Pre-operational risk study in deep geothermal modeling: insights from a dual medium synthetic model

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Research question
A common form of geothermal extraction involves extracting hot water from an aquifer from a production well and re-injecting cooled water in a second injection well within the same aquifer. This system is a typical well-doublet scheme.

Reinjection of cooled water within the reservoir started as a method of wastewater disposal [1], but has now become one of the key factors in the success or failure of the field. Reinjection provides pressure support, reducing drawdown and the potential for subsidence [2]. Also, this process increases the longevity of geothermal resources and the amount of energy that can be recovered [3].

As the operation takes place, a cooled water zone will spread over time from the injection well, eventually reaching the production well. After thermal breakthrough occurs, the outlet temperature is no longer constant, which may have significant consequences for the overall sustainability of the project. Therefore, a careful design of the production–injection system is required for an optimal geothermal development of the field, as well as to prevent an early thermal breakthrough at the production well [4].

The development of geothermal energy generation is closely linked to thermal and hydrogeological knowledge of the subsurface aquifers. Numerical modeling here appears as a tool to delineate development risks induced by limited geological data at great depths.

Computational tools capable of simulating complex geothermal systems coupled to adapted numerical methods of uncertainty design are tailored to evaluate the pre-operational risk associated with the deep geothermal site-specific operation.

Model development
IFPEN in-house reservoir numerical model PumaFlow™ currently commercialized by Beicip Franlab, is used to investigate coupled transient hydraulic and thermal responses of geothermal operation on a deep sloped reservoir. Selected dual medium approach accounts for fractured reservoirs through the modeling of exchange mechanisms between matrix and fractures. The geothermal system, consisting of a fully saturated reservoir, overburden and underburden, is assumed to be part of a typical deep sedimentary basin (fig. 1). The injection well and the production well are located 500 m away at the center of the 3D domain.

Based on the results of the steady-state study, the hydraulic and thermal performances of the geothermal doublet were investigated in terms of transient temperature and pressure variations over 30 years of operation.

Model analysis
Deep geothermal targets are generally located within complex geological systems, such as multi-scale fault zones, generally characterized by a strong spatial variability of many of its spatially distributed properties among which permeability, porosity, compressibility, thermal conductivity, volumetric heat capacity.

CougarFlow™ is an extensive uncertainty and optimization analysis software [5, 6]. Coupled with simulator PumaFlow™, it constitutes a reservoir modeling chain capable of investigating effects of input parameters on simulation results.

Through a multiple realizations approach based on experimental design and state of the art optimization algorithms, two computational methods are retained. A thorough screening of uncertainties on a given range of input parameters allows the identification of key reservoir simulation outputs due to their respective influence on hydraulic and thermal performances of the geothermal system. This qualitative step is used to organize the main characteristics of the mining reservoir and the associated geothermal operation into a hierarchy in order to discard minor parameters from further (and time-consuming) analysis.

This reduced set of parameters is subsequently used to carry out the uncertainty analysis that enables quantifying parameter impacts on modeled pressures, temperatures and complex output variables. Model
execution being time-consuming, the use of response surface method allows simulating thousands of automated scenarios using a Latin Hypercube experimental design. The stochastic method would allow determining the settings for input factors that meet technical feasibility constraints, resulting in the prediction probabilities of success of the overall project [7].

Using these results, investors may further calculate the financial risk, and operators may adjust their exploitation strategy for the entire life-cycle of the reservoir [8]. This integrated work tackles challenges faced in classical stochastic hydrogeological modeling by providing an operational and process-based approach for deep geothermal energy system.

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References


