Management of complex energy objects for large scale future electricity networks

Laurynas Šikšnys (supervisor - Torben B. Pedersen)
Department of Computer Science, Aalborg University

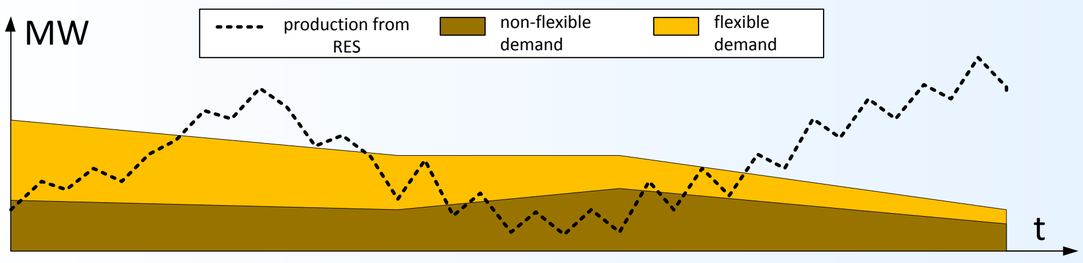
My Ph.D. study

My Ph.D. study is closely related to the EU FP7 project MIRABEL *(Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution)*. The objectives of this study are:

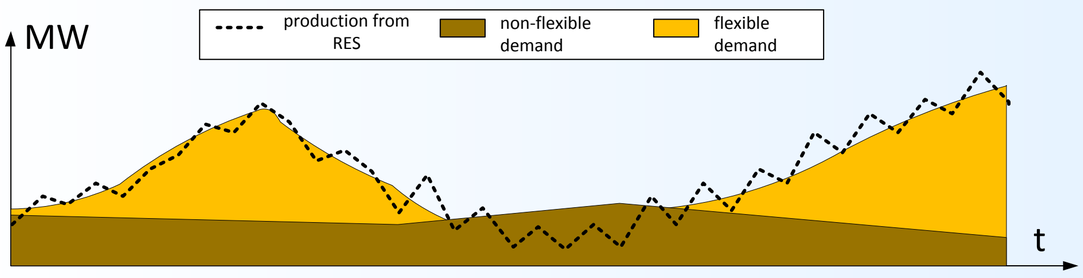
- Support tasks of the MIRACLE project;
- Address the challenge of aggregating *complex energy planning objects* (see below);
- Disseminate knowledge about the developed solutions.

Background information

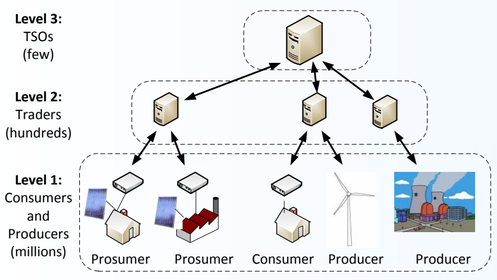
Integration of renewable energy (e.g., from sunlight, wind) is challenging as production highly depends on weather conditions and thus cannot be planned.

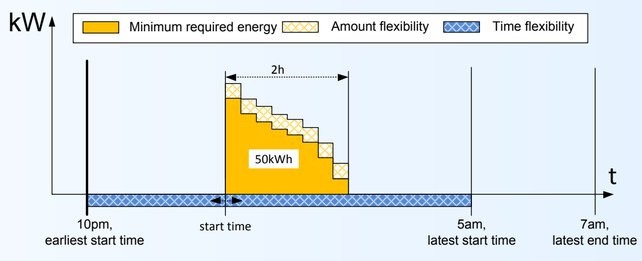


To tackle the problem, the MIRABEL project designs and prototypes an *Energy Data Management System* (EDMS) that "shifts" *flexible demand* to times when production from RES is available.

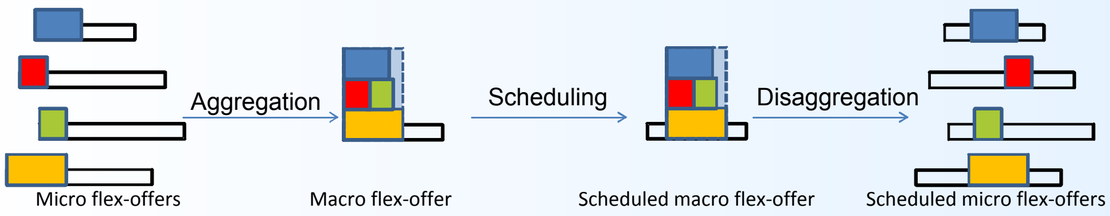


The EDMS architecture aligns the European electricity market (left figure). The EDMS manages a very large number of *flex-offers*. A flex-offer is a complex energy planing object that defines an intent to consume or produce energy in a flexible manner (right figure).





At level $\geq$2, flex-offers are collected, aggregated, scheduled, disaggregated, and distributed back to respective issuers.



Flex-offer aggregation is important because:

- The scheduling is NP-complete;
- Summaries of flexibilities are needed;
- Trading of flexibilities is needed;

It is non-trivial since the underlying energy profiles can be shifted in time prior to the aggregation.

Requirements for the aggregation

The flex-offer aggregation has to satisfy the disaggregation condition and achieve 3 objectives:

Disaggregation condition: No matter how flex-offers are scheduled, it must always be possible to disaggregate them into their respective scheduled micro flex-offers;

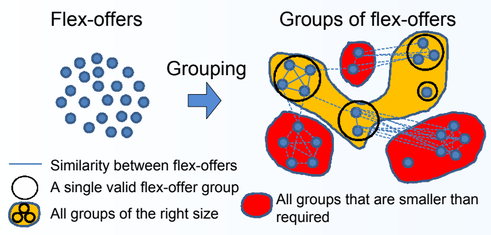
Efficiency objective: The flex-offer aggregation must be efficient enough to be able to complete the flex-offer processing within a given time window.

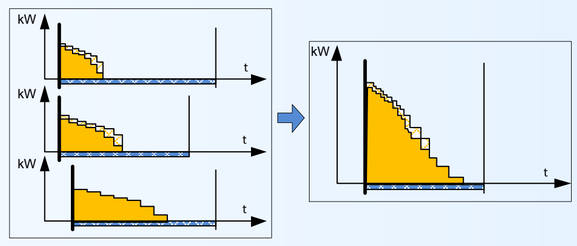
Compression objective: The number of macro flex-offers has to be as small as possible;

Flexibility objective: As much as possible of micro flex-offers flexibilities must be preserved;

Static flex-offer aggregation

Static flex-offer aggregation is performed in two steps: the grouping step (left figure) and the many-to-one aggregation step (right figure).

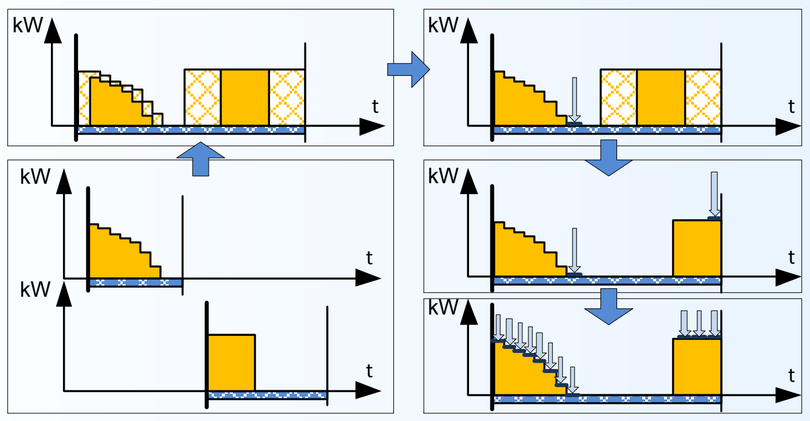




First, the static aggregation groups all flex-offers and then merges flex-offers from intermediate groups into aggregated flex-offers. The method requires that all flex-offers within a group have overlapping (equal or similar) time flexibilities. Additionally, groups (and thus aggregates) may be required to be of a certain size.

Dynamic flex-offer aggregation

In dynamic flex-offer aggregation, aggregates are represented by dynamic objects, which capture (few or all) combinations of how energy profiles of micro flex-offers can be arranged in time. During the scheduling, flexibilities of these aggregates are updated iteratively.



Initially, a macro flex-offer represents maximally feasible energy amount flexibilities at every time interval in its profile. These - later are reduced when values from flexibility intervals are chosen (fixed).

Summary

My Ph.D. study addresses the challenge of aggregating complex energy planning objects. This includes 1) modeling of flexibilities, 2) efficient grouping of similar objects, 3) and design of efficient solutions for static and dynamic aggregation.