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MIRABEL – Efficiently managing more renewable energy using explicit demand and supply flexibilities

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Abstract

The MIRABEL project has developed a groundbreaking ICT system that fits the future liberalised energy sector and enables the integration of much higher rates of distributed and renewable energy sources (RES) into the electricity grid. This is done using a radical novel approach for active demand (and supply) side management in which electricity consumers and producers issue explicit so-called *flex-offers* indicating their available flexibilities in time and electricity amount. The MIRABEL system processes large amounts of flex-offers in order to balance electricity supply and demand in near real-time and thus supports the integration of non-schedulable renewable energy sources much better than earlier approaches.

1 Introduction

The energy sector is in transition. Firstly, the liberalisation process forces companies to restructure their value chain in order to increase their market efficiency. Secondly, in order to reduce CO2 emissions, the use of renewable energy sources is enforced by national and international regulations. Thirdly, smart metering is being widely adopted and thus consumers become actively involved.

2 Flex-offers

The MIRABEL project set out to develop an approach for managing increased penetration of renewable energy sources and to balance supply and demand accordingly. We have tackled this challenge by leveraging the *total* flexibility in electricity demand and supply, making this flexibility *explicit* and allowing *trading* of this flexibility.
The flex-offer concept allows *parties connected to the grid* to provide their demand/supply flexibilities to other relevant parties e.g., their *Balance responsible parties* (BRPs), in a standardized, yet powerful, way. A simple example flex-offer is "I need 1.5 kwh for my dishwasher over a 2 hour period starting no earlier than 7PM and finishing no later than 6AM," but flex-offers generalize to capture electric vehicle charging, heatpumps, and all other types of flexible demand (or supply).
The parties acquiring the flexibilities in demand and supply can then *pool* the flexibility as an additional element in their portfolio and use it to *compensate* for the intermittent generation by renewable sources.
The MIRABEL conceptual architecture is seen in Figure 1 and describes the involvement of *Prosumers* (providers of flexibility) and Balance Responsible Parties (acquirers of flexibility) in a business interaction of:
1) Providing flex-offers, which specify the available flexibility in power and time,
2) Acceptance by the BRP of attractive offers, and
3) Assignment, i.e. specification of how the flexibility is to be exercised (e.g. operation schedules), resulting in a better balance between supply and demand, with higher integration of intermittent renewable energy sources.

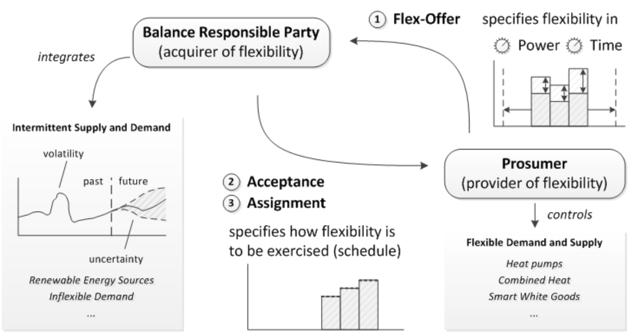

Figure 1 MIRABEL conceptual architecture

The flex-offer life-cycle phases are shown in figure 2. In the negotiation phase, the price for the flexibility is determined. The planning phase is iterative and ends with the assignment of the flex-offer. Now, there is an obligation to execute the flex-offer according to the contracted parameters. After the execution, the contracted energy and the negotiated price for each flex-offer is deducted from the invoice amount for the open contracts.

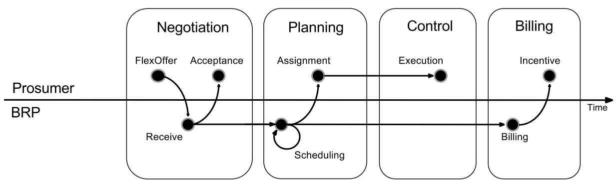

Figure 2 The flex-offer life-cycle phases

3 Technological Impact

We identified the following main achievements with potential impact on the future energy market:
(1) The concept of Flexibility Trading (FT), together with the MIRABEL roles and process model, gives a new look at the role of demand side management in balancing the grid: As opposed to supply side control, the dominant balancing tool so far, the demand side is gaining in im-

portance with the increasing dispersed energy production, especially RES. FT enables localized optimization processes of energy production and consumption at a large numbers of consumers and prosumers.

FT gives the BRP – the central *role* in the electricity market trading processes - a meaningful tool for communication with its *Balance Group* (BG) members and enables setting up a coherent business model for operations. The FT concept thus influences both the BRP business models and the technologies used for it: technologies for communication with its BG members should address as many prosumers as possible, e.g., by merging the BRP BG function with mobile communication platforms and services. FT also gives to BRP a tool to act as service supplier to the TSO (and DSO) - using FT as a separate category of *tertiary TSO reserves*. We predict further evolution of this communication and its impact on the technology of trading in the energy reserves market.

(2) The conceptual approach to flexibility trading and the structure of the developed energy trading process in the BG through acceptance, aggregation, scheduling and assignment of both consumption and production flex-offers while optimizing imbalances and price, achieves three important tasks:

(1) Introduces the trading concept to the *consumer* level

(2) Enables dealing with large numbers of flex-offers, and

(3) Respects the *Harmonized market model* constraints.

All three are important for the market deployment of our approach, both horizontally (in the Balance Groups) and vertically, to the Market Balance Area, and later also to the Balance Area, after further harmonization of the electricity market.

(3) The roles and process model, based on the Harmonized Electricity Market model, builds on classifying the processes in the electricity market system into the primary process of energy trading and into joint supportive processes for operation of the grid, and on observing that the former can be vertically structured following the concept of nested subsystems. This enables *scalability*: each subsystem has (essentially) the same set of functions, and the MIRABEL solution can apply to all. Scalability implies usage the levels of a single subsystem, several subsystems, and the overall system. This influences both the possibilities for deployment of the solution in vertical levels (BG, MBA, and BA) and for standardization of messages in the system.

(4) Flex-offer trading introduces closed contract between issuer of the flex-offer and the BRP. Bringing the concept of a *closed contract* to the consumer and prosumer level imposes new requirements and roles for the internal energy management system especially for residential consumers and prosumers, leading to new functions of smart meters:

(1) Measuring in parallel both open contract and closed contract (flex-offers) consumption.

(2) Assuming the function of energy trading subsystem of the internal energy management system of the consumer or prosumer. Scheduling prosumer appliances will be one of the basic functions.

Alternatively, a new *intelligent energy (trading) interface* may evolve on the market as a competing product, especially for prosumers with comprehensive internal energy systems, which might include both RES production and energy storage.

(5) The developed methodologies and solutions of forecasting, aggregation and scheduling have several important features:

(1) Composed multi-level forecasting methodology enables forecasting an energy flow which is the combined result of several forecasts of different energy flows in different conditions, e.g. RES production in different geographical areas (weather conditions) etc.

(2) Aggregation and de-aggregation algorithms enable processing of a large number of flex-offers for scheduling and enable contracting of individual assigned flex-offers

(3) The scheduling algorithms make possible concurrent minimization of energy imbalances and energy price of scheduled flex-offers.

The experimentally validated results of MIRABEL can be summarized as follows:

- *Flexible demand and supply can lead to* ***7-13% cost reduction*** *for BRPs.*
- ***Peak-load reduction by 13-50%*** *and an increase of the base-load in general improve the overall efficiency of the system.*
- *Flexible demand and supply improves the integration of renewable energy sources significantly:* ***70% of the negative impact*** *caused by fluctuating energy supply of renewables like wind* ***can be neutralized*** *given that* ***15%*** *of the energy consumption will be intelligently controlled by the BRP.*
- *Households can* ***reduce their energy bill by 10-20%.***
- *In combination with energy storages flexible demand and supply can lead to up to* ***50% reduction of CO_2 emissions****.*

(6) The successful integration of the complete solution and testing it on large number of flex-offers (10.000, 100.000) which has proved the feasibility of the developed technologies will influence other projects in the field of demand side management and may bring the focus of this work closer to the market. In this respect, the *proposed standardization of flex-offer messages* provides one necessary condition for penetration of solutions based on these technologies on the European electricity market.

MIRABEL contributed to the working groups of the Smart Grid Coordination Group that were formed to execute mandate M490. The MIRABEL use case was elaborated further and adopted as one of the use cases to consider when developing standards related to demand/response coordination.

Future work includes using the flex-offer concept to solve (local) grid constraint problems and automatically detecting available flexibility at the prosumer level.

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Further Reading:

www.mirabel-project.eu

www.totalflex.dk