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Modelling Long-Term Thermal Energy Storage in Water-Gravel-Filled Artificial Basin Systems

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With the growing prevalence of renewable energy sources in innovative energy systems, interactions between energy supply and demand become more dynamic and complex. Therefore, along with the deployment of efficient and low-emission energy sources and sinks, energy storage is a central element of the energy transition. Especially for the case of thermal energy, a mismatch between high energy supply and low demand in summer and vice versa in winter is striking—resulting in a critical demand for seasonal solutions.
In the past, various concepts were established for large-scale, sensible, low-temperature applications. Closed systems (tank and pit thermal energy storages) have been developed as site-independent solutions, differing in their constructional design with different building components. Further, water-gravel thermal energy storage (WGTES) feature a water-saturated matrix filling (i.e., gravel, sand) with an indirect charging and discharging system (usually multi-level piping loops). Among the closed concepts, WGTES is considered the most complex variant, which simultaneously offers less maximum storage capacity due to a reduced effective volume. In addition to the resulting sophisticated internal thermal behavior, a number of additional components (sealing, insulation, static components: wall, roof, foundation) are decisive for the storage's capacity, power and efficiency.
Modelling of WGTES during the planning phase represents a challenging step, requiring simplifications of the system. Detailed finite element method/ computational fluid dynamics approaches are not well suited for investigating a variety of possible design scenarios due to excessive computation times. Consequently, there is a high demand for the development and improvement of alternative models for the simulation and performance estimation of WGTES. In our study, we exploit a recently established model "STORE", which depicts a storage within a 2.5-D approach (vertically structured as layers, horizontally structured in predefined directions, cf. abstract figure) and resolves the facility on the building component level. Since "STORE"is characterized by a high level of versatility, it can be used to analyze a range of design scenarios and employed as a planning instrument.
In our presentation, a case study is set up to investigate a variety of technical specifications and to find optimum design solutions: For a given location with climatic and subsurface conditions, we analyze different geometries of artificial storage basins, various insulation material selections, thicknesses, as well as strategies for WGTES charging and discharging. For this, we focus on different technical solutions for indirect energy transfer from and to the basin and on strategies for storage operation. Using the flexibility of "STORE"for evaluation, the component-design simulations are further used to highlight those key factors with the highest impact on the relevant performance indicators. We compare resulting temperature distributions, capacities, charging/discharging power, and efficiencies of the scenarios. Based on this, we finally deduce recommendations for improved construction and operation of WGTES.

Participation

In-Person

References

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