



Investigation of induced geochemical reactions by compressed air energy storage in porous formations

Bo Wang and Sebastian Bauer

University of Kiel, Institute of Geosciences, Geohydromodelling, Kiel, Germany (bo.wang@ifg.uni-kiel.de)

Compressed air energy storage (CAES) is a power-to-power energy storage, which converts electricity to mechanical energy as highly pressurized air and stores it in the subsurface. Using a porous formation as storage reservoir for CAES is an option if salt caverns are not feasible, and it can also offer large potential storage capacities. However, the injection of air into geological formations long free of oxygen may cause geochemical reactions if redox-sensitive minerals are present. This study thus aims at investigating induced geochemical reactions of a CAES operation in a porous sandstone formation containing pyrite, and quantifying the potential impacts on storage performance by numerical simulations.

A hypothetic diabatic CAES scenario using the Rhaetian sandstone formation in northern Germany was investigated. Using a prior gas reservoir as storage site, this CAES operates on a daily basis with a 6-hour injection and 6-hour extraction cycle in the early morning and late afternoon. The Rhaetian sandstone formation is assumed to have a porosity and permeability of 0.35 and 500 mD, respectively. The mineral composition of the Rhaetian sandstone shows the presence of pyrite, carbonates and silicates. Injection of air thus results in pyrite oxidation and carbonate dissolution due to the produced acid, which also cause a change in air composition, air pressure and formation properties. To quantify these processes and potential impacts on storage performance, kinetic batch simulations were performed using the coupled multiphase-multicomponent ECLIPSE-OpenGeoSys-PHREEQC simulator.

The simulation results show that within one storage cycle of air injection and extraction, i.e. a residence time of 12 hours for the injected air, only a very small change of 0.03% in the O₂ mole fraction can be found due to chemical reactions. This minor change is barely observable and will not affect the storage performance of one storage cycle. Considering a longer residence time of two years, the storage pressure can drop from 71 bar to 69 bar, and the mole fraction of O₂ in air decreases to 15.18%. The corresponding air mass flow rate for a thirty-minute extraction drops from 564 kg/s to 516 kg/s, and the estimated power output decreases from 433 MW to 396 MW assuming that the combustion efficiency of the gas turbine remains constant. After about 14.5 years of storage time, storage pressure drops to 63 bar and all O₂ has reacted. The stored air can thus not be used for burning in this hypothetic diabatic CAES without a refill. After 20 years of cyclic operation, the pH of the formation fluid can drop below 1.0 to about 0.8 near the injection wells due to the ongoing supply of O₂. This will increase the risk of corrosion in the wells. However, the overall mineral dissolution and precipitation in the storage formation results in only minor increases of porosity and permeability with relative changes of 0.3% and 1.2 %, respectively.