Dynamic Modelling of a District Cooling Network with Modelica

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Agenda

- Objectives & Methodology
- Description of the District Cooling System
- Chilled-Water Production Flow Chart
- Centrifugal Chiller Model
- Simulation & Validation Results
- Conclusion & Research perspectives
Objectives & Methodology

• Long-term objective: Optimal control of Chilled-Water Production of a real District Cooling System
  → Detailed representation of main energy equipments

• 1st step: Modelling and Calibration of the Chilled-Water Production Plant (CWPP) with Modelica
  → Modelling of all production modes
  → Relevant boundaries (load, weather and controls as inputs)
  → Validation of model outputs against measured values

AIM OF TODAY’S PRESENTATION
Description of the District Cooling System

• Eastern Part of Paris District Cooling Network
• 44 MW Chilled-Water Production Plant (CWPP)
• Cooling by Seine river
• ≈ 50 substations
Chilled-Water Production Flow Chart

CHILLER + FREE-COOLING MODE

District Cooling Network

Chillers evaporators

Chillers condensers

Cooling secondary

Cooling primary

River
Chilled-Water Production Flow Chart

FREE-COOLING MODE

District Cooling Network

Cooling secondary

Cooling primary

HX1
HX2
HX3
HX4

River

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Chilled-water production statistics

Chilled-water production plant configurations annual statistics

CHILLER MODE

CHILLER + FREE-COOLING MODE

FREE-COOLING MODE

CHILLER MODE

% Hours  % Chilled-water production

0%  10%  20%  30%  40%  50%  60%  70%

1 chiller without free-cooling
2 chillers
1 chiller with free-cooling
Free-cooling
3 chillers
4 chillers
5 chillers
6 chillers
7 chillers

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Centrifugal chiller model

CHILLER MODEL

**Parameters** (DOE-2 model [1]):

- Nominal cooling capacity and COP
- Cooling capacity and COP at full-load as biquadratic functions of entering temperatures
- COP as a function of part-load ratio
- Motor heat losses fraction

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Centrifugal chiller model

Calibration of parameters [2]

Comparison between measured and calculated power input over 1 week

![Graph showing comparison between measured and calculated power input over 1 week.]

- **Calculated**
- **Measured**

**Charts:**
- MAPE: 6.5%
- CV: 8.9%
- RMSE: 65.0


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Simulation in chiller mode

- Period: 1 week
- Measured controls, inputs and outputs
- Data time step: 10 minutes
- Simulation environment: Dymola
Simulation in chiller mode

Measured Controls

Evaporator pumps speed
Evaporators leaving temperature
Chillers on/off
Condenser pumps speed
Heat exchanger valves on/off
Cooling primary pumps speed
Simulation in chiller mode

Load and weather inputs

Return temperature
Return volume flow rate

Chiller 1 — Chiller 2 — Chiller 3 — Chiller 7

HX1 — HX2 — HX3 — HX8

Entering temperature from river

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Simulation in chiller mode

Outputs to be compared

Supply temperature

Power input required

Leaving temperature to river

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Validation results

Comparison between measured and calculated electricity consumption per equipment over 1 week

- Chillers: +5.4%
- Evaporator pumps: +40.4%
- Condenser pumps: -23.1%
- Cooling primary pumps: +24.9%

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Validation results

Comparison between measured and calculated total electricity consumption over 1 week

Cooling primary pumps
Condenser pumps
Evaporator pumps
Chillers

+6.2%
Validation results

Comparison between measured and calculated power input over 1 week

- Over-estimation with very low demand
- Under-estimation with high peak demand

- MAPE: 10.9%
- CV: 11.8%
- RMSE: 113.0

CHILLER 1
8.8 MW

CHILLER 2
5.8 MW

CHILLER 3
5.8 MW

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Conclusion & Research perspectives

- Satisfactory total power input modelling for the chiller production mode
- Modelling improvements: pumps
- Validation in progress: other production modes
- Towards operational optimization: add a control model, to be optimized
Questions
Thank you for your attention
Pump model

Representation

Hydraulic model [3]


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Pump model

Representation

Power input model [4] [5]

Pump model

Calibration

Comparison between measured and calculated power input

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Validation results

Comparison between measured and calculated CWPP supply temperature over 1 week

- **CHILLER 1**: 8.8 MW
- **CHILLER 2**: 5.8 MW
- **CHILLER 3**: 5.8 MW

- **Significant over-estimation at chiller start-up phases**

Supply chilled water temperature [K] 0.7

RMSE

\[ \text{Comparison between measured and calculated CWPP supply temperature over 1 week} \]