Hydrodynamic and Thermal Modeling in a Deep Geothermal Aquifer, Faulted Sedimentary Basin, France

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Abstract

Introduction
Within projects of geothermal energy, we need hydrodynamic and thermal modeling to forecast the impacts of geothermal deep wells on existing wells. In case of pumping and reinjection of the geothermal fluid in a deep groundwater reservoir, located in a sedimentary basin with lateral and vertical lithology variations and major faults, it is fundamental to understand the behaviour of the multilayer aquifer system and to determine the geothermal potential of the aquifer before proceeding to its geothermal exploitation. Thus, a predictive model has been set-up using COMSOL Multiphysics®.

Use of COMSOL Multiphysics®
We make use of the version 4.3a of COMSOL Multiphysics®, with 2 modules for hydrodynamic and thermal modeling:
- Earth Science Interface: Fluid Flow with Darcy's law,
- Heat Transfer Interface: Heat transfer in fluids, in solids, by conduction and convection in porous media.

Modeling was carried out in three steps:

i) First step: 3D geometry of the model
The target study area is a rectangle of 22 km long and 12 km wide, that is to say an extension of 264 km2, with a height of 4 km.
3D geometry has been built taking into account the lateral and vertical variations of facies (lithology) of geological cretaceous and jurassic formations and the presence of faults, which compartment the sedimentary basin into blocks (vertical fault throw can reach 200 m).
The faults have been taken into consideration during the geometry building for each hydrogeological layer, and some faults, which have the strongest geological and hydrogeological impacts, have been represented with their own geometry in order to affect their hydrodynamic and thermal properties (Figure 1).

ii) Second step: hydrodynamic simulation
Thanks to existing well data times series, it was possible to reproduce the piezometric data from

existing deep well in the study area over the last 30 years.
Then the hydrodynamic behaviour of the aquifer over the next years with 6 new deep wells (3 pumping wells and 3 reinjection wells) was simulated over the next 30 years.

iii) Third step: hydrodynamic and thermal coupled modeling
The aim was to predict the impact of the 3 pumping and 3 reinjections wells of geothermal fluid, knowing the energy surface needs and the variable temperatures of fluid reinjection depending on the sites.
The predictive model has been used for design basis and architecture of each geothermal central station.

Results
Using COMSOL Multiphysics® with especially the hydrodynamic interface (Fluid flow with Darcy's Law) and heat transfer interface has allowed building a 3D hydrogeological and thermal model to predict successfully the behaviour of 6 new deep wells in a faulted sedimentary basin, already in use for the geothermal energy needs of a city.

Conclusion
Using COMSOL Multiphysics® has permitted important engineering work in the field of hydrogeology and geothermal deep reservoirs (aquifers). A relevant 3D subsoil representation in a complex geological setting has been created, to simulate the subsoil behaviour and to represent in 3D the evolution of the cold fluid bubbles over time. The impacts of geothermal fluid flow exploitation over 60 years has been simulated, reconstructing the existing geothermal central stations and simulating new geothermal doublets, as part of a project of geothermal energy for a metropolis of nearly one million inhabitants.

Figures used in the abstract

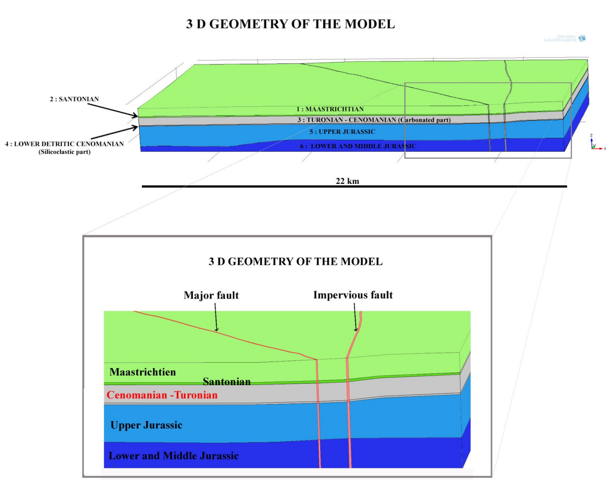

Figure 1: 3D model