4TH INTERNATIONAL CONFERENCE ON

SMART ENERGY SYSTEMS AND
4TH GENERATION DISTRICT HEATING

Aalborg, 13–14 November 2018

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Technologies and Systems

Load shifting of space-heating demand in DHSs based on a building model identifiable at substation level

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Agence de l'Environnement
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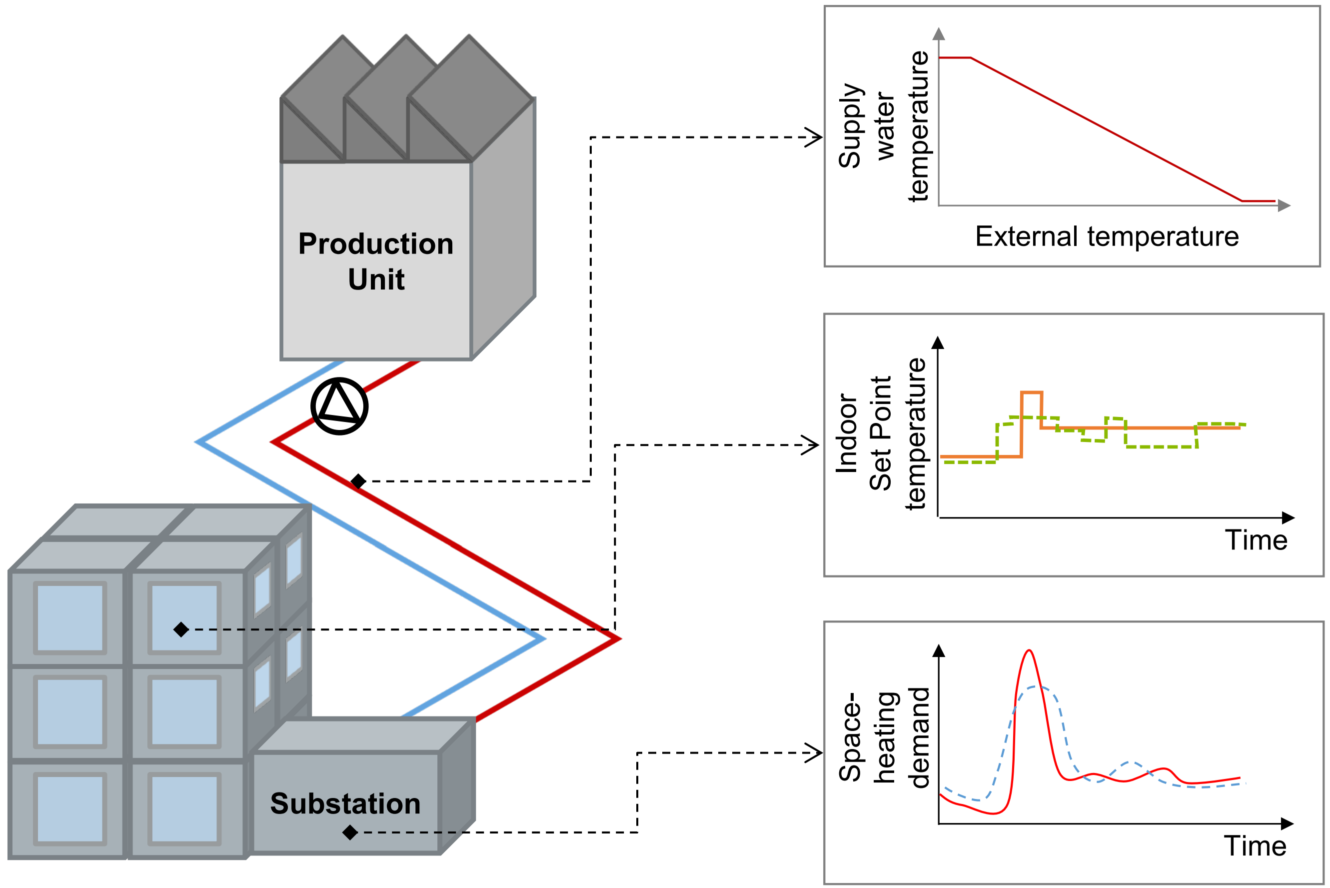
CentraleSupélec

Context
Space-heating demand management



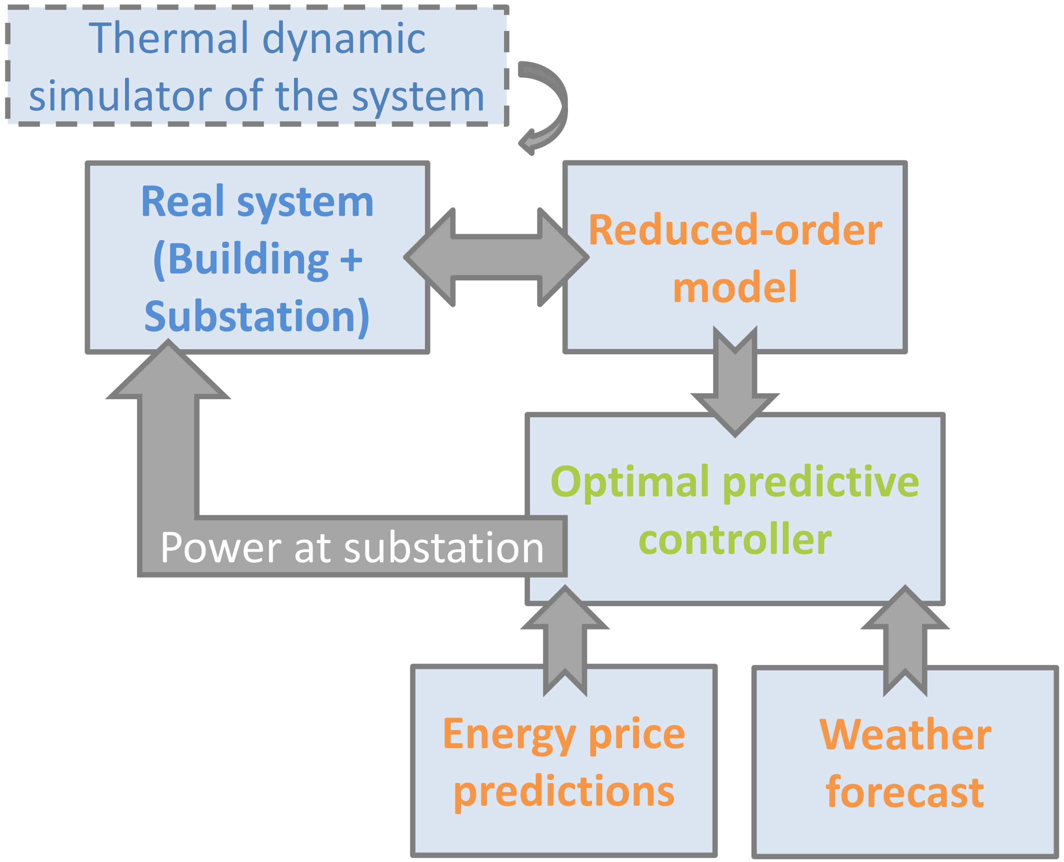
Conventional management

- Driven by consumer's behaviour

Advanced management

- Optimal
- Anticipatory
- Based on semi-physical models

Content
Model Predictive Control



In this presentation

What building model structure is the most reliable and feasible for a large scale application of MPC ?

Considering a case study building:

- Identify 3 different reduced-order models
  - Select the most reliable one
- Demonstrate an elementary test of MPC for load-shifting

Reliable
Well predicting the internal temperature's dynamics

Feasible at large scale
Identifiable using data available at the substation level, not including the internal temperature signal

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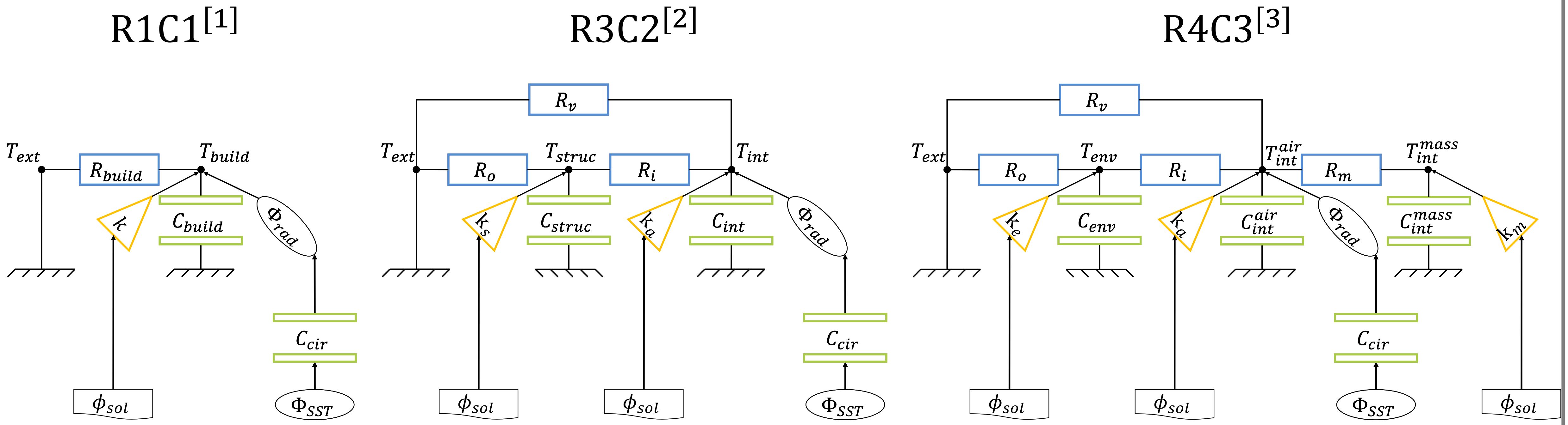
Reduced-order building model Structures



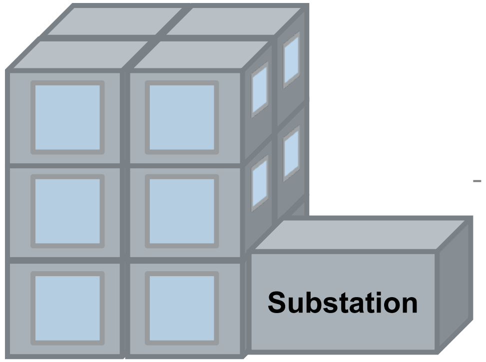
[1] Optimization of the thermal load profile in district heating networks through "virtual storage" at building level – E. Guelpa et V. Verda, Politecnico di Torino, 2016
[2] Identification d'un modèle de comportement thermique de bâtiment à partir de sa courbe de charge – C. Zayane, Ecole Nationale Supérieure des Mines de Paris, 2011
[3] A parametric study to support the modelling of space heating demand in view of developing a load shedding algorithm – N. Aoun, R. Bavière, M. Vallée et G. Sandou, CEA, 2017

Reduced-order building model Parameters Identification

Reduced-order model

$\hat{y} = f(\theta)$

$\begin{pmatrix} \hat{\Phi}_{SST}, \\ \hat{\Phi}_{rad}, \\ \hat{T}_{int} \cdots \end{pmatrix} \in \hat{y}$



$\begin{pmatrix} \Phi_{SST}, \\ \Phi_{rad}, \\ T_{int} \cdots \end{pmatrix} \in y$

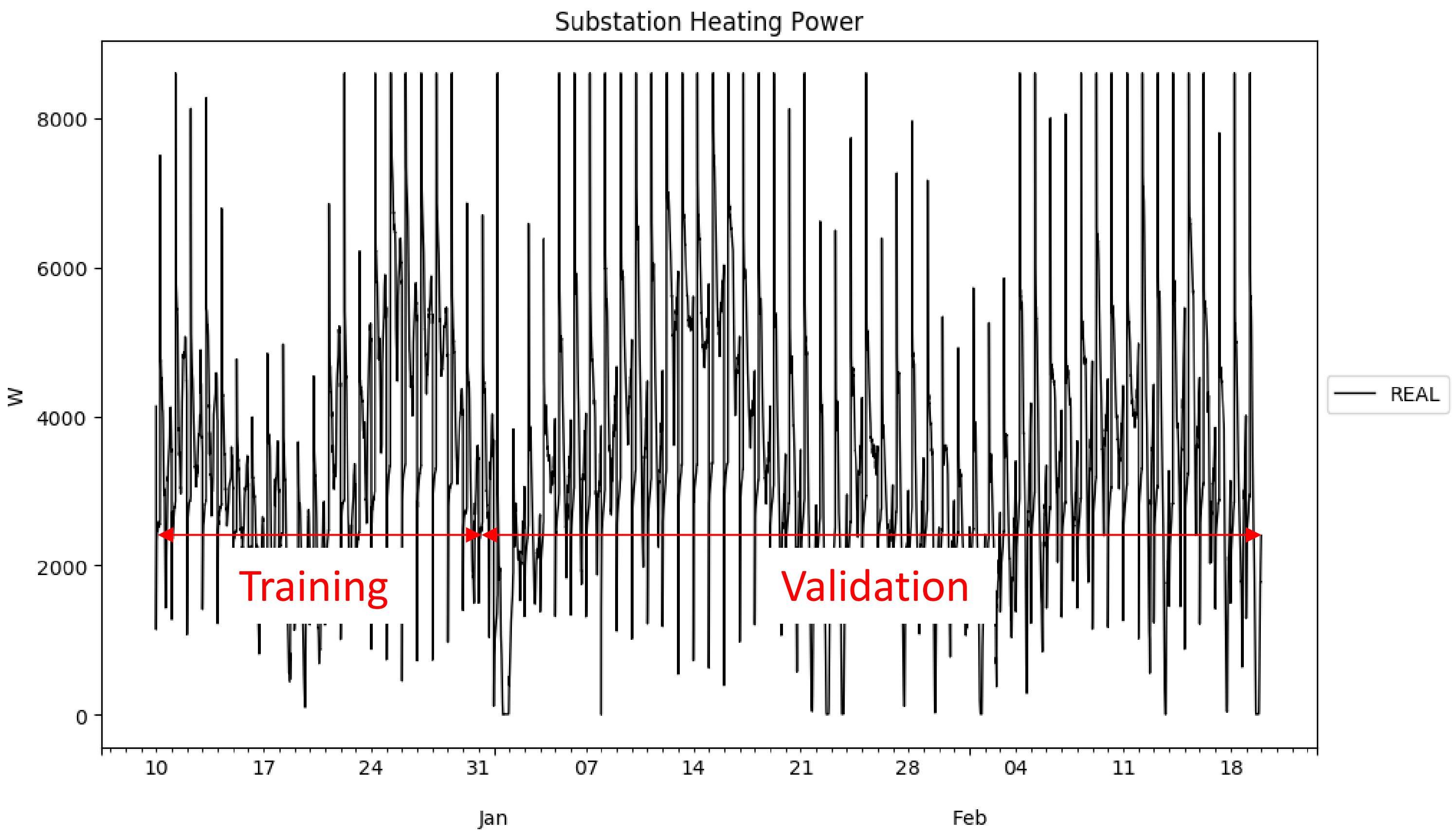
$$\theta_{opt} = argmin\left(\int_{0}^{training} |y - \hat{y}|\, dt\right)$$

Hybrid PSO – HJ algorithm

GenOpt

GenOpt ® is developed at Lawrence Berkeley National Laboratory, University of California.
https://simulationresearch.lbl.gov/GO/

Reduced-order building model
Demonstration



Reduced-order building model Demonstration

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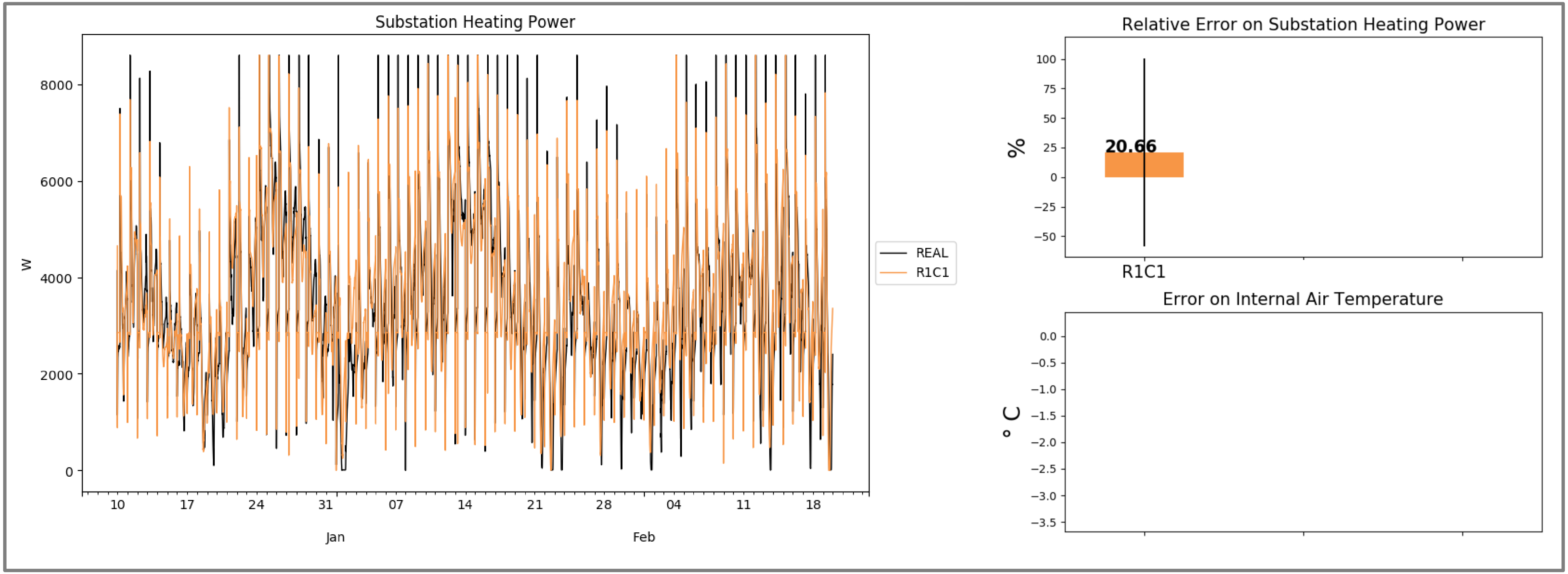
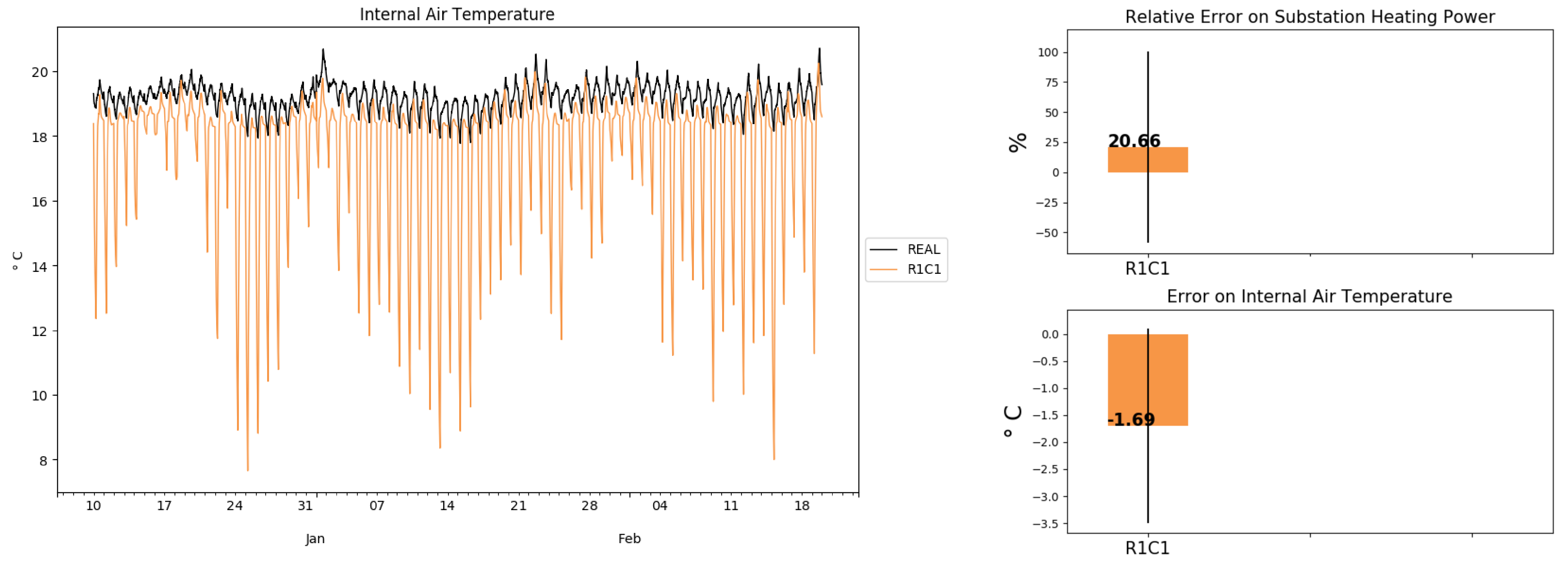


Reduced-order building model Demonstration



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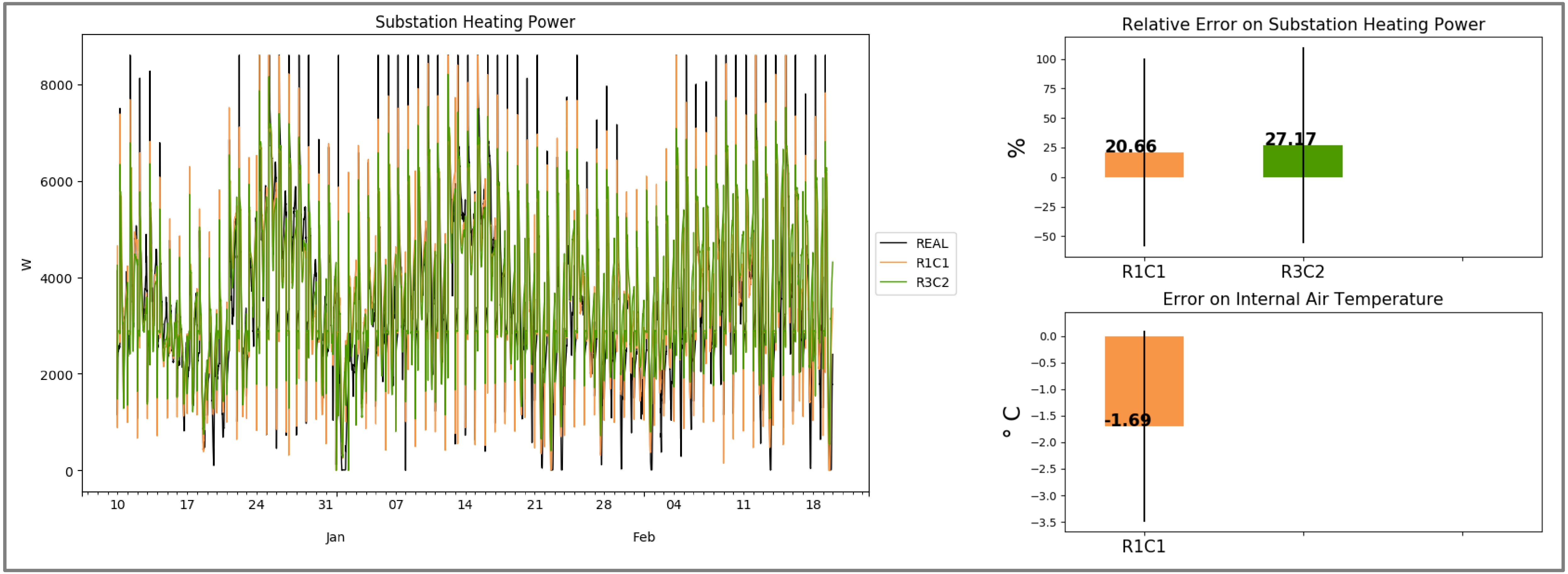

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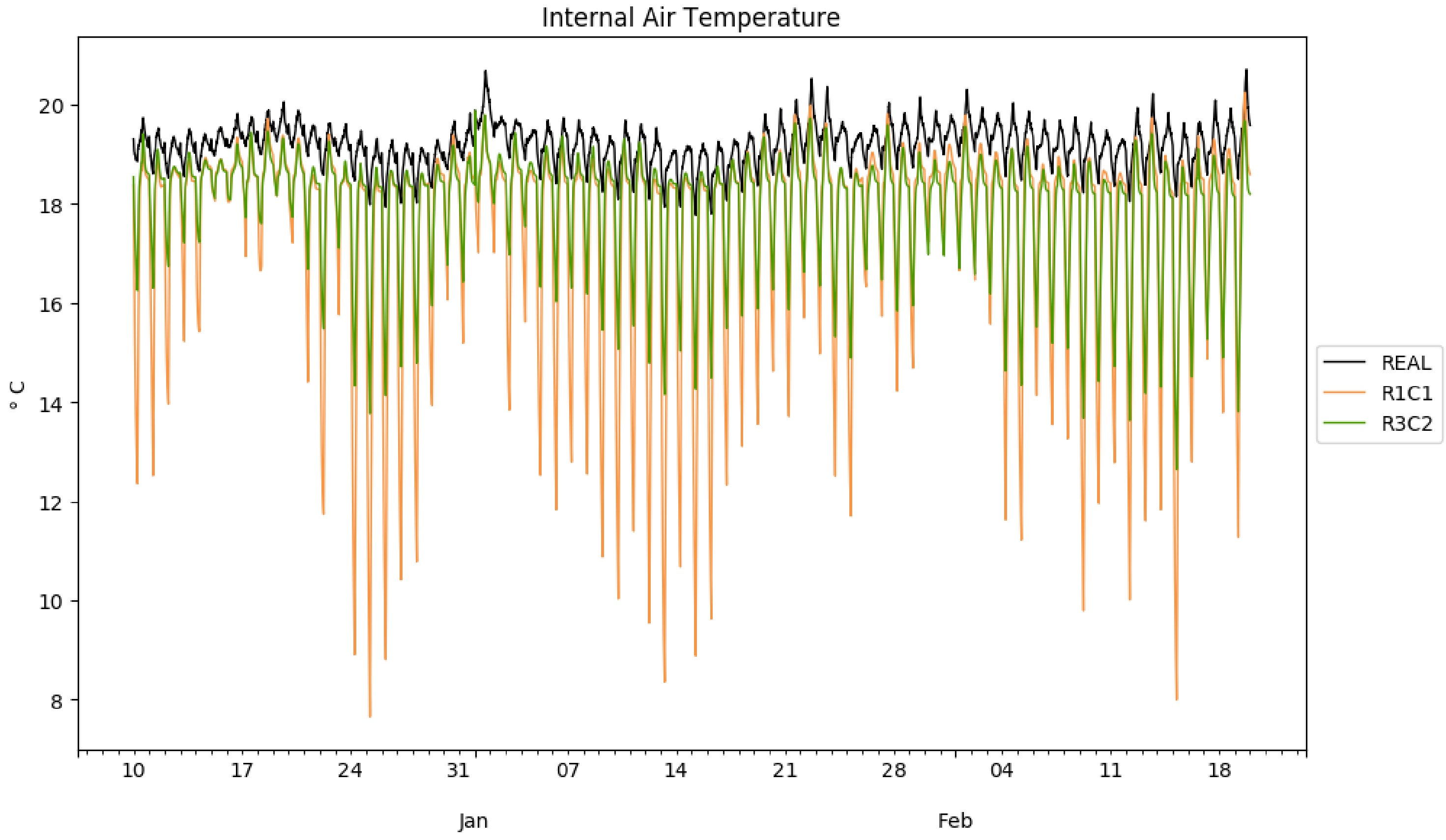
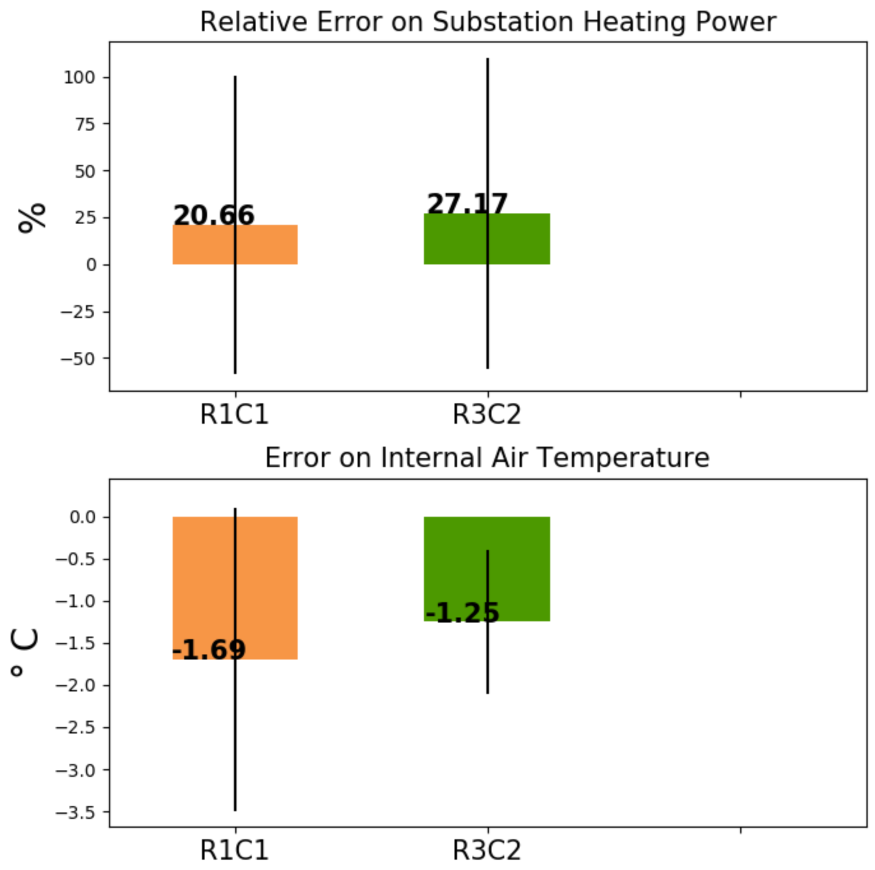
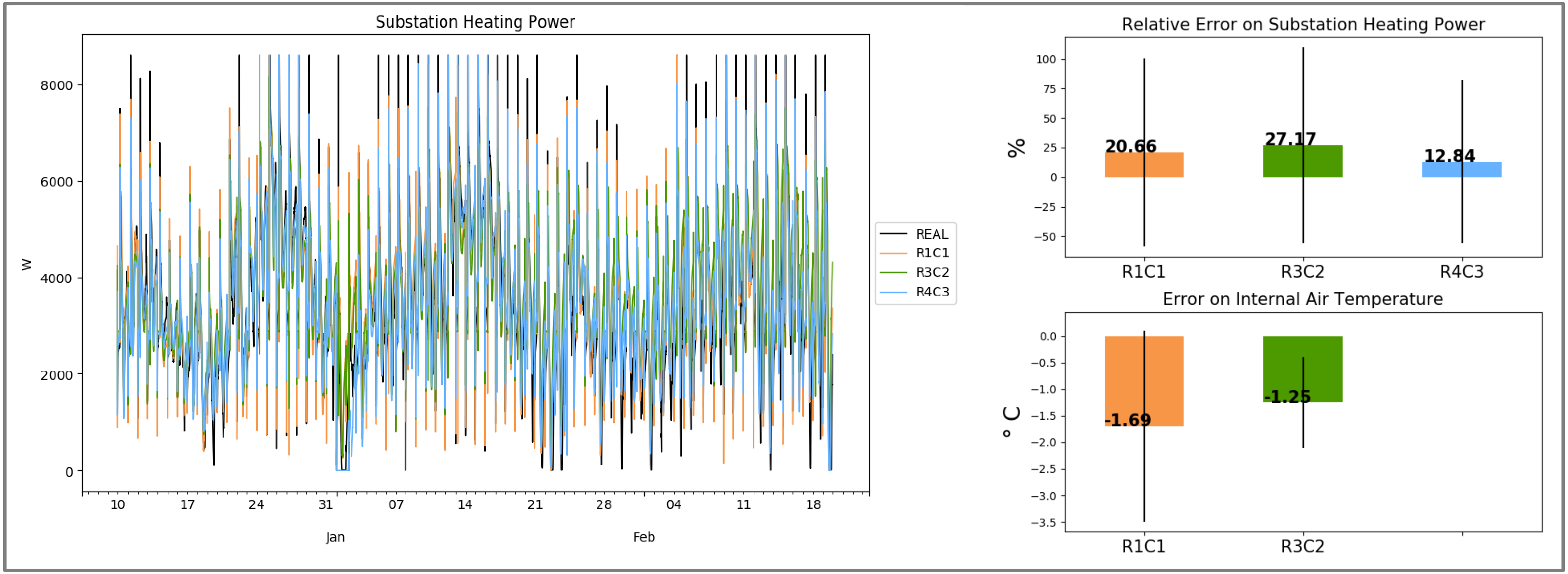




Reduced-order building model
Demonstration



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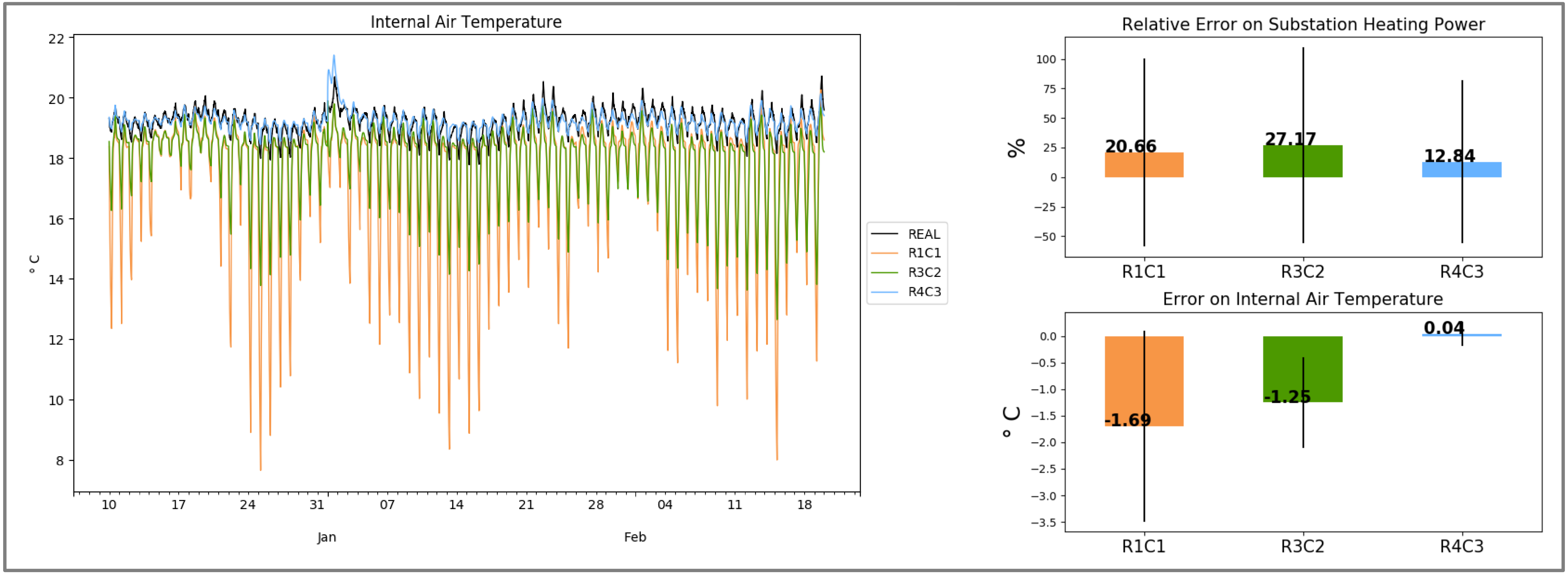

Model Predictive Control Controller

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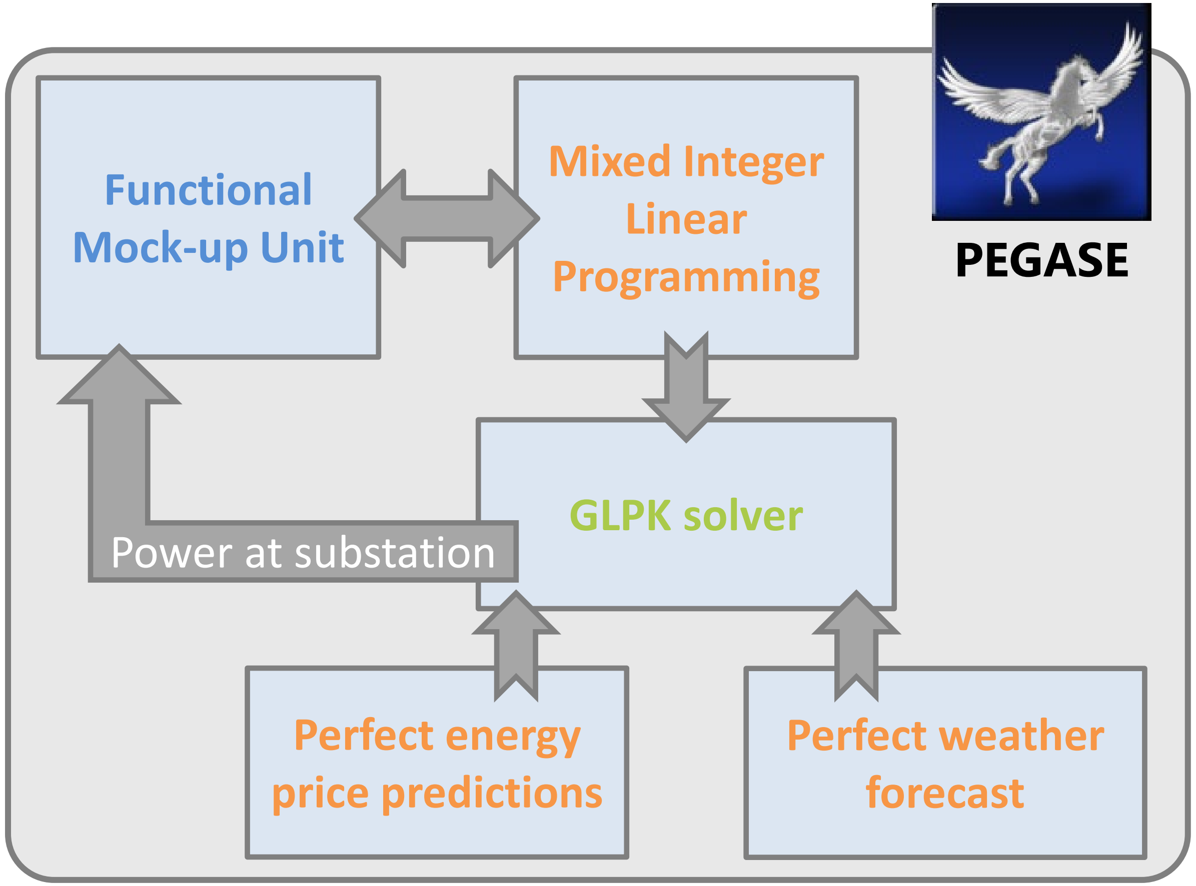
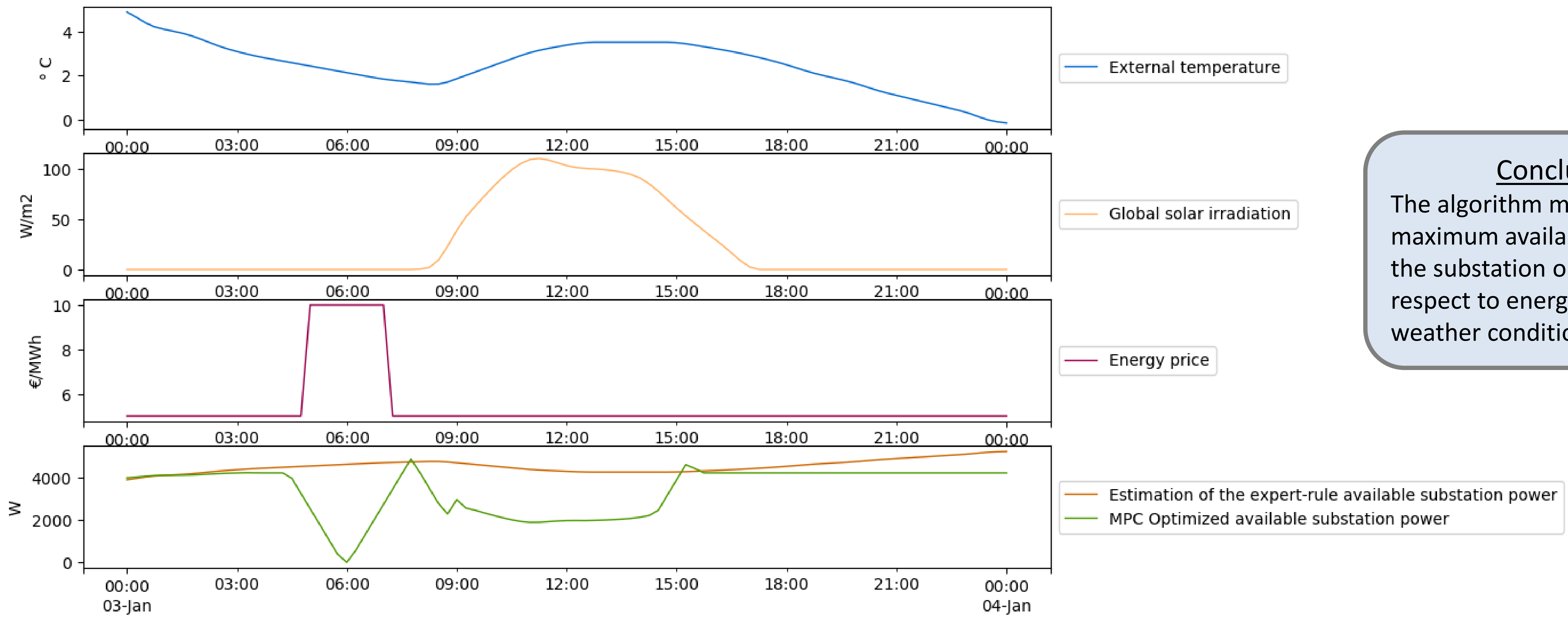


Objective function

$$\int_{t_0}^{t_0+H} \langle \{c^{NRJ}(t) \cdot \Phi_{SST}(t)\} + \{c^{overheat}(t) \cdot [\delta T^{target}(t)]_+\} + \{c^{unmet}(t) \cdot [\delta T^{target}(t)]_-\} \rangle dt$$

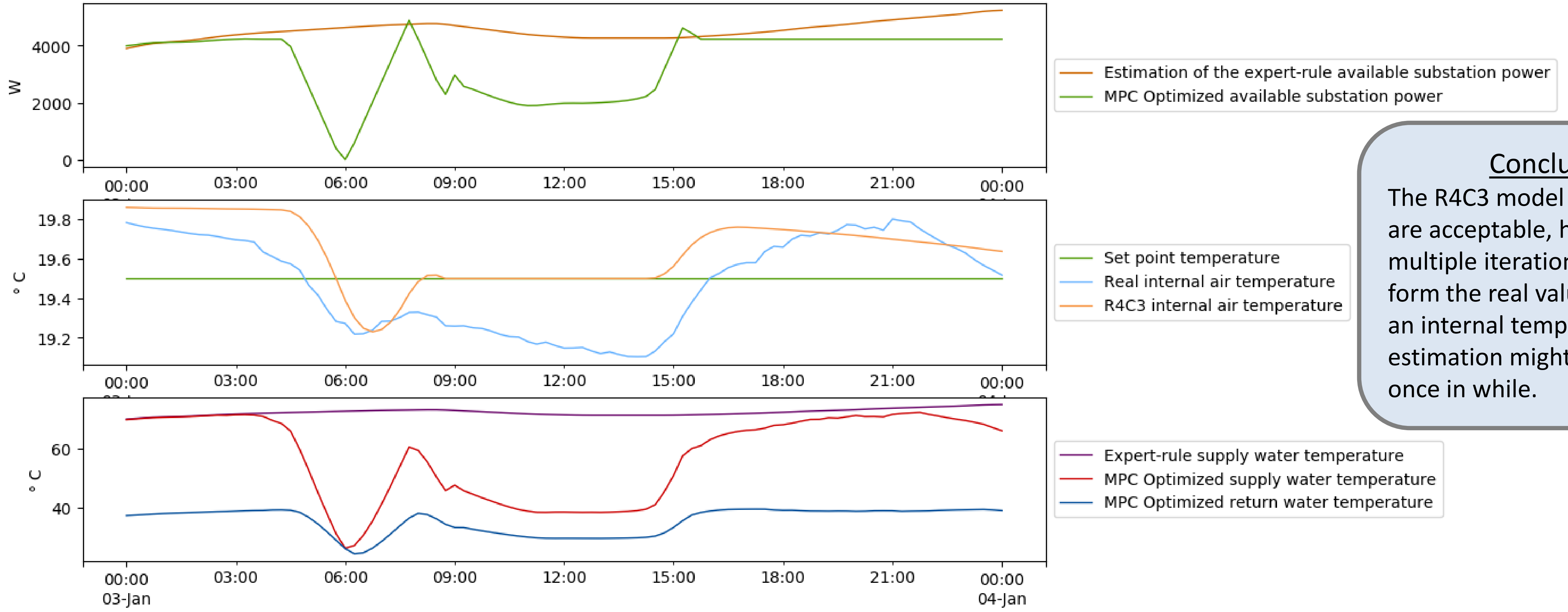
Model Predictive Control Demonstration



Conclusion

The algorithm manages the maximum available power at the substation optimally with respect to energy prices and weather conditions.

Model Predictive Control Demonstration



Conclusion

The R4C3 model predictions are acceptable, however after multiple iterations they stray form the real value, therefore an internal temperature estimation might be necessary once in while.

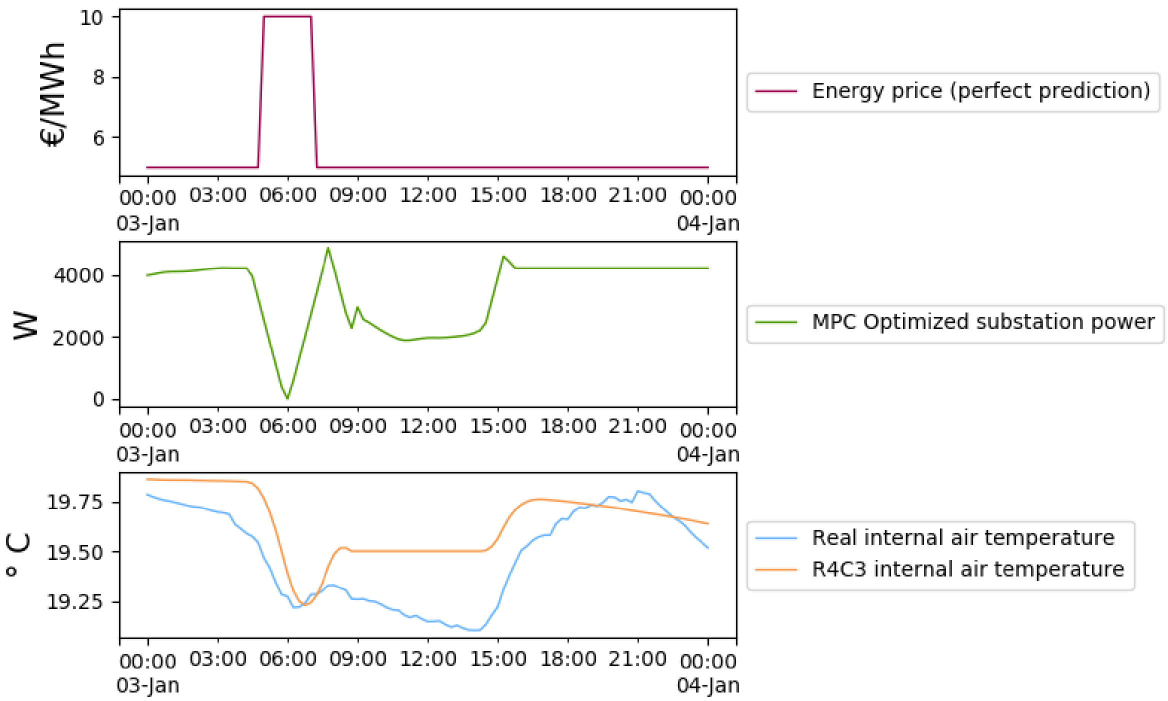
Summary & Conclusions

We assessed the performance of 3 identifies reduced-order building models

- The R4C3 model seems to be the most reliable for MPC

We performed an elementary test of MPC

- The optimal control adapts with energy prices predictions and shifts the load accordingly.
- The R4C3 model predicts well the indoor temperature dynamics but could be enhanced.
- Further research is needed to assess other DSM measures such as night-time set-back



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Thank you

nadine.aoun@cea.fr

Reduced-order building model Parameters Identification

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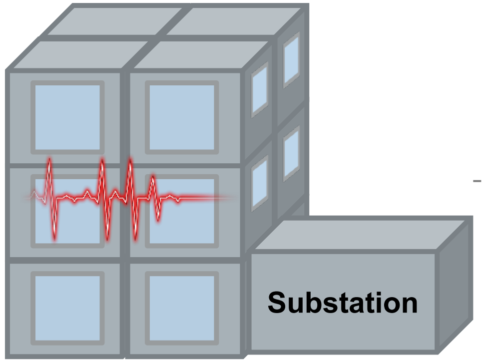

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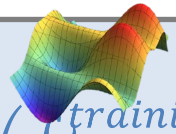

$$\theta_{opt} = argmin\left(\int_0^{training} |y - \hat{y}|\, dt\right)$$

Hybrid PSO – HJ algorithm

GenOpt

CHALLENGES

- Non-convex optimization function
- Sensitivity to initialization
- Presence of disturbance signals simulating internal heat gain

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Model Predictive Control Controller

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$$\int_{t_0}^{t_0+H} \left\langle \{c^{NRJ}(t)\cdot\Phi_{SST}(t)\} + \left\{c^{overheat}(t)\cdot\left[\left(T_{int}^{air}(t)-T_{SP}(t)\right)-\delta T^{tol}(t)\right]_+\right\} + \left\{c^{unmet}(t)\cdot\left[\left(T_{int}^{air}(t)-T_{SP}(t)\right)-\delta T^{tol}(t)\right]_-\right\}\right\rangle dt$$

Handles constraints on internal comfort and technical limitations

Applies the receding horizon principle

PEGASE