Formulation and assessment of multi-objective sizing: application to low temperature DH networks

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In the literature

Optimal design of DH Networks

Layout (topology)

Sizing (fixed layout)

Local design rules

Global system sizing

Mono-objective optimization

Multi-objective optimization

Almost only Genetic Algorithms

From Mertz et al, 2017

From Frederiksen and Werner, 2013

From Pizzolato et al, 2018

From Vesterlund and Toffolo, 2017
Outlook of the presentation

I. Introduction

II. Methodology for the optimal sizing

III. Validation method for the framework

IV. Validation results

V. Conclusion
Optimization problem

• Decision parameters:
  • diameters of the pipes
  • (insulation thickness)

• Objectives:
  • CAPEX
  • Pumping cost
  • (thermal power)

• Constraints:
  • Satisfaction of the consumers
  • Fluid velocity
  • Absolute pressure
Meta-heuristics known issues:

- Interpretability
- Parametrization

Quality of the results of our implementation considering those issues?

From xkcd, https://xkcd.com/1691
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Validation method

- Generation of reference solution for the optimization
- Optimization results using our framework
- Local sizing method

Comparison of the results
3 Validation Test cases

- Simple line:
  - Section 1
  - SST 1
  - SST 2
  - SST 3
  - SST N
  - Return line

- Loop
  - Supply line
  - Section 1
  - Section 2
  - Section 3
  - Section N
  - Return line
  - Branches of 1km

- Simple line with branches
  - Supply line of 10km total length
  - Section 1
  - SST 1
  - SST 2
  - SST 3
  - SST N
  - Return line
  - Branches of 1km

Application to real-size DH network
3 Validation Test cases

- Simple line:
  - Section 1
  - SST 1
  - Section 2
  - SST 2
  - Section 3
  - SST 3
  - Section N

- Loop
  - Supply line
  - Section 1
  - SST 1
  - Section 2
  - SST 2
  - Section 3
  - SST 3
  - Return line

- Simple line with branches
  - Application to real-size DH network
  - Supply line of 10km total length
  - Branches of 1km
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Validation Test case

Constraints:
- Absolute pressure < 25 bar
- Fluid velocity < 5 m/s
- Consumer heat demand satisfaction > 98%

Optimization:
- Individuals: 300
- Generations: 300
- Mutation probability: 0.2

<table>
<thead>
<tr>
<th>Total power demand</th>
<th>50 MW : 2.5 MW for each SST except SST10 : 5 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total length</td>
<td>10 km main supply line + 10 km main return line</td>
</tr>
<tr>
<td></td>
<td>1 km branch supply line + 10 km branch return line</td>
</tr>
<tr>
<td>Boundary condition</td>
<td>P=2 bars on return line at boiler</td>
</tr>
<tr>
<td>Temperature primary circuit</td>
<td>90°C/40°C</td>
</tr>
<tr>
<td>Temperature secondary circuit</td>
<td>70°C/50°C</td>
</tr>
</tbody>
</table>
Validation Test case

10 Substations + 9 branches : convergence

Reference solution and optimization solution are close

Solutions with higher pumping cost may have a critical substation in the branches
Validation Test case

10 Substations + 9 branches

Difference local sizing/optimization:
- 100k€ of savings per year compared to closest solution
→ 7% of savings for a 40 years lifetime of the system

From Frederiksen and Werner, 2013
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Conclusion

• Presentation of an optimal sizing method for pipe diameters in DH networks

• Validation methodology for optimal sizing in DH network approaches

• Validation of the framework with branched networks
  • Elaboration of a reference solution for a branched test case
  • Comparison to optimization results
    → Great quality of the Pareto front and good convergence

• Comparison to a local sizing method
  • Optimal solution are at least 7% less costly in tested cases
  • Qualitative difference in the solutions
Thank you for your attention!

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