Popular science summary of the PhD thesis

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Title of the PhD thesis	Large scale heat storage for solar district heating
PhD school/Department	Department of Civil and Mechanical Engineering

Science summary

Integrating Pit Thermal Energy Storage (PTES) with Solar District Heating (SDH) systems can significantly enhance solar heating efficiency and mitigate the limitations posed by temporal and climatic variations. However, only 19 such systems are currently operational worldwide, and the lack of suitable simulation and analysis methods has hindered the broader application of this technology. The research questions focus on how to expand practical experience, improve simulation accuracy, and enhance system performance and economic viability. Therefore, this doctoral thesis aims to address these issues through data analysis, model validation, system integration, control optimization, and multi-energy complementation.

The Danish Dronninglund Solar District Heating plant serves as the data source for all research conducted in this thesis. The research includes: (1). System performance analysis using energy and exergy methods, with data correction via bidirectional long short-term memory (LSTM). Additionally, economic and environmental impacts are studied. (2). Introduction of an improved semi-analytical PTES model (Type 1535-1301), validated against long-term measured data. The influence of structural parameters and soil properties on PTES thermal performance is then analyzed. (3). A comparative evaluation of six different PTES models in TRNSYS is conducted to assess their strengths and weaknesses. (4). The impact of heat pump control strategies on system performance and economic outcomes is investigated. (5). A novel approach is proposed, where excess electricity is stored in PTES to reduce electricity waste and lower heating costs.

In conclusion, this thesis provides a data analysis method, extended results from a real-world project, a validated PTES model, an optimized heat pump control strategy, a solution for storing excess electricity in PTES, and an MPC strategy for future engineering and research. Additionally, it offers insights into the impact of PTES design parameters on thermal performance and the applicability of different PTES models.

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