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Modeling and simulation of combined basin structures for seasonal thermal energy storage

Christoph Bott and Peter Bayer
Martin Luther University Halle Wittenberg, Institute of Geosciences and Geography, Applied Geology, Halle (Saale), Germany (Christoph.Bott@geo.uni-halle.de)

Seasonal thermal energy storage (sTES) plays a crucial role in driving forward the global energy transition by tackling the intermittent nature of renewable energy sources. While communities increasingly rely on sustainable yet variable sources such as solar thermal, photovoltaics, and wind power, the importance of efficient energy storage solutions becomes key. These solutions need to contribute to grid stability, diminish reliance on fossil fuels, and optimize energy utilization while supporting resilient and sustainable energy systems. Among the technological variants for sTES, closed-loop alternatives for in-ground, artificial basin systems involve water-gravel thermal energy storage (WGTES) and tank thermal energy storage (TTES). They consist of a filling medium operated via a direct or indirect charging/discharging system and which is enclosed by a membrane consisting of sealing layers, insulation materials, and, if necessary, static structures [1].

Especially for supplying modern, dynamic district energy systems, high requirements apply to sTES in terms of temperature levels as well as volume flow rates. At the same time, high costs for the construction of new systems are an enormous hurdle that hinders global market availability. For this reason, re-using existing basin structures, for example, at locations of transforming commercial and industrial areas, is a new concept that also offers new opportunities for innovations of sTES concepts. Especially at sites with the option of re-using existing infrastructures, not only single but multiple structures may be available. These may, for example, feature subdivided infrastructure compounds yielding an extra challenge for design, construction, and operation. Connecting several separately tuneable sTES units in one system in parallel or as a cascade offers enhanced flexibility. For this purpose, we present a modification of a recently developed model for WGTES, “STORE” [2], that is capable of simulating the behavior of a variety of sTES combinations with different configurations, designs, and operational principles. Based on a realistic case study, and taking several reference units (e.g., energy, storage capacity, power) into consideration, we investigate technical issues, e.g., optimal interconnection, insulation designs, and interference with ambient ground, in contrast to static integrations of a single sTES facility. In particular, we reveal the effects of the combined placement of multi-sTES systems and their thermal interference through internal walls, and with the ambient ground. We present the findings of a parameter study to investigate ideal combinations and sophisticated modes of operation, e.g., by operating a central basin at the highest temperature level whereas outer basins are kept at lower temperatures. Based on this analysis, we infer favorable application windows for combined basin structures and strategies to increase overall efficiency.

References

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