FLEXIBILITY MARKETPLACE TO FOSTER USE OF DISTRIBUTED ENERGY RESOURCES

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ABSTRACT

Distributed Energy Resources (DER) connected to Smartgrids are most of the time addressed on a grid operation point of view or on a commercial point of view, moreover focusing only on one layer of the overall electricity grids structure. However, interdependencies between grid and commercial operation as well as interconnection of more and more systems and involvement of numerous actors at various levels of the electricity value chain raise growing challenges that are presented in this paper. A market-based approach called Next Generation Marketplace (NGM) is introduced as a potential response and solution to these challenges. The paper presents several NGM aspects such as underlying rationale and pillars, a practical illustration through a detailed use case, and recommendations on corresponding IT infrastructure. The paper concludes that a NGM approach is a necessary step to see Smartgrids evolving towards Smarter markets but still requires regulation evolutions.

INTRODUCTION

Electricity markets as of today are structured around two major marketplaces: wholesale and retail. However, this dual scheme is facing significant challenges today. Even if some initiatives have shown some benefits, such as market coupling in Europe, the grid and market operations are more and more complex. Stronger and stronger penetration of distributed and in some cases intermittent resources has increased the occurrence of internal congestions within countries as well as increased balancing operation costs for system operators. Balancing markets, under Transmission System Operator's (TSO) responsibility, are not solved at a regional level while sharing of reserves and mutualisation of balancing resources could bring significant savings. Moreover, electricity markets, whether at power exchange level or at TSO level for balancing, do not explicitly model the physics of the grid, still relying on the so-called copper-plate model.

In addition, significant recent advances in the Smart Grid area clearly demonstrate that there are many sources of flexibility that could be leveraged on the distribution side. Recently launched EU financed pilot projects like NiceGrid and Reflexe will actually study how Demand Response (DR) and storage can be sold or purchased on local marketplaces to provide greater flexibility.

Last but not least, many countries in Europe, such as France Germany and UK, have initiated discussions on capacity markets in order to make sure that resource adequacy problems and peak load issues can be mitigated by providing enough incentives for new investments in source of flexibilities such as Demand Response.

All this put together calls for a paradigm shift that the authors have unified in a so-called Next Generation Marketplace (NGM). It should be noted, however, the term "Marketplace" in NGM is intended to cover not only classical centralized markets but also other value-transfer mechanism that may be appropriately associated distribution systems where classical markets could be difficult to establish due to issues such as market power, etc...

NEXT GENERATION MARKETPLACE PILLARS

The Next Generation Marketplace (NGM) addresses a certain number of short-comings presented in the above introduction and features a structure around four pillars: ensure grid reliability, enable synergies, mitigate resource uncertainties and foster grid flexibility [Figure 1].

Figure 1: Next Generation Marketplace pillars

Ensure grid reliability

Grid reliability is one of the main responsibilities of Transmission System Operators (TSO) and Distribution System Operators (DSO). Many factors such as lack of investments, delay in new infrastructure building and development of distributed and intermittent resources over the last few years increased the stress on wires and grid equipments. Most of European electricity markets today rely on the "copper plate" model without explicit representation of the physical grid model. This position starts to change with for instance the introduction of flow-based market coupling in Central Western Europe that demonstrated social welfare benefits compared to previous ATC based coupling [1]. As a result, taking into account more physics representation (grid model) into markets problem formulation appears as an important direction to follow to ensure an optimal technical – economical optimization of the electricity markets.

Enable synergies

Residential loads as well as Commercial and Industrial (C&I) loads provide a large potential of flexibility at various levels of the grid. Peak shaving and demand response programs are concrete actuators operators can leverage to solve power balance issues or network constraints on their systems. Load flexibility can also be complemented by distributed energy resources and storage capabilities. Several projects such as the European funded FENIX project already demonstrated the benefits of operating all these flexible resources as a portfolio called Virtual Power Plant (VPP) [2]. Two aspects have to be considered when dealing with VPPs: the technical VPP and the commercial VPP. The technical VPP focuses on the physical aspect of the resources and their impact on the electrical grid and is thus managed by network or distribution system operators. The commercial VPP focuses on resources portfolio aggregation and how it could be leveraged by markets. The commercial VPP is typically managed by aggregators.

Aggregators act as market participants in electricity marketplaces. Designing market rules enabling VPPs participation at wholesale or national balancing market levels is thus another key principle of NGM. Other synergies can be achieved by introducing dynamic pricing to provide incentives to Price Responsive Demand to markets [3]. Finally, social welfare has been increased over the last years by coupling electricity markets across Europe paving the way for a Single European Electricity Market. Further optimization related to power balancing and congestion management could be achieved by organizing regional Balancing Markets. Nordic countries TSOs for instance implemented the Nordic Operation Information System (NOIS) to mutualise balancing capabilities across a region instead of limiting it on a TSO by TSO basis [4].

Mitigate resource uncertainties

Incentives to develop renewable generation lead to increased uncertainties when dealing with operational planning and system operation for both TSOs and DSOs. Several tools have been introduced by TSOs and DSOs to better manage intermittency of renewable resources in their grid: either through dedicated renewable management system like the one of the French TSO [5] or though wind or PV forecast solutions with a focus on close to real time operation and importance of look-ahead capabilities. Such solutions have already brought benefits to system operation. On the other side, markets are still operated based on power exchange cleared in real-time with some intraday markets in some countries. Moving towards closer to real-time for market operation seems also a direction to follow to give further opportunities to market actors to re-balance their portfolio and positions and for operators to better anticipate and counteract uncertainty.

Foster grid flexibility

Flexibility traditionally exists in transmission grids leveraging fast-ramping generation resources like combustion turbines, hydro power plants or pump storage. Once it comes to distribution, flexibility also exists within lower voltage levels by leveraging ability of C&I or residential loads to offer their flexibility. This service offer could be seen as a set of ancillary services that for example could solve voltage problems issues on distribution networks or also provide additional power balance capabilities to the transmission grid operation through flexible demand. This service offer will only develop if incentives are put in place for Distributed Energy Resources (or an actor like an aggregator) to bring their flexibility through market mechanisms within local marketplaces.

MARKETPLACE STRUCTURE

A multi-tier market-based structure named in the context of this paper Next Generation Marketplace (NGM) is proposed. NGM on one hand seamlessly integrates both Commercial Operation (markets) and System Operation (physics) with commercial to grid operation exchanges at the same tier level. On the other hand, it also enables vertical interactions between tiers that as of now used to have very limited exchanges due to their respective footprint and levels of responsibilities [Figure 2].

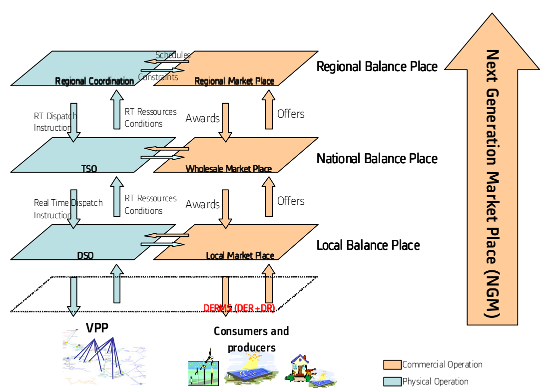

Figure 2: Next Generation Marketplace multi-tier structure

Flexibility located at the lower level (Distributed Energy Resources or Demand Response are integrated at the Local Balance Place through technical VPPs and operated on a system point of view by the DSO. The DSO manages these resources typically using a Distribution Management System (DMS) embedding Distributed Energy Resources

Management System (DERMS) capabilities. Real-Time conditions of these resources can be sent to an upper level for instance to the National Balance Place providing visibility to the TSO on what is happening at lower levels. Should system operation conditions require power balance actions, the TSO can then leverage this flexibility and instruct dispatch instructions to the lower levels. These instructions can be based on market principles implemented into a local market place. Flexibility offers are done by market agents (like aggregators) and in return receive market awards as flexibility orders (instructions). The top level layer features the Regional Balance place where the Regional Coordination centre exchanges schedule and cross-countries constraints. At this level too, flexibility and reserves across multiple countries are shared and mutualised providing a larger sets of possibilities to market and system operators to optimize system balance and congestion management.

USECASE

Many use cases fit into the Next Generation Marketplace. This section details one use case that leverages the local balance place. In some countries, distribution grids management becomes more and more complex. In case of distribution sub-networks with high level of Distributed Energy Resources (DER) like residential Photo-Voltaic (PV), it becomes harder and harder to manage loads.

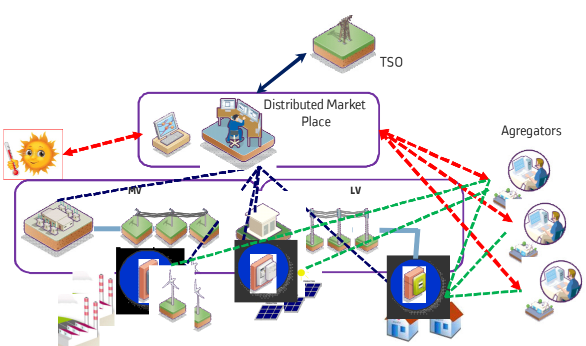

Figure 3: Distributed flexibility Marketplace

To mitigate this complexity, DSO or DNO shall be in a position to leverage as much as possible local load reduction for the sake of grid reliability. Depending on the technical infrastructure, several flexible resources may be used and called for that purpose. For example, load elasticity can be used by activating load shifting, load displacement or load reduction through interactive management and communication with C&I building energy management systems or residential appliances. In the case the grid also encompass network batteries or customer storage facilities, charging and discharging cycles of the batteries can also provide additional flexibilities. Figure 3 provides an overview of such a configuration.

If we consider a flexibility management system, market-based mechanisms could be put in place to provide a platform for actors like aggregators operating demand side flexibility to a central actor like DSOs. For each sub-network, the DSO can assess its flexibility needs for the next day leveraging the historical loads corrected by weather factors as well as renewable projection forecasts (like PV forecast). This look-ahead operating plan can also incorporate network restrictions. Once this information processed, the DSO is in a position to forecast its needs in terms of power balance flexibility for the next day and to quantify those. Leveraging market-based mechanism, the DSO translate these power requests to market products and can launch electronic call for tenders to let the flexibility market actors know about the various power flexibility needs. Based on their load forecast (residential and industrial), planned outages and the normal operation of their resources to ensure service level agreements, the participants can then bid into the market place how much flexibility they can offer. On the Local Balance Place, the Network Energy Management System (NEMS) used for distribution grid operation can then interact with the commercial operation of the local flexibility market place for power balance problems. It takes advantage of the flexibility demands and offers, still taking into account network grid reliability concerns.

The local flexibility marketplace can mimic day-ahead market mechanisms timelines already well spread at power exchange wholesale electricity markets. In the morning for the next day, the DSO collects all necessary forecasts information to publish information to the market. Market participants can then prepare their bidding and offering strategy and post their price-based bids and offers for flexibility up to a firm deadline say mid-day. In the beginning of the afternoon, a matching optimization algorithm is run by the DSO to clear market offers. Depending on the complexity of the grid, optimization tools embedding explicit modelling of the impact of resources on the network congestion can be put in place. This however requires that market actors bidding on the marketplace indicate the resource location as part of their bid/offers which may be difficult in case of aggregated demand response offers. In this case, a zonal approach could offer a good trade-off between complexity and technical constraints consideration. Once the market cleared, dispatch instructions are sent to the participants for the next day. It must be noted that thanks to the described mechanism, available flexibility not cleared by the local marketplace can be offered to an upper level of NGM. For instance, aggregated flexibility of the sub-network could be made available on the TSO balancing market. Providing that balancing market barriers of entry are minimized (like minimum level of capacity to be allowed to bid into the national balancing market), flexibility located at low level of the grids can be managed locally and then communicated at upper level providing a huge benefits compared to traditional balancing market classically run at transmission levels.

NGM IT ARCHITECTURE

The multi-tier structure of NGM has been designed to fully leverage all the work done across the world on smart grids reference architecture. It indeed nicely fits with Smart Grid Architecture Model – delivered by the SG-CG-RA team as part of the mandated deliveries of M/490, which proposes 3 different axes to map a Smart Grid feature (Domains, Zones and Layers) [Figure 4] [6].

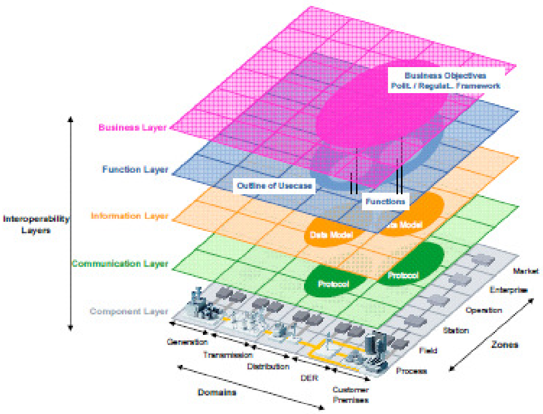

Figure 4: Smart Grid reference Architecture Model [6]

In order to fully leverage all NGM layers and minimize implementation costs and deadlines, a strong emphasis is paid on interoperability of the various layers and systems whether intended for the grid operation side or from the market/commercial side. Various organizations such as NIST in the US, or CEN, CENELEC and ETSI on the European side already performed a significant valuable work in identifying standards already applicable in the framework discussed as part of this paper. For instance, NGM layers and modules can be easily mapped to the various domains and systems identified as part of the First Sets of Smart Grids Standards [7]. Based on this mapping, the recommended sets of standards to be applied can be easily derived covering marketplace systems (both local and global), transmission and distribution management systems, DER management systems and Demand and production (generation) flexibility systems.

One of the key challenges in multi-tier and distributed infrastructure relies on data information model and data communication and exchange. The Common Information Model (CIM) standard developed under IEC already provides an already established interoperable standard directly applicable to NGM approach. CIM is indeed continuously integrating new requirements; most recent evolutions are addressing markets and DER requirements.

Last but not least, special attention shall be put on cyber security. NGM actually involves many actors and connects various grid operation and commercial operation environments with their underlying grid reliability, commercial sensitivity, data integrity and confidentiality requirements. Several organizations already looked after such requirements and provided an inventory of applicable cyber security standards [8] that should be followed when actually implementing a NGM approach.

CONCLUSION

The aggressive regulatory and political targets leading to fast developing DER integration require innovative solutions such as NGM to consistently manage both operation and commercial sides of the Smartgrid. The developments outlined in this paper are intended to provide a holistic market and grid operation view paving the way for smarter markets. However, smarter markets won't evolve without regulation changes which should aim at reducing barriers of entry to new actors bringing more flexibility to the electrical systems. This may lead to the creation of new incentives schemes and further developments of capacity markets or emergence of real-time market pricing that could be communicated to demand response actors ready to provide flexibility in a market-based mechanism under the form of new products or services.

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