GENERATION OF DAILY LOAD TYPOLOGY FOR DISTRICT HEATING SIMULATION AND OPTIMISATION

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Contents:

1. Context
   - Nantes Centre Loire district heating

2. Typology methodology
   - Clustering
   - MCDA

3. Results
   - Typical days characterisation
   - Validation

4. Conclusion & Future works
85 km of pipes
Multi-sources (2 sites, 8 production units)
360 substations (16000 dwellings - sport, health & public facilities ...)
84 % from RES & R

Focus on a specific part:
Connected through a heat exchanger
37 Substations
Context
Nantes Centre Loire district heating

Simulation & optimisation

Combining data from monitoring and DH modelling:

1. Characterisation of the DH (inverse methods)
   - Heat loss coefficient
   - Heat exchangers characterisation

2. Optimisations:
   - Energy systems management
   - Energy in return pipes
   - Control laws of the secondary side
   - Supply temperature in the network

Iterative methods: gradient methods or metaheuristics

\[ 0.5 \, [s/simu] \times 10 \, [it] \times 24 \, [hours] \times 365 \, [days] = 12 \, h \, [of \, simulation] \]

Need of reducing computational costs

→ Simulations from Typical Days (TD) instead of a whole Time Series (TS)?
   For what impact on results?
Typology methodology
Clustering

Substations load time series

Daily characterization
- Energy $E_d$
- Magnitude $R_{pd}$
- Variability $V_{pd}$

$$E_d = \sum_{ss=1}^{N_{ss}} \sum_{h=1}^{24} P_d(ss,h)$$

$$R_{pd} = \max_h \left( \sum_{ss=1}^{N_{ss}} P_d(ss,h) \right) - \min_h \left( \sum_{ss=1}^{N_{ss}} P_d(ss,h) \right)$$

$$V_{pd} = \sum_{ss=1}^{N_{ss}} \sum_{h=1}^{24} \left| \frac{dP_d(ss,h)}{dt} \right|$$
Typology methodology
Clustering

Substations load time series

Daily characterization
- Energy $E_d$
- Magnitude $R_{pd}$
- Variability $V_{pd}$

Clustering $\iff$ k-means

$K$?
- Dense and distant clusters
- Similarity between days
Typology methodology
MCDA

**Clustering Evaluations**

- $(Q_i(d))_{i \in [1,3]}$ & $d_M = \max(d)$ : intra-clusters distances (to be minimized)
- $\Delta_m = \min(\Delta)$ : inter-cluster distances (to be maximized)
- $cc = \min_j (R^2)$ and RMSE : days cross-correlation & differences (resp. maximized and minimized)

Conflicting criteria & Discrimination difficulties

→ MCDA algorithm (Electre1S)
Typology methodology
MCDA

Substations load time series

Daily characterization
- Energy $E_d$
- Magnitude $R_p_d$
- Variability $V_p_d$

Clustering
$\Rightarrow$ k-means

Selection of $k$

MCDA
- Number of cluster $N$
- Density $Q_i(d) & d_M$
- Clusters distances $\Delta_m$
- Similarities $cc & RMSE$

Selection of typical days in the clusters

⚠️ Selection among the days in the cluster
$\Rightarrow$ Possibility characterize the typical day with other variables ($T_{out}$ etc.)
Typology methodology
MCDA

Substations load time series

Daily characterization
- Energy $E_d$
- Magnitude $R_{pd}$
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Clustering
→ k-means

Selection of $k$

MCDA
- Number of cluster $N$
- Density $Q_i(d)$ & $d_M$
- Clusters distances $\Delta_m$
- Similarities $cc$ & RMSE

Selection of typical days in the clusters

Impact on simulation accuracy

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Typology methodology
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Results
Typical days characterisation
Validation

Conclusion & Future works
Contents

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   - Clustering
   - MCDA

3. Results
   - Typical days characterisation
   - Validation

4. Conclusion & Future works
Results
Typical days characterisation
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Simulations with a pseudo-dynamic model

- Masse balance:
  \[ \sum_{j \in \{Pr(i)\}} \dot{m}_{i,j} = \sum_{k \in \{Su(i)\}} (\dot{m}_{k,i} + \dot{m}_{i}) \]

- Thermal losses:
  \[ T_{\bullet,i,j,out} = T_{\text{ext}} + (T_{\bullet,i,j,in} - T_{\text{ext}}) \exp \left( - \frac{SU}{C_p \dot{m}_{i,j}} \right) \]

- Pressure drops:
  \[ \Delta H = k_{i,j} \cdot |\dot{m}_{i,j}| \]
SIMULATIONS WITH A PSEUDO-DYNAMIC MODEL

Results
Validation

Context
Nantes Centre Loire
district heating

Typology methodology
Clustering
MCDA

Results
Typical days
characterisation

Validation

Conclusion & Future
works
Results
Validation

Typology impact on inputs

Typology impact on outputs

My SMART Life
IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Telecom
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Conclusion & Future works

A ROBUST LOAD TYPOLUTION METHOD

- Based on k-means clustering method
- k is chosen through MCDA
- Typical days extracted from the database
- Validation by evaluating the impact on simulations
Simulation & optimisation

Combining data from monitoring and DH modelling:

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Iterative methods: gradient methods or metaheuristics

\[
0.5 \text{ [s/simu]} \times 10 \text{ [it]} \times 24 \text{ [hours]} \times 365 \text{ [days]} = 12 \text{ h [of simulation]}
\]

Need of reducing computational costs

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Conclusion & Future works

SIMULATION & OPTIMISATION

Combining data from monitoring and DH modelling:

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Iterative methods with typical days

0.5 [s/simu] × 10 [it] × 24 [hours] × 5 [typic days] = 10 min [of simulation]
Conclusion & Future works

A robust load typology method

- Based on k-means clustering method
- k chosen through MCDA
- Typical days extract from the database
- Validation by evaluating the impact on simulations

Other applications

- Complete/Replace TS of some substations
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Conclusion & Future works

**TIMES SERIES GENERATION FROM TYPICAL DAYS**

Subs₅

Subs₁₄

Context
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Results
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Conclusion & Future works
Conclusion & Future works

**TIMES SERIES GENERATION FROM TYPICAL DAYS**

**INFLUENCE OF K IN THE TYPICAL TIMES SERIES**

$\iff \quad \text{Better typical time series accuracy}$
Typical days characterisation

Conclusion & Future works

Typical days characterisation

subst5

 subst14

P_Ti [W]

$10^4$

$10^5$

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

P_Ji [W]

$10^4$

$10^5$

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Conclusion & Future works

**Times series and clustering comparisons**

- **Context**
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  - MCDA
- **Results**
  - Typical days characterisation
  - Validation
- **Conclusion & Future works**

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Conclusion & Future works
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**21**

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