Smart Energy Features

Application to Lifts and Hoisting Systems

CEA, Grenoble INP, Schneider Electric, Sodimas

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Introduction

Customers are looking for integrated solutions that make their lives easier while optimizing costs. Innovation is essential to satisfying those requirements.

The convergence of automation, information, and communication technology has created dramatic new opportunities for advancing energy efficiency.

Innovation is about combining these opportunities with smart services to deliver high-value yet easy-to-deploy solutions.

Pascal Brosset, SVP Innovation, Schneider Electric

Schneider Electric at a glance

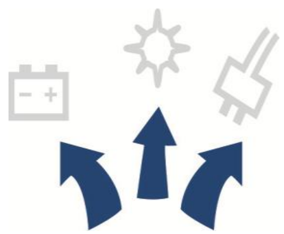
- ❑ 24 billion € sales in 2012
- ❑ 41% of sales in new economies
- ❑ 140 000+ people in 100+ countries
- ❑ 4-5% of sales devoted to R&D

Smart Energy features

for machines, for plants, for infrastructures

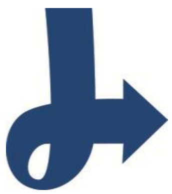
- To reduce energy costs and/or CO2 by leveraging

Energy recovery



Distributed energy resources

Variable energy tariffs

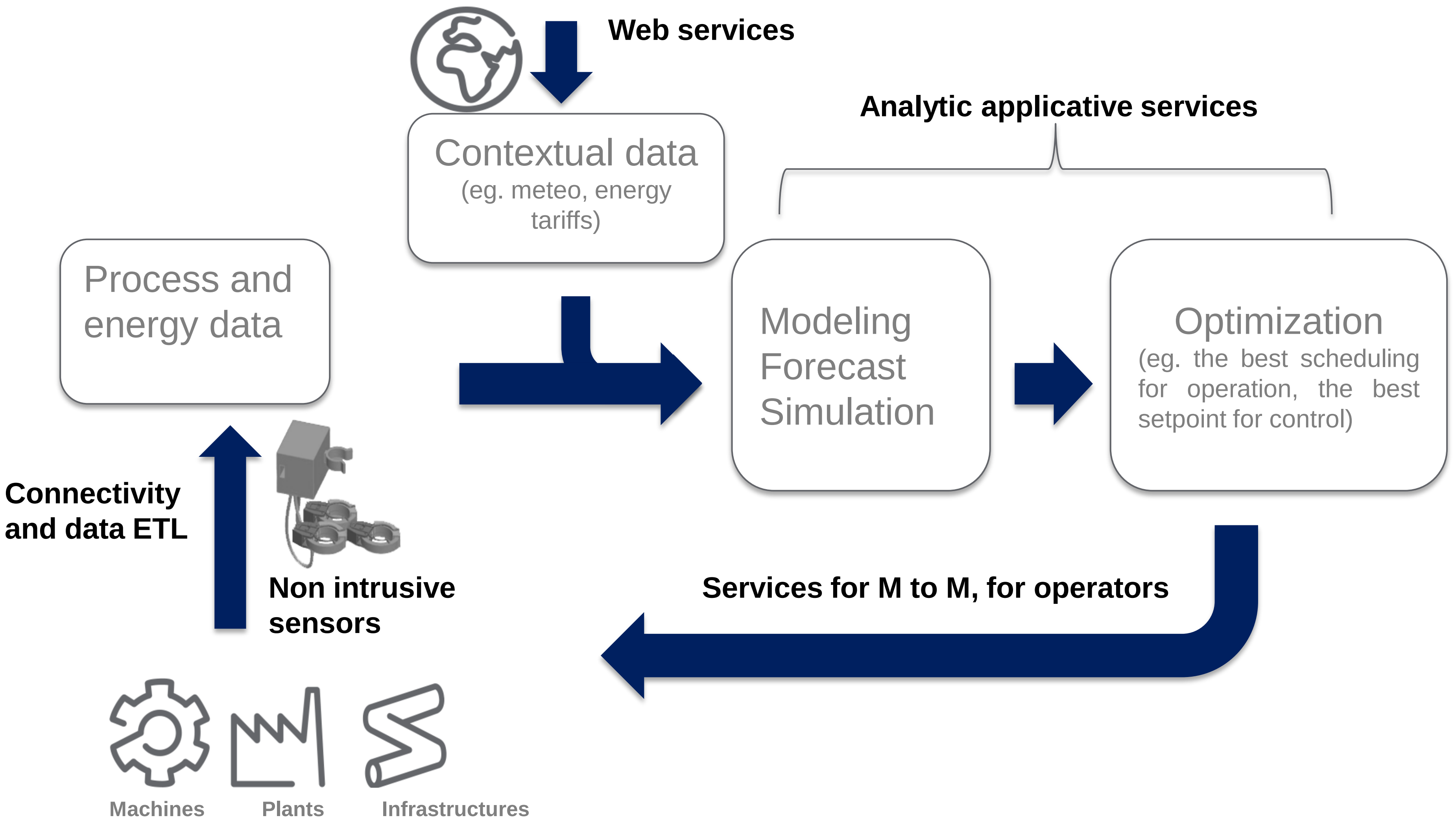


Process flexibilities

- Thanks to optimization and cooperative automation

for the best operations schedule, the best control set-points

Principles and technical enablers



3 pilot demonstrations

Arrowhead cooperative project

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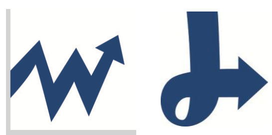
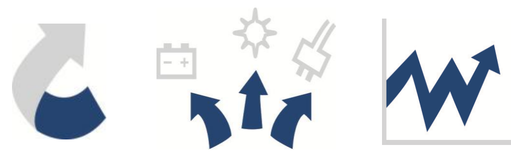
MANUFACTURING



OPTIMIZE SCHEDULE of production operations, leveraging sub-assembly storage and variable tariffs

- ❑ Minimize cost without any risk regarding demand

LIFT



OPTIMIZE CONTROL of multiple sources of energy

- ❑ Reduced environmental footprint
- ❑ Autonomy in case of grid breakdown in order to Increase safety

WATER NETWORK

OPTIMIZE SCHEDULE of pumping, leveraging water tower storage and variable tariffs

- ❑ Minimize cost without any risk regarding demand

Focus on the Lift pilot

- Cooperation between CEA, Grenoble INP, Schneider Electric, Sodimas

- Arrowhead European Project (Artemis)

Enable collaborative automation by networked embedded devices

- CIFRE PhD, Chloé Desdouits

Gipsa-lab, Control department, SYSCO team
Schneider Electric, Strategy & Technology, Analytics for Solutions

Reduction of peak power consumption: optimization problems induced at consumer side, resolution methods, genericity, efficiency

The Lift context in a nutshell

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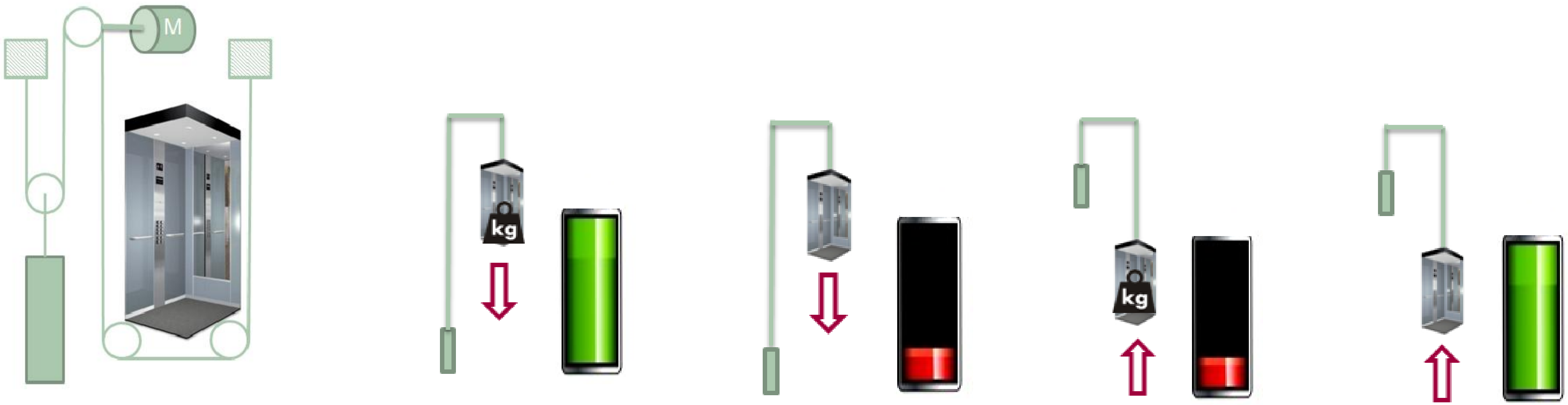
- Energy can be recovered



- Autonomy is needed

To ensure return to safe position in case of energy breakdown

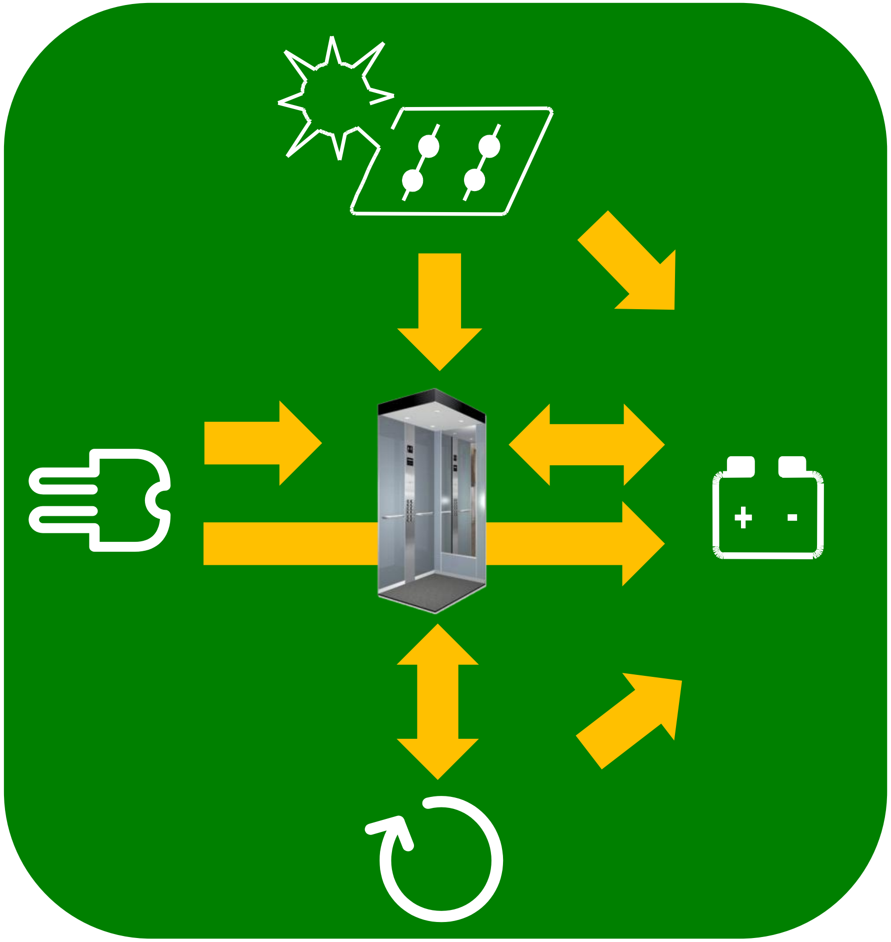
To evacuate disabled persons in case of fire

- Green is a market value

Near Zero Energy Buildings

Problems

regarding the control of the multi-sources system



- Decide what to do with the energy in real time: buy it, store it or select the best local energy source
- Reduce the global cost
  - Minimize energy costs
  - Optimize the life of storage devices
- Keep a given energy reserve for safety reasons
- Taking into account the variability of energy prices, of solar production, of travels demand

Solutions

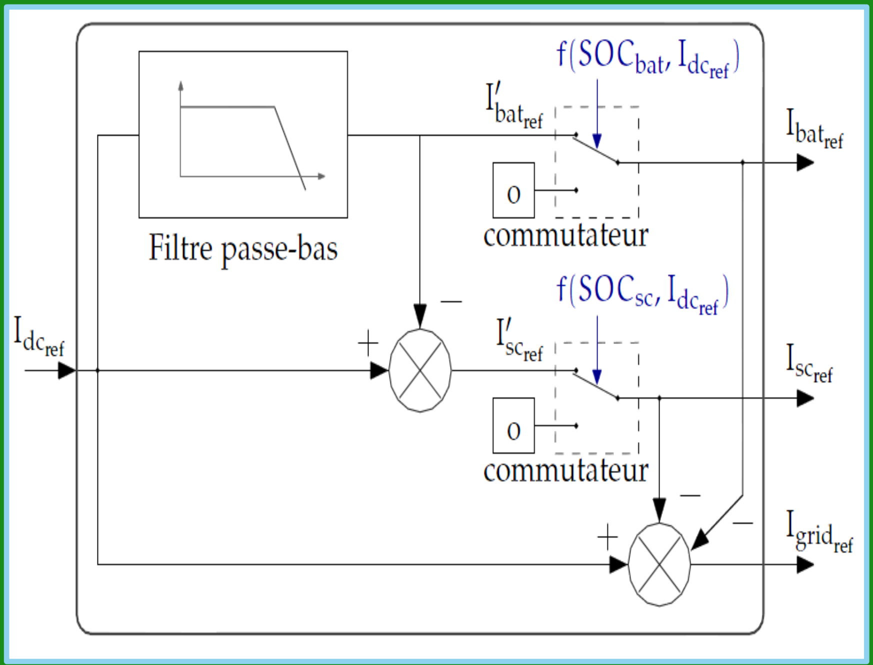
State of the art solutions

- Rule-based low-level elevator control
- Off line strategy calculation
- Distributed control (agents)

Our solution

Low-level elevator control

- Rule-based control
- Real-time operation
- Reactive system / Sub-optimal



$$I_{bat_{ref}} = \begin{cases} 0, \text{ if } \begin{cases} I_{dc_{ref}} < 0 \text{ and } SOC_{bat} > 95\%, \\ I_{dc_{ref}} > 0 \text{ and } SOC_{bat} < 25\% \end{cases} \\ I'_{bat_{ref}}, \text{ if } \begin{cases} I_{dc_{ref}} < 0 \text{ and } SOC_{bat} < 95\%, \\ I_{dc_{ref}} > 0 \text{ and } SOC_{bat} > 25\% \end{cases} \end{cases}$$

$$I_{sc_{ref}} = \begin{cases} 0, \text{ if } \begin{cases} I_{dc_{ref}} < 0 \text{ and } SOC_{sc} > 95\%, \\ I_{dc_{ref}} > 0 \text{ and } SOC_{sc} < 25\% \end{cases} \\ I'_{sc_{ref}}, \text{ if } \begin{cases} I_{dc_{ref}} < 0 \text{ and } SOC_{sc} < 95\%, \\ I_{dc_{ref}} > 0 \text{ and } SOC_{sc} > 25\% \end{cases} \end{cases}$$

Paire, D., Simoes, M. G., Lagorse, J., and Miraoui, A. (2010). A real-time sharing reference voltage for hybrid generation power system. In Industry Applications Society Annual Meeting (IAS), 2010 IEEE, pages 1—8. IEEE.

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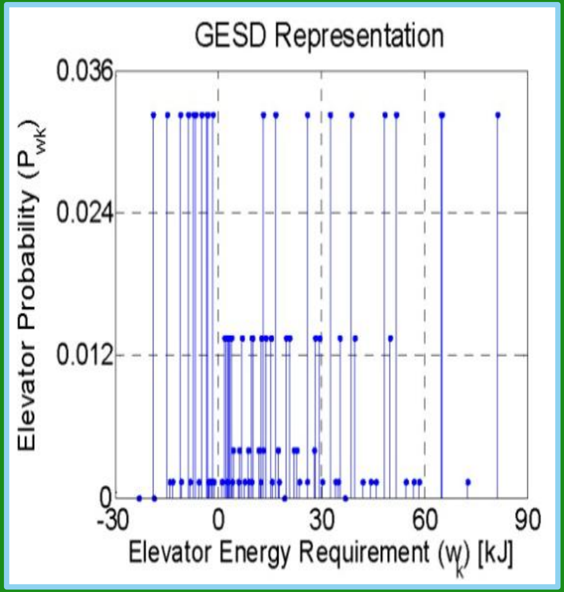
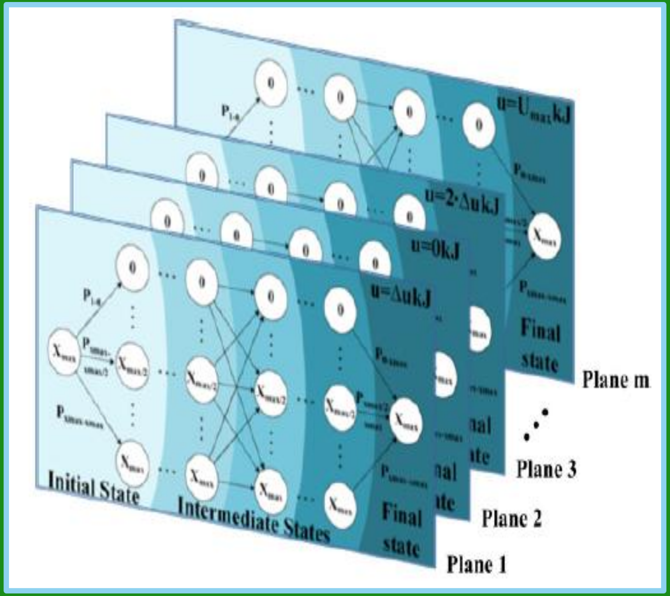
Off-line strategy for elevator control

- Dynamic programming controller
- Goal: (total cost) = (energy cost) + (dissipation cost) + (shortage cost)
- Optimal solution / high computation time

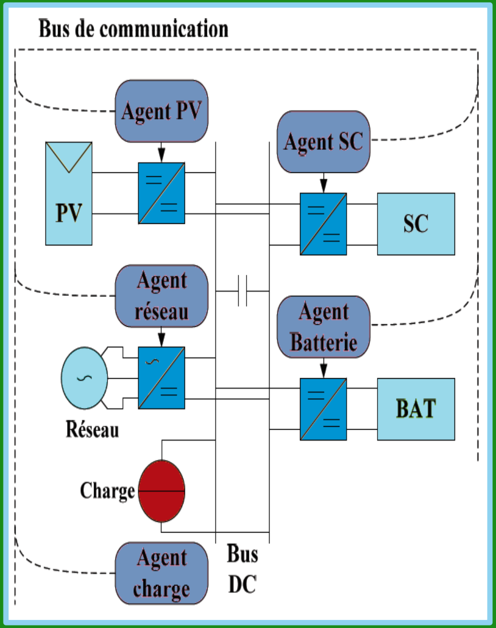


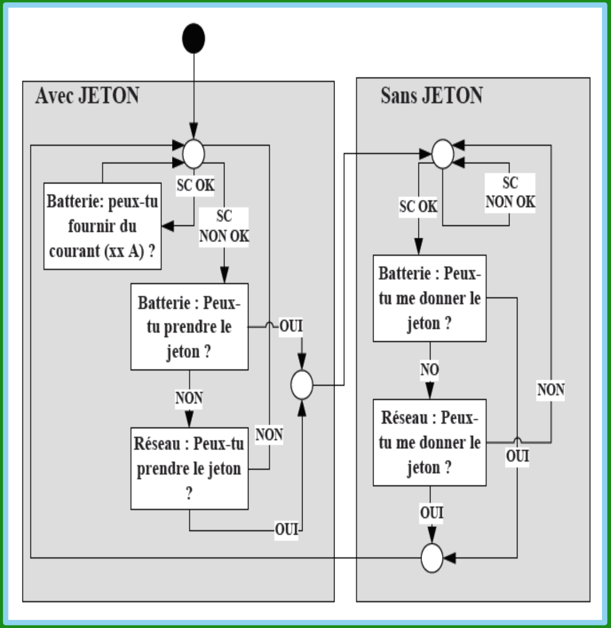


Bilbao, E. and Barrade, P. (2012). Optimal energy management of an improved elevator with energy storage capacity based on dynamic programming. In Energy Conversion Congress and Exposition (ECCE), 2012 IEEE, page 3479–3484.

Distributed control of multi-source systems

- Distributed control: multi agent
- Virtual token for voltage bus control / current control for other agents
- Fault tolerance / no anticipation nor optimality





Lagorse, J. (2009). Modélisation, dimensionnement et optimisation des systèmes d'alimentation décentralisés à énergie renouvelable - application des systèmes multi-agents pour la gestion de l'énergie. PhD thesis.

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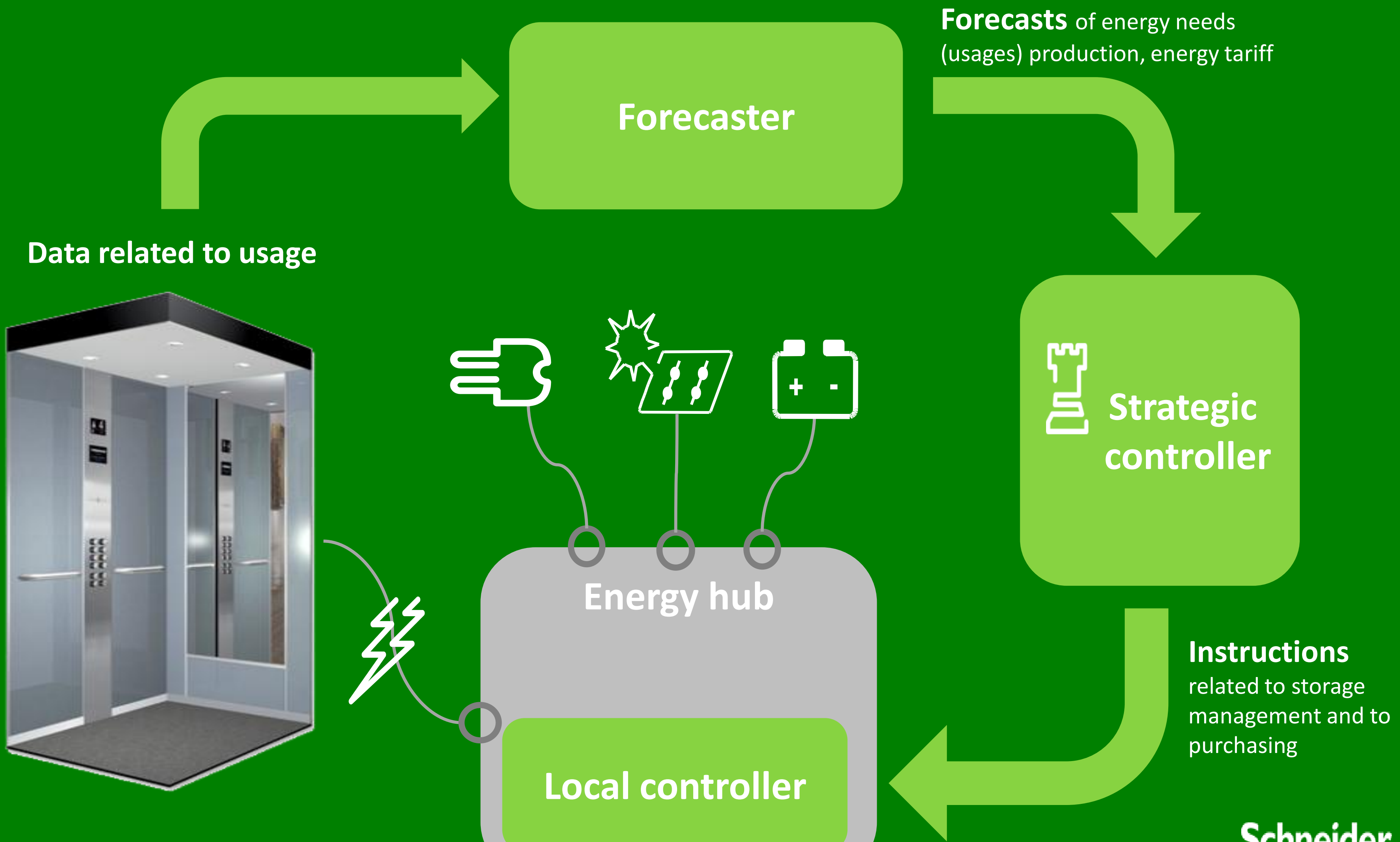
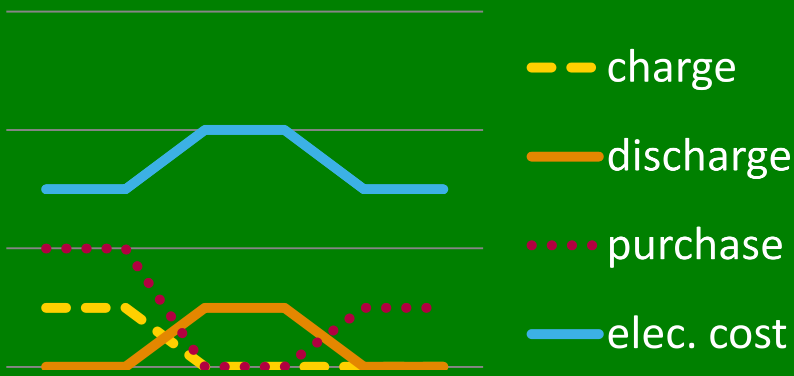
Our solution



The strategic controller



- Exact method
  - Linear programming
  - Model Predictive Control
- Approximation
  - Taking forecasts into account
  - Linear approximation of the battery ageing

$$\text{Minimize}\left[10000 \times \mathrm{c_e} \cdot \mathrm{u_{pc}} + 10000 \times \frac{c_{inve}}{2*c_{cye}*c_{ce}} \times \mathrm{u_s} + 10000 \times \frac{c_{inve}}{2*c_{cye}*c_{ce}} \times \mathrm{u_d} + 0.0001 \times \mathrm{w_{ps}} + 1000000 \times \rho_{e,\min}\right]$$

Goal : energy cost, battery usage cost

Constraints

Energetic equation

$$\mathrm{u_{pc}} + \mathrm{u_d} + \mathrm{w_{pd}} - \mathrm{w_{ps}} - \mathrm{u_s} - \mathrm{w_d} = -\mathrm{w_{pr}} - \mathrm{w}$$

Subscribed power

$$\mathrm{u_{pc}} \leq c_{ppc} \times \tau$$

Battery

- state of charge

$$\mathrm{x_e^+} - x_e[t_1] + \mathrm{A} \times \mathrm{u_s} + \mathrm{B} \times \mathrm{u_d} = 0$$

- min/max power

$$\mathrm{u_s} \leq \frac{c_{ce} \times \tau}{c_{tce}}$$

$$\mathrm{u_d} \leq \frac{c_{ce} \times \tau}{c_{tde}}$$

- autonomy

$$-\mathrm{x_e^+} - \rho_{e,\min} \leq -c_{autonomie}$$

Super-capacitor

- state of charge

$$\mathrm{x_p^+} - x_p[t_1] + \mathrm{A}' \times \mathrm{w_{ps}} + \mathrm{B}' \times \mathrm{w_{pd}} = 0$$

- min/max power

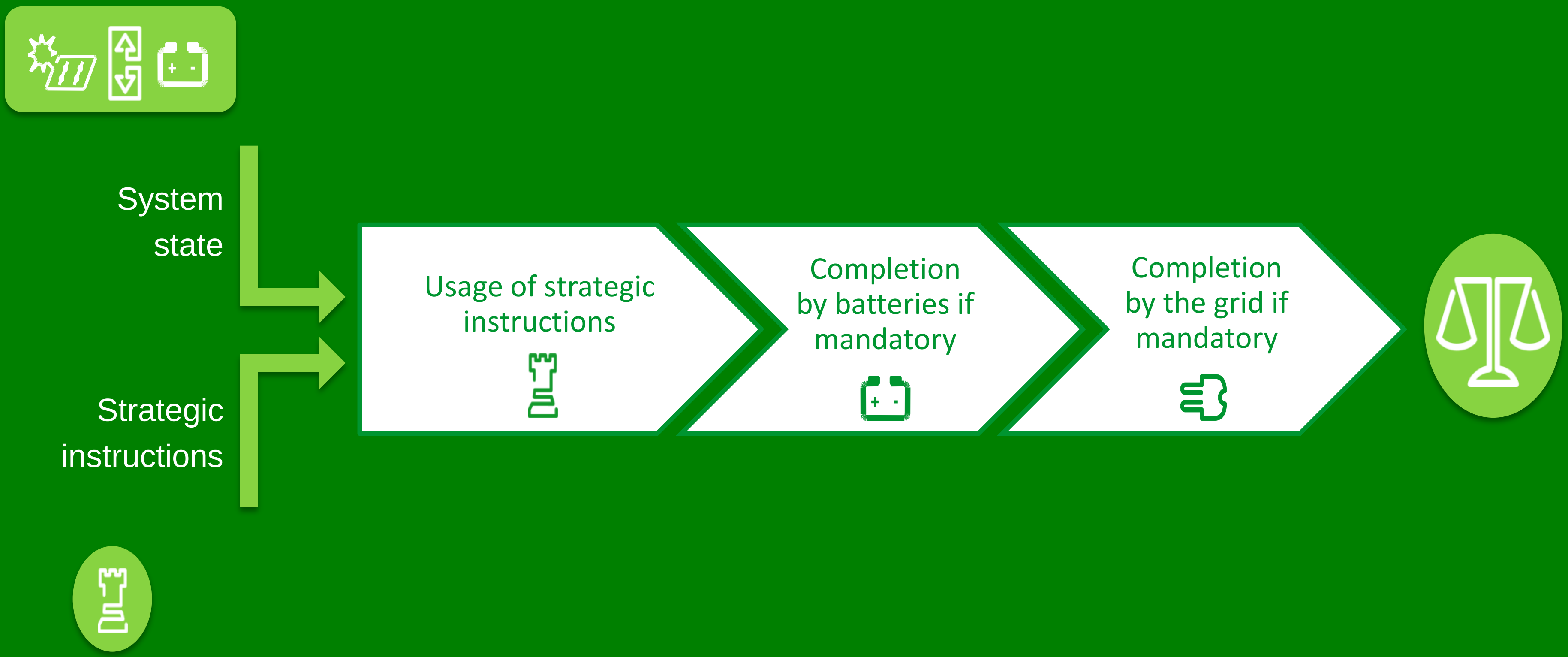
$$\mathrm{w_{ps}} \leq \frac{c_{cp} \times \tau}{c_{tcp}}$$

$$\mathrm{w_{pd}} \leq \frac{c_{cp} \times \tau}{c_{tdp}}$$

We want to mimize purchased energy cost and battery usage cost while satisfying physical and minimum autonomy constraints.

The local controller

- Simple rules



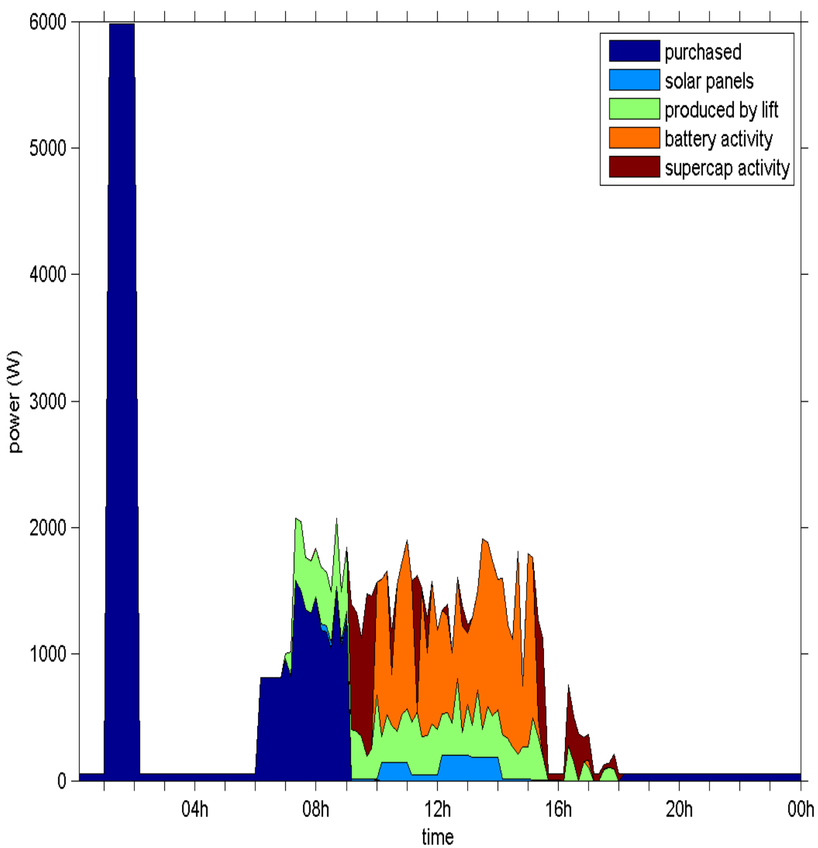
Preliminary results based on simulated data

Hypothesis

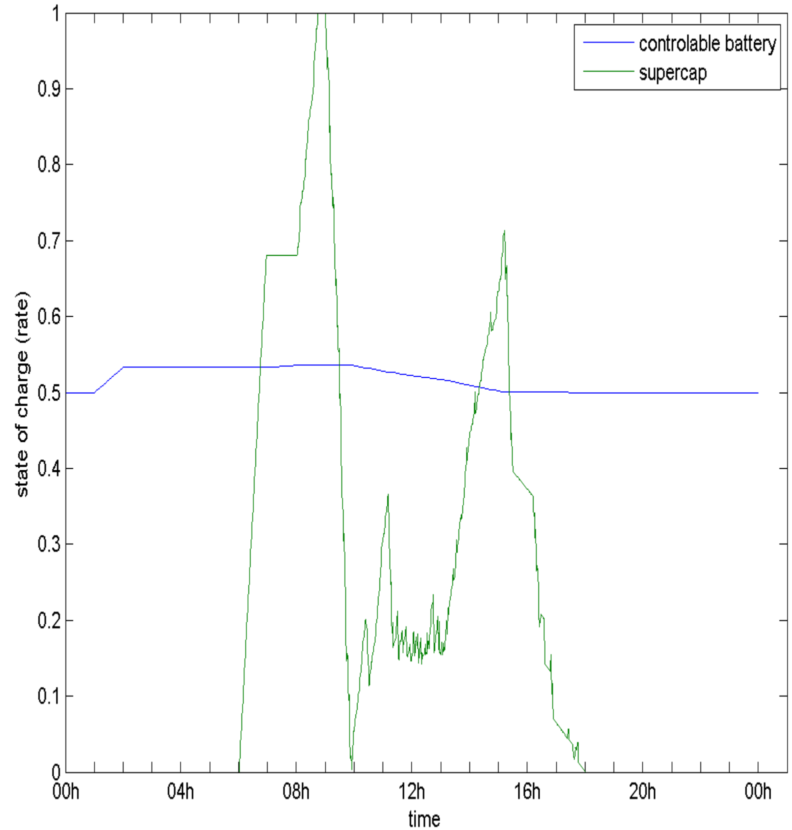
- High usage of the elevator (Poisson distribution)
- 2m^2 of solar panels and a cloudy day
- Energy prices: Peak / off-peak prices between 9 AM and 6 PM
- Storage:
  - Controllable lead acid battery with a 160 kWh energy capacity
  - Non controllable super-capacitor with a 1 kWh energy capacity

The example of one simulated day

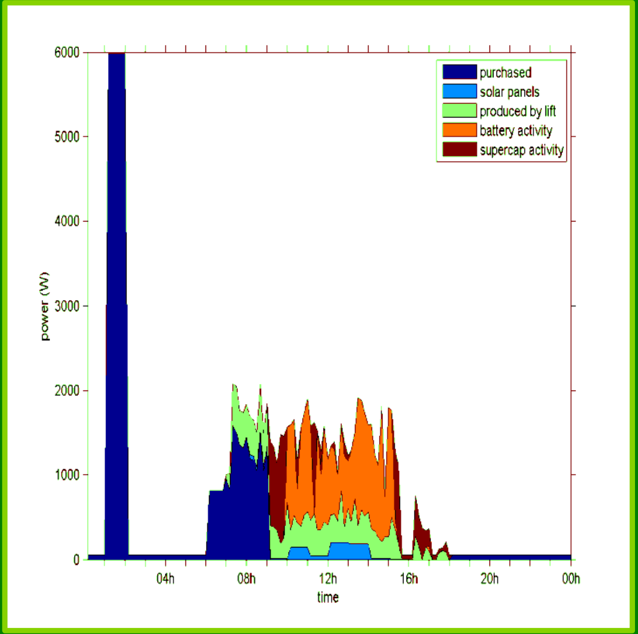
Where energy comes from?



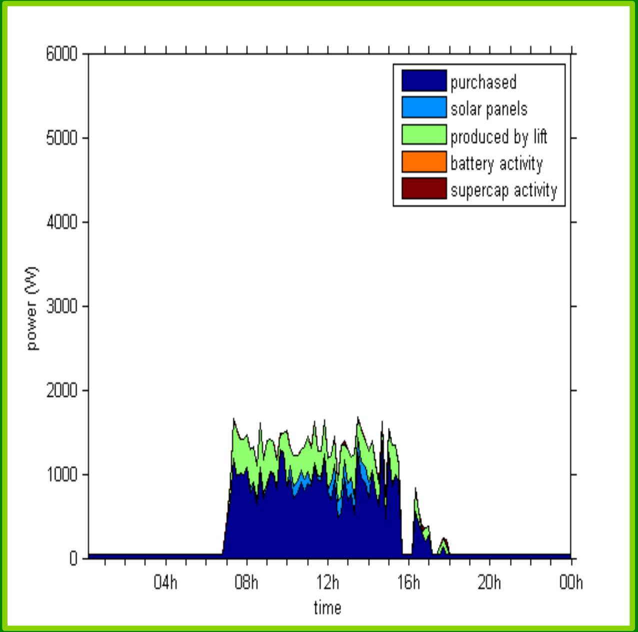
How is storage used?



Our results



Naive controller results



optimization method	uncertainty	electricity bill compared to the cost of all energy used	battery usage cost compared to the investment cost
proposed method	0%	34.4%	0.0060%
proposed method	10%	47.3%	0.0049%
proposed method	50%	51.3%	0.0046%
rules	-	70.4%	0%

Daily gains

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Take Away

- We have prototyped a solution for the control of a multi-sources system in the context of lift. The solution is based on the close cooperation between a forecaster, an optimizer, and a local controller

- Our vision is that this cooperation could be implemented through web-services (as demonstrated in Arrowhead project) and that the same principles could be applied to other contexts such as hoisting machines, micro-grids, smart cities,…

The next steps will be:

- To add consumption peaks reduction objectives
- To improve the forecaster thanks to real energy measurement, connection with a tariffs server and real meteorological prediction
- To improve the local controller and the battery management, in particular taking into account a more realistic (non linear?) battery ageing model

For more information

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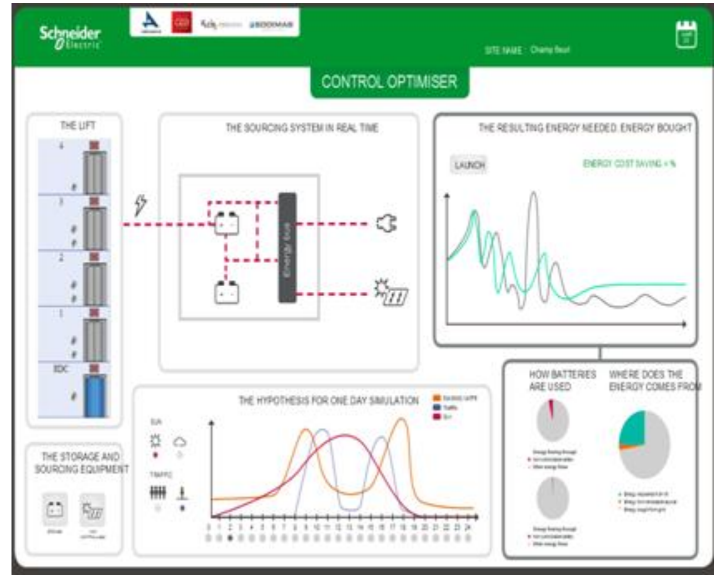
- A video of the demonstration is available on the Arrowhead web site
- Publication at ETFA 2014
- Publication submitted to ECC 2015



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Thank you for your attention !