BUSINESS, REGULATORY, AND TECHNICAL CHALLENGES FOR INTEGRATION OF NETWORK AWARE ALGORITHMS IN LOCAL FLEXIBILITY MARKETS

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Pau PLANA I OLLÉ
Smart Innovation Norway – Norway
pau.plana.olle@
smartinnovationnorway.com

Farhan FARRUKH
Smart Innovation Norway – Norway
farhan.farrukh@
smartinnovationnorway.com

Andrea MAZZA
Politecnico di Torino - Italy
andrea.mazza@polito.it

ABSTRACT

Local flexibility market (LFM) concepts are currently under development by several actors to reduce the cost of distribution system infrastructure upgrades, as well as to enhance the integration of distributed renewable energy sources. New mathematical algorithms and ICT tools are required to improve the LFM clearing. The paper identifies the main barriers and enablers for the implementation of network aware LFMs and presents a discussion on the role of market architecture in the integration of LFMs. After a literature review about the LFM concepts, the Business Modelling scenarios methodology is presented, with reference to short, medium, and long-term scenarios. Then, the business model of network aware LFMs is defined, by highlighting the main challenges that can affect their commercial viability. The paper examines the business model, in each of the three scenarios, and addresses the challenges from regulatory, technical, and business perspectives. The conclusions show that even if network-aware market clearing algorithms will become relevant in the future, the business case for network-aware LFMs is quite uncertain. It currently faces technical and regulatory challenges, and in the future, it might be threatened by the inclusion of distribution grids to power-flow calculations in the Day Ahead market.

INTRODUCTION

Europe's power system is undergoing a period of transformation, which was recently accelerated by the current geopolitical situation. On the one hand, power generation is transitioning from dispatchable and centralized power plants towards the massive use of variable Renewable Energy Sources (vRES)-based power plants. On the other hand, energy demand is being electrified and digitalized. This transformation process can create both challenges to the power system and new business opportunities. In recent years, the aim of European energy directives and regulations has been principally focused on fostering Distributed Energy Resources (DERs) active participation in the power system. Demand-side Flexibility (DSF) has emerged in recent years, from the regulatory side, as an enabler, if not a need, for a smoother energy transition in a power system evolving from a load-following to a generation-following operation [1]. Explicit DSF, particularly coming from the medium voltage (MV) and low voltage (LV) grids, requires platforms and tools where actors can trade and valorize their flexible assets. These places are known as *local flexibility platforms*, and, according to [2], there are currently three existing platform models:

- *Administrative flexibility scheme coordinator* – Provides support for a centralized cost-based allocation of flexibility.
- *Market Intermediary* – Only provides enabling services for assets to sell flexibility, within a wider market-based framework.
- *Marketplace* – Flexibility platforms that perform the functions of a marketplace: they host auctions, clear transactions, and settle payments.

This paper is focused on the "marketplace local flexibility platform" model. Local flexibility marketplaces are currently emerging, even though they are still at piloting phase or early implementation stages (e.g., NODES [3], and Piclo Flex [4]), and hence a lot of uncertainties surround the development of their business models. Market intermediary platforms are also a relevant market-based approach, but they do not face the challenges and uncertainties of creating new local markets. Instead, they are enablers to access already existing markets for power system actors, by either easing the participation of the players or enabling the definition of new product types. Some relevant examples are GOPACS [5] and Equigy [6].

Nowadays, Local Flexibility Markets (LFMs) are poorly integrated in the power market architecture. The existing markets operate in a reactive manner to the defined Day Ahead (DA) market clearing. The reactive operation does not disturb the rest of the market operation; however, it might be an inefficient way to operate the markets. In [7], innovative market architectures integrating LFM, and distribution grid power flows calculations are presented. The paper differentiates between *Reactive* and *Proactive* market architectures. The reactive approach is currently the only one available, where local flexibility is procured considering the DA dispatch of wholesale markets (WM), whereas the proactive approach looks towards a future where LFMs are integrated in the power system and distribution grid dispatching can be an input to wholesale energy markets. The paper [7] proposes three conceptual architectures of how local markets can be integrated in the power system:

i) Reactive distribution network aware flexibility market. In this architecture the LFM receives the DA dispatch from WM and then local flexibility is procured based on the needs of the local grid. This architecture is by nature inefficient since the LFM exists to correct operational challenges created by the DA dispatch. Additionally, due to their novelty, there are still challenges regarding the balance of flexibility provisioning assets. **ii)** Proactive distribution network aware flexibility market. This architecture considers a future scenario where local energy markets (LEMs) are cleared first considering the network constraints, and then the local DA is sent as an input to the WM. This poses challenges and risks linked to the forecasting by local grids of the transmission location marginal prices (TLMP). However, this approach leaves behind the LFM approach (correcting errors) and becomes a LEM (trading energy, considering the grid constraints). **iii)** Fully integrated proactive distribution network aware flexibility market: it represents an integrated solution where both distribution and transmission level energy markets work iteratively to define the DA dispatch for the whole network. The process is similar to the Case **ii)**, but the WM operator is responsible to estimate the TLMP for the DSO, and then both markets are cleared in an iterative way until a solution is reached for the DA dispatch of the system.

In this paper the scope is focused on the business model of reactive network aware LFMs. The integration of LFMs within the electricity market architecture is a relevant factor influencing its business model. For instance, in any Proactive market, there would be a shift from flexibility towards energy trading, and the Market Operator (MO) business model could shift to one closer to the current WM operators.

METHODOLOGY

In FLEXGRID Deliverable 8.2 [8] a methodological framework was developed to evaluate the business models of innovative solutions for the power system. This framework enables a stepwise understanding of business models considering regulatory, technology, and market conditions evolution in time. This time division considers three scenarios.

Scenario 1 – Today

Nowadays, the regulatory framework for local flexibility procurement is still under development [9], and only few LFMs are operative, most of them at the piloting stage. Furthermore, despite the growing digitalization of assets, grid observability (at distribution level) is low. On the other hand, asset control and transmission level flexibility are well stablished enabling the distributed loads to participate in balancing markets.
The current distribution grids are starting to require an active management, due to the increasing electrification of the loads, and a constantly growing penetration of v-RES. However, currently DSO's regulated revenue models incentivize CAPEX investments over OPEX or TOTEX [10] for grid operation and management. This situation pushes DSOs towards grid upgrades and asset investments in situations where the deployment of local flexibility initiatives might be a more cost-efficient option.

Scenario 2 – 2025 to 2030

This scenario looks at a time horizon where the mandates of the Clean Energy Package have already been transposed into national regulations and DSOs regulated revenue models have evolved to consider active management approaches. In this scenario, congestion and voltage support with flexibility services are actively used by DSOs. Furthermore, observability of the grid has significantly increased allowing DSOs for improved dynamic grid observability. However, LFMs are still lacking a unified regulatory framework, and therefore there is uncertainty around them.

Scenario 3 – After 2030

In this scenario the smart grid paradigm has been fully deployed. Grid observability is high, and the regulatory frameworks are consolidated, creating a solid ecosystem for the implementation of flexibility solutions at distribution level. Long term scenarios such as this have high amounts of uncertainties, but in a scenario post 2030 it is likely to have a power system with high rates of vehicle electrification, high penetration of distributed generation assets, and a wide deployment of energy storage systems. In this scenario, it is likely to have highly integrated power markets, potentially including distribution grids in the power flows calculations.

NETWORK AWARE LOCAL FLEXIBILITY MARKETS

Business Model

The business model of network aware LFMs builds on top of the current business model for LFMs, therefore there are similarities. The identified customer segments are mainly DSOs that will be able to access local flexible assets. Furthermore, TSOs and Balancing Responsible Parties (BRPs) can also benefit from LFMs for their own interest. For instance, to access distributed energy resources and to re-balance their position in the market, respectively. In this paper the business model presented is highly focused towards the DSO, since LFMs suppose a new horizon of opportunities for them. Additionally, part of its benefits is also applicable to TSOs. The following are the network aware LFM value propositions identified:

- Easy access to local flexibility resources,
- Increased security of supply (SoS) and quality of supply (QoS),
- Cost reduction on grid operation,
- Capacity to create a more complex flexibility marketplace (multiple players, more complex products, etc.).

There are multiple alternatives to network aware LFMs for DSOs; however, the comparison of all the different approaches for local flexibility procurement is out of the scope of this paper. Instead, in this paper the research focuses on the differences between network and non-network aware LFMs. From this perspective, in FLEXGRID Deliverable 8.3 [11] the main value proposition differences have been identified together with the main challenges for the implementation of the network aware LFM business model.

The main value proposition of network aware LFMs, compared to traditional LFMs, **is the increased SoS and QoS provided by a market clearing algorithm that calculates the power flows and respects the grid constraints.** This has multiple implications for DSOs and other market participants. For instance, it enables the implementation of LFMs where multiple actors (DSO, TSO, and BRPs) compete for the local flexibility, breaking the current monopsony model for LFMs. It also enables the dynamic calculation of the market participant capacity. The fact that the clearing algorithm can respect grid constraints allows to qualify market participants not considering the worst-case scenario but setting the limit of injection/consumption of their node based on the capacity of the grid at any given time. In [12] the economic implications of network aware LFMs are analysed for all market participants (DSO and flexibility providers). In the simulations performed, the use of network-aware algorithms showed no negative effect on the flexibility providers revenue and the DSOs costs. This is relevant, because lower incentives for FSPs or higher costs for DSOs could represent a challenge for the business model.

On the other hand, significant challenges for the network aware LFM business model have been identified. The current more relevant challenges for network aware LFMs are three:

- Liability over market clearing,
- Data access and grid observability
- Regulatory framework

The *Liability over market clearing* challenge is something at the core of the business model for LFMs operated by independent market operators such as NODES and Piclo. Network aware market clearing algorithms inherently blur the lines between DSOs and MOs. SoS and QoS at distribution level is responsibility of DSOs, and LFMs are a tool they can use to fulfil this responsibility. A network aware market clearing which leads to a congestion or any kind of reduction in QoS and SoS could have a direct impact on the DSO revenue. Therefore, it is very relevant for flexibility market operators (FMOs) (that are not the DSO itself) to properly clarify the limits of their responsibilities over the state of the grid. On the other hand, another problem that could arise for the network aware LFM business model is that DSOs might be reluctant to partially "externalize" their core activity.

The second challenge identified is related to data access and grid observability, and it has two different interpretations. On the one hand, it comes back to the potential diffidence from DSOs to share confidential data of their assets. On the other hand, as of today the Smart Grid Paradigm is far from being implemented, and MV and LV grid observability is still a challenge. Additionally, the collection and storage of data necessary to operate a network aware LFM becomes a relevant task and responsibility for FMOs operating network aware LFMs.

The third and final challenge, which is strongly correlated with the previous ones, is the lack of a proper regulatory framework for LFMs; however, things are starting to change. The 20th of December 2022 ACER submitted to the European Commission the first Framework Guideline (FG) on Demand Response [9] which addresses topics related to local flexibility provision, such as:

- General requirements for market access,
- Prequalification phase,
- Data exchange and System Operators coordination,
- Congestion Management and Voltage Control.

The Framework Guideline on Demand Response is a non-binding document pursuant to Article 59 (e) of the Clean Energy Package (CEP) Electricity Regulation (2019/943), which aims to "*set out clear and objective principles for the development of harmonised rules regarding demand response, […] and to contribute to market integration, non-discrimination, effective competition and the efficient functioning of the market pursuant to Article 59(4) of the Electricity Regulation.*" The establishment of such guidelines is an important step towards the creation of a proper (and up to a certain extent harmonized) framework for local flexibility at European level. This should remove some of the risk and uncertainties that nowadays affect not only LFMs but most kinds of local flexibility practices.

In the following paragraphs a projection into the future is made, trying to understand the evolution of the electricity grid in the coming years, and how the business model of network aware LFMs will be affected (positively or negatively) by it.

Scenario 1

This scenario represents the current situation. As of today, there are a few LFMs in operation. The company NODES is currently implementing multiple pilot LFMs (none of them network aware) where DSOs are the single buyer of flexibility. Additionally, in projects such as sthlmflex [13] NODES is experimenting with participation of distributed flexibility to ancillary services markets, but in a step-wise approach, acting like an aggregator of un-used local flexibility to join the manual Frequency Restoration Reserve (mFRR) market. The other main European FMO is Piclo, which has already an operational LFM in UK with multiple DSOs involved. Piclo is also starting pilot projects in USA and Portugal.

As of today, the implementation of network aware LFMs is far from being a reality. “Traditional” LFMs face many challenges as can be extracted from the sthlmflex and NorFlex documentation. For instance, NorFlex shows in [14] how the rollout of Internet of Things (IoT) devices that enable for automated flexibility trading will play relevant role in the widespread of local flexibility. Another challenge faced during these projects has been the calculation of baselines for flexibility provision. This is another issue related to the lack of data and complexity of day-ahead forecasting of small stochastic loads. In this sense ACER FG works towards the implementation of objective and standardized baseline calculations methodologies.

Scenario 1 shows that the current distribution system is not ready for the network aware LFM paradigm yet. However, from the technology perspective, the technology already exists and is slowly being deployed. From the regulatory perspective, the European Commission, in collaboration with ACER, is starting to define the framework for local flexibility provision, and from the business perspective DSOs are showing a growing interest towards active management of their grids.

Scenario 2

This scenario depicts a close future with higher penetration of IoT devices at distribution grid level, combined with a high share of RES and fast ramp up of the electrified mobility paradigm [15], which on the one hand will increase the load in the system and therefore increase the need for flexibility (at least in the short term), but also expand the pool of flexible assets at distribution level. Furthermore, the regulatory frameworks for local flexibility provision will be more mature. The conditions in this scenario are enhanced for LFM deployment. However, it is expected to have a significant uncertainty around network aware LFMs. The transposition of the CEP regulation, guided by ACER’s FG, should become a reality during this period; however, it does not tackle the core challenges of network aware LFMs. At this point, the main challenge the authors of this paper envision for network aware LFMs is the *Liability over market clearing* which could cause significant challenges between DSOs and FMOs.

One interesting element of Scenario 2 is the potential growing interest from TSOs and BRPs to become market participants [16]. From the TSO perspective the pool of assets connected to the distribution grid could be a way to reduce the costs of procurement of their ancillary services (particularly with electric mobility and the V2G paradigm). In the case of BRPs they could use local flexibility to balance their portfolios. The combination of market participants with different business goals in a local electricity market, and therefore local distribution grid, is one of the main potential applications of network aware LFMs. They would allow for the implementation of a competitive market model without the need intervention of the DSO as grid owner.

Scenario 3

Scenario 3 is the most promising for network aware LFMs, since it is expected a full implementation of the Smart Grid paradigm after 2030. At regulatory level the EU will have published the new energy directives and regulations package which should promote even further the inclusion of DERs as active electricity market participants. It is in this context where the authors of this paper envision a possible resolution to the main business challenge of network aware LFMs *Liability over market clearing*. Furthermore, during the coming years it is expected to see a change of the regulatory frameworks for DSOs, oriented towards the adoption of the most cost-effective solution for grid operation, independently of the nature of the investment/cost (CAPEX, OPEX, or TOTEX). This new playing field should incentivize DSOs to create new products for the operation of their grids, which could benefit from network aware algorithms.

However, in a context where ICT technologies are well stablished at all grid levels, figures such as aggregators are normal, and technologies such as energy storage and electric mobility are widespread, the business model for network aware LFMs might be in danger, due to the possibility of including distribution grid power flow calculations in the DA market. As presented in [7], the concept of Proactive LEMs is something that might be interesting in the future of power grids. Improved grid observability, combined with higher computational power could lead to the inclusion of distribution grid topology in the DA market clearing algorithms, as it is nowadays happening with the Euphemia algorithm [17] and its Price Coupling of Regions (PCR). In any case, flexibility will be still required (for instance for balancing purposes), and therefore network aware LFMs still will have a business case.

DISCUSSION

This paper has provided context on the current state of LFMs around Europe, as well as a projection into the future of how technology, regulatory, and business developments can create a stronger business case for the implementation of network aware LFMs.

Overall, and as presented throughout the paper, the development of network aware local flexibility markets shows a high level of risk and uncertainties at the current stage of the energy transition. As of today, non-network aware LFMs are still at piloting stage, and there is only one local flexibility market platform that includes power flow calculations on its clearing algorithms (with very low availability of public information): EPEX SPOT Localflex ([12], [18]). The evolution towards a market-based approach for local flexibility procurement (even if stated in the CEP) is proving to be challenging due to the nature of the distribution grid, the current regulatory framework, and the energy system actors involved. However, the need for local flexibility procurement is constantly increasing in parallel to a higher penetration of RES and the electrification of new loads. The creation of the ACER Guidelines FW on Demand Response [9] shows the path that Europe envisions for local flexibility procurement in the coming years.

However, network aware LFMs might be in an even more uncertain position. Their capabilities seem to go beyond the flexibility market model and expand towards the energy market model. As presented in [7], proactive local energy markets, or the integration of Distribution Grids on the DA power flow calculations might be a logical step for energy markets in a future scenario (Scenario 3) where grid observability is high and forecasting algorithms have evolved.

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