Advantages of dynamic system simulation for planning and operation of decentralized energy systems

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Overview

- **Introduction and motivation**
  - Properties of (renewable) energy systems
  - Advantages of dynamic system simulation
- **Software and methods**
  - Modeling concepts
  - Simulation software
- **Application case study**
  - Based on solar thermal test plant at Karlsruhe UAS
  - Simulation studies for different component dimensions

- **Properties of (renewable) energy systems**
  - Efficiency and applicability of components varies for different operation conditions
  - Strong dependencies on immutable but forecastable external influences, such as weather conditions and electricity prices
  - Typically include storage facilities such as (stratified) water storages, batteries, and also thermal masses of buildings which can be utilized for energy storage and load shifting
- **Advantages of dynamic system simulation**
  - Display component interaction under different operation conditions
  - Depiction of inter-temporal interaction and effects between storages and components

Introduction and motivation II

- Modeling concepts
  - **Black box modeling**
    - Purely date-driven models
    - Data collected during normal operation or specific tests
  - **White box modeling**
    - Models purely derived from physical laws
    - Requires detailed knowledge of underlying process
  - **Grey box modeling**
    - Basic structure formed using physical correlations
    - Model parameters are estimated from system data

    - Example: Heat storage model describe by mass an energy balances, whose heat loss coefficients are determined from measurement data

Introduction and motivation III

- **Simulation software**
  - Scientific computing frameworks such as **Matlab**, **SciPy**
  - **Modelica**-based simulation software
    - Both commercial (e. g. **Dymola**) and open-source (e. g. **OpenModelica**) simulation environments
    - Existing toolboxes for energy system simulations, e. g.:

      TIL (commercial model library for thermodynamic systems),
      Modelica Buildings Library (open-source model library for district energy and control systems),
      IDEAS (open-source model library for district energy systems)

Application case study I

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- The solar thermal test plant at Karlsruhe UAS

Control cabinet, cold storage, ACM, hot storage, pumps (cellar)

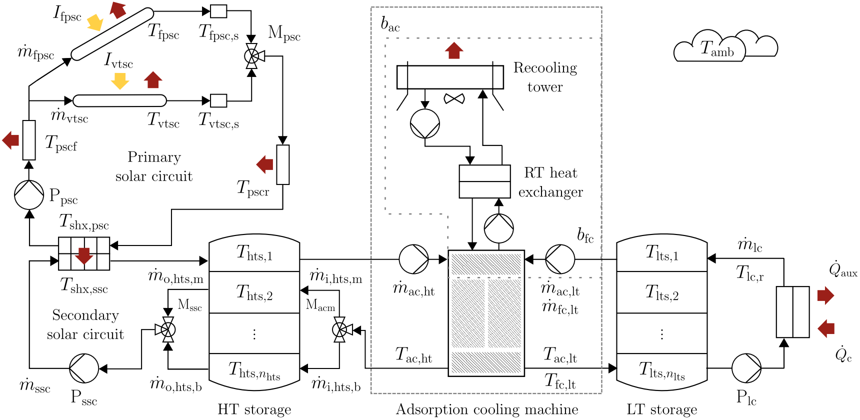
Recooling unit (roof)

Fan coils (atrium)

Plate collectors (roof)

Vacuum tube collectors (roof)

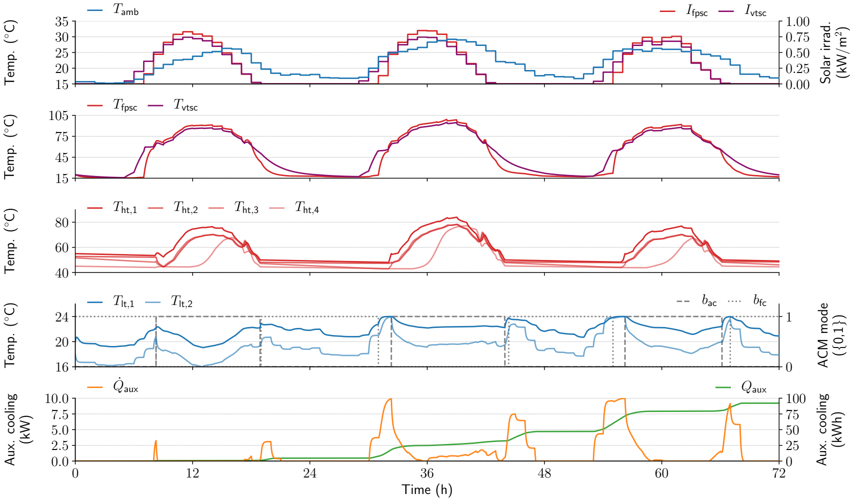
- **Simplified version of the plant**



Application case study III

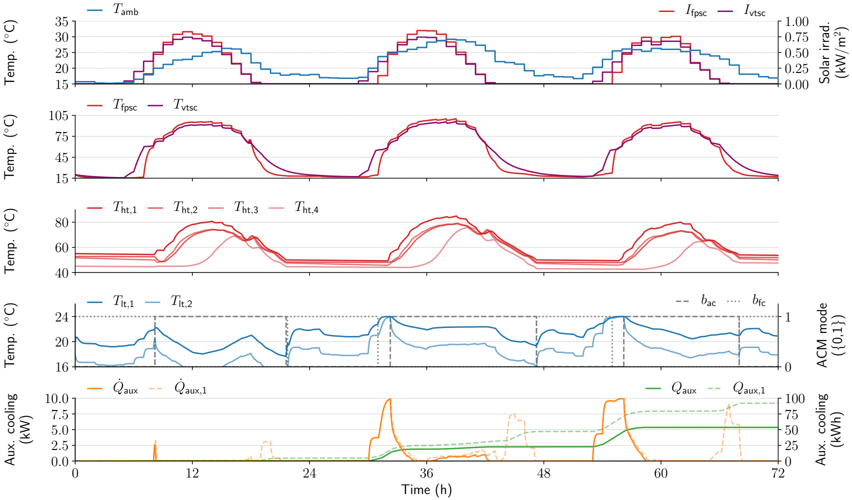
- **Solar cooling for server cooling**
  - System applied for covering of constant cooling load $\dot{Q}_c = 10\,\text{kW}$
  - Auxiliary device provides additional cooling power $\dot{Q}_{aux}$
  - Aim is to optimize system configuration to reduce the use of auxiliary cooling power and energy
- **Simulation setup**
  - Simulation of three successive, exemplary summer days
  - Grey-box dynamic models, self-developed in Modelica
  - Simulations are carried out for:
    - a base scenario,
    - a scenario with increase solar power and HTS
    - a scenario with increase solar power, HTS and LTS

- **Simulation 1: base scenario**

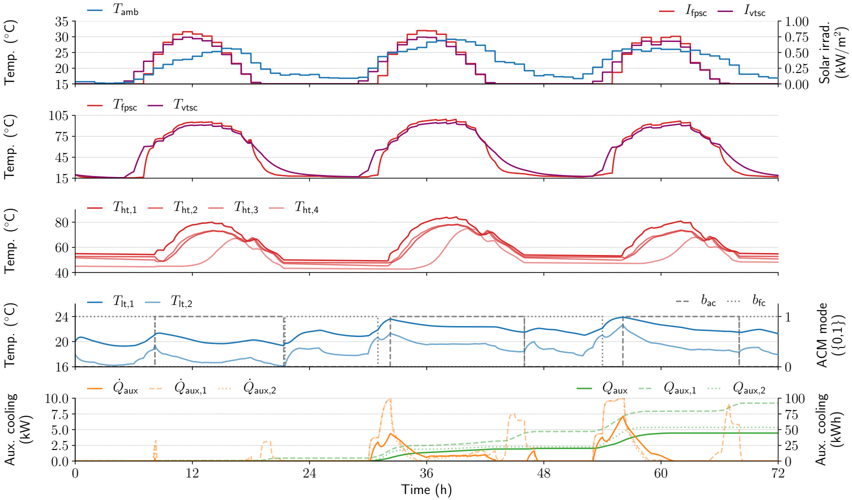


Application case study V

- **Simulation 2: increased solar power and HTS**



- **Simulation 3: increased solar power, HTS, and LTS**



Application case study VII

- **Results of the simulation study**
  - An increase of the solar collector surface by 20 % and an increase of the HTS volume to 4 m^3 reduces the auxiliary energy consumption by ∼42 %
  - An additional increase of the LTS volume to 4 m^3 allows to further reduce auxiliary energy consumption by an additional ∼4 % and the peak auxiliary cooling power demand by ∼29 %
  - Dynamic system simulation allowed to identify possibilities for reduction of both total auxiliary energy and peak power utilization

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Thank you for your attention!

I'm looking forward to your questions

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