

Energy Flexibility in Wastewater Treatment

Rasmus Halvgaard

Peter Tychsen, Thomas Munk-Nielsen,

Morten Grum, Henrik Madsen

KRÜGER

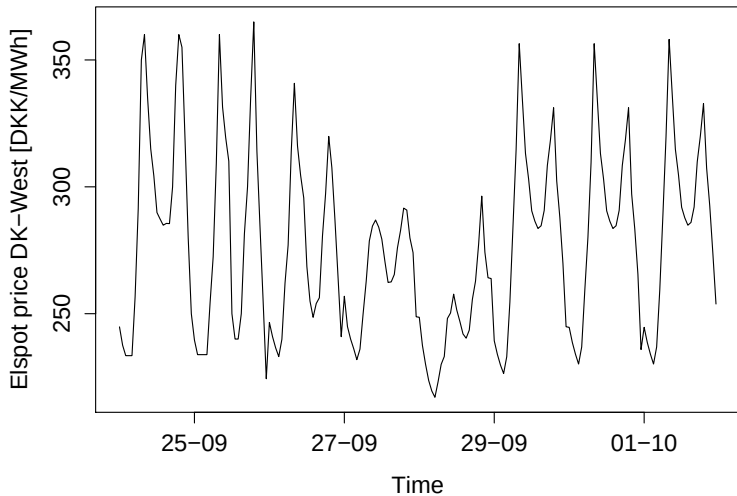


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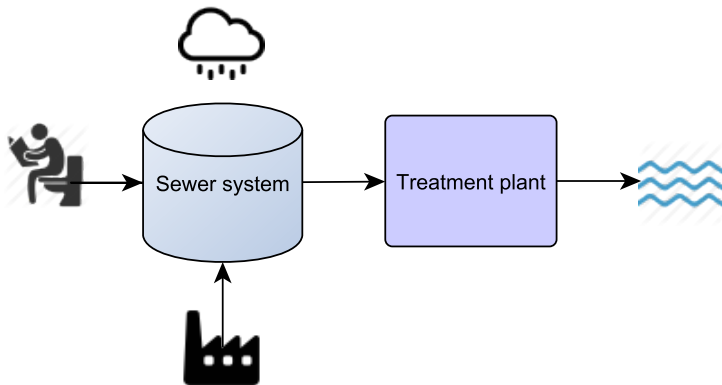
FORSKNING, TEKNOLOGI & VÆKST I DANMARK



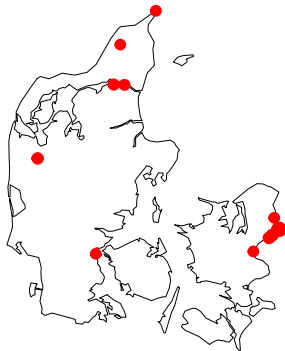
Electricity prices



Wastewater treatment and transport



10 largest Krüger controlled WWTPs in DK



Kolding WWTP



Goal: minimize effluent concentrations and overflow risk

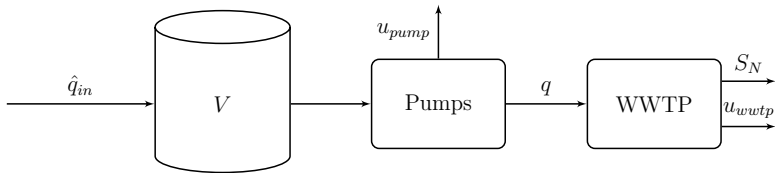
New extra goal of energy flexibility

- ① Power management of the aeration process (720 kW, >50%)
- ② Pumps and waste water storage in sewer system
- ③ Sludge → biogas → gas turbine → electricity + heat

Control goal

$$\text{minimize } \sum_t p_{fee} Q_t S_{N,t} + p_{elspot,t} u_t + risk$$

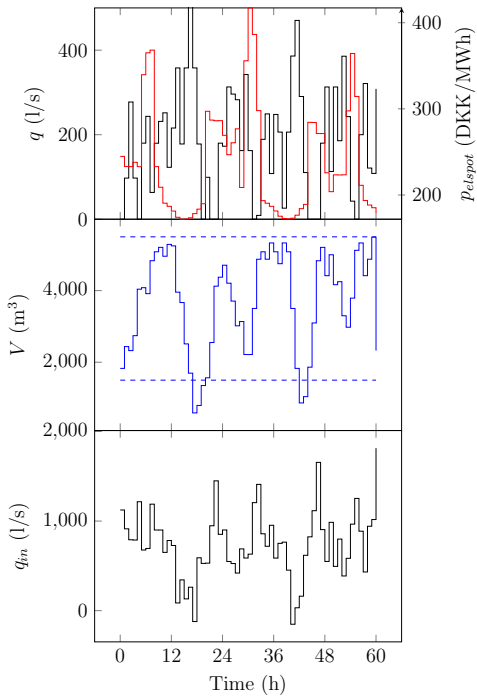
Model Predictive Control (MPC)

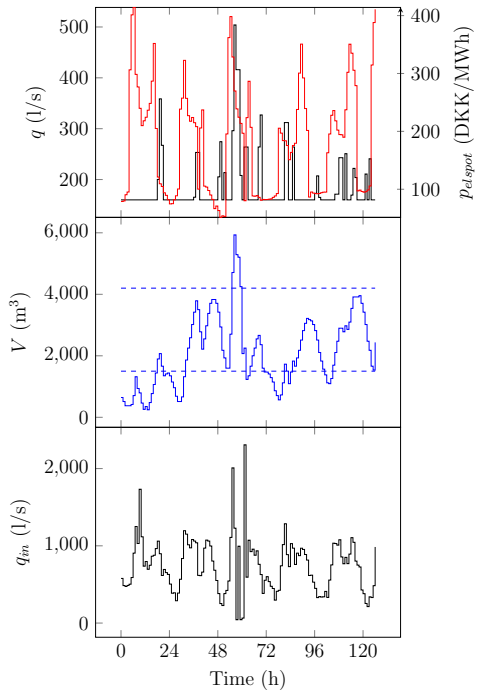


MPC ($p_{fee} = 0$)

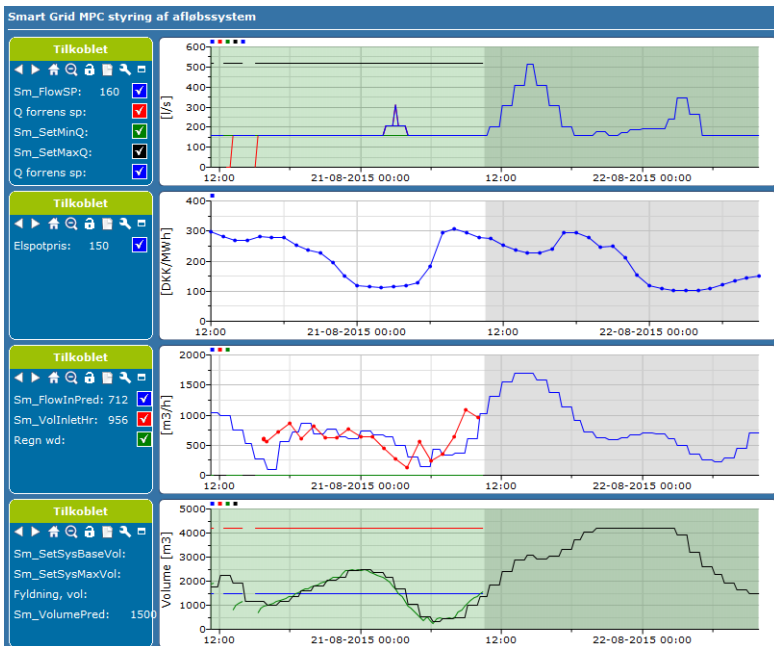
$$\begin{aligned} &\text{minimize} && \hat{p}_{elspot}^T u + \rho^T s \\ &\text{subject to} && \frac{dV(t)}{dt} = \hat{q}_{in} - q \\ &&& q_{\min} \leq q \leq q_{\max} \\ &&& \Delta q_{\min} \leq \Delta q \leq \Delta q_{\max} \\ &&& u = u_{pump}(q) + u_{WWTP}(q) \\ &&& V_{\min} - s \leq V(t) \leq V_{\max} + s \\ &&& s \geq 0 \end{aligned}$$

MPC demonstration results

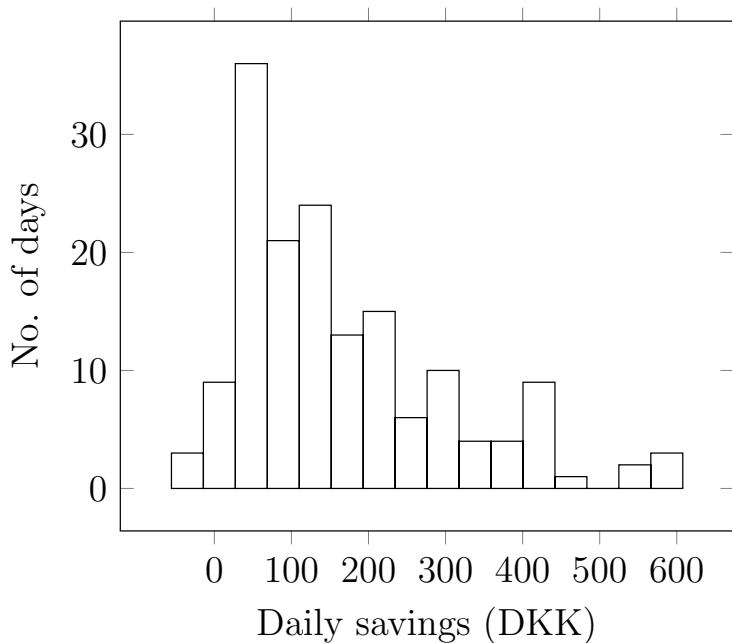




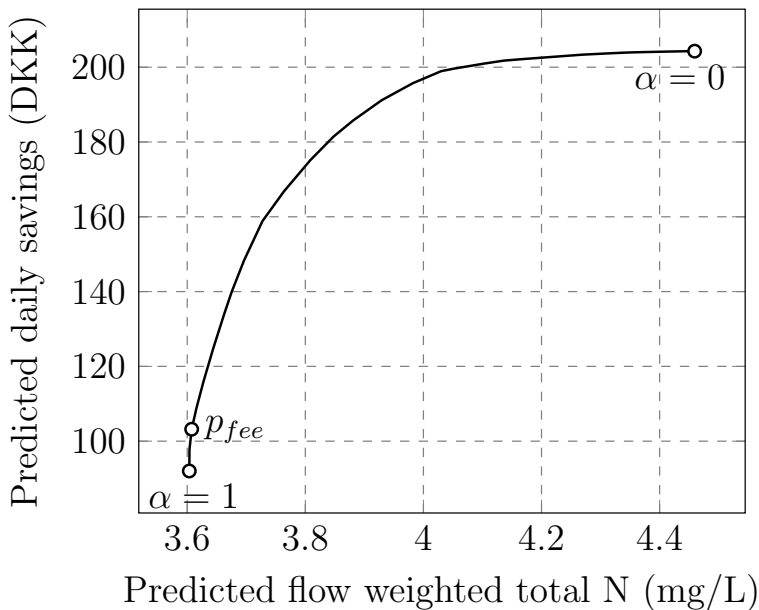
Online control system



Savings from 160 days simulation



$$\alpha p_{fee} S_N + (1 - \alpha) p_{elspot}^T u$$



Flexibility challenges

- $cost_{effluents} + cost_{overflow} \gg cost_{electricity}$ (trade-off)
- Complex nonlinear time-varying treatment processes
- Business case
- Different markets, time scales and control handles

Questions and Comments

Rasmus Halvgaard
rha@DHIGroup.com

www.compute.dtu.dk/~rhal