IBPSA Project 1

BOPTEST Initial tests

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Expert meeting
October 13, 2020

THERMAL SYSTEMS SIMULATION

KU LEUVEN

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- BOPTEST is ready enough for testing!
  - Three emulator models
  - Module for simulation and data handling
  - KPI calculation module
- Already some history:

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Identification of multi-zone grey-box building models for use in model predictive control

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ABSTRACT
Predictive controllers can greatly improve the performance of energy systems in buildings. An important challenge of these controllers is the need of a building model accurate and simple enough for optimization. Grey-box modelling stands as a popular approach, but the identification of reliable grey-box models is hampered by the complexity of the parameter estimation process, specifically for multi-zone models. Hence, single-zone models are commonly used, limiting the performance and applicability of the predictive controller. This paper investigates the feasibility of the identification of multi-zone grey-box building models and the benefits of using these models in predictive control. For this purpose, the parameter estimation process is split by individual zones to obtain an educated initial guess. A virtual test case from the BOPTEST framework is contemplated to assess the simulation and control performance. The results show the relevance of modelling thermal interactions between zones in the multi-zone building.

ARTICLE HISTORY
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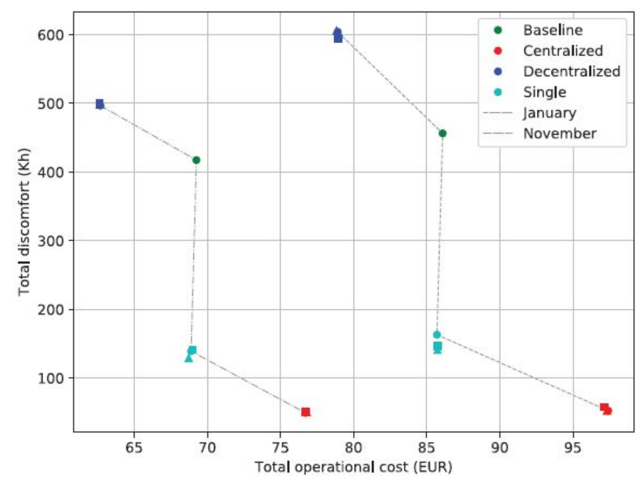
KEYWORDS
Model predictive control; building modelling; grey-box modelling; multi-zone; BOPTEST



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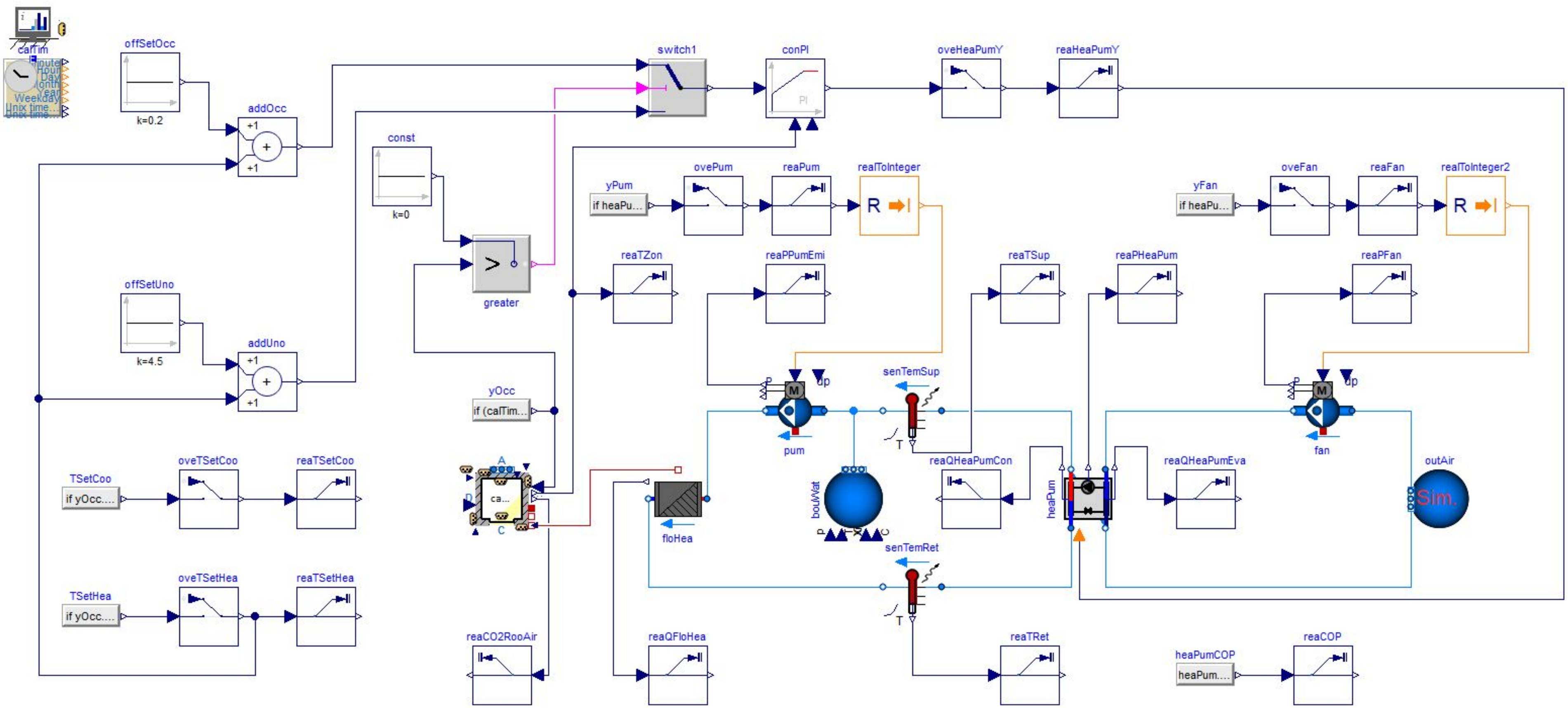
- Bestest hydronic case with heat pump



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Single zone residential hydronic example using a heat pump as heating production system

Information

This is a single zone residential hydronic system model with an air-source heat pump and floor heating for WP 1.2 of IBPSA project 1.

Building Design and Use

Architecture

This model represents a simplified residential dwelling for a family of 5 members. The building envelope model is based on the BESTEST case 900 test case. The envelope model is therefore similar to the one used in IDEAS.Examples.IBPSA.SingleZoneResidentialHydronic but it is scaled to an area that is 5 times larger. Particularly, the model consists of a single zone with a rectangular floor plan of 13.4 by 17.9 meters and a height of 2.7 m. The zone further consists of several south-oriented windows, which are modelled using a single window of 24 m2.

Constructions

Exterior walls

The walls are modeled using IDEAS.Buildings.Components.OuterWall and consist of the following layers:

Name	Thickness [m]	Thermal Conductivity [W/m-K]	Specific Heat Capacity [J/kg-K]	Density [kg/m3]
Layer 1 (wood siding)	0.009	0.14	900	530
Layer 2 (insulation)	0.0615	0.04	1400	10
Layer 3 (concrete)	0.1	0.51	1000	1400

Floor

The floor is modeled using IDEAS.Buildings.Components.SlabOnGround and consists of the following layers:

Name	Thickness [m]	Thermal Conductivity [W/m-K]	Specific Heat Capacity [J/kg-K]	Density [kg/m3]
Layer 1 (roof deck)	0.019	0.14	900	530
Layer 2 (insulation)	0.20	0.02	1470	30
Layer 3 (screed)	0.05	0.6	840	1100
Layer 4 (tile)	0.01	1.4	840	2100

Roof

The roof is modeled using IDEAS.Buildings.Components.OuterWall and consist of the following layers:

Name	Thickness [m]	Thermal Conductivity [W/m-K]	Specific Heat Capacity [J/kg-K]	Density [kg/m3]
Layer 1 (wood siding)	0.009	0.14	900	530

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Model IO's

Inputs

The model inputs are:

- `oveTSetHea_u` [K] [min=288.15, max=296.15]: Zone operative temperature setpoint for heating
- `oveTSetCoo_u` [K] [min=296.15, max=303.15]: Zone operative temperature setpoint for cooling
- `ovePum_u` [1] [min=0.0, max=1.0]: Integer signal to control the emission circuit pump either on or off
- `oveHeaPumY_u` [1] [min=0.0, max=1.0]: Heat pump modulating signal for compressor speed between 0 (not working) and 1 (working at maximum capacity)
- `oveFan_u` [1] [min=0.0, max=1.0]: Integer signal to control the heat pump evaporator fan either on or off

Outputs

The model outputs are:

- `reaQFloHea_y` [W] [min=None, max=None]: Floor heating thermal power released to the zone
- `reaCOP_y` [1] [min=None, max=None]: Heat pump COP
- `reaTZon_y` [K] [min=None, max=None]: Operative zone temperature
- `reaTSetHea_y` [K] [min=None, max=None]: Zone operative temperature setpoint for heating
- `reaPFan_y` [W] [min=None, max=None]: Electrical power of the heat pump evaporator fan
- `reaFan_y` [1] [min=None, max=None]: Control signal for fan
- `reaCO2RooAir_y` [ppm] [min=None, max=None]: CO2 concentration in the zone
- `reaPum_y` [1] [min=None, max=None]: Control signal for emission cirquit pump
- `reaPPumEmi_y` [W] [min=None, max=None]: Emission circuit pump electrical power
- `reaQHeaPumCon_y` [W] [min=None, max=None]: Heat pump thermal power exchanged in the condenser
- `reaHeaPumY_y` [1] [min=None, max=None]: Block for reading the heat pump modulating signal
- `reaPHeaPum_y` [W] [min=None, max=None]: Heat pump electrical power
- `reaTSetCoo_y` [K] [min=None, max=None]: Zone operative temperature setpoint for cooling
- `reaQHeaPumEva_y` [W] [min=None, max=None]: Heat pump thermal power exchanged in the evaporator
- `reaTRet_y` [K] [min=None, max=None]: Return water temperature from radiant floor
- `reaTSup_y` [K] [min=None, max=None]: Supply water temperature to radiant floor

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- Data generation from baseline controller → what it takes:

```
import requests

url = 'http://127.0.0.1:5000'

for _ in range(24):
    mea = requests.post('{0}/advance'.format(url), data={}).json()

data = requests.get('{0}/results'.format(url)).json()

kpis = requests.get('{0}/kpi'.format(url)).json()
print(kpis)
```

```
'ener_tot':     64.06364911022155
'emis_tot':     10.698629401406995
'idis_tot':     0.0
'tdis_tot':     1.4326337463676793
'time_rat':     0.0248040721517699
'cost_tot':     3.4274052273968523
```

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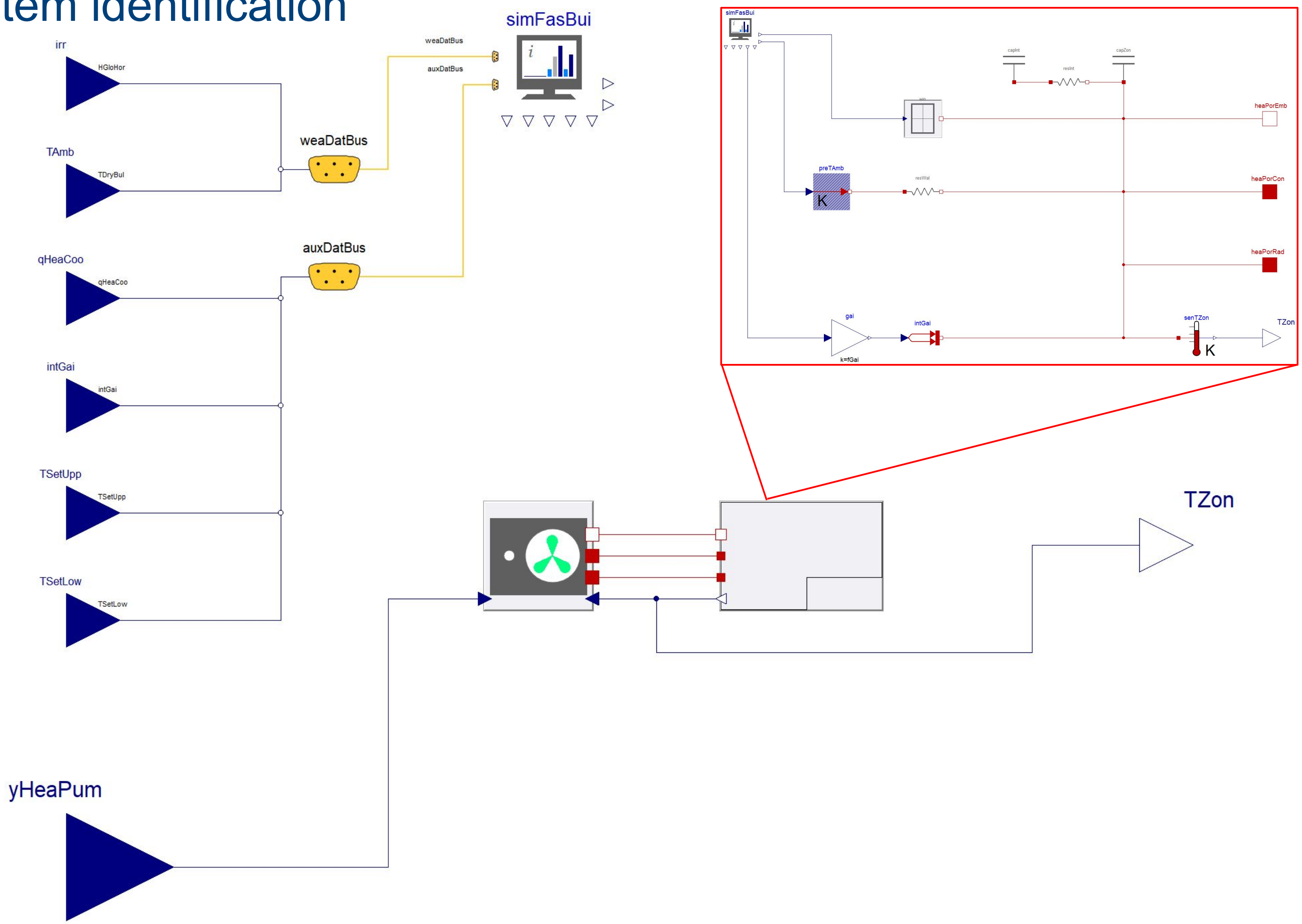
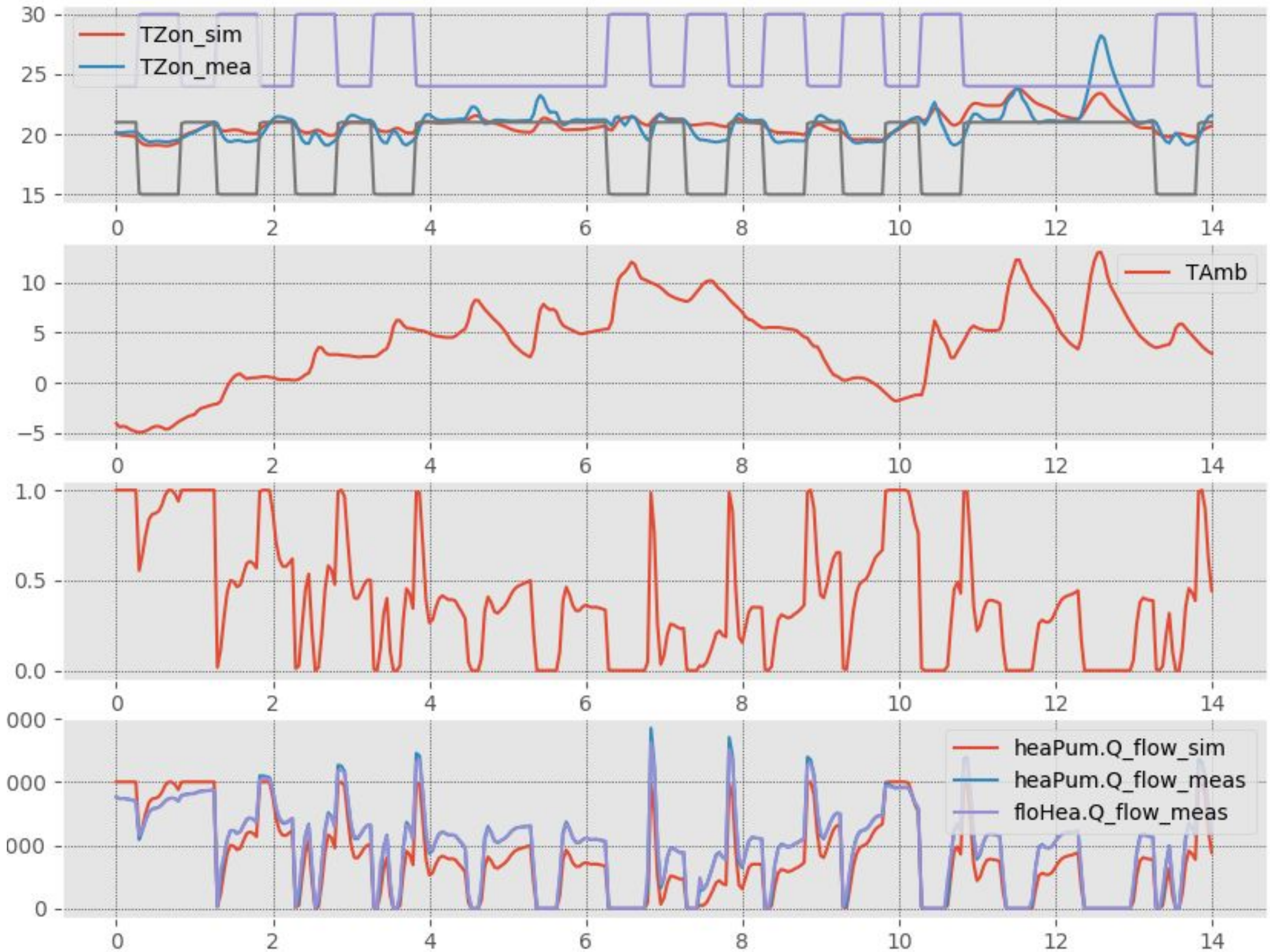
- System identification



BOPTEST Initial tests

- System identification



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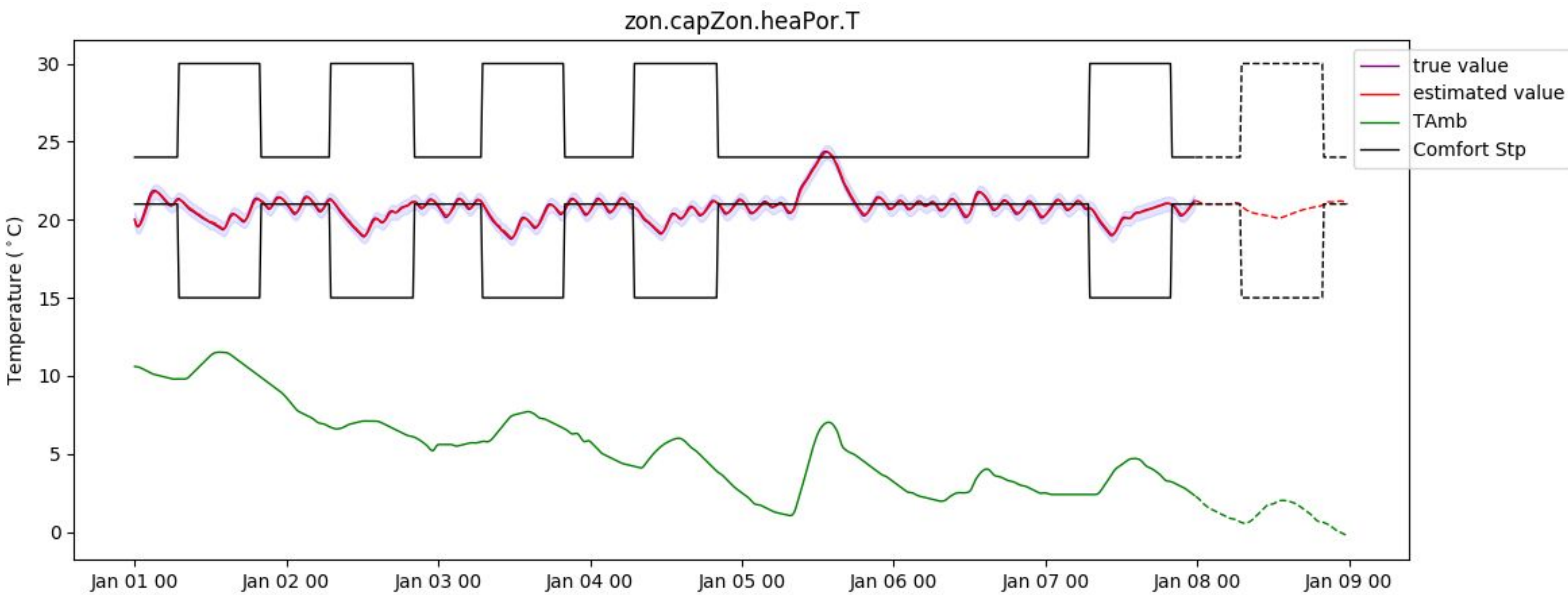
- MPC:
  - Perfect information
  - UKF
  - Min (Q + w*discomfort)



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