THESIS REVIEWER'S REPORT

Thesis title:	Stratification in storage tanks for heat pumps
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Description

The dissertation is prepared in the method "Thesis by publication." In total 5 papers are attached together to accompanying text in this thesis.

The first paper contains mainly a research on the issue of stratified heat storage tanks. The developed models of the storage tank behaviour were experimentally verified. The optimization then focused mainly on the solution of the inflow into the storage tank. (Paper 1, 2)

The second study uses a data-driven Long Short-Term Memory neural network approach. An exergy model of the reservoir was used. (Paper 3)

The third study is mainly concerned with visualizing the energy performance of heat storage. (Paper 4, 5)

Objectives

The aims of the thesis were defined on page 5 of the dissertation in the form of 3 points.

1. Design and simulate the methodology to separate the good from the bad operational parameters during TES operation from the view of stratification quality and thus efficiency of renewable heat sources connected to TES.
2. Design and validate own custom built second law model to quantify the availability of the energy that is being added and subsequently removed during charge and discharge cycle of TES.
3. Design and build an intelligent IoT stream processing unit to fit the second law model previously developed and predict the second law stratification efficiency in real time.

Achievements of objectives

The fulfilment of the objectives is described with references to the individual Studies and Publications on page 21.

The first objective of the thesis is presented in Study 1. MIX number was experimentally utilized and various CFD models were developed and validated.

The second objective of the thesis is in Study 2. A validated own custom built second law model describing TES charging and discharging was adapted. Stratification was described using Neural Networks.

The third objective of the thesis is in Study 3. A system for visualization and analysis of real time data of heat pump source behavior and stratified thermal energy storage was developed. Minicomputers were used. Statistical uncertainty analysis was also performed.

I positively evaluate the careful research of the assigned issue. The developed models are validated by means of own experimental measurements. The use of neural network analysis has extended the application of the developed models to the prediction of the behaviour of a thermally stratified heat storage tank.

For the above reasons, it can be concluded that the stated objectives of the dissertation have been fulfilled.

Theoretical contribution of the thesis

The thesis in the research part summarizes the issues in the field of heat storage using thermal stratification. I evaluate the performed research as good with sufficient information that can be used as the theoretical basis of the thesis.

The contribution of the thesis is in the development of a mathematical models of a thermally stratified storage tank and its experimental verification.. I consider the mathematical methods and procedures used to be appropriate.

Practical contribution of the work

The developed model allows to predict the energy contribution of a stratified heat store. It can thus be used for analyses related to the energy performance of building systems. Data visualization and data analysis allows a better understanding of the processes taking place in the heat storage tank.

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Formal level of work

The thesis has a total of 115 pages and is clearly structured with regard to the dissertation method. The formatting of the thesis corresponds to the requirements of individual publishers.

In the introduction of the thesis, an overview of the variables used is given. Citations are given in the thesis according to the citation principles. The thesis is very well prepared from the formal and language point of view. Most of the figures are original, created by the author. Minor typos in the thesis are acceptable.

The PhD student has demonstrated the ability to analyse the current state of knowledge, to choose appropriate methods and procedures for experimental measurements, to evaluate and draw conclusions from the measurements. The PhD student has demonstrated adequate knowledge in the field. Overall, I consider the thesis a success.

Dissertation questions

What are the limitations of the developed thermal stratification storage tank model. Can the model be applied to a storage tank of any size?

Dissertation focuses on analysis of full charge and discharge cycle. Is it possible to describe the differences in partial charge or discharge behaviour?

Is it possible to use a different energy source than heat pump and solar collectors for the developed model of the storage tank?

I recommend the award of the Ph.D. degree after successful defence of the dissertation.

8.5.2024 Michal Kabrhel