KEM Research Question (max. 4 pages + annex)

KEM-52 *Hazards of use of multiple reservoirs in geothermal operations*

Objective

To determine the effect of reservoir and fluid properties on fluid circulation and pressures in geothermal operations with production from multiple reservoirs and the implications, associated hazards and mitigation measures.

State of the art, background

Fluid circulation in geothermal systems with matrix-dominated flow may involve multiple reservoirs where heat is extracted from two or more reservoirs separated by low-permeability layers. In the Dutch geothermal industry these fluid flows are not separated inside the wells by using multiple injection/production strings, but are commingled. This type of production involves the assumption that the volume ratio between the reservoirs for the extracted fluid is equal to the volume ratio between the reservoirs for the injected fluid. In other words, the distribution of flow in each reservoir is balanced, where the volumes of water that are extracted from and re-injected into one reservoir are equal. The average reservoir pressures are expected to be close or equal to initial conditions in such a system. Differences in the reservoir properties between the injection and production well within one reservoir, such as differences in thickness or permeability, could potentially affect the fluid circulation and cause unbalanced flow. Unbalanced flow could also result from differences in well completion between the injector and producer, and/or differences in the connection between the well and reservoir ('skin factor[1]') for the injector and producer. Finally, differences in the properties of the fluids between the reservoirs, such as salinity or temperature, could also potentially cause unbalanced flow. The latter could result because the injection fluid is a homogenised fluid in which the produced fluids with different properties are no longer separated but mixed. Possible effects of unbalanced flow are expected to include a change in the reservoir pressures. The effects of unbalanced flow, in turn, may result in hazards such as seismicity or uplift / subsidence.

Thermo-hydro-mechanical models (THM) to understand geothermal systems better such as their lifetime (e.g., Crooijmans et al., 2016; Daniilidis et al., 2021) or mechanical issues (see KEM-15 project, Pandey et al., 2018), have so far been applied to cases where a single reservoir is present. Geothermal systems with production from multiple reservoirs have not yet been systematically investigated. Potential mitigation measures of the effects of unbalanced flow, e.g. via well design, have not been examined either. This proposed research is aimed at providing this information, by determining the effect of reservoir and fluid properties on fluid circulation in geothermal operations with production from multiple reservoirs and the implications, associated hazards and mitigation measures.

Research Question

RQ1) What is the effect of reservoir and fluid properties on fluid circulation and pressures in geothermal systems with production from multiple reservoirs? Properties to consider should include:

a) difference in reservoir permeability between the injection and production well within one reservoir;
b) difference in reservoir thickness between the injection and production well within one reservoir;
c) difference in formation water salinity (i.e. density) between the reservoirs;
d) difference in temperature (i.e. density) between the reservoirs;
e) any other relevant properties.

a) and b) should include the extreme case of zero permeability or zero thickness of one of the reservoirs in either the injection or production well.

RQ2) What are the possible effects of unbalanced fluid circulation per reservoir and what are the associated hazards? Hazards that should be considered include:

[1] https://testwells.com/the-skin-factor

a) seismic hazard;
b) uplift / subsidence;
c) hazards that affect the well productivity or integrity, such as skin formation;
d) any other relevant hazards.

RQ3) What are potential mitigation measures of the effects of unbalanced flow, such as potential pressure gradients?
a) Can the production/injection wells facilitate pressure re-equilibration?
b) Is a special well design required?
c) Any other potential mitigations not mentioned here?

Deliverables expected

1) Report on the model and model setup:
a) A (detailed) description of assumptions, parameters/parameter space, sensitivities, uncertainties and model limitations
b) A (detailed) model description (detailed enough so others could reproduce it)
2) Report on RQ1
3) Report on RQ2
4) Report on RQ3
5) Report summarizing the entire research (RQ1-RQ3)

The reports should be of the quality of a manuscript that can readily be submitted to a peer-reviewed journal (and reasonably make it to publication). SSM can imagine that the work will be published, but recognises that this is unlikely to happen within the timeframe of the project.

Timeline

M0: Kick-off meeting, focus on goal and scope of research.
M3: D1 to SSM, followed by a progress meeting with go/no-go decision..
M5: D2 to SSM, followed by a progress meeting.
M6: D3 to SSM, followed by a progress meeting.
M8: D4 to SSM, followed by a progress meeting.
M9: D5 to SSM /KEM panel, followed by final presentation.

Based on the progress at M3 a go/no-go decision is envisioned. In case of a potential no-go decision SSM will seek advice from the KEM panel.

Expected use

Identifying and quantifying potential effects of use of multiple reservoirs in geothermal systems will help SSM to advice the Ministry of Economic Affairs and Climate Policy on license applications where such use is envisioned. In addition, it will help SSM to make risk-based decisions for supervision. Finally, the geothermal sector will benefit from more knowledge on the topic, and may proactively take the necessary steps that allow for safe production from multiple reservoirs.

Expertise and tools preferred for the team

Expertise:
- Operation of geothermal systems with matrix-dominated flow.
- Modelling of THM processes.
- Geomechanics.
- Well engineering.
- Scientific writing.

Tools:

- Tool for numerical modelling of THM processes in geothermal systems with matrix-dominated flow. This tool should also be able to calculate flow on the well-scale.

Quality assurance, Organisational and communication requirements

Quality assurance will happen via review of the progress reports by SSM and by discussions during the associated progress meetings. The draft final report will be reviewed by both SSM and the KEM panel and further discussed during the final presentation. Further quality assurance will happen by peer review of the final publication (possibly beyond the timeline of the project).

The project plan includes a kick-off meeting and regular progress meetings with SSM, with a go/no-go decision after 3 months. For the go/no-go decision SSM will seek advice from the KEM panel in case of a potential no-go situation. A presentation of the final findings to SSM and the KEM panel is planned at the end of the project.

SSM expects to receive the deliverables 1-2 weeks prior to the progress meetings, which means that the milestones reflect the deadlines of report submission rather then the deadlines of the progress meetings.

References

Crooijmans, R. A., Willems, C. J. L., Nick, H. M., & Bruhn, D. F. (2016). The influence of facies heterogeneity on the doublet performance in low-enthalpy geothermal sedimentary reservoirs. Geothermics, 64, 209-219.

Daniilidis, A., Nick, H. M., & Bruhn, D. F. (2021). Interference between geothermal doublets across a fault under subsurface uncertainty; implications for field development and regulation. Geothermics, 91, 102041.

Pandey, S. N., Vishal, V., & Chaudhuri, A. (2018). Geothermal reservoir modeling in a coupled thermo-hydro-mechanical-chemical approach: a review. Earth-Science Reviews, 185, 1157-1169.

KEM-15 project, see website