Energy recovery in the water distribution system by intelligent pressure management

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Agenda

• Current challenges for drinking water systems and urban infrastructures

• Background of research project EWID
  • approach
  • project plan

• Methods and results

• Conclusions
Current challenges for drinking water systems (and urban infrastructures)

- Climate change (extreme weather events, spread $Q_{\text{min}}/Q_{\text{max}}$, raining events, droughts)
- Demographic change/migration events: increasing/decreasing population → increasing/decreasing drinking water consumption
- Strict requirements for optimizing water supply systems and enhancing the energy efficiency
- Aging of water supply systems

http://www.bmbf.wasserfluesse.de/
Current challenges for drinking water systems

- saving of resources (water & energy)
- supply reliability and safety
- asset management
- costs-effectiveness, fee stability
- compliance with legal requirements
- decrease of government funding
EWID - Energy recovery in the water distribution system by intelligent pressure management

**Approach:** Improvement of the classic energy-dissipation-based pressure management in the water distribution system by means of valves with the implementation of an energy-based pressure management.
Pressure management

[Guidelines for water loss reduction; GIZ, VAG]

1. Without pressure module
2. Fixed outlet pressure
3. Flow-based/remote-controlled pressure modulation

Excess pressure causes Minimised excess pressure -> minimised leak flow
Project plan

1. Determination of basic data
2. Hydraulic modelling and network characterization
3. System design and development
4. Experimentation and testing
5. Verification on a real network and potential/economic analysis
6. Guideline for planners and consultants
Boundary conditions and potential for involved water utilities

<table>
<thead>
<tr>
<th></th>
<th>AWA</th>
<th>PER</th>
</tr>
</thead>
<tbody>
<tr>
<td>pressure situation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p_{\text{in}}$</td>
<td>8.5 bar</td>
<td>9.4 bar</td>
</tr>
<tr>
<td>$p_{\text{out}}$</td>
<td>3.7 bar</td>
<td>1.0 bar</td>
</tr>
<tr>
<td>$\Delta p$</td>
<td>4.8 bar</td>
<td>8.4 bar</td>
</tr>
<tr>
<td>mean flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Q_{\text{m}}$</td>
<td>1.3 l/s</td>
<td>7.0 l/s</td>
</tr>
<tr>
<td>inhabitants supplied</td>
<td>EW</td>
<td>700</td>
</tr>
<tr>
<td>Theoretical energy yield ($\eta_{\text{tot}} = 50%$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_{\text{th}}$</td>
<td>0.3 kW</td>
<td>3.0 kW</td>
</tr>
</tbody>
</table>

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Methodology

Case study: Perlenbach-Schafberg (PER)

<table>
<thead>
<tr>
<th></th>
<th>PER</th>
</tr>
</thead>
<tbody>
<tr>
<td>pressure situation</td>
<td>$p_{in}$ 9.4 bar, $p_{out}$ 1.0 bar, $\Delta p$ 8.4 bar</td>
</tr>
<tr>
<td>mean flow</td>
<td>$Q_m$ 7.0 l/s</td>
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<tr>
<td>inhabitants supplied</td>
<td>EW 1,200</td>
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<tr>
<td>Theoretical energy yield ($n_{tot}$=50 %)</td>
<td>$P_{th}$ 3.0 kW</td>
</tr>
</tbody>
</table>

Key data:
- 1,200 inhabitants
- 940 service connections
- 27 km water pipelines
- 4 pressure zones
Methodology

Data analysis and hydraulic modelling

- Base data:
  - GIS network
  - Water outflow, inlet and outlet pressure (PRV)
  - Annual billed water consumption per village, etc.

- Modelling with EPANET 2.0:
  - Evaluate hydraulic situation
  - Identification of critical points
  - Calibration to determine the friction coefficient of the pipelines and verify the input data
  - Predict potential water loss reduction
Methodology

Experimentation and system development

- complete installation is controlled by a PLC (programmable logic controller) provided by EWID partner
- All recorded data (Q, p, T, n, P): collected and visualized on the PC (10 sec. intervals)
Methodology

Optimised pressure control

\[ h_v = f(Q) = aQ^2 + bQ + c \]

\[ p_{out,target} = p_{crit,limit} + h_v \]

- First approximation: a, b and c (network dependent parameters) derived / calculated from calibrated hydraulic model
- Later on: parameters continuously adjusted using real time measured data as input for the hydraulic model
## Results

### System configuration and PAT design

<table>
<thead>
<tr>
<th></th>
<th>Q</th>
<th>$p_{\text{in}}$</th>
<th>$p_{\text{out}}$</th>
<th>$\Delta p$</th>
<th>$p_{\text{crit}}$</th>
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</thead>
<tbody>
<tr>
<td><strong>actual</strong></td>
<td>7</td>
<td>9.4</td>
<td>4.0 (constant)</td>
<td>5.4</td>
<td>$\approx 10.0$</td>
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<tr>
<td><strong>target</strong></td>
<td>7</td>
<td>9.4</td>
<td>dynamic $\approx 1.0$</td>
<td>8.4</td>
<td>8.0 (constant)</td>
</tr>
<tr>
<td><strong>experimentation</strong></td>
<td>7</td>
<td>9.4</td>
<td>dynamic $\approx 6.1$</td>
<td>dynamic</td>
<td>2.5 (constant)</td>
</tr>
</tbody>
</table>

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![Diagram of system configuration and PAT design](image.png)
## Results

### Potential and pressure control

- PAT 17 h in operation (7 am – 23 pm)
- Pressure at the critical point successfully maintained at the target value (2.5 bar)
- Due to the low variability in the demand profile: outlet pressure → quite narrow course
- Max 2.2 kW electrical energy recovered and fed back into the grid, when the turbine works under full load ($Q_{\text{PAT}} = 9.7 \text{ l/s}$ and $p_{\text{out}} = 6.1 \text{ bar}$). Total efficiency of the system: approx. 40 %
- A higher energy yield can be achieved by optimizing the electrical and hydraulic losses in the system
Conclusions

• **Functionality of the EWID** successfully verified at the testing plant:
  - Advanced / intelligent pressure management (critical point approach) works
  - Interaction between PRV and PAT works (magnetic valve: drive and shutdown functions)
  - Up to 2.3 kW energy recovery with the applied PAT at the tested hydraulic conditions ($Q_{\text{PAT}} = 9.7 \text{ l/s}$ and $p_{\text{out}} = 6.1 \text{ bar}$). For the real network the potential might be higher!

• **Benefits** of the system:
  - energy recovery
  - water loss reduction (16.5% higher than using classic PRVs) + network alleviation
  - monitoring

• **System is recommended / might be profitable in:**
  - Networks with high operational pressures and high differences in altitude (e.g. mountainous regions)
  - Networks with large differences in the water demand during the day

• **Next steps:** detailed profitability analysis, verification of the system in two real networks (AWA and PER), analysis of options for island operation (decentral energy storage)
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