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Abstract

An innovative cavern simulation software has been developed combining physical and statistical modeling methods, based on an exclusively top-down driven approach. Encouraging precision in wellhead as well as cavern pressure and temperature calculation has been obtained in both situations, history matching and forecasting scenarios.

While an initial series of SMRI presentations has given modeling fundamentals, experience feedback from a first year of use by an UGS operator in North-Germany (Crystal) as well as the extension of functionalities oriented towards traders, the present follow-up paper provides simulation details that have been obtained on two additional UGS sites with differing physical and operational conditions.

In a first case, the simulated EDF Energy high flexibility caverns located in Great Britain presents wide-spread physical and operation differences in comparison to the North-German site. While salt rock conditions remain comparable, the considered site consists of several times smaller caverns in extremely shallow geological depth (-250m/-320m vs. -1400m @ cavern centre). Consequently, their injection and withdrawal operations are opposite to the more general case, namely that injection takes place exclusively through throttling down from the network pressure and withdrawal is obtained through gas compression up to the network pressure. Model modification included not only flow direction correlated sign conversions. The shortened distance between cavern centre and wellhead demonstrated a stronger influence of cavern temperatures on actual wellhead pressures. Consequently, the pressure model now re-incorporates temperature terms. The obtained history matching results in precision ranges in line with those obtained on the original North-German site. So far, history matching has been executed with resulting average deviations of respectively less than 1 bar and 2-3 °C at wellhead. It has to be noticed that the developed model will form part of a subsurface monitoring scheme in addition to subsidence, passive micro-seismic and sonar surveys.

In a second case, the modeling method has been tested to a third party UGS site, owned by China National Petroleum Company (CNPC) and located in Jintan (China). Although the depth of the simulated caverns remains comparable with the North-German site where the PVT software had been originally developed on, geological salt-rock compositions as well as injection & withdrawal capacities and cavity volumes (smaller) differ significantly. The combined statistical and physical model has been overtaken in its identical form. Solely statistical determination (re-matching) of model parameters has proven sufficient for a successful simulation. So far, history matching has been executed with resulting standard deviations of respectively less than 1 bar and 5 °C at wellhead.

Therefore, the portability of the here-considered PVT software to UGS sites with differing geo-physical and operating conditions is proven. Also worth to mention, from a practical point of view, the presence of the here described PVT software on the operator's desk has proven several times successful in detecting data inconsistencies stemming from not only physical but also IT related data collection malfunctions on all three considered UGS caverns.

Eventually, the present paper introduces additional tests about potential functions of the PVT software that are currently under consideration. The functions are situated in the domain of subsurface integrity monitoring with simulations for leakage, creep and cavern disorder detection.

EDF intends the further development of its PVT software tool (such as the modeling of porous reservoir as well as liquid storage applications) also in the aim to provide third party operators with services through UGS development and operational phases.