3 (the results of case 1). We recognize that temperature distribution of the unsaturated zone; the saturated zone (6 - 36 m) and the deep saturated zone (36m -) are different. The temperature of saturated zone is most influenced but the injected water.

Also, variation of temperature of the aquifer is larger than that of the ground surface because of the lack of fluid movement in the unsaturated zone and thus the heat transfer to the surface is limited to heat conduction. These effects cause the cycle of the variation of temperature in the aquifer (a half-year) to be different than that of the unsaturated zone.

Discussion

In order to evaluate the results of each case, we calculated the balance of thermal energy using formula (1).

$$\text{Balance of thermal energy} = W_{inj} \times T_{inj} - W_{pro} \times T_{pro} \qquad (1)$$

Where W is the flow rate, T is the temperature, and "inj" and "pro" refer to the injection well and production well respectively.
The results of this arrangement are shown in Figure 4. This value is normalized by the results of case3. A positive value means injected energy is larger than produced energy; a negative value mean produced energy is larger than injected energy.   A zero mean balance of thermal energy is the most desirable case.

As shown in Figure 4, the balance of thermal energy decreases in the all case. As the temperature of circulated fluid changes 25 ^{o}C / 5 ^{o}C for a half year, the temperature of the 2-well model eventually becomes 15 ^{o}C, the average temperature. Since the initial temperature of this model is 17.5 ^{o}C, the balance of thermal energy is negative. The results of case1, case2, and case4 are almost similar; the result of case3 is different. The conditions of case3 indicate a strong sensitivity to the depth of the production zone. As a depth of the outlet zone is higher than the inlet zone, circulated flow did not reach the outlet zone. After two years of circulation, the results of case1, case2 and case4 are almost identical.   Range of variation of case5 is the smallest and case6 is the biggest. It is due to the magnitude of circulated flow. As the net change of thermal energy is small, we think that the low flow condition of case5 is promising.

Future task

We plan on examining the underground design using low-temperature geothermal resources at a range of conditions, with the 2-well model using FEHM. In the future we will try to optimize the design of the 2-well model.

Reference

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