Applications of a heat load forecast with dynamic uncertainties

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Risk and reward
Risks and rewards in DH

- Inability to meet demand
  - Economic risk
  - System failure
  - Investment risk

- Reduce heat losses
  - Reduce CO₂-emission
  - Produce cheaper heat
  - Facilitate RES integration
Application: Operation of area substations

\[ P = c \rho Q \left[ T_{sup} - T_{ret} \right] \]

**Reward:** Lower supply temperature → reduced heat loss

**Risk:** Inability to cover heat demand
Case from Aarhus – Denmark

- Area substations:
  - Holme
  - Hørning
  - Rundhøj

- Scenarios
  - Scenario 1: Current operation
  - Scenario 2: Optimized temperature control
  - Scenario 3: Optimized temperature control + dynamic uncertainties
Scenario 1: Current operation

\[ P = c \rho Q [T_{sup} - T_{ret}] \]
Scenario 2: Optimized temperature control

\[ T_{t+1}^{\text{sup}} = \max \left\{ T_{t+1}^{\text{min}}(\hat{T}_{t+1}^{\text{out}}), \hat{T}_{t+1}^{\text{ret}} + \frac{\hat{P}_{t+1}}{c\rho Q_{t+1}^{\text{ref}}} \right\} \]

- Consumer constraint
- System constraint

\[ Q_{t+1}^{\text{ref}} = \arg\min_{Q_{t+1}^{\text{ref}} \in Q_{t+1}^{\text{ref}}} \left| Q_{t+1}^{\text{ref}} - Q_{\max} - \frac{\hat{P}_{t+1} + \delta\hat{P}}{c\rho \left[ T_{t+1}^{\text{sup}}(Q_{t+1}^{\text{ref}}) - T_{t}^{\text{ret}} \right]} \right| \]

Inspired by PRESS by Enfor:
Scenario 1 and 2 – Holme
Scenario 3: Optimized temperature control

\[
T_{t+1}^{\text{sup}} = \max \left\{ T_{t+1}^{\text{min}} (\hat{T}_{t+1}^{\text{out}}, \hat{T}_{t+1}^{\text{ret}}), \frac{\hat{P}_{t+1}}{c\rho Q_{t+1}^{\text{ref}}} \right\}
\]

Consumer constraint

System constraint

\[
Q_{t+1}^{\text{ref}} = \arg\min_{Q_{t+1}^{\text{ref}}'} \left| Q_{t+1}^{\text{max}} - \frac{\hat{P}_{t+1} + \delta \hat{P}}{c\rho \left[ T_{t+1}^{\text{sup}} (Q_{t+1}^{\text{ref}}') - T_{t+1}^{\text{ret}} \right]} \right|
\]

Forecast uncertainty: \( \delta \hat{P} \)
- Scenario 2: constant
- Scenario 3: time–dependent, ensemble–based
Ensemble forecasting

Scenario 2 and 3 – Holme

- Heat consumption [MW]
  - Actual
  - Forecast

- Supply temperature [°C]
  - Scenario 2
  - Scenario 3

- Flow rate [m³/h]
  - Scenario 2
  - Scenario 3

Dates:
- Dec 27 2015
- Jan 10 2016
- Jan 24 2016
- Feb 07 2016
- Feb 21 2016
Supply temperature reduction

Holme

Supplied temperature reduction [°C]

Hørning

Supplied temperature reduction [°C]

Rundhøj

Supplied temperature reduction [°C]
Size matters

\[ \hat{P} + \delta \hat{P} > \rho c Q_{\text{max}} \left[ T_{\text{sup}}^{\text{min}} (\hat{T}_{\text{out}}) - \hat{T}_{\text{ret}} \right] \]
Conclusions

- Implementing optimized control:
  - Significant supply temperature reductions

- Improving optimized control w. dynamic uncertainties:
  - Smaller additional supply temperature reductions

- Substations with limited capacity can benefit most

Paper submitted to Applied Energy:
Dahl, M., Brun, A. and Andresen, G.B.
"Using ensemble weather predictions in district heating operation and load forecasting"
Outlook – other applications

- Operation of heat storage to cover economic risk
  - What is the price of always keeping your promises?

- Qualify risk estimates for unit commitment decisions
  - Should we start up a more expensive production unit?

How much are we willing to gamble?

VS
Thank you for listening! Questions?

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