Model Predictive Control for Smart Energy Systems

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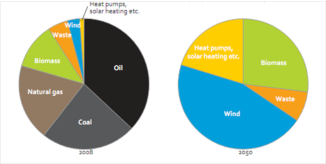
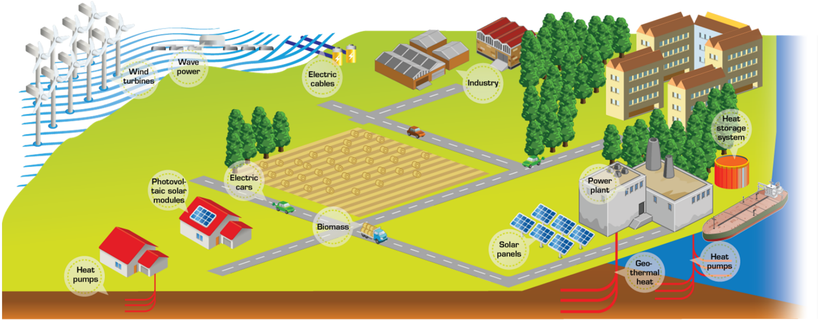
Fossil-fuel free future[1]





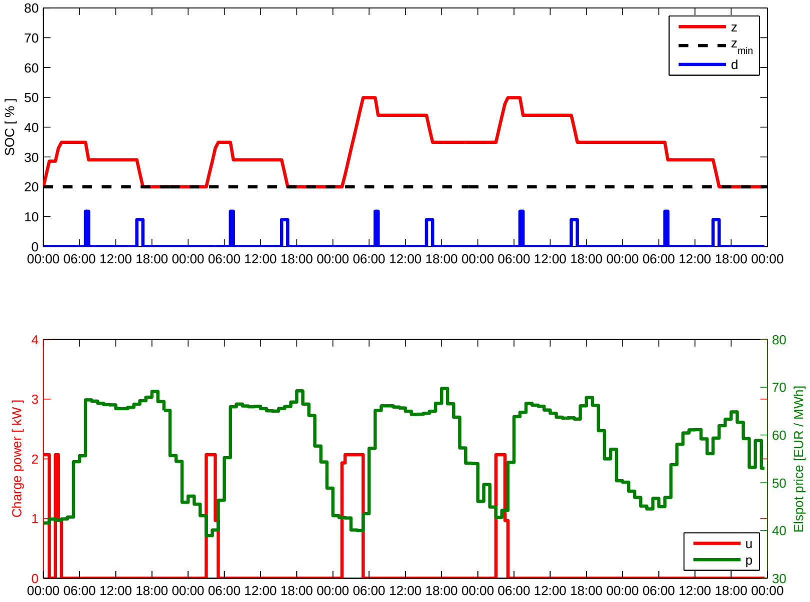
[1]Danish Commission on Climate Change Policy, 2010

Agenda

Economic Model Predictive Control

$$
\begin{aligned}
\text{minimize} \quad & \sum_{k=0}^{N} c_k u_k \\
\text{subject to} \quad & x_{k+1} = Ax_k + Bu_k + Ed_k \\
& y_k = Cx_k \\
& u_{\min} \leq u_k \leq u_{\max} \\
& y_{\min} \leq y_k \leq y_{\max}
\end{aligned}
$$

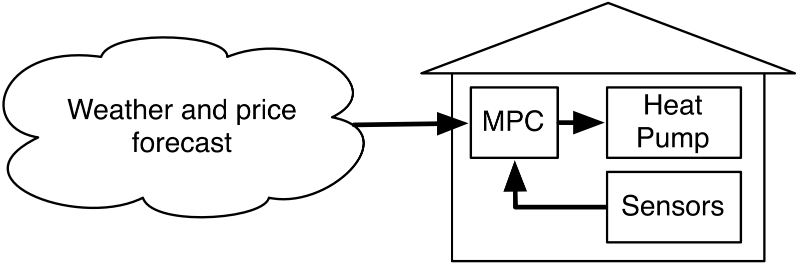
Example 1: EV charging



Why MPC?

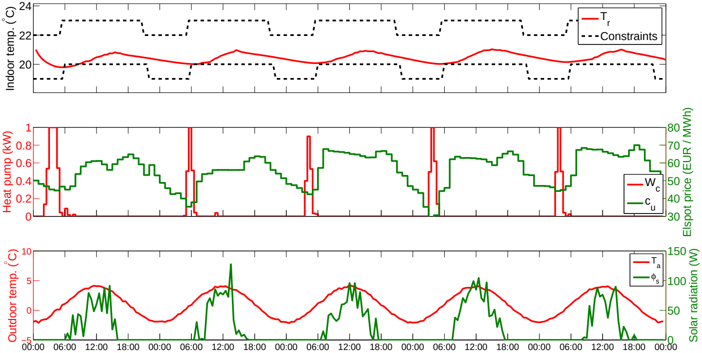
- Controllable loads (EV, Thermal storage)
- Exploits predictions to react ahead of time (prices, demand, wind)
- Flexible control architecture
- Handles system constraints
- Feedback and disturbance rejection

Heat pump and building

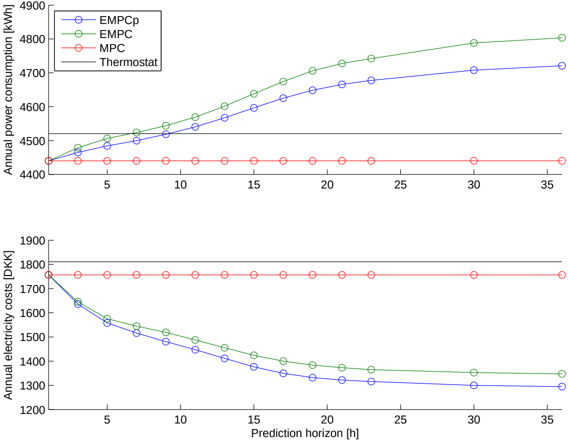


Heat pump MPC

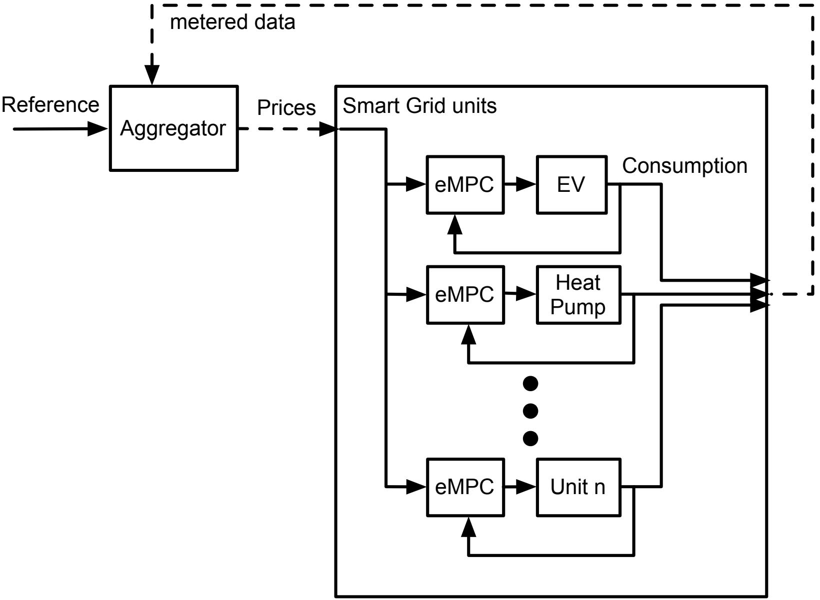
5 day simulation, 48 h prediction horizon using known inputs.
Savings up to 35% compared to MPC with fixed price.



Annual energy consumption and cost



Aggregator strategies

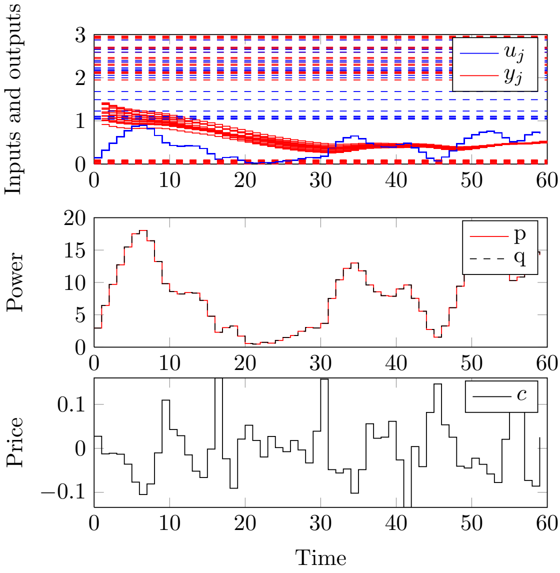


Decomposition methods

Solve the aggregator problem using

1. Dual decomposition
2. Douglas-Rachford splitting
3. Indirect set point MPC

Dual decomposition



Douglas-Rachford splitting

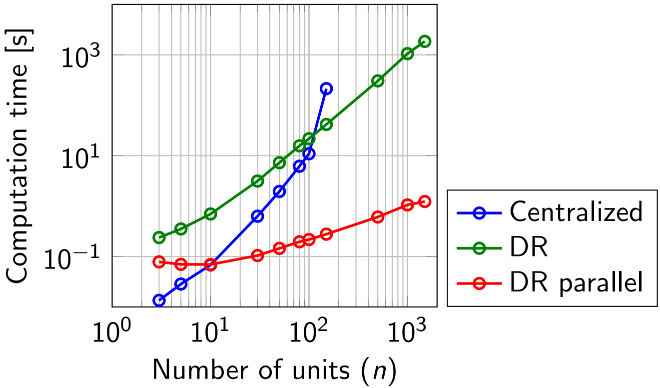
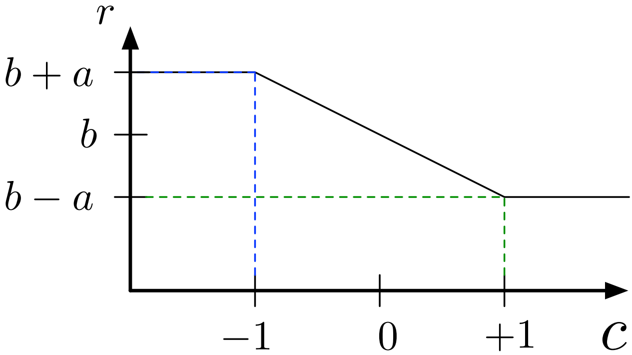


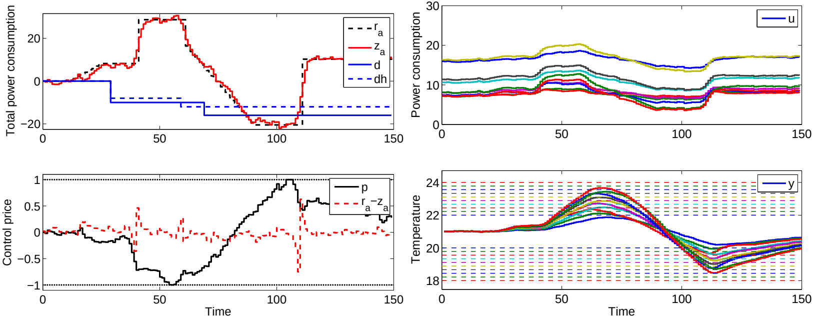
Figure : Convergence for open-loop problem with tuned step sizes t.

Price to temperature set point

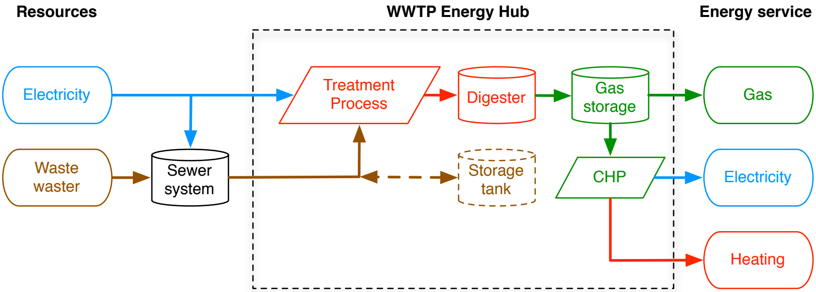


$f_j(c) = -a_j c + b_j.$

Indirect set point MPC



Waste Water Treatment Plant (WWTP)



Conclusions

- Linear dynamic models of heat pumps in buildings, heat storage tanks, electric vehicles, refrigeration systems, power plants, and wind farms.
- Economic MPC that demonstrates load shifting capabilities of these flexible units.
- Distributed large-scale aggregation methods based on MPC, convex optimization, and decomposition methods.
- Several strategies for controlling the power consumption of a large portfolio of flexible consumers using MPC.

Future work

- Energy management of flexible waste water treatment plants
- Model Predictive Control and forecasts
- Interface to Smart Grid markets
- WWTP aggregation strategies

Questions and Comments

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