# Scheduling of flexible electricity production and consumption in a future energy data management system: Problem formulation

Tea Tušar, Erik Dovgan and Bogdan Filipič

Department of Intelligent Systems
Jožef Stefan Institute

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# Introduction

New conditions

- Deregulation of energy markets
- Higher utilization of RES (renewable energy sources, e.g. solar panels, windmills)
- Smart metering

Challenges

- Support flexibility on electricity markets
- Ensure reliable supply
- Balance costs and benefits

European 7FP project MIRABEL (Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution)

# MIRABEL

MIRABEL proposes

- A conceptual and infrastructural approach to supply and demand side management
- Electricity *prosumers* issue *flex-offers*
- Balance supply and demand
- Enable higher utilization of RES

Harmonized Electricity Market Role Model

- A coherent view of the electricity markets in Europe
- Roles
  - Prosumers
  - Balance group
  - Balance responsible party (BRP)

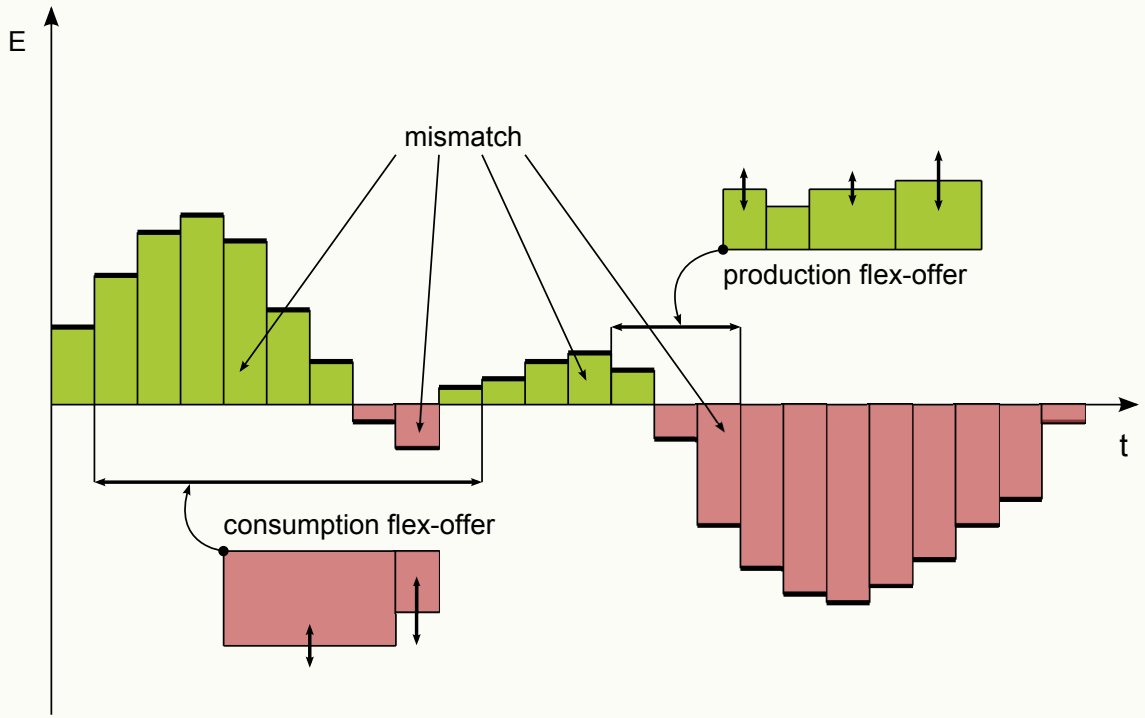
# MIRABEL

MIRABEL provides

- Handling flex-offers
- Forecasting electricity production and consumption
- Aggregation of flex-offers
- Scheduling of aggregated flex-offers
- Disaggregation of scheduled flex-offers for contracting
- A distributed, decentralized and scalable computer infrastructure

# Concepts

- Time intervals
  - Time step interval
  - Scheduling interval
- Mismatch and imbalance prices
- Flex-offers
- Market energy and prices



# Problem formulation

Given

- The scheduling interval
- Mismatch and imbalance prices (for every time step interval)
- Market prices (for some time step intervals)
- Aggregated flex-offers with all their defining information

We need to

- Fix time and energy flexibilities of all flex-offers
- Establish the amount of energy to be bought (sold) on the market

Goal

- All constraints are satisfied and the cost for the BRP is minimized

# Problem formulation

Define

- Decision variables

$s_k = (t_k, E_k^1, \ldots, E_k^{n_k})$

$E_{\mathrm{M}}^l$

- Constraints
- Objective function

| Variable | Meaning |
|---|---|
| $n$ | number of flex-offers |
| $m$ | number of time step intervals in the scheduling interval |
| $E_{\mathrm{I}}$ | remaining mismatch amount |
| $p_{\mathrm{I}+}$, $p_{\mathrm{I}-}$ | price of positive/negative imbalance |
| $E_{\mathrm{M}}$ | market energy amount |
| $p_{\mathrm{M}+}$, $p_{\mathrm{M}-}$ | price of energy that can be sold/bought on the market |
| $s_k$ | schedule for the $k$-th flex-offer |
| $t_k$ | start time of the $k$-th flex-offer |
| $E_k^j$ | energy amount of the $j$-th energy interval of the $k$-th flex-offer |
| $p_k^j$ | price of the $j$-th energy interval of the $k$-th flex-offer |

$$c\left(\begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_n \end{bmatrix}, \begin{bmatrix} E_{\mathrm{M}}^1 \\ E_{\mathrm{M}}^2 \\ \vdots \\ E_{\mathrm{M}}^m \end{bmatrix}\right) = \underbrace{\sum_{\substack{i=1 \\ E_{\mathrm{I}}^i<0}}^{m} p_{\mathrm{I}-}^i \left|E_{\mathrm{I}}^i\right|}_{c_{\mathrm{I}-}} + \underbrace{\sum_{\substack{i=1 \\ E_{\mathrm{I}}^i>0}}^{m} p_{\mathrm{I}+}^i E_{\mathrm{I}}^i}_{c_{\mathrm{I}+}} + \underbrace{\sum_{k=1}^{n}\left(\sum_{j=1}^{n_k} p_k^j E_k^j\right)}_{c_{\mathrm{FO}}} + \underbrace{\sum_{\substack{i=1 \\ E_{\mathrm{M}}^i<0}}^{m} p_{\mathrm{M}-}^i \left|E_{\mathrm{M}}^i\right|}_{c_{\mathrm{M}-}} - \underbrace{\sum_{\substack{i=1 \\ E_{\mathrm{M}}^i>0}}^{m} p_{\mathrm{M}+}^i E_{\mathrm{M}}^i}_{c_{\mathrm{M}+}}$$

# Conclusion

Discussion

- Presented scheduling problem different from related work
  - Structure of flex-offers
  - Need to set start time and energy amounts (continuous)
  - Need to set market energy amounts
  - Minimization of cost
- Non-standard and highly complex problem

Future work

- Solve the problem using optimization algorithms
  - Greedy search
  - Evolutionary algorithm hybridized with local optimization