Decentralized Control for RES By Fast Market-based MAS

IRP 1.2

Hazem Abdelghany
PhD candidate, TU Delft.

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Introduction

- Background.
- Motivation:
  - flexibility from DER.
  - market-based control.
  - Real-time MBC of DER.
- Improved MBC of DER.
- Methodology.
- Conclusion.
- References.

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Background

- An isolated microgrid.
- Connected DERs.
  - Demand response.
  - Distributed storage.
  - Renewable energy sources.
  - Distributed generation.
- Inflexible loads.

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Background

- An isolated microgrid.
- Connected DERs.
  - Demand response.
  - Distributed storage.
  - Renewable energy sources.
  - Distributed generation.
- Inflexible loads.
- Further Expansion.
- South Germany, Bornholm.

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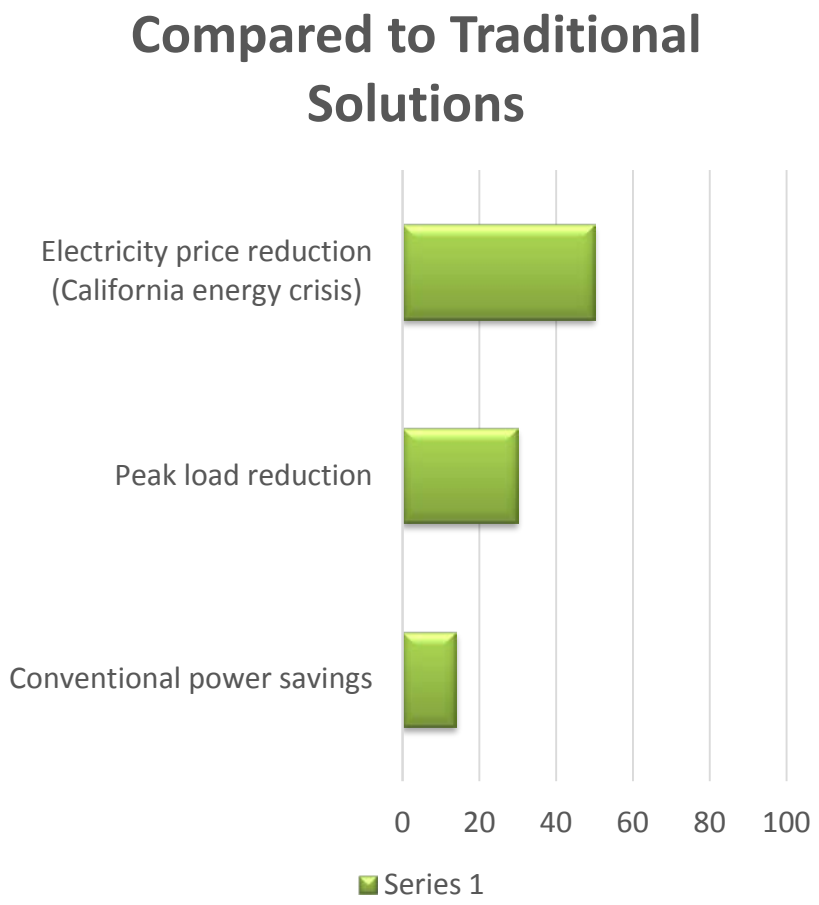
Motivation
Flexibility from DERs

- Some Technical Difficulties
  - Uncertainties introduced by inflexible DERs.
  - Decentralization of generation.
  - Need for constant supply/demand matching.
  - Growing demand.
- Flexibility use is necessary.



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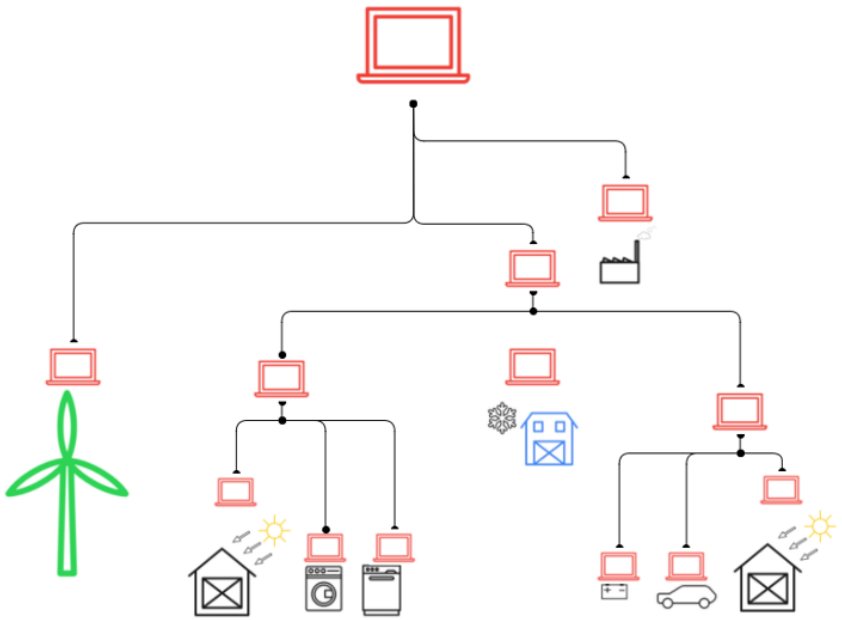
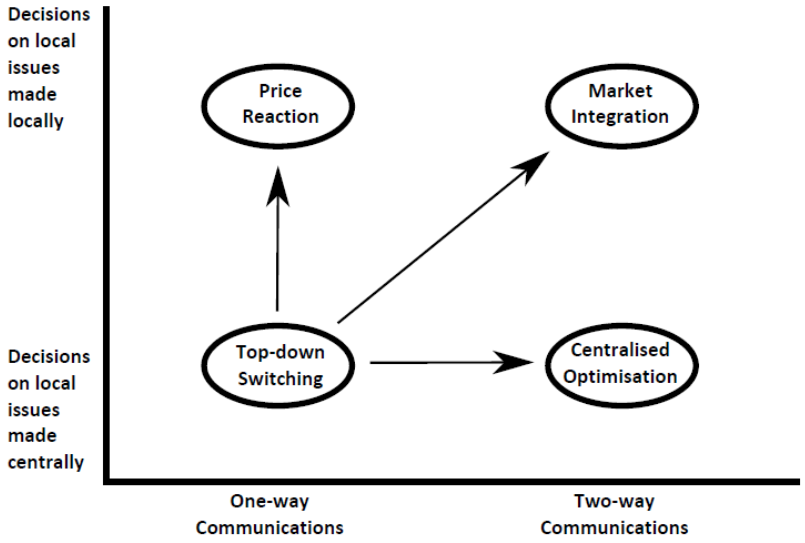
Motivation
Market-Based Control





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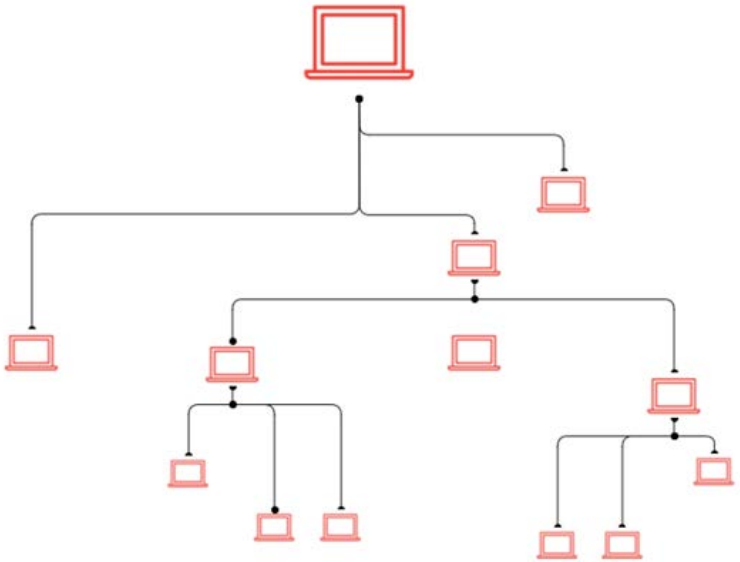
Motivation
Market-Based Control

- As opposed to other techniques.
  - Openness.
  - Privacy preservation.
  - Scalability.
  - Decentralized decision making.
  - Social optimality.
  - Certainty of response.



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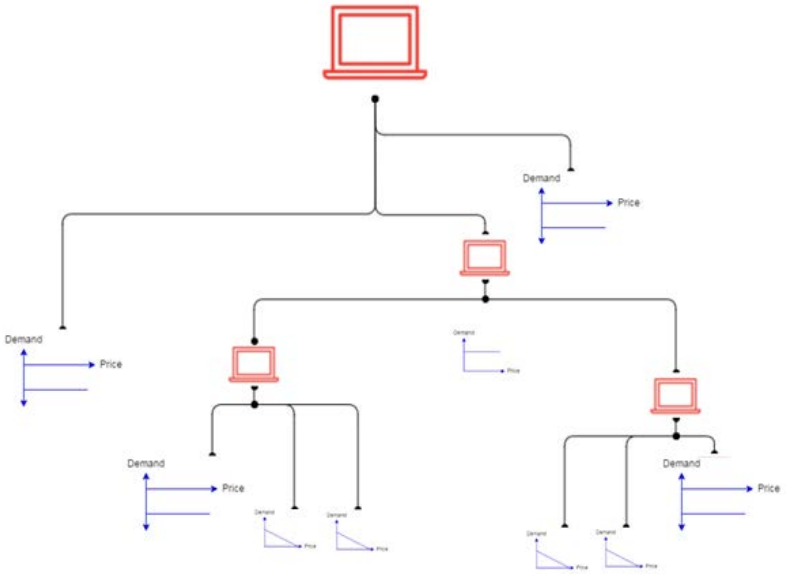

$$b_a = d_a(p)$$

This is an autonomous process

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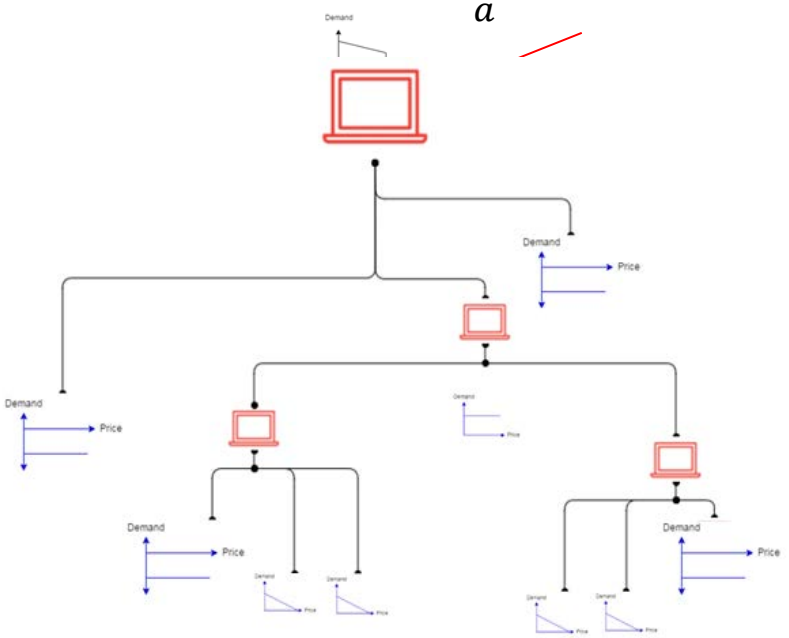
$$\sum_a d_a(p^*) = 0$$



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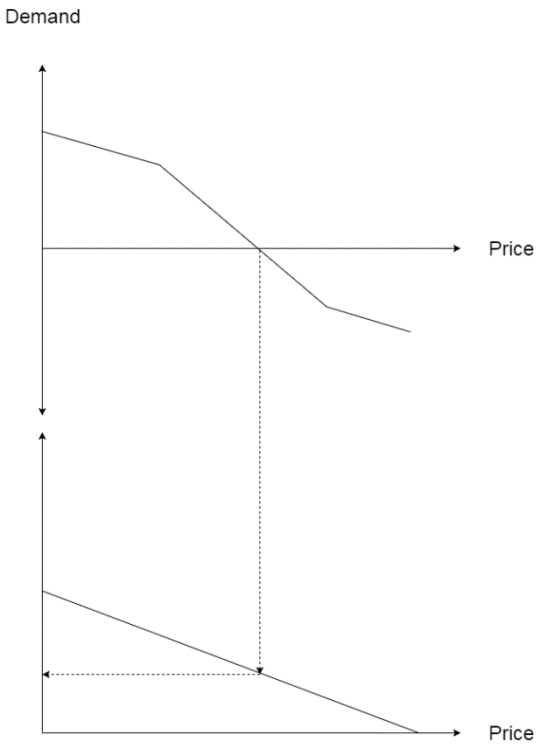

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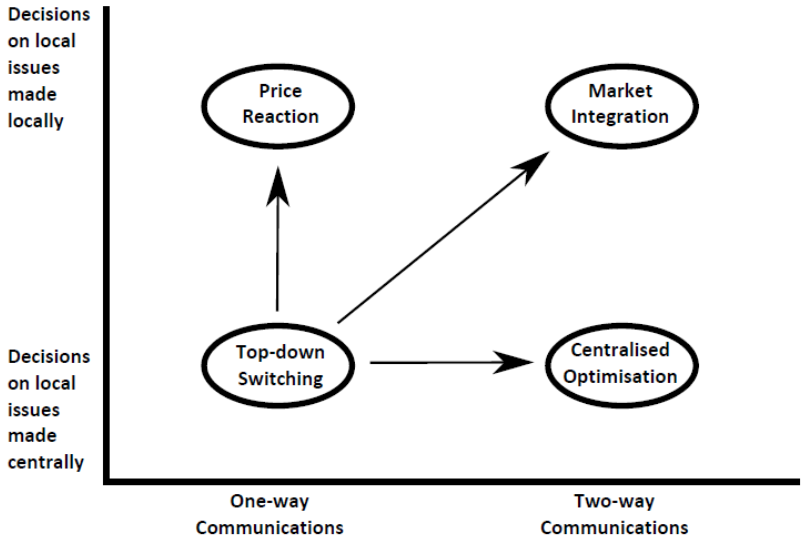
- As opposed to other techniques.
  - Openness.
  - Privacy preservation.
  - Scalability.
  - Decentralized decision making.
  - Social optimality.
  - Certainty of response.
- But, Real-time?



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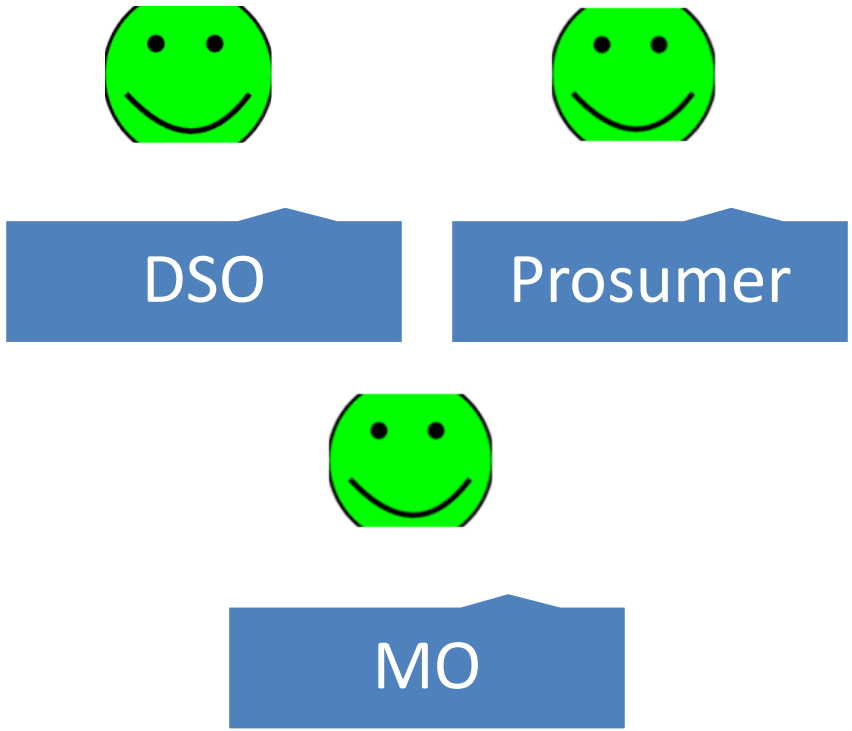
Motivation



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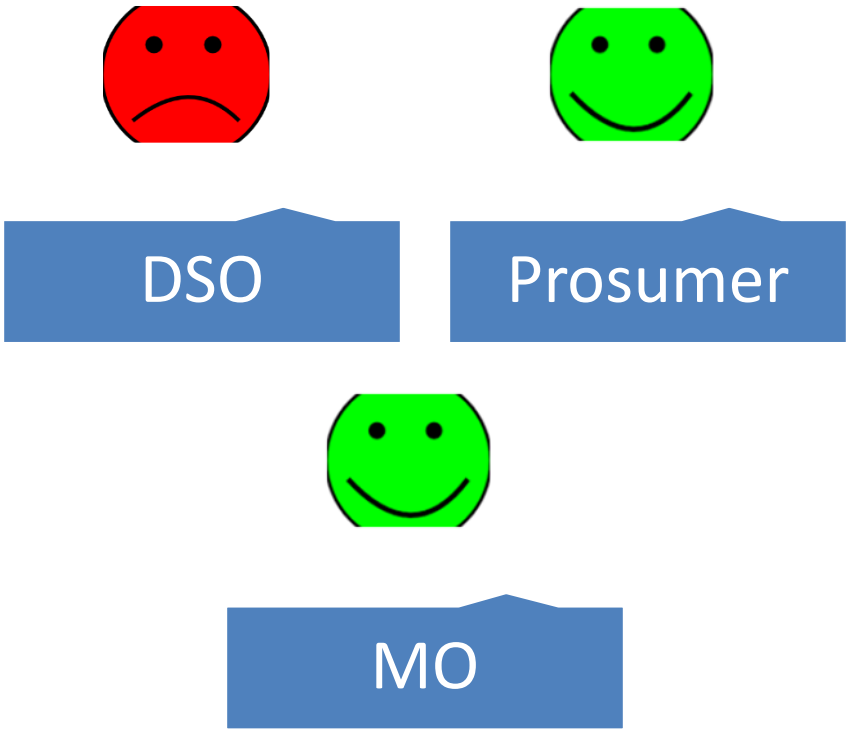
Motivation
Real-time MBC of DER

- Suboptimal use of flexibility.
  - Sub-optimal network operation conditions.
  - Sub-optimal coordination over time.



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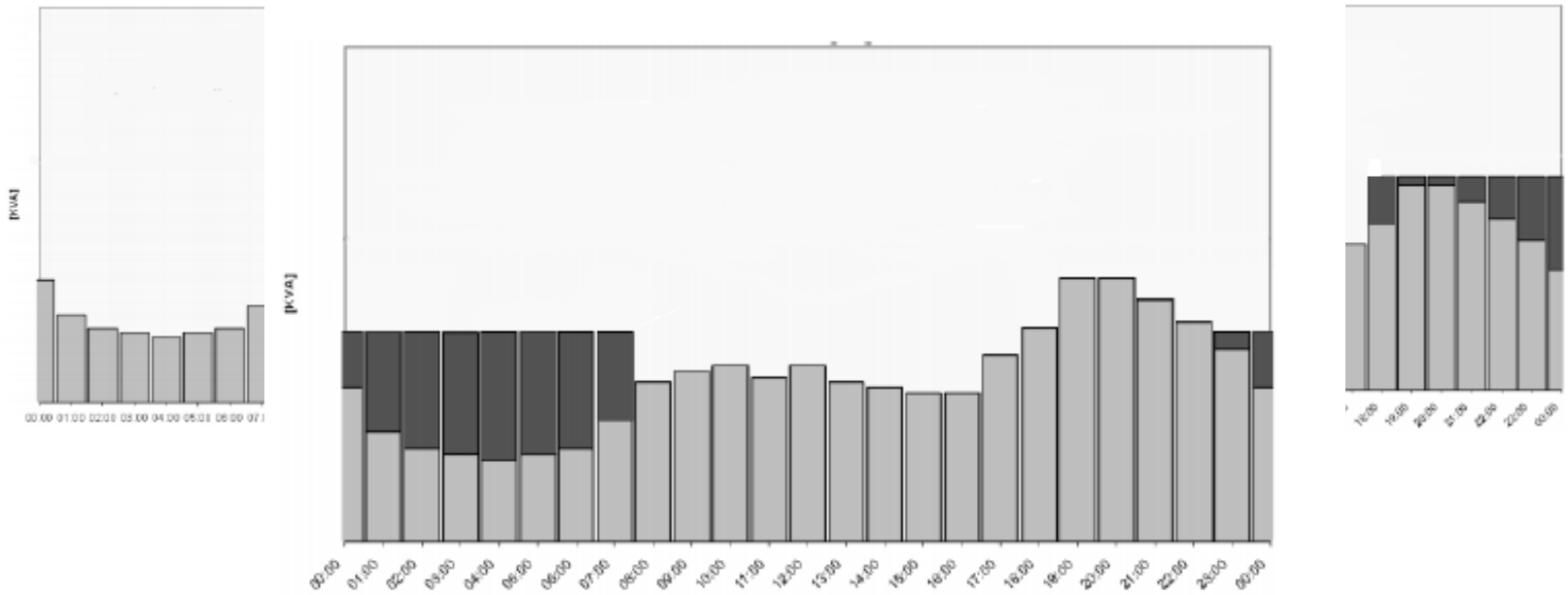

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Real-time MBC of DER

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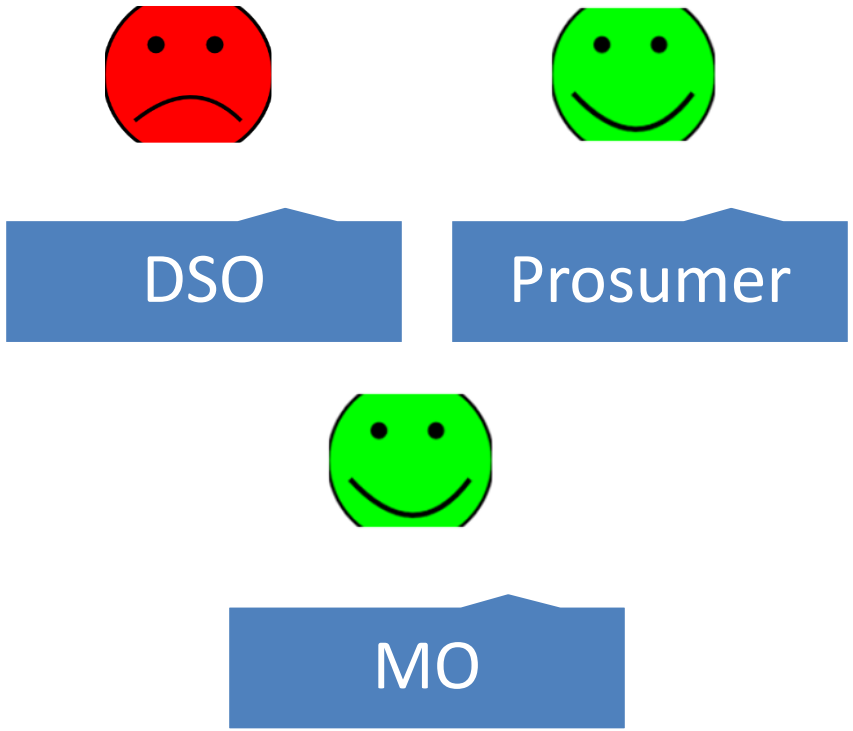
  - Violation of operational constraints.



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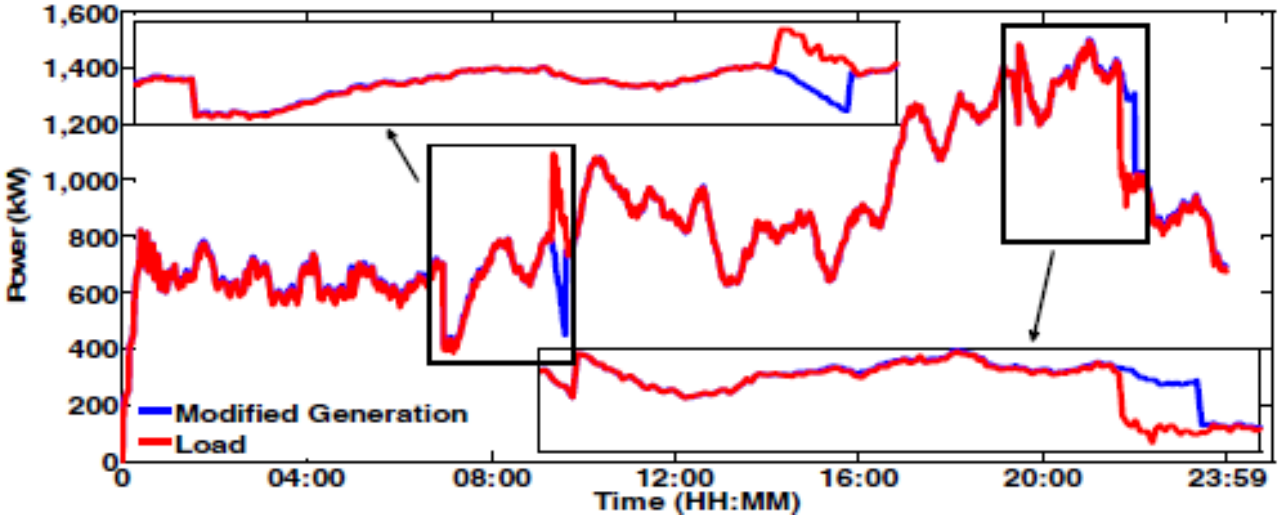

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Real-time MBC of DER

- Suboptimal use of flexibility.
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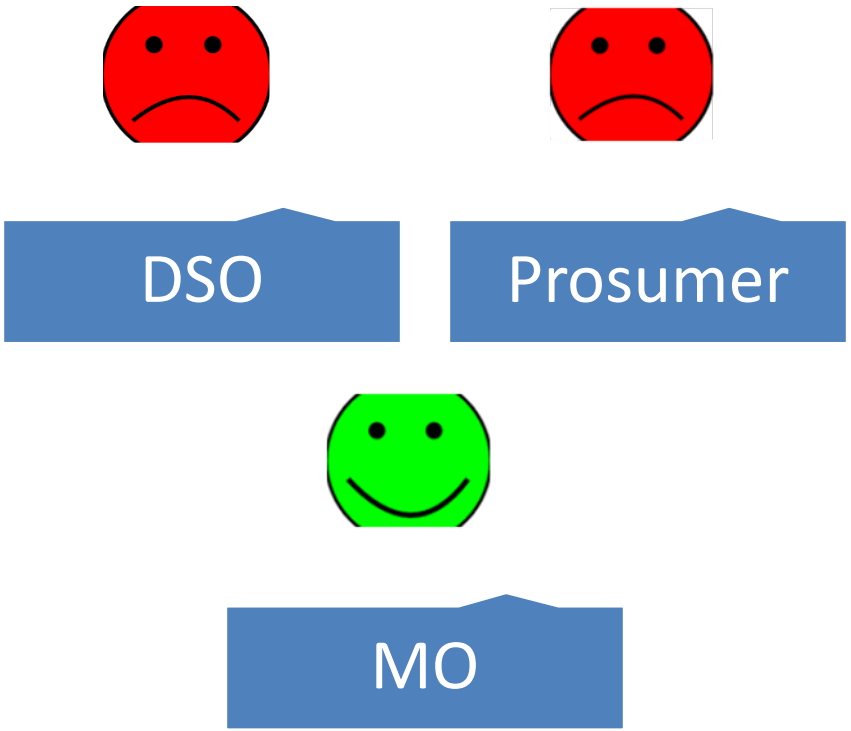
  - Sub-optimal coordination over time.
  - Violation of operational constraints.
  - Violation of comfort constraints.
  - Incentive clipping.



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Real-time MBC of DER

- Suboptimal use of flexibility.
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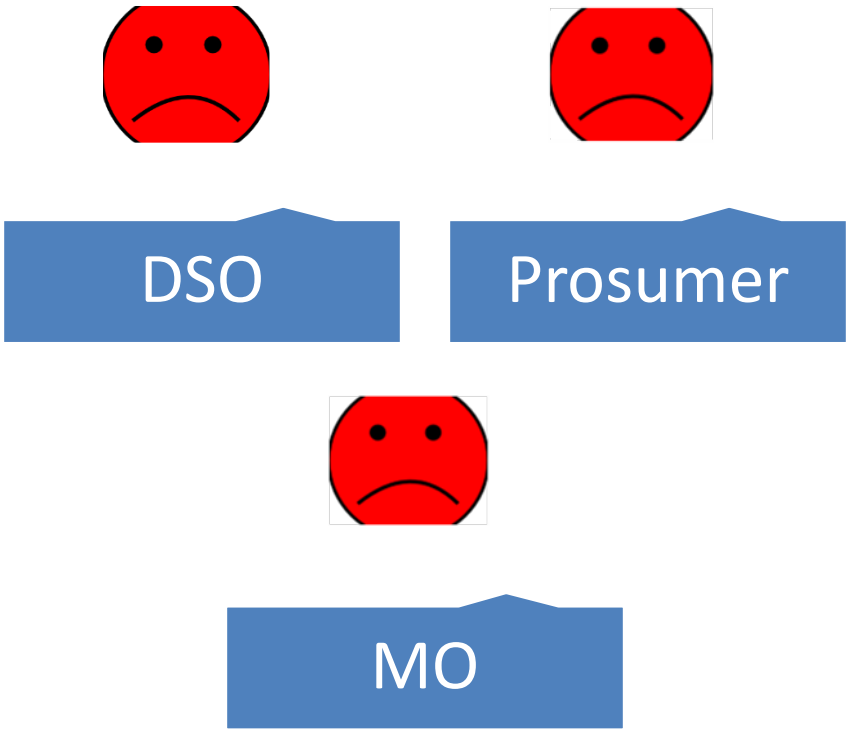
  - Sub-optimal coordination over time.
  - Violation of operational constraints.
  - Violation of comfort constraints.
  - Incentive clipping.
  - Bad integration in wholesale markets.



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Improved MBC of DER

- To improve the performance of real-time MBC systems used for DER coordination.

…heterogeneous, Numerous, self-interested DERs.

…scalability, openness, privacy, simplicity.

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Improved MBC of DER

Planning ahead

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Improved MBC of DER

Planning ahead

- Multi-time step.
  - Sequential.
  - Simultaneous.
- Negotiation schemes
- Cooperative mechanisms.
- Iterative mechanisms.
- Central planning

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Methodology

- Planning ahead in real-time MBC.
- Market steering and forecasting.
- Evaluation of the approach.
- Connection to the main grid
- Effect of grid constraints.

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Methodology

- Planning ahead by agents

$$min \sum_{i=1}^{nt} p_i^* d_i$$

$$s.t. \sum_{i=1}^{nt} d_i = E_{nt}\text{-}E_1$$

$$E_{i+1}^{min} - E_i \leq d_i \leq E_{i+1}^{max} - E_i$$

$$T = \{t_1, \ldots t_{nt}\}$$

$$i = 1, \ldots nt$$

$$E_1 \geq 0$$

$$E_{nt} \geq 0$$

$$d = \{d_1, \ldots d_{nt}\}$$

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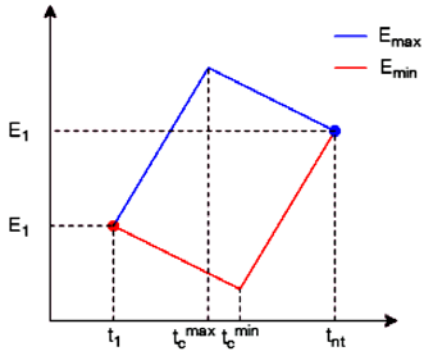
Methodology

$$E_i^{min} = \begin{cases} E_1 + d_{min}(t_i - t_1) & t_i < t_c^{min} \\ E_{nt} - d_{max}(t_{nt} - t_i) & t_i \geq t_c^{min} \end{cases}$$

$$E_i^{max} = \begin{cases} E_1 + d_{max}(t_i - t_1) & t_i < t_c^{max} \\ E_{nt} - d_{min}(t_{nt} - t_i) & t_i \geq t_c^{max} \end{cases}$$



- DR agents
  - power flow is unidirectional
  - non-flexible once turned on

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Methodology

- Flexible Device Agent:
  - Small, with local objectives.
  - Self-interested.
  - Given a steering signal (forecasted price, accuracy).
  - Determines bid curve for current time step, within a planned bidding profile, to achieve local objective.
  - Updates the plan when updated forecasts are available.

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Methodology

- Case 1: fixed prices
  - Resource allocation problem.
  - Polynomial time (simplified).
  - Requires extension, simplification.
- Case 2: including uncertainty
  - MDP,SDP.
  - Still, a lot of work to be done here.

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Methodology

- Given perfectly predicted prices, how to plan a DER agent's demand profile over a period of time?

- Given a steering signal (e.g. price forecast), how can a flexible device agent plan future bidding profile to achieve local objectives?

…in real-time.

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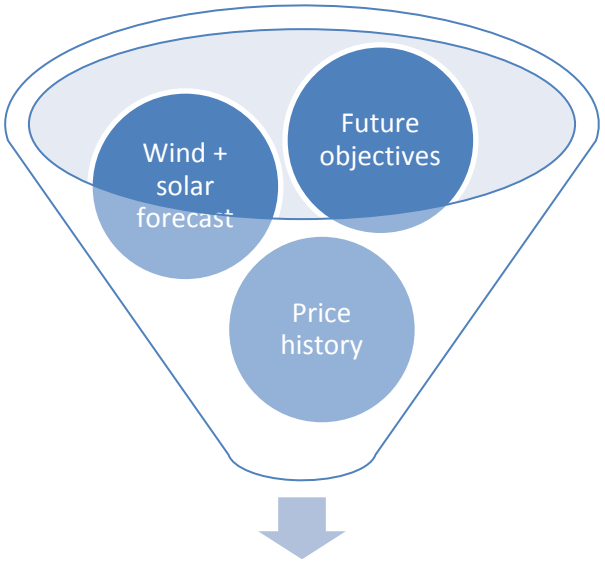
Methodology

- Forecasting and Market steering
  - One agent, to provide market steering signal.
  - How to include future DSO/MO objectives?
  - Forecasting is updated periodically, less forecasting errors, better planning(unlike day-ahead).



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Methodology

- Given non-private data (e.g. weather forecast, price history, DSO objectives) how can a steering signal be generated with the aim of improving overall performance over a time period?

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Methodology

- Evaluation of overall system performance.
  - 1000 households with inflexible LP.
  - Randomly allocated DER.
    - Inflexible RES.
    - Flexible storage and DR.
- Base case, no planning ahead.
- Optimal case, planning ahead with complete information by central controller.
- Proposed methodology, real-time MBC with market steering and local planning.
- Comparison between different cases.

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Methodology

- What is the effect of such behavior on the overall performance of the system?
  - Incentive for prosumers?
  - Improved use of flexibility?
  - Violation of prosumer constraints?

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Methodology

- Main grid connection
  - Model the main grid as a storage device, with “infinite” capacity.
- How can we include grid constraints?
  - DSO/MO agents to affect market outcome.

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Conclusion

- Improved real-time MBC of heterogeneous, numerous, self-interested DER.

  …scalability, openness, simplicity, privacy.
- Local planning based on market steering.
- Expected outcome:
  - Improved performance “utilization of flexibility”.
  - Improved WSM integration.
  - Incentives for prosumers.

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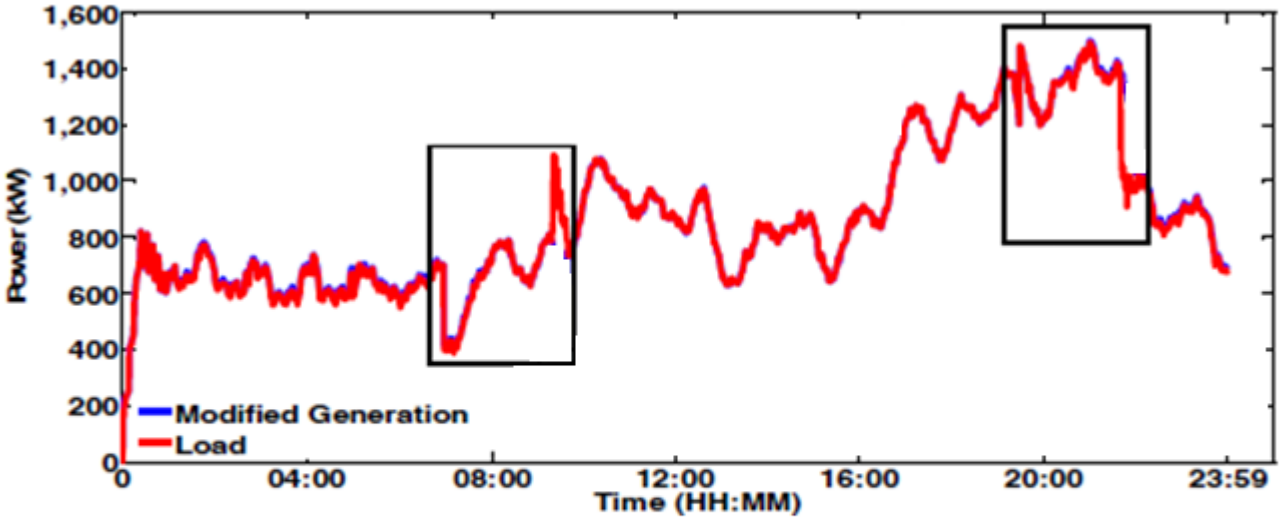
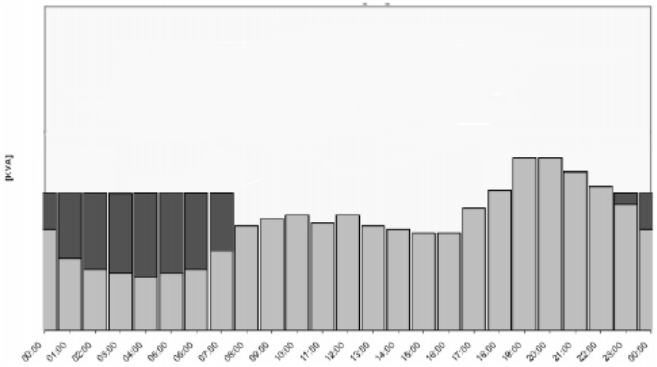
Conclusion





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Thank you!

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