An efficient algorithm for the provision of a day-ahead modulation service by a load aggregator

ISGT 2013

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8^{th} October 2013

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1. Context
   - Balancing service & consumption
   - Flexible loads management
   - Example of modulation
2. Day-ahead optimization
3. Heuristic algorithm
4. Conclusion

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Balancing service & consumption

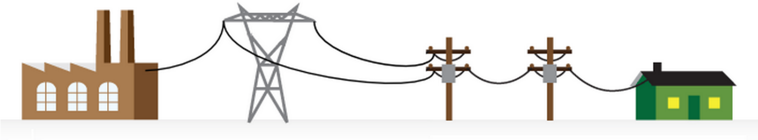
Production = *Consumption*: How?

Throughout the day: Balancing service

- Use flexibility of production/consumption
- $\nearrow$ needs with renewable energies

Topic of the presentation

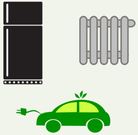
- Objective: Modulation of the consumption to offer a balancing service to the electric network.
- Coordination entity: **Aggregator**



Flexible loads management

Loads

1. Flexible:
   Heat pump, Electric heater, Electric car, ...
2. Non-flexible:
   TV, light, computer, micro-wave, ...



Aggregator

- Controls the consumptions of flexible loads in its portfolio.
- Provides services to the TSO.

Service proposed

- Upward/downward modulation of the consumption.
- Option available once a day.
- Activation period unknown one day ahead.

Example of modulation

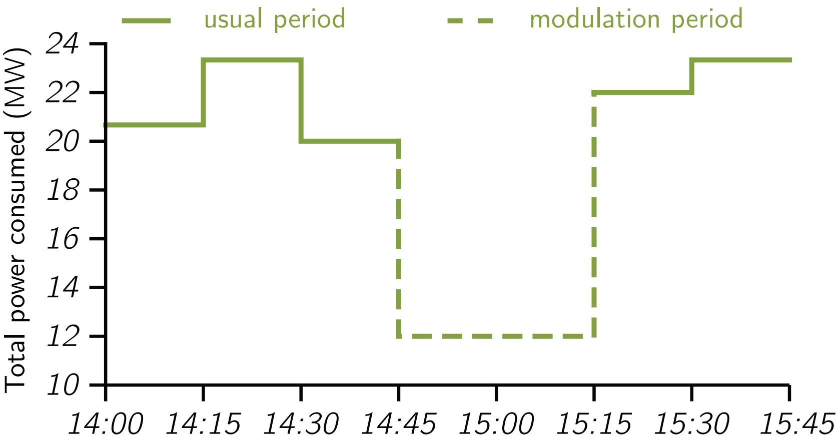


Figure: 8 MW modulation for 30 minutes.

Overview

Problem considered

How to **know** and **maximize** the **quantity** of load **modulation** that can be provided given a portfolio of loads?

Optimization problem

max Upward and downward modulation quantities

subject to

- Feasible delivery of the modulation at any period.
  ex: *Can I deliver at 3 p.m?*
- Load constraints
  ex: *The room should stay between* $18^{\circ}C$ *and* $22^{\circ}C$.

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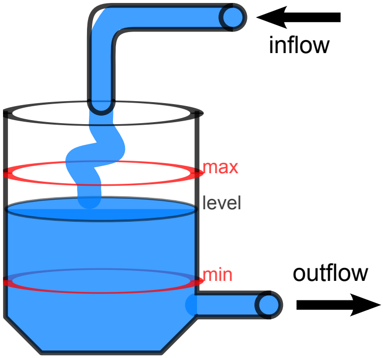
Generic load model

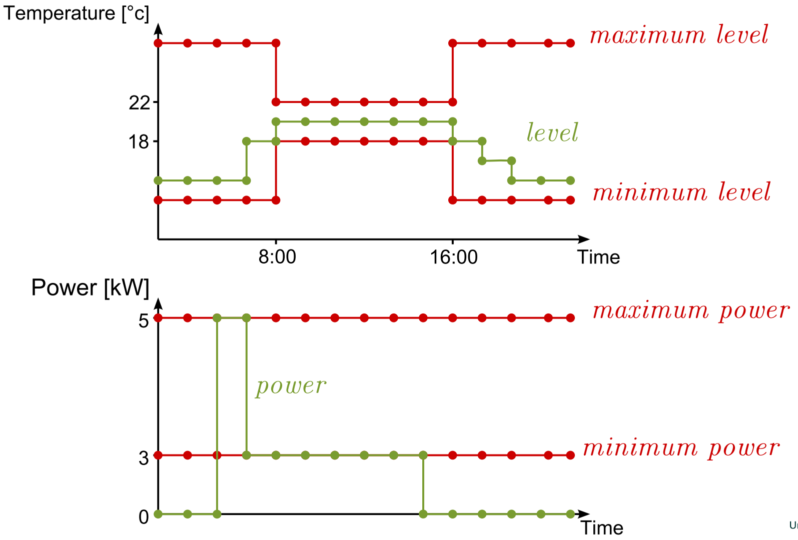


- Various type of load, one model
- Deterministic
- Related to storage
- Simple
- Level inflow = f(power)

Level evolution

$$\Delta\text{level} = \underbrace{a_{t-\delta} \times \text{power}_{t-\delta} + b_{t-\delta} \times \text{on}_{t-\delta}}_{\text{inflow}} - \underbrace{\phi\text{out}_t}_{\text{outflow}}$$

Example: Modeling of an electric heater.

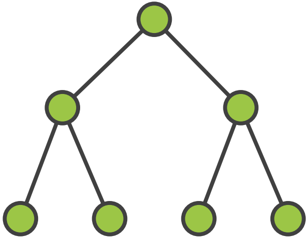


Mixed Integer Linear Programming

- Mixed Integer Linear Program
- Number of binary variables:
  - One by load and by period for each possibility of modulation call.

⇒ $M \times T^2$: With M loads and T periods.

⇒ Intractable for real instances



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The algorithm

Summary

1. Check that a feasible consumption pattern exists for each load
   - Simple set of inequations to check
2. Build initial solution
   - From a target total consumption at each period,
   - dispatch this consumption to every load,
   - ensure that each level is within bounds.
3. Local search
   - Modify the target total consumption

Complexity

$$\mathbf{M.T.log(M) + 2.M.T^3} \text{ in the worst case.}$$

$M =$ number of loads and $T =$ number of periods.

1. Check feasibility for each load

Aggregator has to ensure that at least one feasible consumption pattern exists :

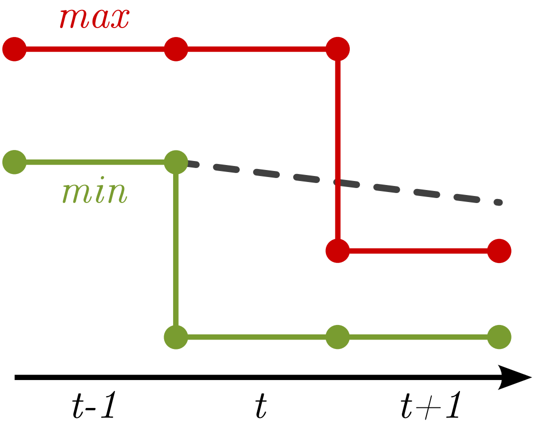

Figure: Infeasible level margins due to a too sharp decrease in the level bounds.

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2. Build initial solution

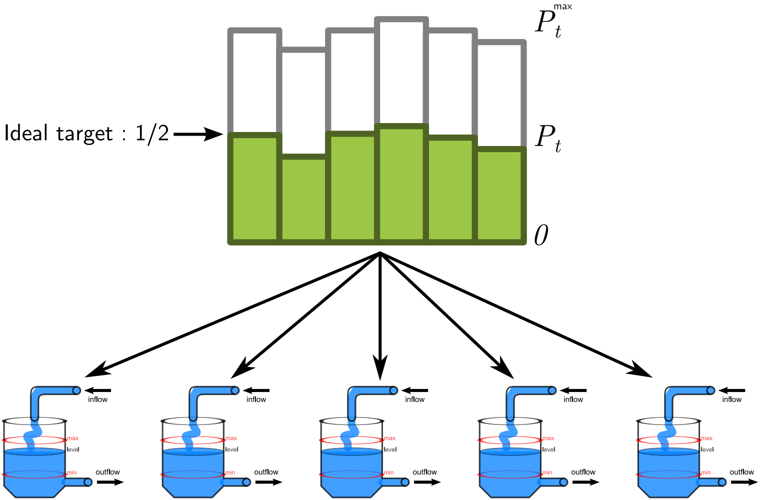

Figure: Dispatch of the reference power to every load.

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3. Local search

Insight on the solution

Maximize the modulation quantity available the whole day

$\Downarrow$

Maximize the **minimum** available modulation quantity.

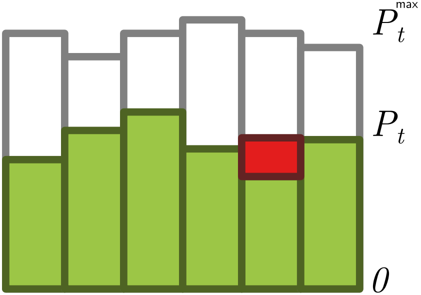

Figure: Increase of the total power reference to increase the potential of a downward modulation.

Results

- Quality :

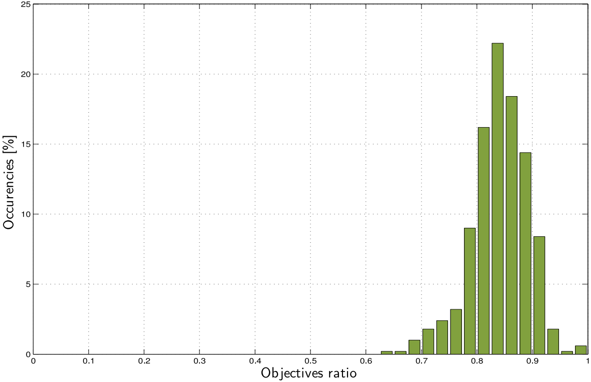

Figure: Comparison between the MIP objective value and the heuristic for 500 small instances.

- Time : 5 seconds to compare with 3 minutes for CPLEX

Conclusion

Acknowledgments :

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Gredor

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