EXTENDING THE ELECTRICITY MARKETPLACE TO DISTRIBUTION ENTITIES

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ABSTRACT

The DREAM FP7 RTD project develops solutions for active distribution energy networks with integrated distributed renewable energy resources. It is a collaborative research project with a project duration of 36 months (2013 – 2016) involving R&D institutions, ICT and manufacturing industry partners, and DSOs. Over the course of the project, 12 partners from seven European countries work on the foundations for a novel heterarchical management approach of electric power grids based on agent systems and considering current and future designs of electricity market systems.
The present paper describes market specific results from the initial phase of the project and discusses challenges and solution approaches associated with the creation of a new electricity distribution scenario.

INTRODUCTION

In line with the overall objectives defined by the European Technology Platform for Smart Grids [1], the DREAM project develops elements of an electricity network that integrates the generators, consumers, transferring entities and intermediaries, in view of delivering sustainable, economic, and secure electricity supplies.
DREAM's contribution towards this goal for smart grids is the design of an innovative architecture and novel commercial mechanisms which transfer market-driven approaches and constraints from the transmission level to the distribution level. The DREAM architecture and software framework thereby allows the introduction of distributed energy resources (DER) into an active distribution system management. The technical solution uses autonomous, heterarchical agent-based systems to control and manage the participating entities in the grid and to ensure stable service at all local operating conditions.
This paper specifically focuses on the project results related to a market and commercial point of view. It summarizes the findings regarding different market mechanisms in the European Union and the resulting challenges for the design of a working new marketplace for the distribution market.
The paper is structured into four sections: the first one establishes the core concepts of the DREAM project pertaining to an active network organization; the second one presents the identified commonalities and differences of European electricity market designs and the consequences for new mechanisms; the third focuses on a selection of critical issues to be considered in a market design for new active distribution markets, focusing on market roles and commercial implications; the last section summarizes the findings and provides an outlook on future work planned in DREAM.

FUNDAMENTAL CONCEPTS

As in most smart grid approaches, a core DREAM concept is that DER contain a flexibility potential that currently largely lies idle due to a lack of technical and commercial integration of distribution-level actors into electricity markets. DER here include a number of distributed grid devices such as generators, storage devices, or loads that are present at LV and/or MV network levels, e.g photovoltaic stations, small wind turbines, combined heat power plants and storage, or potentially programmable devices like electric appliances and vehicle batteries. Flexibility comes from certain DER's ability to deliberately change their consumption and/or generation patterns within specific technical and behavioural boundaries. DREAM proposes the identification, classification and aggregation of individual flexibilities for introducing them to the overall market, with the expectation that command over those flexibilities provides value to market participants and to the grid as a whole because of its potential to make the distribution system more stable and efficient. A conceptual view on the position of the DREAM market view on the integration of DER within Smart Grid Architecture Model (SGAM) [2]. is provided in ***Fig. 1***

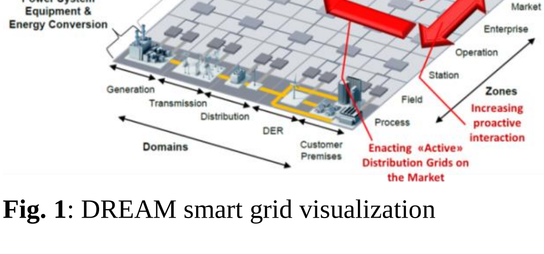

Fig. 1: DREAM smart grid visualization

The notion of aggregated flexibility is often associated to the Virtual Power Plant (VPP) concept, which refers to the aggregation of decentralized generators and consuming devices in a coordinated way. In DREAM, a VPP is extended to integrate the operation of supply- and demand-side assets to meet customer demand for energy services in both the short and long term in a way similar to a controllable conventional power plant, with the additional possibility to have negative generation. To match short-interval load fluctuations, the VPP makes extensive and sophisticated use of information technology, advanced metering, automated control capabilities, flexible DER and electricity storage. The VPP concept also accommodates long-term load reduction achieved through energy efficiency investments, distributed generation, and verified demand response (DR) on an equal footing with supply expansion. As the DREAM understanding of a VPP goes beyond the established definition, the term "Extended VPP" is used to refer to the complex bundle of functionalities described above.

Changing roles and new actors

The DREAM framework requires existing market partners' roles to change, with the possible introduction of new actors into the marketplace of specific nations.
Instead of large generation companies, retail and business segment (so called) prosumers invest in electricity generation hardware like PV, (μ)CHP and in electricity storage. At the same time these systems can easily be connected to end-customer owned public Internet based communication systems like WiFi or 4G-LTE to exchange their data. In terms of SGAM, this pertains to the green area in figure 2.
Also, the tasks of the DSO are changing to enable an active distribution network, which pre-emptively can react by having extended operational knowledge on the data and the behavioural patterns of electricity demand and supply.

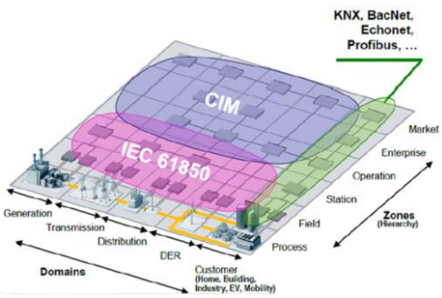

Fig. 2: SGAM standards mapping

A new "flexibility aggregator" role is for example needed to execute the aggregation of the individual DER flexibilities described above, in order to collect, pool and market the flexibilities from different customers. He accesses the flexibilities through "customer energy managers" (CEMs), which are the electric and commercial interfaces for customers with manageable customer energy devices. Furthermore, to the flexibility aggregator might be allocated the role of activating the flexibilities during the electric network operation, and the responsibility on billing (refunds, penalties, etc.) in the market settlement phase.

The following sections establish the core elements of the European electricity market designs to prepare the ground for the subsequent discussion on requirements and challenges pertaining to the introduction of the above-mentioned concepts into the markets.

EUROPEAN MARKET DESIGNS

All European electricity markets have seen considerable market liberalization in the last decades, albeit to varying degrees. Generally speaking, traditional monopolies of energy production, transmission and distribution were reduced, the number of active participants in the electricity market increased, and new market-based mechanisms for the trade of electricity were introduced. A necessary condition for DREAM's objectives of creating new active distribution systems management across European countries is the awareness for current commonalities and differences of the functioning of wholesale markets. The basis for the following comparisons are the markets in France, the Netherlands, Germany, Italy, Spain, and Greece, as these are the DREAM project consortium partners' home markets.

Common market features

These national markets belong to the European Union's internal electricity market and their transmission system operators (TSOs) are part of ENTSO-E, the European Network of Transmission System Operators for Electricity, which became operational in July 2009. The wholesale markets share common elements.
Firstly, market participants like producers, consumers, network operators, and others engage in wholesale electricity markets to trade their respective positions in the electricity market based on forecasts. Trading occurs both via bilateral contracts (over-the-counter trades) and on central national or even multi-national markets.
Secondly, trading occurs in different time frames, which are forward markets (long-term contracts), day-ahead and intraday markets (short-term planning), and real-time balancing markets. The allowed trades and exact time frames for these time frames differ among markets.
Thirdly, final responsibility for grid frequency control at all times lies with the TSOs in all markets. On the one hand, they ensure the real-time balance in their network by dispatching reserve power, and on the other hand they are responsible for charging the market participants for imbalances, which are differences between projected and real electricity committed.

Differences between market features

Despite these common elements, current European market designs can be categorized into two major groups based on their functioning on a more detailed level. The first group comprises Germany, the Netherlands, and France, which all feature full bilateral energy-only market designs, in which some actors take the role of a Balance Responsible Party (BRP), who has commercial responsibility for the imbalances in its area. BRPs communicated forecasted consumption and production schedules for their areas to TSOs. By means of electricity sale and purchase transactions on the energy markets, the BRPs try to anticipate and solve imbalances they foresee in their areas. If imbalances occur despite these efforts, TSOs provide balancing reserves as BRPs responsibilities do not involve maintaining frequency. After dispatch TSOs hold the BRPs financially accountable for deviations between forecasted and real-time positions. These accounts are based on the energy balance in PTUs (program time units; typically 5-15 mins). Intra-PTU balancing on power is done by the TSO.

In Italy, Spain, and Greece, there is no BRP role. The markets function as “pools” supervised by a market operators (GME in Italy or OMEL in Spain), who reconcile purchase and sell positions and the prices formed in different trading stages and forward them to TSOs for checking of technical constraints. Based on these checks, dispatch is determined centrally by TSOs. In the imbalance settlement process, TSOs debit or credit market participants (producers and consumers) based on the negative or positive deviations from the day-ahead schedules.

Balancing responsibility thus lies with TSOs in both market designs, but in the DE-NL-FR design BRPs have the possibility to optimize their own portfolios in forward, day-ahead and intraday markets. They have a clear commercial incentive to balance their portfolios because they are directly charged the cost of imbalances. However, strategies for BRPs in these markets may differ depending on the imbalance pricing models in place. Especially with dual pricing schemes (different prices for positive and negative reserve power depending on the sign of imbalance in the BRP area in comparison to the overall control area), incentives may be given to BRPs to “overcontract” their positions, thereby leading to a suboptimal balance situation in the grid where the overall demand forecast is too high.

A look at the role of distribution system operators (DSOs) in these markets, however, reveals that their interest regarding network balance may differ from BRPs’. Whereas the BRPs are only concerned with the overall, aggregated flows in their areas, DSOs also care about the individual, technical distribution flows through their networks. They are obliged to route the quantities as contracted with the BRPs through their networks for a fee, but have no possibility to actually engage in real-time balancing in case an emergency happens in their grid area. Of course, in some areas DSO and BRP are equivalent, but as an outcome of unbundling this is not necessarily the case and BRPs do not have to actually own the distribution network through which their customers are supplied.

The DREAM objective is to give distribution-level actors (BRPs, DSOs, Aggregators) the opportunity to participate in the balancing markets to optimize network stability and to utilize the flexibilities inherent in the distributed grid devices. Current market structures and incentive schemes are not ready for this involvement and raise several issues to be solved in DREAM’s heterarchical management approach where different objectives by various actors influencing the network conditions can be coordinated toward the achievement of sustainable win-win scenarios.

CRITICAL ISSUES FOR A NEW ACTIVE DISTRIBUTION MARKET

A new market design based on heterarchical management of the distribution needs to consider both technical and commercial issues. On the one hand, the market design needs to fulfil technical energy-flow requirements. This for instance includes response to current operation modes of the grid (normal, critical and emergency) and technical realization of appropriate responses of elements in the grid based on the real-time status of the primary processes of supply and demand.

On the other hand, a practical implementation of the DREAM concepts needs to consider several market-based requirements. More precisely, the following paragraphs focus on three issues with commercial repercussions:

1. Flexibility management reliability
2. Flexibility sizing
3. ICT requirements

For the sake of simplicity, these issues are considered in market designs with BRPs as these are present in the more liberalized market designs that will most likely prevail in the future.

Flexibility management reliability

The first issue highlights a requirement for the proper functioning of the Extended VPPs managed by Flexibility Aggregators. In the current market designs, only reliable and easily controllable producers can contract with TSOs (or offer via markets) their positive and negative reserve power for the balancing markets. Usually only the production level is adjusted because consumption cannot be controlled. Hydro and thermal power generation units are used most often for this task as they are easily controllable. In events where secondary or tertiary control needs to be exerted, TSOs rely on the availability and reliability of these reserves to prevent system failures. This means for the provision of flexibilities for the balancing market from DER that

they have to be as reliable as conventional reserve power sources. Otherwise they will either not be purchased at all or at a considerably lower price to compensate for the uncertainty. From an overall network point of view, this situation is undesirable because it will require TSOs to schedule a larger safety margin of reserves than in the current situation, which is exactly what a more active distribution management market aims to mitigate. From the Aggregators' point of view, lower prices for these services reduce their business model's profitability.
A possible solution for this challenge from a market or business point of view that will be evaluated in DREAM is to give the right incentives to the Aggregators in their role of commercial responsibility for the flexibilities so that they meticulously control their manageable customer energy devices. This issue also highlights the fact that although a system of heterarchical autonomous agents on distribution level is highly attractive from a technical point of view, commercial and legal responsibility needs to be taken by a central actor at some point to make the system ready for a real market environment.
Summarizing, this point is very critical because the feasibility of the heterarchical management principle with distributed resources fully depends on the reliability of the products offered to the markets.

Flexibility sizing

Regarding the size increments of the flexibilities which will be aggregated and offered to markets, it is necessary to align them with the standard volumes present in the respective energy markets. Currently, the volumes differ among the markets, implying that the DREAM system would need to be adjustable to the different environments. This has implications for both the software development of the DREAM framework and for the design of compensation flows and incentive schemes. During the DREAM project duration, concept development and field tests will only consider the requirements in the respective test markets.

ICT requirements

The topic of ICT requirements for DREAM's heterarchical distribution system management comprises several issues, of which only a few will be mentioned here.
A first issue refers to the future of communication infrastructure for the interaction between actors in the grid. Currently, network operators like TSOs and DSOs use their power lines not only for energy transmission and distribution, but also to exchange system status and related information. Considering the ownership structures and investments in power lines, this behaviour is understandable. From the perspective of commercial parties like BRPs or Aggregators, there is no reason why they should not draw on standard communication lines like the telephone network, for which they can be expected to have convenient contracts instead of relying on communication via power lines. Firstly, they are required to pay the network operators for this usage and secondly those lines are more vulnerable in the case of system failures, whereas the telephone network is meshed and built for maximum stability.
Another commercially-relevant ICT issue clearly is the required broad coverage of ICT infrastructure at customer homes, e.g. smart meters and customer energy managers, which are a necessary condition for the whole project. DREAM assumes that in the near future this equipment will be available over a wide area. Similarly, the required agents at LV and MV substation levels as well as the control stations for Aggregators, DSOs and BRPs need to be widely available for the DREAM framework to become operational. Up to the substation level the required ICT infrastructure from the DSO perspective already is in place. Below this level and the end-user customer end-user energy management system DREAM will define the ICT-framework for a distributed approach for coordinating RES and structuring and storing the data for the aggregator.

Field tests

The mechanisms developed during the project will be tested in several field tests to demonstrate the technical and economic feasibility of the concepts.
Feasibility will be tested against several criteria that will be developed in details over the course of the project, including, but not being limited to, quality of service for several stages of grid operation, and economic viability for the involved actors.

CONCLUSIONS

The Dream-project will implement a number of new hierarchical concepts using a common software/hardware framework for facilitating the operations in active distribution networks on various timescales serving commercial as well as operational and technical functionality in energy and power balancing.

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