HSLU Hochschule Luzern

Technik & Architektur

Master-Thesis Mechanical Engineering

Optimization of the heat storage cells of a STES

using multiphysics simulations, dynamic models and experimental tests

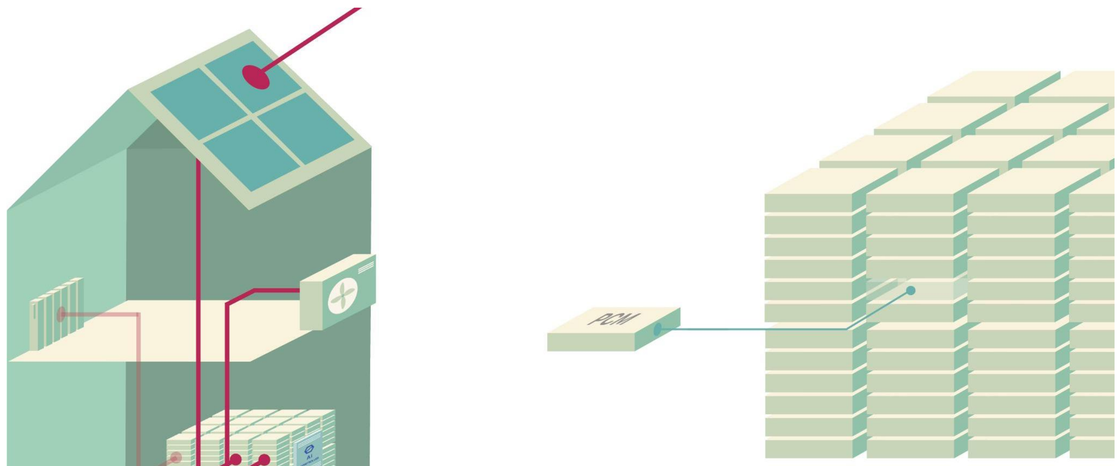

Figure 1: Illustration of the SeasonCell concept and the cell like storage unit

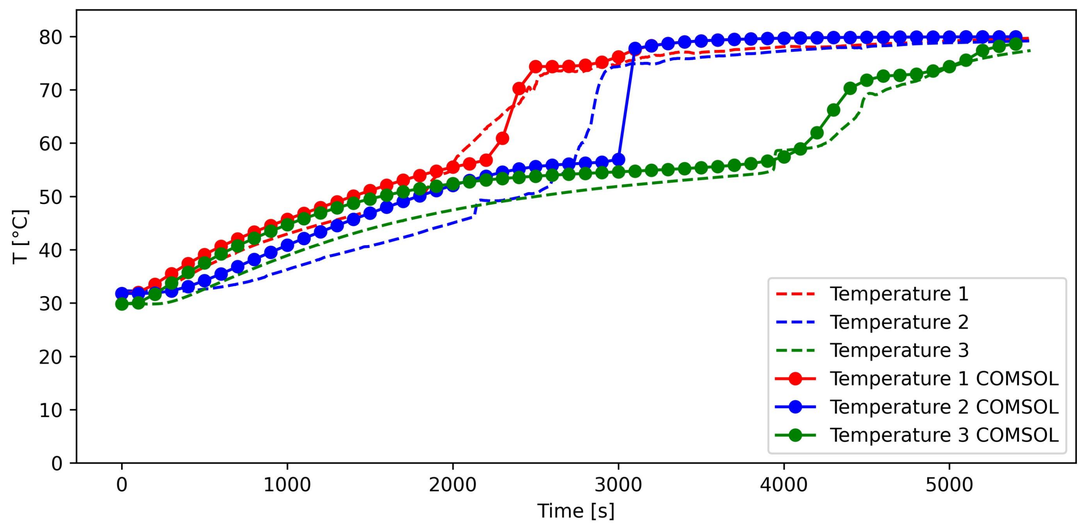

Figure 2: Comparison between measured temperature values and calculated temperature values of a melting cell

Figure 3: Comparison of the charging time of different concepts until the entire PCM domain is molten.

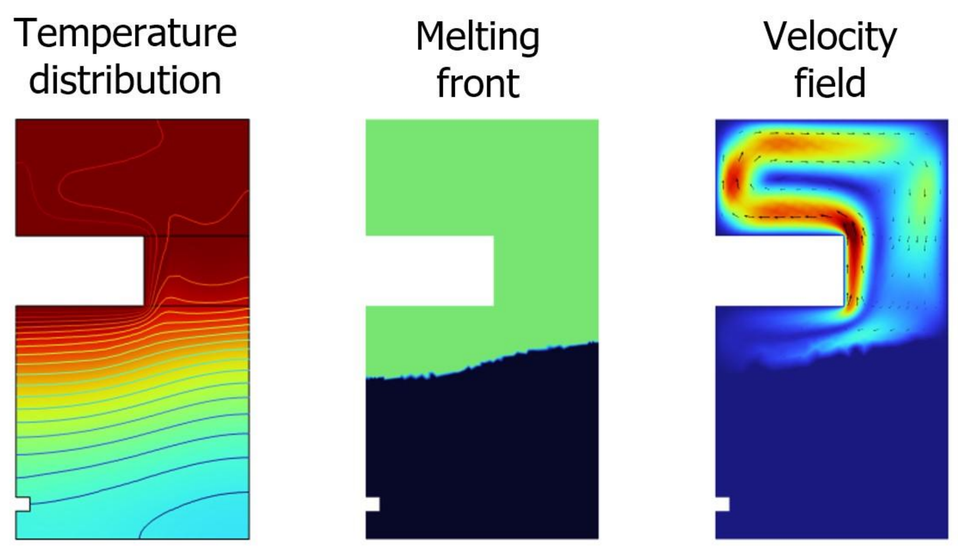

Figure 4: Visualization of the phase change material modeling with the temperature distribution on the left, the melting front in the middle, and the velocity field due to natural convection on the right.

Introduction

SeasonCell is developing a seasonal thermal energy storage system (STES) for the building sector. Heat is stored in cells with phase change material (PCM) and the phenomenon has been used in hand warmers for over 100 years. In summer, the cells are charged by excess CO2-neutral energy from photovoltaics in combination with a heat pump, and in winter the required heat is extracted by activating the respective cells. Since the storage system consists of several hundreds of such cells, the design of these cells is an important part of the overall concept. The design of the cell significantly determines the charging and discharging performance of the storage unit.

Procedure

In order to optimize such a cell, the behavior and properties of the individual components must first be known. Since the simulation of phase change materials has still not been completely researched, a more in-depth search was first carried out and the optimal software was selected.

With the multiphysics programme COMSOL, the different phenomena of the PCM could then be worked out and a simulation tool was developed in it, which allows the measured parameters of the PCM samples to be easily entered and the melting behavior and a novel variant of the crystallization behavior were successfully implemented. Thus, different cell designs could be investigated, and the simulation could be verified experimentally with the testing of a real cell.

Results

In this thesis, a customizable simulation tool was successfully developed, which allows to directly enter the parameters from the analytical laboratory measure-ments and thus to quickly store and use new materials in the multiphysics simulation. The crystallization behavior was verified with different papers and the melting behavior was experimentally verified with temperature sensors in a real cell. In the graph on the top right, it can be seen that the temperature curves in the simulation correspond very well with the measurements.

In addition, optimizations were made to the cell geometry and time savings in the charging process of as much as 40% were achieved. As a result, losses during the charging process are much lower due to the shorter charging time.

Raphael Moretti

Advisor
Prof. Dr. Gerhard S. Székely

Expert
Dr. Gianfranco Guidati

Industry partner
SeasonCell

SEASON CELL

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