Comparative Analysis of Price-based Control Strategies for a High Temperature Thermal Energy Storage System

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Agenda

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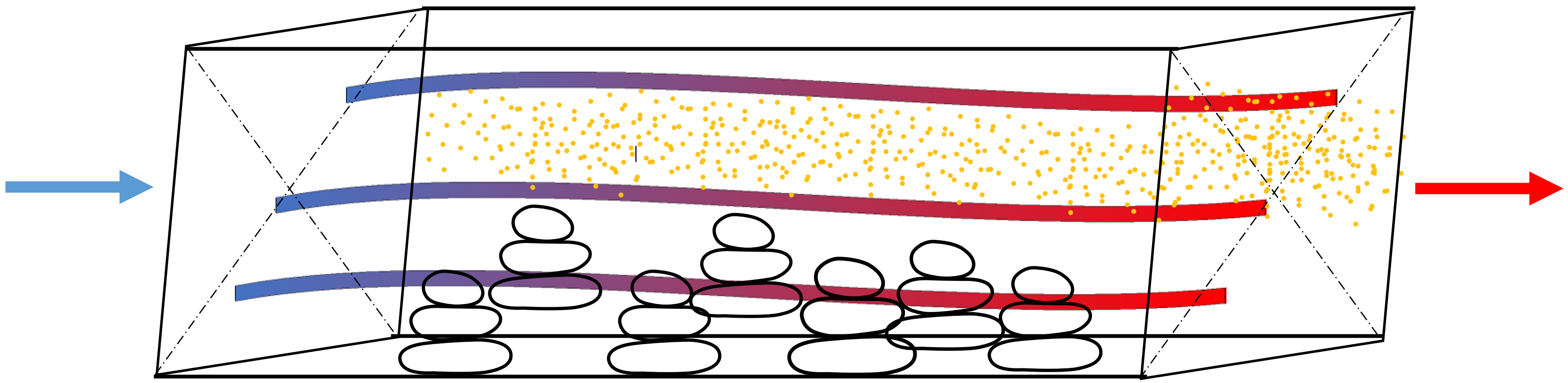
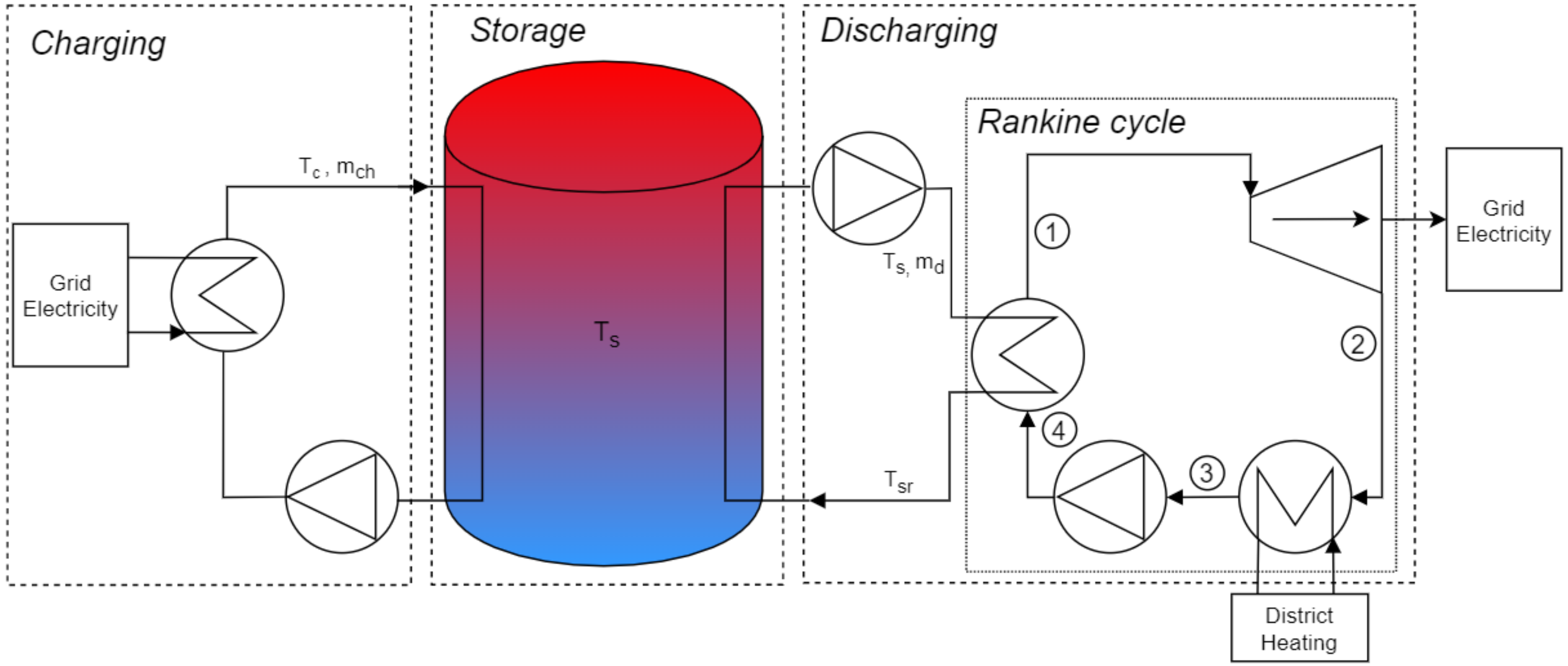
- Background and motivation
- Models
- Simulation setup
- Preliminary results
- Conclusions and future works

Background and motivation

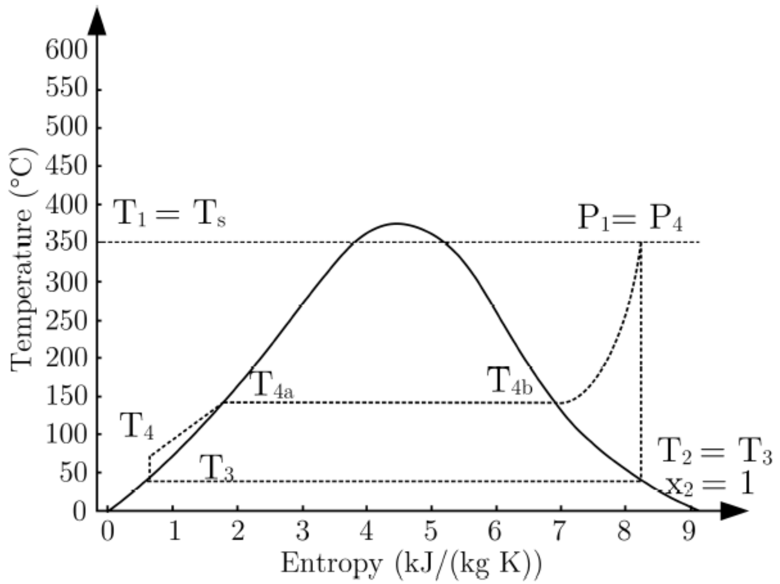
- The common use energy storage systems to deal with mismatch between energy demand and supply
- The use of advanced control strategies (eg. MPC) to enhance energy efficiency
- A lot of works focus on MPC for water-based thermal storage
- In this work, an MPC for high temperature thermal storage (HTTES) systems is developed



Models



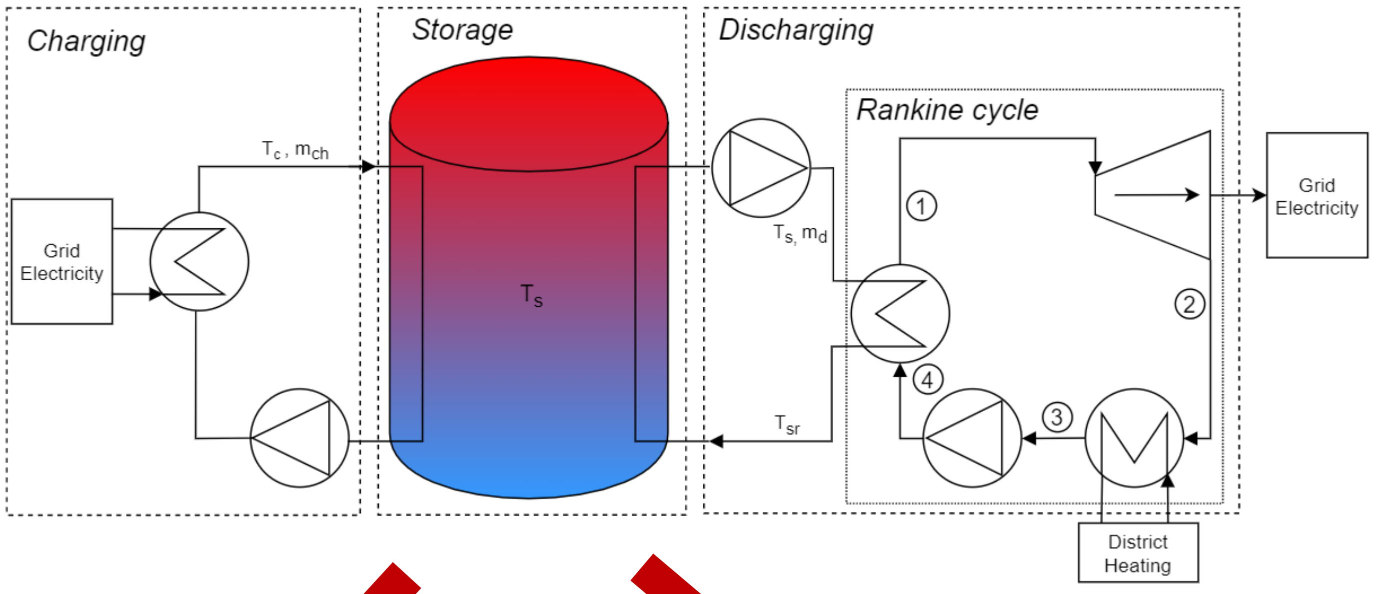
Schematic diagram of the HTTES



Rankine cycle

Charging	Discharging	Heat loss
$\dot{Q}_{ch} = \dot{Q}_{ch,in} - \dot{Q}_{ch,out} = \dot{m}_{ch} \cdot c_{air} \cdot (T_c - T_s)$ $P_{el} = \dot{m}_{ch} \cdot c_{air} \cdot (T_c - T_s)$	$\dot{Q}_d = \dot{Q}_{d,out} - \dot{Q}_{d,in} = \dot{m}_d \cdot c_{air} \cdot (T_s - T_{sr})$	$\dot{Q}_{loss} = U \cdot A_s \cdot (T_s - T_{amb})$

Models



- The rock is Swedish diabase
- The volume of the rocks is 1.5 m^3, and the mass of the rocks is 2495 kg. The storage measures 1 m by 1 m by 1.5 m

Specification of relevant physical properties

Property	Unit	Symbol	Value
Heat capacity of air	$[J/kg \cdot K]$	cp_{air}	1000
Density of Swedish Diabase (solid)	$[kg/m^3]$	$\rho_{r,s}$	3007
Volumetric heat capacity of Swedish Diabase (solid)	$[J/m^3 \cdot K]$	$cp_r \cdot \rho_{r,s}$	3,824,900
Specific heat capacity of Swedish Diabase (solid)	$[J/kg \cdot K]$	cp_r	1272
Density of Swedish Diabase (packed bed)	$[kg/m^3]$	$\rho_{r,p}$	1663.33

Model predictive controller

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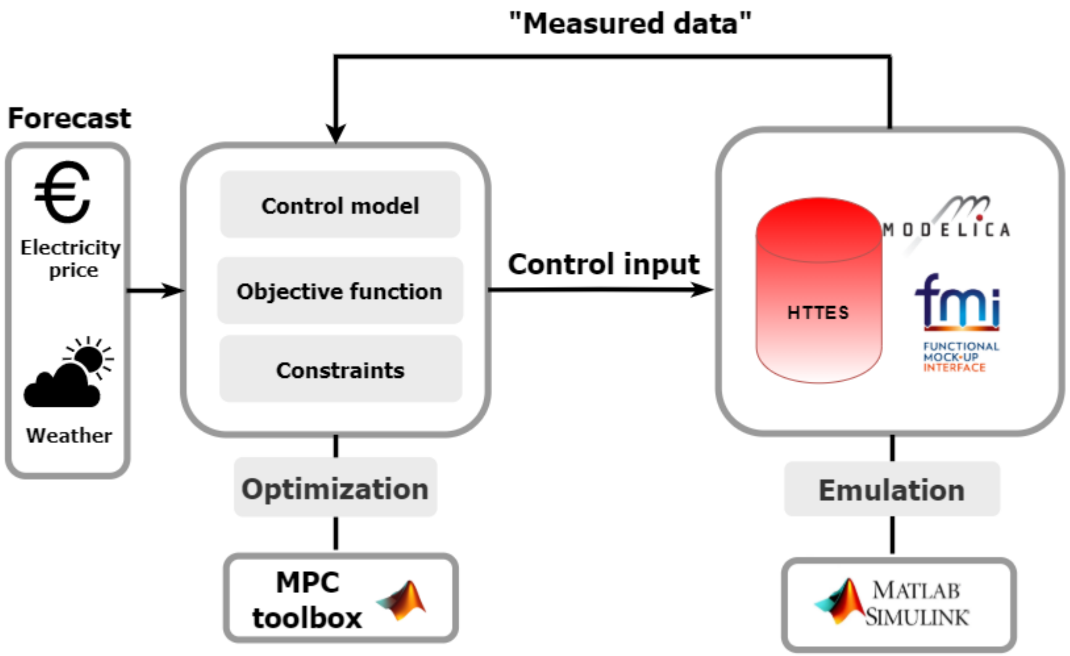
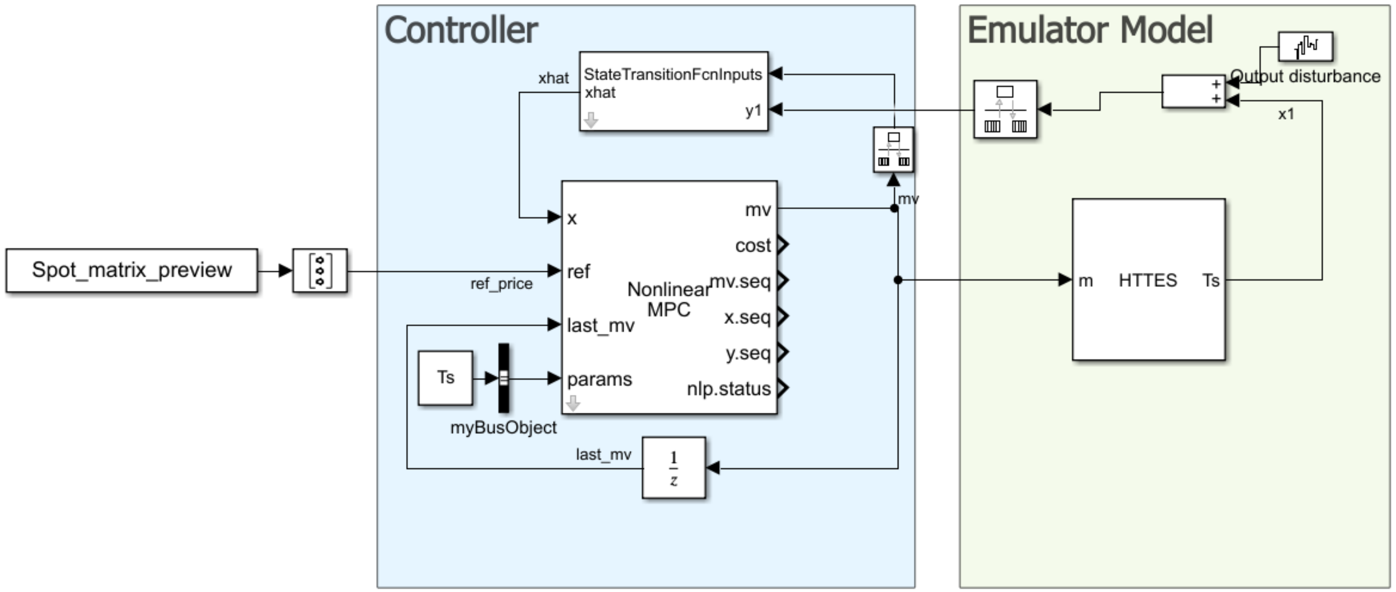


Overview of the simulation setup



Implementation of model predictive controller

Model predictive controller

- Control model: nonlinear state space model

- Economic MPC

$$J_{rev} = -\sum_{i=k}^{P} \left(\frac{P_{g,i}}{3.6 \cdot 10^9} \cdot spot_{e,i} + \frac{\dot{Q}_{c,i}}{3.6 \cdot 10^9} \cdot price_{DH,i} - \frac{P_{el,i}}{3.6 \cdot 10^9} \cdot spot_{e,i} \right)$$

Subject to:

System dynamics

100 °C < Ts < 600 °C

-3 < u < 3

- Prediction horizon: 24 h
- Control horizon: 15 minutes

Rule-based controller

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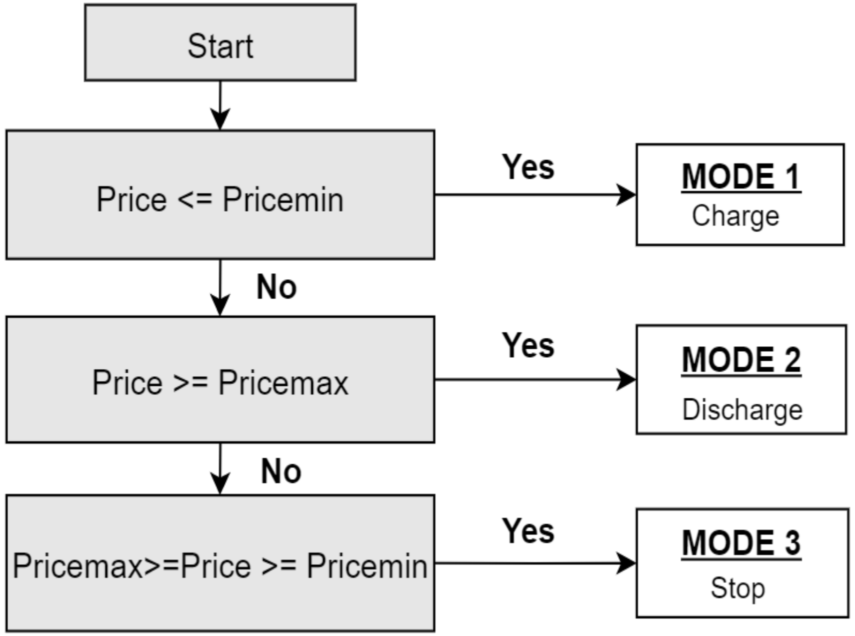
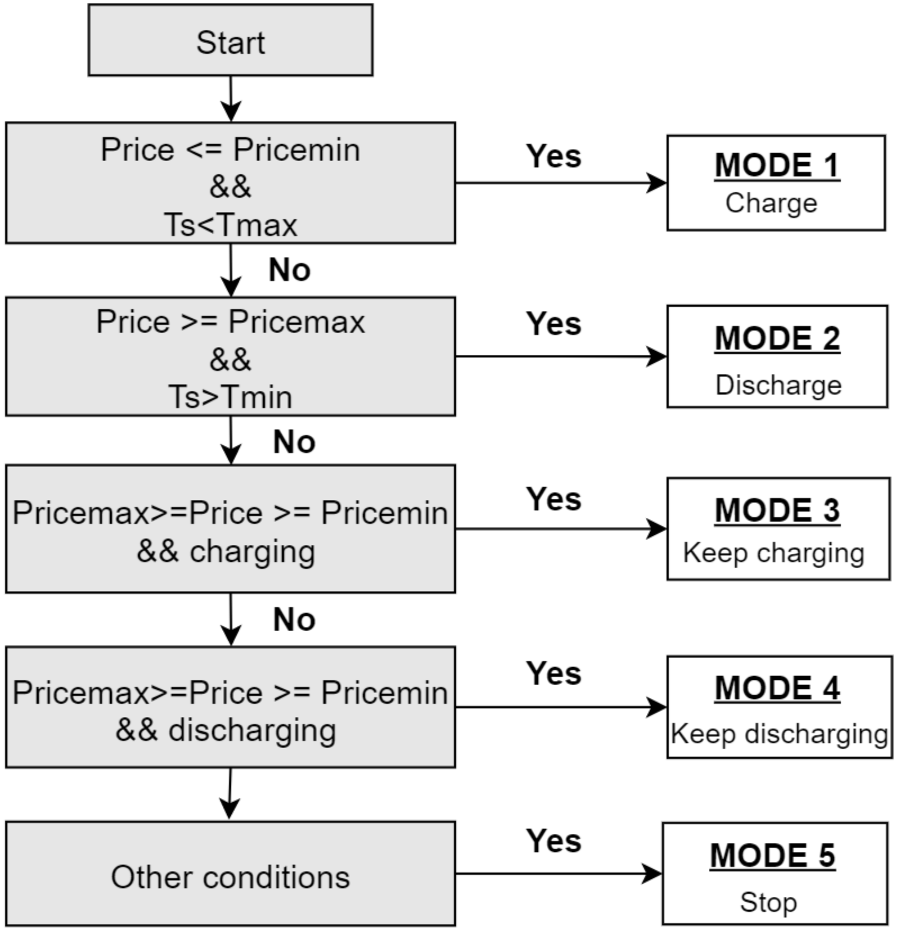


Control logic of RBC 1



Control logic of RBC 2

Rule-based controller

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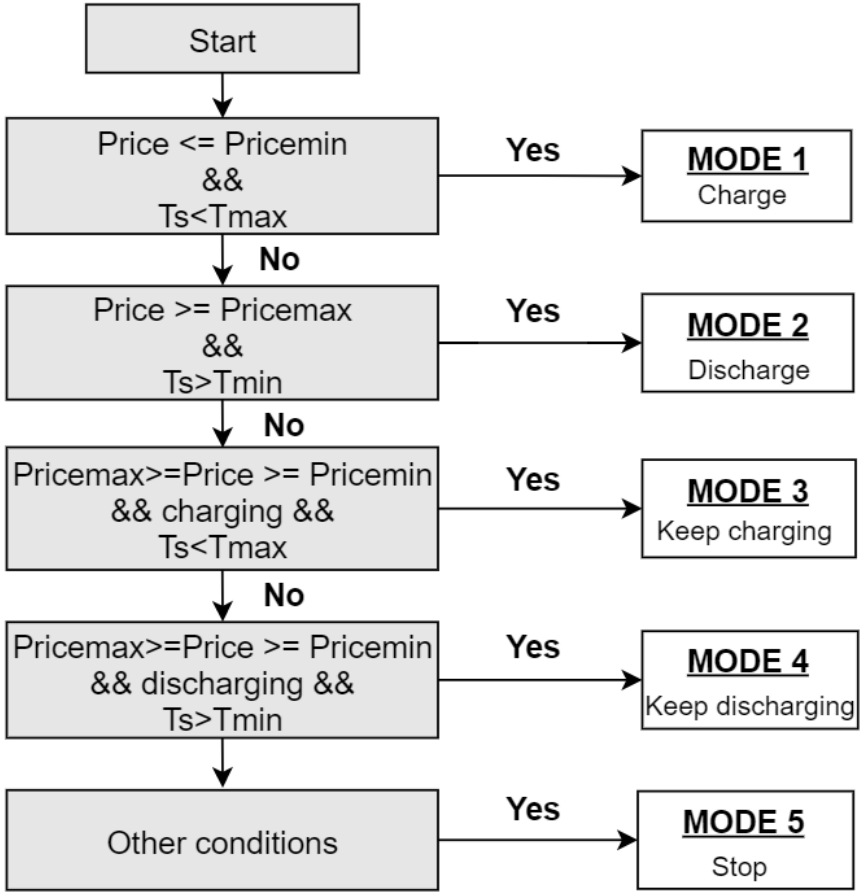


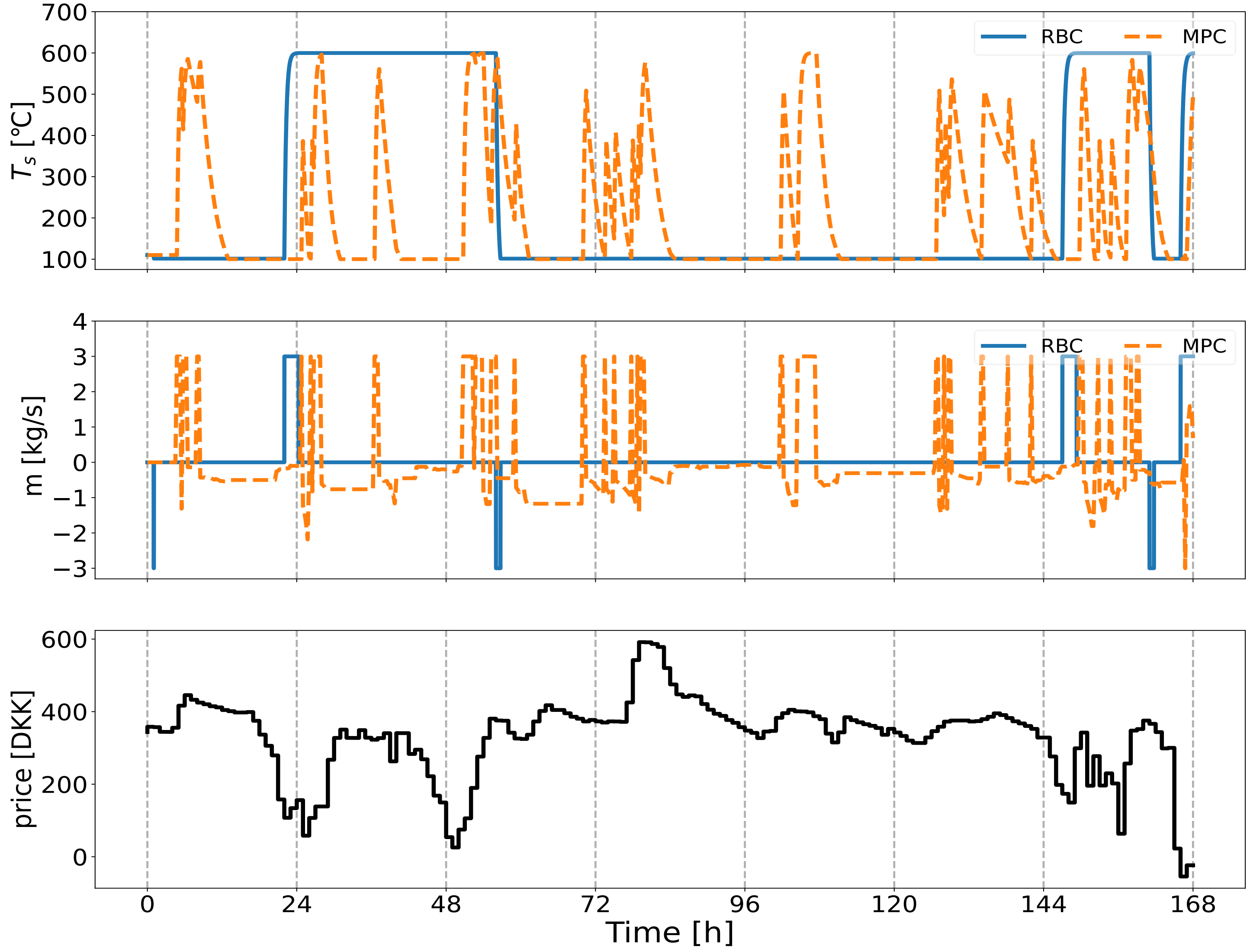
Control logic of RBC 3

- Pricemin = 258 DKK/MWh
- Pricemax = 358 DKK/MWh

KPI for simulating 7 days

KPI	RBC 1	RBC 2	RBC 3
Total net revenues [DKK]	86	105	171

Preliminary results



MPC vs. RBC 3

KPI	RBC 3	MPC
Total net revenues [DKK]	171	469.7

Conclusions and future works

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- The preliminary results show that MPC outperforms RBC. However, the current RBC performance highly relies on the choice of electricity price threshold.

- The continuation of the work involves development of a more detailed emulation model.

- The continuation of the work involves tuning the Modelica-based RBC settings based on price margin including customizing different RBCs under different price scenarios.

THANK YOU FOR YOUR ATTENTION

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