AMBASSADOR project

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Energy flow management at district level for electrical and hot/cold water networks

Define the optimal energy flows answering to a specific mission assigned to the district

Typical missions
- Optimize net cost of energy
- Minimize CO2 footprint
- Mitigate energy outages impact
Key developments

• Distributed optimization framework to...
  • Coordinate the behavior of a large number of district actors in an optimal way

• Develop a District Simulation Platform (DSP) to...
  • Annual simulations of complete districts
  • Host and validate the optimization algorithms
  • Evaluate potentials

• Deploy validated algorithms on test sites (software-in-the-loop)
Distributed optimization approach

Schneider Electric
Distributed MPC approach

- Why distributed MPC?
  - Scalability
  - Modularity
  - Robustness
  - Privacy!
- Principle
  - xMS solve local optimization problems
  - DEMIS influences the local controllers in such a way that the global objective is achieved
Distributed MPC approach

• Information exchange:

• Optimization objectives:
  • Minimize the cost of energy
  • Fulfill the actors’ missions (comfort in buildings,...)
  • Respect district power limitation (coupling constraint!)
  • Enhance auto-consumption (coupling objective!)
Exemplary results (power limitation)

Battery supplies power during reduction period

Buildings use their inertia
District Simulation Platform

Simulation Platform:
CEA, Schneider Electric
Features for district simulation platform

- Configurable model with evolutive models/libraries.
- Electric/water distribution networks.
- Stochastic occupancy/load.
- Simulation time target: full year in few hours (>x1000).
- Optimization algorithm coupling.
- Use real data to replace some simulation input.
- Post-treatment and analysis (GUI).
From detailed building models to reduced models in DSP and optimization

Automatic Process

IDA-ICE model
Data exported to MATLAB
Building Identification
Model generated for the DSP
Integration in the DSP
Simulation in the DSP

Extraction of IDA-ICE data with MATLAB script
Identify models in MATLAB
Generate Sfunction (Simulink) file of the models for the DSP
Simulate over one year with reduced models in a few minutes
Posttreatment: KPI, graphical display, sensitive analysis, ...
Test sites

Simulation Platform:
CEA, Schneider Electric
Demonstration sites

Ines – Chambéry
France

LTPC - Athens
Greece

BedZed - Sutton
United Kingdom
Questions?
Backup – Optimization
Optimization objectives

• Minimize the sum of the sub-systems’ objectives while taking into account some objectives on district level

• Local objectives:
  • Minimize the cost of the consumed energy
  • Fulfill the sub-systems mission (comfort in buildings,...)

• District objectives:
  • Respect global limitation on the power consumption
  • Enhance auto-consumption
Dual decomposition method

• Centralized problem:

\[
\begin{aligned}
& \text{Minimize} \\
& \sum_{l \in S} J_l(x_l, r_l) \\
& \sum_{l \in S} r_l \leq R_{lim}
\end{aligned}
\]

• Build Lagrangian:

\[
L(x_l, r_l, \lambda) = \sum_{l \in S} J_l(x_l, r_l) + \lambda \left( \sum_{l \in S} r_l - R_{lim} \right)
\]

• Decomposability:

\[
L(x_l, r_l, \lambda) = \sum_{l \in S} \left[ J_l(x_l, r_l) + \lambda \cdot r_l \right] - \lambda \cdot R_{lim}
\]

• Dual problem:

\[
\begin{aligned}
& \text{Maximize} \\
& \inf_{\{x_l, r_l\}} L(x_l, r_l, \lambda) \\
& \text{Subject to:} \quad \lambda \geq 0
\end{aligned}
\]

• Maximization problem over the dual variable \( \lambda \)
Solving the optimization

- Control update period: 15 minutes
- Prediction horizon: 24 hours
- Iterative scheme: 10-30 iterations

- At each iteration:
  - The sub-systems solve their local problems in parallel and send their predicted power consumption and objective value to the DEMIS
  - The DEMIS aggregates the total power consumption and updates the energy tariff ($\lambda$) for the next iteration
Unified interface « eNode »

- Exchange between DEMIS and eNodes:
  - DEMIS → eNode: tariff profile
  - eNode → DEMIS: opt. power profile + cost value
- No knowledge of the sub-systems at DEMIS level
Backup – Optimization results
Some results (power limitation)

- **District:**
  - 10 buildings
  - 1 battery

- **Use case:**
  - Utility asks for consumption reduction of 2 hours
  - 3 day simulation in closed-loop
Exemplary results (power limitation)

battery supplies power during reduction period

buildings use their inertia
Some results (auto-consumption)

Energy to grid: 155 kWh

Battery & Buildings anticipate to consume locally produced energy.