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Operation strategies guideline for packed bed thermal energy storage systems

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Summary

Packed bed thermal energy storage (TES) systems have been identified in the last years as one of the most promising TES alternatives in terms of thermal efficiency and economic viability. The relative simplicity of this storage concept opens an important opportunity to its implementation in many environments, from the renewable solar-thermal frame to the industrial waste heat recovery. In addition, its implicit flexibility allows the use of a wide variety of solid materials and heat transfer fluids, which leads to its deployment in very different applications. Its potential to overcome current heat storage system limitations regarding suitable temperature ranges or storage capacities has also been pointed out. However, the full implementation of the packed bed storage concept is still incomplete since no industrial scale units are under operation. The main underlying reasons are associated to the lack of a complete extraction of the full potential of this storage technology, derived from a successful system optimization in terms of material selection, design, and thermal management. These points have been evidenced as critical in order to attain high thermal efficiency values, comparable to the state-of-the-art storage technologies, with improved technoeconomic performance. In order to bring this storage technology to a more mature status, closer to a successful industrial deployment, this paper proposes a double approach. First, a low-cost by-product material with high thermal performance is used as heat storage material in the packed bed. Second, a complete energetic and efficiency analysis of the storage system is introduced as a function of the thermal operation. Overall, the impact of both the selected storage material and the different thermal operation strategies is discussed by means of a thermal model which permits a careful discussion about the implications of each TES deployment strategy and the underlying governing mechanisms. The results show the paramount importance of the selected operation method, able to increase the resulting cycle and material usage efficiency up to values comparable to standard currently used TES solutions.

Highlights

- Operation strategies and thermal management of packed bed TES systems.
- Cyclic and material use efficiencies in packed bed TES systems.
- Transient and stationary performance analysis of packed bed TES systems.

KEYWORDS

packed bed, thermocline, thermal energy storage (TES), operation strategy, thermal management