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Towards, Competitive, Reliable, Safe and Sustainable Concentrated Solar Power (CSP) Plants

Midterm meeting REA, 18-19 April 2024

DC 3 - Task 1.3: Improved steam cycle layouts to improve flexibility and reduce cost of the CSP plants power block

Eylül Gedik

Supervisor: Univ.-Prof. Dr.-Ing. habil. Manfred Wirsum

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Background

ODTÜ METU Middle East Technical University
Mechanical Engineering

Lowest: 0.00 **CPGA:3.13/4.00** Highest: 4.00

ODTÜ METU Middle East Technical University
Mechanical Engineering

Lowest: 0.00 **CPGA:3.93/4.00** Highest: 4.00

Early Stage Researcher

SolarTwins | **Solar Twinning to Create Solar Research Twins**

SolarTwins has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 856619.

Consortium

ODTÜ METU | ODTÜ GÜNAM | Ciemat PSA | DLR

Coordinator

M.Sc. Thesis: PV CSP Hybridization to Produce Irrigation Water Using Desalination and Wastewater Treatment, Middle East Technical University, 2023.

Trainings

- Workshops and Courses
  - German Language Course, RWTH Aachen University, *10.2023-02.2024*
  - Open Access Publishing, RWTH Aachen University, *03.2024*
  - DFG Funding Opportunities for Academic Careers, Germany, *01.2024*
  - CST4ALL Workshops, EU CST4ALL Project
    - Cross-Cutting Materials Challenges of Renewable Energy Technologies, *11.2023*
    - Hybridisation of Concentrated Solar Thermal Technologies (CST) with PV, *02.2024*
    - R&I Challenges for the Hybridization of CST with Other Renewable Energy Technologies, *03.2024*
- Decarbonising Electricity and Heat Supply with Concentrating Solar Thermal Technologies, German Solar Association, *03.2024*

Networks, Visits and Selected DEC

- Collaboration and Networking Meetings
  - John Cockerill, Former TOPCSP Project Partner, *02.2024*
  - Soliterm, SME in Germany, *02.2024*
- Site Visits
  - Heliosteam Demo Solar Tower, Türkiye, *12.2023*
  - DLR Jülich Solar Tower, Germany, *12.2023*
- Memberships
  - Marie Curie Alumni Association (MCAA), *03.2024*
- Selected DEC
  - Presentation of TOPCSP at EU-SolarHub Meeting, *12.2023*
  - Article on TOPCSP in EU-CST4ALL Project Newsletter, *04.2024*

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Research Management

- Supervised Student Theses
  - An Assessment of the Cooling Systems for CSP Plants

  Mini Thesis, Double Degree M.Sc. Program in collaboration with Tschingua University (completed)
  - How to unlock the market opportunities for CSP?

    B.Sc. Thesis (in progress)
  - Application of an electrical salt heater to the TES to decrease the minimum load of CSP plant

    M.Sc. Thesis (in progress)

Anticipated Conferences, Events and Publications

- Conferences
  - EuroSun 2024, Cyprus
  - SolarPACES 2024, Italy
- Colloquia
  - EU-Solaris Doctoral Colloquium, 2024, France
- Magazine Commentary Article
  - Redefining the Role of CSP: Revisiting the Performance Parameters

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Research Project: Improved steam cycle layouts to improve **flexibility** and **reduce cost** of the CSP plants power block

Overview of the Concepts

- Flexibility of the Power Block
  - Shortening the start-up time
  - Lowering the minimum load
  - Improving ramp rate
  - Off-design performance
  - Environmental compatibility

- Cost Reduction of the Power Block
  - Decreasing the $CAPEX$
  - Decreasing the $OPEX$
  - Increasing the life time
  - Increasing the capacity factor
  - Valuable electricity production

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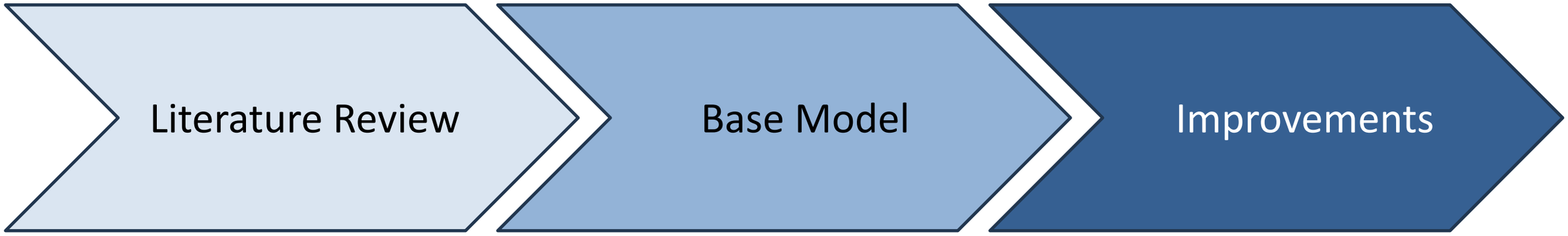
Research Plan: Phases and Current State



- Literature Review
  - GAP: Focus on the commercial steam cycle of CSP Plants
  - GAP: New KPIs are required
- Breakdown of the Cost Structure
  - GAP: Lack of up-to-date, detailed data

- Construction of the Base Model
  Dynamic Simulations through Modelica
- Investigation of the Libraries
- Sizing and Preliminary Design of Components
- Input Collection
- Validation

- Application of the Improved Layouts
- Assesment of the Improved Layouts

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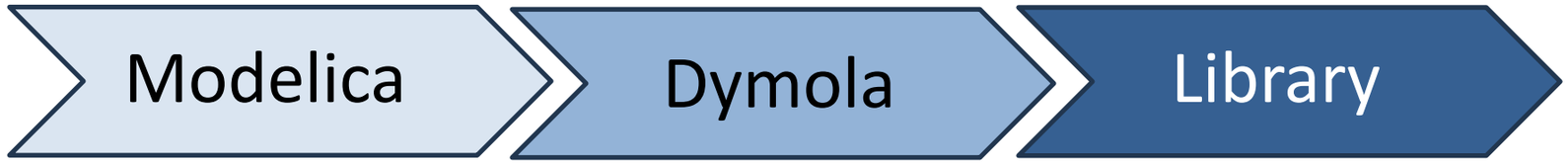
Research Tools



Library	Advantages	Disadvantages
ThermoPower	Well-proven	Not maintained
ThermoSysPro	Well-documented	Non-compatible with MSL
ClaRa	Well-proven	Commercial Not maintained
TIL	Compatible with Modelica 4.0	Commercial Lack of detailed component models for PB
SolarTherm	Tailored for CSP	Lack of detailed component models for PB
TRANSFORM	Compatible with Modelica 4.0 Compatible with MSL Detailed component models for PB	Beta Stage

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Research: Component Models and Inputs

Steady Components	Non-steady Components
Steam Turbine	Heat Exchangers
Pump	Feed Water Tanks
Valve	Pipes

(Hirsch et al., 2011; Richter et al., 2015)

Inputs and Preliminary Design

- Heat Balances:
  - Currently: (Kolb, 2011)
  - Alternative: Literature
  - Alternative: Analysis
  - Preferred: Manufacturer data
- Heat Exchangers Sizing:
  - Currently: Kern's Method
- Further Sizing: Secondment of Vladimir Naumov at RWTH, IKDG.

Hirsch, T., Ahlbrink, N., Pitz-Paal, R., Boura, C. J. T., Hoffschmidt, B., Gall, J., Abel, D., Nolte, V., Wirsum, M., Andersson, J. A. E., & Diehl, M. (2011). *Dynamic Simulation of a solar tower system with open volumetic receiver - a review on the vICERP project*.
Kolb, G. (2011). *An evaluation of possible next-generation high temperature molten-salt power towers.* https://doi.org/10.2172/1035342
Richter, M., Möllenbruck, F., Starinsk, A., Oeljeklaus, G., & Görner, K. (2015). *Flexibilization of Coal-fired Power Plants by Dynamic Simulation*. 715–723. https://doi.org/10.3384/ecp15118715

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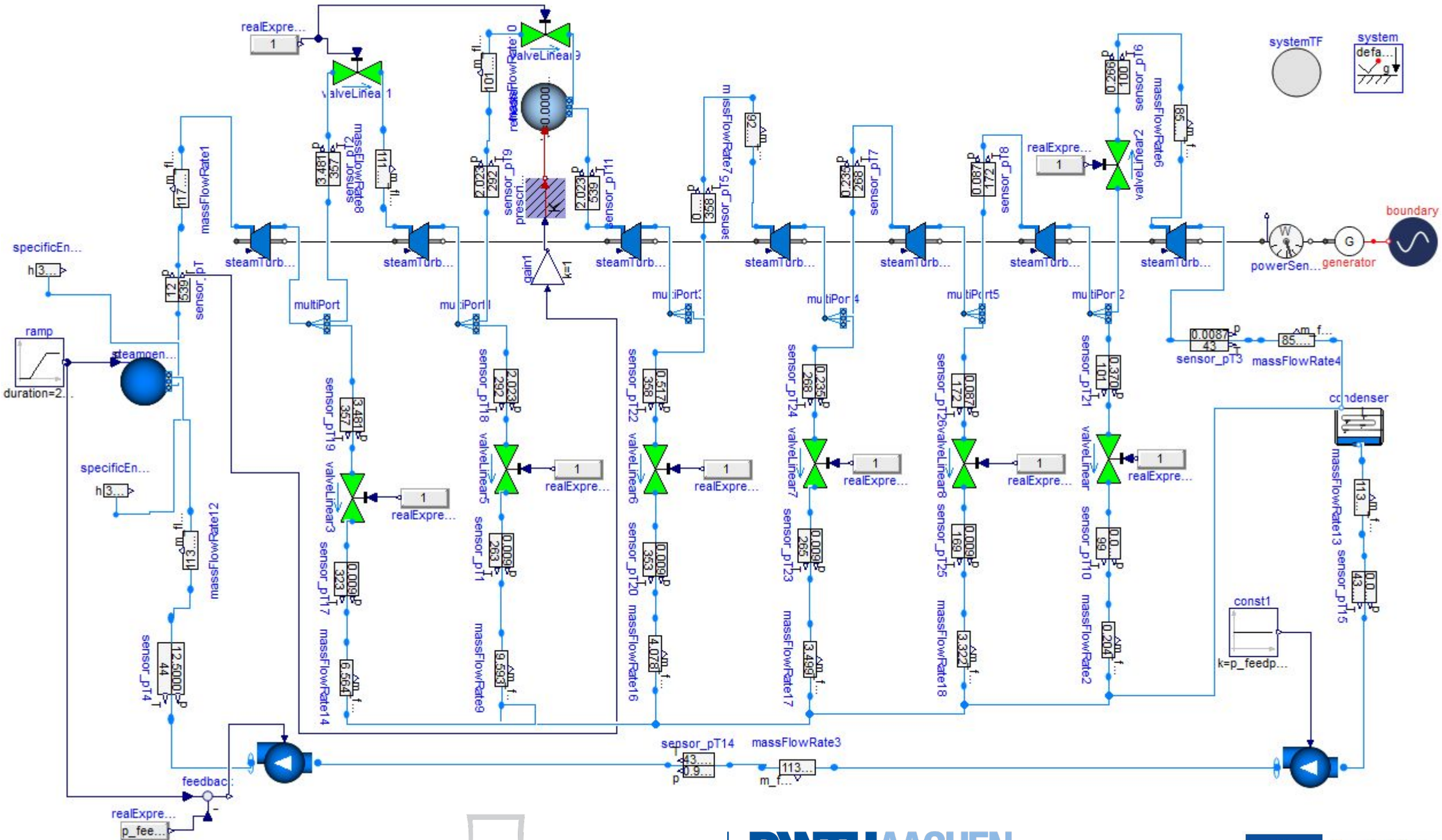
Research: Current State of the Model



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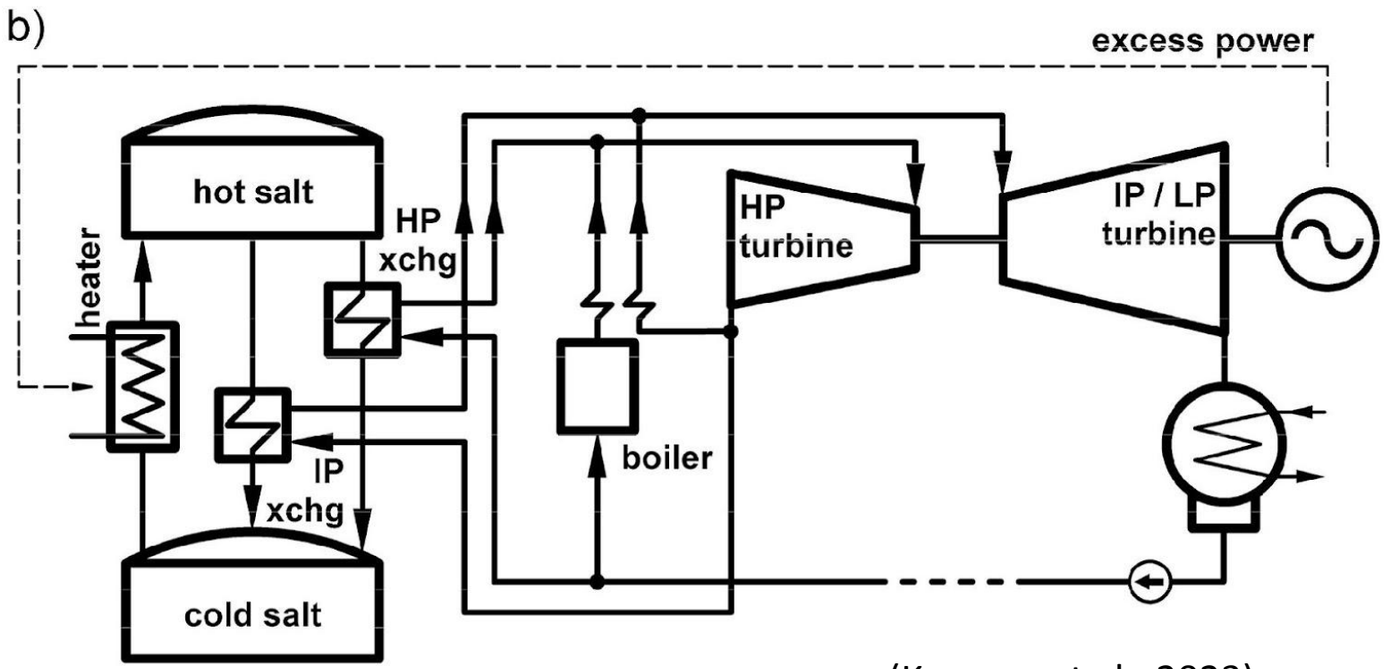
Research: Outlook and Improvements

- Lowering the minimum load
  - Utilizing the turbine output inside the power plant
    - Excess electricity
      - TES recharging
      - Lowering the molten salt temperature at the receiver
      - Heating the steam

    by electrical heaters



(Kosman et al., 2023)

First Secondment at University of Sevilla!

Kosman, W., Rusin, A., & Reichel, P. (2023). Application of an energy storage system with molten salt to a steam turbine cycle to decrease the minimal acceptable load. *Energy*, *266*, 126480. https://doi.org/10.1016/j.energy.2022.126480

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Challenges and Opportunities

Challenges

- Input Data
- Validation Data
- Control Structure
- Cost Structure

Further Outlook & Opportunities

- Fast Load Changes
  - Steam accumulators
  - Hot water tanks
  - Extraction valves
- Water Considerations
  - Boiler and cooling tower blowdown
  - Cooling system
- Start-up
  - PV+CSP Hybridization
    - Prewarming of the steam generator
    - Prewarming of the steam turbine

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Thank you for your attention!

Contact

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