State of charge determination of an ICE STORAGE

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Capacitive sensors are utilized to determine the state of charge (SoC) of an ice storage.

Capacitive sensors rely on the distinct difference in dielectric properties between the water and ice phases to determine the ice layer thickness.

The simulation of the ice storage model and the capacitive sensor readings from the experimental setup showed good agreement. This enables the SoC determination of ice storage and further effective operational control strategies.
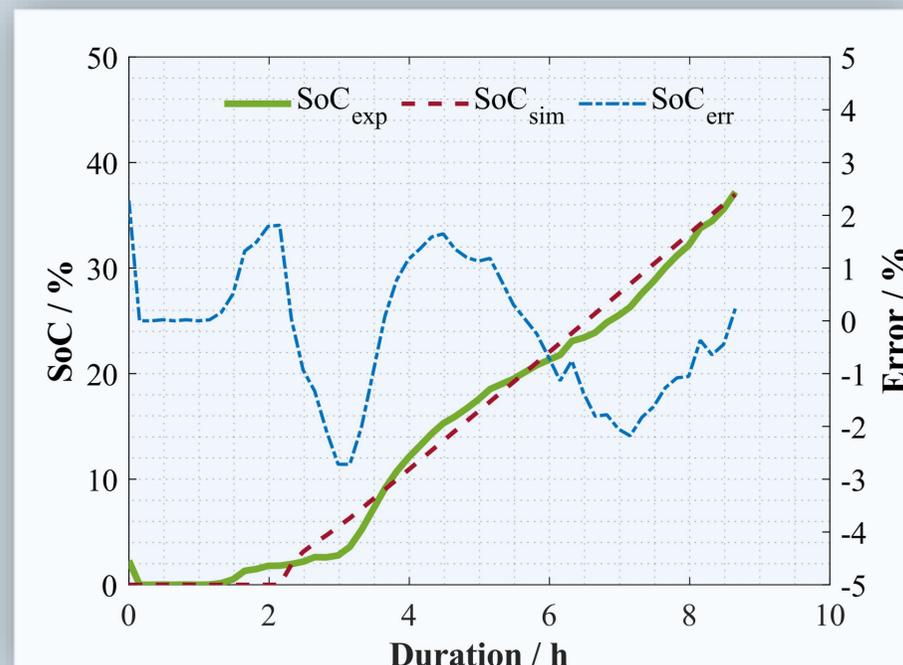

Comparing experimental and simulated SoC results.

Introduction

The adequate state of charge (SoC) determination of ice storages remains a challenge due to complex **phase changes**. However, SoC is vitally important for improving control strategies and maximizing their impact.

Hence, an **experimental ice storage setup** with steel coil heat exchanger equipped with a capacitive sensor was introduced to determine the ice layer thickness. The experimental efforts were paired with **numerical simulations of an ice storage model** to describe the SoC of the storage system. This work presents the correlation of the measurements and simulation results.

Experimental Setup
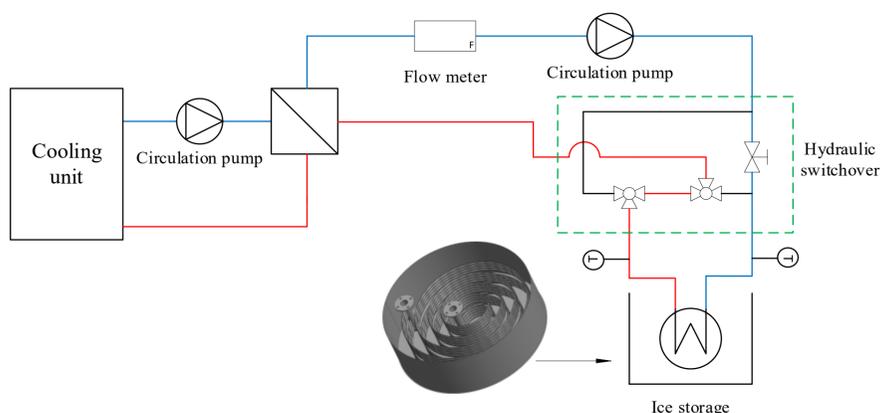
The setup, consisting of a steel spiral heat exchanger and cylindrical tank, is integrated in a hydraulic circuit with a cooling unit, pumps and flow meter. A **switchover** for changing the flow direction of the carrier fluid trough the heat exchanger was facilitated.

The setup is equipped with six temperature sensors and a commercial **capacitive sensor**[1] detecting icing degree is installed along the heat exchanger.

[1] Ice bank sensor, HB Products A/S

Modelling & Simulation

A discrete dynamic model of the ice store was developed for comparison with the experimental results and for subsequent system modelling. The model is based on a **one-dimensional energy balance**[2] and considers temperature-dependent fluid properties for the calculation of the heat transfer and phase change.

Temperature and SoC are calculated for each discrete node. This allows direct comparison with local temperature sensors or the capacitive SoC sensor for validation and subsequent calculation of the **global SoC** of the storage.

[2] H. Bastida et al., "Dynamic modelling of ice-based thermal energy storage for cooling applications," IET Energy Syst. Integr. 1–18, 2022, https://doi.org/10.1049/esi2.12061

Results
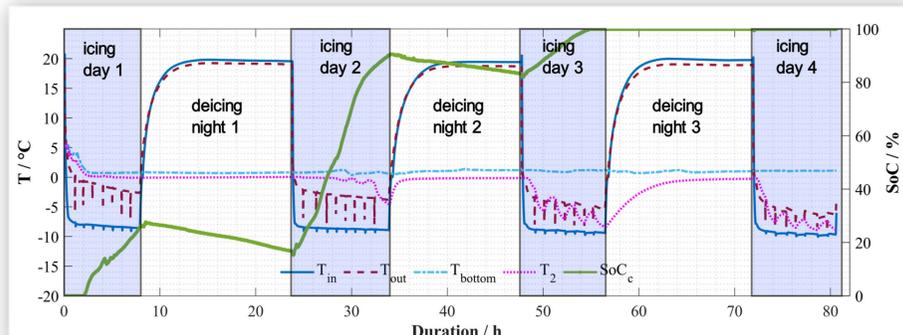
Exemplary measurement week: bidirectional icing routine.

The figure displays a typical **bidirectional icing** routine, where the flow direction is alternated in heat exchanger during the operation. The icing cycles are performed during working days and stopped over night, resulting in uncontrolled deicing at ambient conditions.