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Storage of mechanical energy and heat extraction via artificial fractures in low permeable rock

Torsten Tischner[1] and Reinhard Jung[2]
[1]Federal Institute for Geosciences and Natural Resources, Hannover (Germany)
[2]Jung Geotherm UG, Isernhagen (Germany)

The storage of surplus power generated by wind turbines or solar panels under favourable weather conditions is of significant importance for the successful transition of current energy systems. Surplus power can be used for hydrogen production or for charging batteries. However, there is also an option to store surplus power as mechanical energy due to the injection of water into the deep underground.

Basic investigations for the storage of mechanical energy were performed at the geothermal research well “Horstberg” in Germany. Here a large and highly conductive artificial fracture was created in the Buntsandstone formation at approximately 3800 m depth. For the hydraulic stimulation 20.000 m^3 of fresh water were injected at a pressure of about 300 bar. In succeeding production tests, the water was produced back at a pressure level of about 200 bar and a significant portion of the energy used for injection would have been retrievable. Further injection and production tests, originally designed for cyclic heat extraction, showed that approximately half of the electric energy necessary for injection could have been recovered while producing. Obviously, a large portion of the hydraulic pump energy is stored in the underground as mechanical energy due to ballooning of the fracture and due to elastic compression of water and rock surrounding the fracture.

The efficiency of energy storage can be improved significantly by implementing a horizontal well design with multiple fractures. This is shown based on model calculations. If water is injected in parallel artificial fractures the static pressure level between the fractures increases, water losses into the far field decrease and the back-production is improved. Furthermore, overpressure reservoirs and low permeable rock are favourable. Thereby the injected water remains in the closed surrounding of the fractures and the complete artesian back production at high pressure is ensured. Overpressure formations seem to be widespread in the deep underground of sedimentary basins as in the North German Basin.

Mechanical energy storage in the deep underground should be combined with geothermal heat extraction. At the test site Horstberg thermal water at a temperature of more than 100°C was produced in cyclic tests. Numeric modelling results suggest that a thermal power of appr. 1 MW can be extracted by cyclic production in the long term via the large fracture in Horstberg.

For the realisation of this storage concept several challenges have to be met. Besides the creation of good underground conditions, the handling of the produced saline water and its reinjection without scaling or corrosion are serious issues. On the other hand the storage of surplus power as mechanical energy in the underground and its retransformation to power can be more efficient than the conversion into hydrogen and less expensive than battery storage. The reuse of abundant deep wells for energy storage could be a cost-efficient starting point for this concept.