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Thermal Energy Storage Technologies

Fast modelling, realisation and experimental characterisation of innovative latent heat storage units for system integration

By

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The building sector alone is responsible for roughly 1/3 of the global final energy consumption and almost half of this energy demand is destined to space and water heating. Although low-carbon heating technologies are growing, such an energy demand is mostly met by fossil fuels. Hence, thermal energy storage (TES) technologies are a pivotal element for supporting high shares of renewable energy and increased demand flexibility in the heating sector. Among the available energy storage options, Latent Heat Thermal Storage (LHTS) has gained increasing attention because it offers considerably higher energy density at a nearly constant temperature level if compared to sensible storage systems. Such features are particularly attractive for applications in urban contexts, which are generally characterised by a limited installation space for TES units. Despite this great potential, only a limited number of commercial devices has reached market deployment. This may be ascribed to two existing conditions: the lack of fast and accurate models facilitating the integration of LHTS units in energy systems and the limited knowledge on how full-scale LHTS devices interact with the heating systems in which they are incorporated.

In an attempt to overcome these gaps, this thesis provides some contributions both from a methodological and an application point of view. The method-related advances concern the presentation of a fast, accurate and experimentally validated dynamic model for system-level simulations of shell-and-tube latent heat storage units. Such a model is entirely based on a-priori known physical and geometrical parameters and does not require any experimental parameter calibration. Moreover, this modelling approach is rather general and has the potential to support both LHTS optimal sizing and LHTS system level performance investigation. On the other hand, the application-oriented advances regard the documentation of the realization process and the experimental measurements of two 40-kWh shell-and-tube LHTS prototypes characterised by a different inner heat exchanger design. These storage units are studied and analyzed from two perspectives. On the one hand, the experimental facility is used to validate the aforementioned dynamic model comparing the numerical outcomes against the experimentally measured quantities for both the LHTS prototypes. On the other hand, a comparative analysis centred on the performance of the two LHTS tanks is performed. To conclude, the role of latent heat thermal storage is assessed in the framework of the EU research project RE-cognition, which aims at an intelligent integration of multiple energy and storage technologies in buildings.