Flexibility markets in the EU: Emerging approaches and new options for market design

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***Abstract* — The Clean Energy Package aims to transit towards cleaner energy in the European Union and requires market reforms towards small-scale flexibility provision and the creation of local flexibility markets. However, the progress in many Member States is slow. While several Member States have initiated a reform of their existing energy market structures, only few have started the creation of local flexibility markets. This paper provides an overview of emerging flexibility markets in the EU. This paper also provides an analysis of important elements of local flexibility markets based on literature review and assessments made in the Horizon 2020 project X-FLEX. Seven key characteristics of local flexibility markets have been retained from this literature review. Small-scale flexibility is still a relatively new concept, and a lot of barriers prevent it to enter the markets. Two main types of gaps were identified: (i) market-related gaps, such as aggregation rules that are not open enough, and (ii) operational gaps, such as the need for the large-scale smart metering infrastructure rollout and a large amount of data streams. The operation of local flexibility markets should depend on the network conditions they are applied to, as the conditions are different from one network to another. For this reason, the need for local flexibility markets has to be assessed depending on the problems the network is currently facing or will be facing in the future due to foreseen increased amount of distributed generation sources and electrified demand. A detailed analysis in terms of flexibility provision for the four demonstration sites in three European Member States participating in the X-FLEX project is presented in this paper, along with recommendations and activities for local flexibility market development performed in these demonstration sites.**

***Keywords* – Flexibility market, Local flexibility market, Regulation, X-FLEX project**

I. Introduction

Flexibility needs are increasing for electric networks with the expansion of renewable energy sources and electrified demand. Flexibility markets in particular are gaining a lot of recognition in Europe as new markets emerge and the European Union legislation supports such mechanisms. Namely, the Clean Energy Package and its Electricity Market Directive (EMD) (EU 2019/944) [1] and the new Electricity Market Regulation (EMR) (EU 2019/943) [2] endorse:

- A better integration of aggregators in the electricity markets and the non-discriminatory participation of demand response (DR) in all markets (EMD, Art. 17).
- The introduction of local flexibility markets (EMD, Art. 32).
- New actors for flexibility provision: Renewable Energy Communities and Citizens Energy Communities respectively, the latter being a new small-scale market actor.

And compel the following:

- Products for trading in day-ahead and intraday markets are sufficiently small in size, with minimum bid sizes of 500 kW or less, to allow for the effective participation of DR, energy storage and small-scale renewables including direct participation by customers.
- Non-discriminatory participation of all distributed energy resources (DERs) for capacity mechanisms and strategic reserves (EMR, Art. 20-22).
- The recast of the Renewable Energy Directive (EU 2018/2001) and Electricity Market Directive also create new actors that can provide flexibilities.

However, the implementation of the provisions in Member States is only at its beginning. This paper aims at presenting the state of the art in Europe in terms of flexibility markets. Most implemented frameworks are done at the national level and for wholesale trading. Nevertheless, new approaches and designs at the distribution level, what is commonly called "local flexibility market" (LFM), and this paper tries to provide an overview of the key elements that enable to distinguish local markets designs.

Section II describes emerging flexibility markets frameworks in the EU, section III identifies the key elements of local flexibility markets, section IV presents the current gaps in terms of market access, requirements, and market operation. Section V finally introduces the local market platform which is being developed in the X-FLEX project, its key elements, and the gaps it wants to bridge.

II. EMERGING FLEXIBILITY MARKETS

An analysis of the regulatory aspects for transmission and distribution-level flexibility provision has been conducted for three European countries: Slovenia, Bulgaria and Greece, as these are the three pilot countries of X-FLEX project.

A. Slovenia

In Slovenia the wholesale market is open for demand-side participation and aggregation is allowed as well. There is no distinction between energy provided through demand-side and energy provided by flexible production. The minimum capacity for entering the wholesale day-ahead and intraday markets is 1MW. In terms of balancing market, the situation is a bit different. Frequency containment reserves (FCR) is not open for demand-side participation. All units connected to high voltage grid are obliged to provide FCR, distributed sources are excluded. Automatic frequency restoration reserve (aFRR) and manual frequency restoration reserve (mFRR) allow the participation of demand-side flexibilities with a minimum capacity of 1 and 5 MW respectively. Replacement reserve (RR) is also open for demand-side flexibility and aggregation. In general, aFRR and mFRR are handled through yearly and monthly tenders. In addition, services may also be offered on daily auctions. It should be stressed that penalties for non-availability and not delivering services as promised are high, which discourages many potential bidders [3].

In Slovenia, the balancing market is an activity of the Slovenian Market operator Borzen within its public utility service of organizing the electricity market, stipulated in Article 24 of the Energy Act [4]. Trading is implemented through a market platform for collecting purchase and sale bids, through which Slovenian Transmission system operator (TSO) ELES buys and sells electricity intended for the settlement of imbalances in the network. The main barriers for demand response to access the market are low prices and limited market size. Assets connected to the distribution network are not able to participate in the balancing markets, which exclude households. However, they can participate in the case of aggregation. However, markets are dominated rather by big actors; in 2018 demand response offered 33 MW of upwards and 10 MW of downwards regulation on the tertiary reserve market. The total size of the market was 315 MW up and 175 MW down [5]. Constraint management is also not open for aggregation or demand flexibility. The transmission system offers sufficient capacity for normal operation, due to the current lower RES (Renewable energy resources) penetration compared to the other countries, so no market is needed.

Regarding the establishment of a flexibility market in Slovenia, the Slovenian energy market regulator AGEN initiated a public consultation process as part of the new Energy law in 2019. The draft law provides that DSO shall foster a flexibility market by 2030 [6]. This market should provide all services necessary to improve the efficiency of operation and development of the distribution grid. The services should include distribution grid congestion management. The aim should be to specify the market in a way to ensure the effective and non-discriminatory participation of all market participants. The regulator also plans to introduce an independent aggregator, who will not necessarily be also a supplier of electricity. Contracts to supply electricity and contracts for flexibility aggregation should therefore be separate to stimulate competition and prevent electricity suppliers from monopolizing aggregation of available flexibility through contracts for energy supply [6].

B. Bulgaria

The Bulgarian power market has been liberalised to all commercial and administration consumers (connected to the HV (High voltage), MV (Medium voltage) or LV (Low voltage) network), only household consumers are part of the regulated (tariff) market. The minimum capacity to participate is 0.1 MW for the day-ahead market (DAM) and the intraday market (IDM) [7]. Aggregation and demand-side flexibility are permitted [8]. The balancing energy market is currently under reform to be in line with the electricity market regulation and Regulation (EU) 2017/2195 of 23 November 2017 [9]. The entire balancing capacities of FCR, aFRR and mFRR are procured on a day-ahead base. RR is not remunerated, but providers that are able to provide such kind of reserve offer it to the balancing energy market, especially hydropower plants participating in controlled islanding. The balancing capacity market is open for individual units/modules (≥5 MW) and aggregators (group of units connected to more than one connection) with a total capacity of ≥5 MW that can be producers, prosumers, storage and hybrid flexible assets.

Until the end of 2022, it is planned that the balancing energy auctions have gate closure after the intraday cross-zonal transmission capacity gate closure time. Further improvement of auctions includes dividing the daily auctions into several time periods (4, 6, or 8 hours), to promote new flexible technologies and prosumers [10]. Currently, there is no licensing scheme in place for aggregators [8]. The NRA approved derogation for the active participation of the Bulgarian TSO in the balancing platforms of ENTSO-E (FCR Cooperation, PICASSO, MARI and TERRE) till 2024. As first step forward, Bulgarian TSO will join to IGCC (International Grid Control Cooperation) by the end of 2022. The current price cap for the BSPs' prices applied by the regulator is a barrier for flexible technologies entrance. Voltage control is mandatory for all producers connected to the transmission network, but is free of charge.

However, the minimum capacity of 5 MW will remain a barrier for small-scale RES. Local flexibility markets are not yet being discussed. According to the National Recovery and Resilience Plan [11], reforms for full liberalization of electricity market, including balancing market, are planned as follows:

- full liberalization of retail market for households in two steps (2023 and 2025).
- smart metering deployment.
- rejection of balancing energy price cap after Bulgarian TSO active participation in the balancing platforms of ENTSO-E.
- introduction of a unit balancing price for periods without activation of balancing energy.

- 15 minutes market time unit (MTU) and bit time unit (BTU).
- Balancing energy gate closure at least 2 hours before real-time balancing, but after IDM.

In addition, support schemes for investors are planned as follows:

- about 2 GW of small-scale RES.
- storage systems of 6 GWh.
- hybrid assets of at least 1.4 GW of RES with storage systems of 0.35 GW/1.4 GWh.
- small pilot projects for hydrogen and biogas.
- small pilot projects for geothermal co-generation.

The assets are to be commissioned by 2026.

C. Greece

The Greek electricity market, concerning the mainland Interconnected Electrical System (IES), was recently transformed to be aligned with the European Target Model leading to the establishment of a wholesale market of forwards electricity products operated by HENEX S.A. (Hellenic Energy Exchange S.A.) and a balancing market operated by the Independent Power Transmission Operator (IPTO, ADMIE SA), as defined by the Law 4512/2018 [12] and EU Law 4425/2016 [9]. The new energy market in Greece has been put into operation on November 1st 2020 (RAE 1298/11.09.2020) [13].

The new balancing market includes the balancing capacity market, the balancing energy market and the imbalance settlement process and the products offered by the participants include the (downward and upward, not necessarily the same) FCR, aFRR and mFRR. It is provided that RES aggregators can participate in the day-ahead, intraday and balancing market, while DR aggregators (including storage systems) and consumers can participate in the new balancing market as/via BRPs according to the decision 1033/2020 of the new law. The minimum offer to enter the capacity or energy balancing market is set at 1 MW, but this can be changed upon the technical decision of the regulator (Greek Government Gazette 4516/B/14-10-2020) [14].

There are two demand-side interruptible programs in Greece aimed to extend the existing Ancillary Services markets by including flexibilities. They are open for HV and MV consumers with 2 MW of flexible load. A prerequisite for them to enter is the installation of smart meters. There are two different product types of interruptibility services. Type 1 comes with a longer notice time but the duration of power reduction (48 hours), makes this type 1 not suitable for DR participation. Type 2 could be an interesting option for flexibilities, as power reduction only has to be provided for one hour. Aggregation is not yet allowed, but developments in this direction are planned. Auctions are held on a monthly basis [15].

A study that explored the flexibility needs of the Greek electricity system ranged the country's mid-term maximum flexibility needs in the order of around 6 GW [16]. In July 2020, Greece adopted a Transitory Electricity Flexibility Remuneration Mechanism (TFRM) to remunerate the availability of flexible generation capacity in €/MW; price that will be set through an auction organised by the regulator. The duration of the mechanism was set until March 31st 2021 or until the adoption of the Long-term Electricity Generation Adequacy Remuneration Mechanism (Greek Government Gazette 2852/B/13-07-2020). The capacity mechanism aims to ensure long-term capacity availability and is based on the obligation of the suppliers to present sufficient guarantees in this direction. The maximum total volume of this mechanism is 4,500 MW and the price will be capped at 39,000 €/MW. Participation is open for power plants, which can ramp at least 8 MW/min for at least three hours, de facto excluding DERs from participation [16]. The suppliers of flexibility requests should respond to the regulator request within 3 hours and provide flexibility for at least 3 consecutive hours. It is also provided that, storage systems will be able to participate in the TFRM upon the operation of the new energy market.

The Greek electricity system has been under change to adjust to the European target model. With the permission for aggregation, a viable first step for small-scale participation has been achieved, however, limited to the generation side on the DAM/IDM. The interruptible service product has shown the aim to include flexibilities within the energy system although the minimum threshold is high for DERs. At the moment Greece has no plans to develop local flexibility markets.

D. Comparison of the legislative frameworks for flexibilities

Table 1 presents a summary of the barriers and enabling factors for the valorisation of flexibilities in Slovenia, Bulgaria and Greece. In Bulgaria and Greece the market accessibility is the prevailing issue, while in Slovenia low revenues pose the main problem. Enabling factors are shorter tendering periods or specific programs for flexibilities. A future flexibility market is only foreseen in Slovenia, but not discussed in other countries.

TABLE 1: COMPARISON OF THE LEGISLATIVE FRAMEWORK FOR FLEXIBILITIES

	Barriers	Enabling factors	Trends
Slovenia	- Low prices - Limited market size - High penalties for non-availability	Aggreggation and DR allowed	Flexibility market by 2030
Bulgaria	- High minimum capacity (5MW) - Aggregation not allowed	Auctions in several time periods to promote new flexible technologies	(Local) flexibility markets not yet discussed
Greece	- Demand-side interruptible programs not open for aggregation - DAM/IDM not open for DR	- Low minimum capacity (1 MW) - Demand-side interruptible programs	- No plans for a (local) flexibility market - Permission for aggregation in interruptible programs

III. Local markets formulations

At the local scale, or in other words, for distribution networks, flexibility services are mostly needed for solving congestions. Some local flexibility mechanisms also aim at solving voltage violations [17] or other technical issues such as the reduction of power losses or the improvement of the network reliability [18, 19]. Various mechanisms exist or are emerging, such as rule-based approaches, bilateral agreements, network tariffs or market-based procurements. In this paper, only the market-based mechanisms are considered. A literature review was conducted to establish a picture of the existing local flexibility markets and the propositions arising.

It was determined that seven key characteristics enable the differentiation of local market mechanisms with one another. The key elements are the following:

i. Formulation of the local market,
ii. Timeframe where flexibility services are purchased,
iii. Product definition, in terms of nature and duration,
iv. Market objective function,
v. Market clearing method,
vi. DSO-TSO coordination scheme
vii. Traffic light signals to signal the network state.

The formulation of the market is the general description of the level of flexibility market (LFM or TSO ancillary services – "TSO AS"). Different formulations and combinations exist as there can be for example a coordination between distributed level dispatch and then aggregation of distributed flexibility for transmission system ancillary services.

The timeframe of the flexibility product is usually copied from the existing electricity markets, which are day-ahead, intraday, and balancing or real-time timeframes. Flexibility, if defined as the "ability of a power system to maintain continuous service in the face of rapid and large swings in supply or demand" [20] is usually a service for near real-time issues for DSOs. However, it was found that some local flexibility markets consider also earlier timeframes for the procurement of flexibility services.

Flexibility products can be defined with various parameters. We decided to consider only two parameters of interest, that are the nature of the product and its duration. The nature of the product is twofold: energy or capacity reservation. When flexibility is sold as energy it is equivalent to the activation (in other words increase or decrease) of the load over a certain duration. Capacity trading inversely, acts as a reservation of the capacity of the network if purchased or as an increase of available capacity in the network if sold. Simple energy products are often referred to as "explicit" products where the capacity and energy markets are separated, on the other hand, it is also possible to combine energy products to capacity which internalises the grid constraints, also known as "implicit" products [21]. The duration of the flexibility product varies from one design to the other, usually ranging from 1 hour-long down to 5-minute long.

The market objective function reflects the optimisation that rules the whole clearing process. In most cases the explicit goal is to maximise the social welfare, i.e. maximising all market participants satisfaction by selecting the best clearing price. Some other objectives such as minimising the aggregator energy cost or minimising prosumers costs can be found in literature. In some cases, this objective function is not explicitly mentioned, but we could argue that the main rationale is the minimisation of grid congestion.

The clearing method in our wording refers to the bidding and pricing processes for the local market. In most market design, LFMs are single-sided auctions as the DSO is the single buyer and requester of flexibility and all flexibility providers offer their flexibility to this call. The trading price can be either defined following current transmission level market clearing prices methods, such as pay-as-cleared when all bids are merged, ranked by a merit order list, and the equilibrium price is found or pay-as-bid for continuous markets, typically employed for the wholesale intra-day market. Most LFM design favour a pay-as-cleared pricing scheme.

DSO-TSO cooperation is of utmost importance for distributed energy resources as they could not only offer flexibility to the DSO they are connect to, but also to the TSO as part of a balancing group. Offering flexibility to the TSO could compromise the power quality and reliability of the distribution network. Different DSO-TSO cooperation schemes have been defined, especially in [22], based on [23]:

- Centralised Ancillary Service (AS) market,
- Local AS market,
- Shared Balance Responsibility,
- Common TSO-DSO AS market model,
- Integrated Flexibility market model.

These cooperation models propose different responsibilities for the system operators, having the market operator role either assumed by the TSO as it is today with the wholesale market, or by both the TSO and the DSO, with different communication and aggregation schemes, or also the market operator being a third-party agent which manages wholesale and local markets centrally. It was noticed that the question of DSO-TSO coordination is often neglected so the local markets are regarded as independent markets, thus ignoring possible conflicts between market agents.

Another aspect of local markets which is still deficient in literature is the traffic light signal utilisation. Few actors have proposed the adoption of traffic lights for operating local markets, one example being the USEF flexibility trading protocol with four grid operation regimes representing the normal operation, a risky situation, and a power outage situation [24]. EURELECTRIC has also mentioned their interest in such signals that could help exchange easy-to-read information between the DSO and the TSO on the network availability [25].

The results of the literature review on LFM designs are summarised in the Table 3. It has to be noted that local markets only in the form of local energy markets (LEMs) were not included in this analysis as they do not explicitly provide flexibility services to the DSO. Combined forms of markets were kept in this analysis. Most of the reviewed local markets considered competitive LFMs where the clearing is done once, based on bids received, rather than predefined bilateral contracts or negotiation mechanisms between the DSO and aggregators. A wide variety of objective functions were observed, the most preeminent being the maximisation of the social welfare and the DSO operation costs minimisation. More occurrences of pay-as-cleared than pay-as-bid were found even though no special incentive was given for any of these two methods. The issue of coordination between the DSO and TSO is well known even though not all articles mentioned it. Finally, the use of traffic light system for the management of the market operation is occasionally used but deserves to be studied more.

IV. IMPLEMENTATION GAPS

A. Market related gaps

The prevailing market-related gap for flexibility is market access. Markets in general are still designed for conventional flexibility providers limiting the possibility for new market actors to offer flexibilities. An example thereof is the requirement for symmetrical offers (same up/downward flexibility) which is simply not feasible for some technologies. As the forecast of flexibilities can be quite challenging for technologies, that are for example weather-dependent, a short procurement period (e.g. daily) is preferable. Specifically for small-scale flexibility offers, the minimum bid size and the permission for aggregation is essential. If the entry requirement is too high and aggregation is not allowed, small-scale DERs cannot participate. Another problem is the low revenues for the flexibilities offered, i.e. the capacity part is not valorized but only the energy part. This especially poses an issue when additional work/expenses are needed to combine several smaller flexibility sources. Moreover, the structure of the current market does not foresee the emergence of local markets; therefore, no clear rules and procedures are defined on how to include local markets in the functioning of the wholesale energy markets and to make local and wholesale markets coexist.

B. Operational gaps

Identified operational gaps are mainly related to the need for the large-scale smart metering infrastructure rollout and a large number of data streams. Smart metering infrastructure is one of the prerequisites to enable the participation of small flexible providers like households. However, this will entail a large amount of data flow, which needs to be handled. The amount of data will also increase in case of shorter contract periods for end consumers. Therefore, working with a clearly defined set of standards would improve data handling. However, many gaps related to the lack of standardization for market participation, that may significantly hinder the mass participation of DERs in the emerging market models, exist. Key market-related standards are broadly comprised of market standards for demand-side DERs, standards related to electric vehicles, blockchain standards, and common standards for the use of energy such as the Universal Smart Energy Framework (USEF) [24].

V. LOCAL MARKET DESIGN IN THE X-FLEX PROJECT

The X-FLEX project is developing a local market for DSOs for the allocation of network capacities between network users. The market platform, called MARKETFLEX, aims to maximise the grid utilisation while keeping all quality and reliability indicators within acceptable boundaries. The deployment of the market platform is twofold:

- For local markets which do not go beyond the distribution system, internal electricity and flexibility markets are deployed;
- For units connected to the distribution system and willing to participate in transmission-level markets, the local market platform acts as an intermediary between the local grid, i.e. the DSO, and the TSO.

In the second case, the local market ensures that any bid coming from the distribution system nor any signal coming from the transmission system jeopardises the local grid. However, no internal clearing is performed as it is already done on the wholesale market platforms.

In the first case, where local market clearing processes are performed, the MARKETFLEX platform can be described, as described in Section III, by a certain number of characteristics that are listed in Table 2.

TABLE 2: KEY ELEMENTS OF THE LOCAL MARKET PLATFORM IN X-FLEX

Market formulation	Hybrid LEM and LFM
Timeframe	- LEM: DAM, IDM - LFM: RT (up to 15 minutes before operation)
Product definition	Capacity,15-minute long
Market objective function	- Maximise network capacities utilisation - Maximise the social welfare
Market clearing method	(for LFM only) single-sided auction, price-time priority, pay-as-clear
DSO-TSO coordination scheme	Local Ancillary Services market model [23]
Traffic Light System	Three stages (green/yellow/red)

During the conception phase of the MARKETFLEX platform development, a review of existing and appearing flexibility markets in the pilot countries was performed in order to adapt the design of the local market platform to the feasibilities of each country. In terms of communication standards, the choice of exploiting the USEF flexibility trading protocol was chosen as the use cases this protocol was developed for comprised the same use cases as for the X-FLEX project. Some extension has been applied, however, because of missing information, in particular the voltages, currents, and available capacities of the distribution grid elements.

VI. CONCLUSION

This paper presented the emerging notion of flexibility markets, both at the transmission and the distribution level. Regulations and progress in three different countries were presented, namely in Slovenia, Greece and Bulgaria, where the X-FLEX project is implementing a local market to solve congestion and voltage issues in the distribution network. Different propositions of local flexibility markets which can be found in the literature were reviewed and compared, while implementation gaps were identified, namely legislation and operational barriers. Last but not least, the proposed LFM and its main characteristics have been described.

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APPENDIX

TABLE 3: REVIEW OF LOCAL FLEXIBILITY MARKET DESIGN PARAMETERS

Ref.	Formulation	Timeframe			Product			Objective function	Clearing method		DSO/TSO coordination	TLS[b]
		DAM	IDM	RT[a]	Ener.	Cap.	Duration		Bidding	Pricing		
[19]	LFM	(✓)	(✓)	✓	✓	-	30 min or 1 h	- DSO operation and flexibility cost min. - Social welfare max.	-	Pay-as-cleared Bilevel optimisation	-	-
[21]	LFM+ bilateral contract+ TSO AS	✓	✓	✓	✓	✓	-	-	-	-	✓	✓
[22]	LFM+ TSO AS	-	-	✓	✓	-	5 min	Activation cost min.	-	-	✓	-
[24]	LFM	-	-	-	-	✓	15 min	-	-		✓	-
[25]	LFM (+ TSO AS)	✓	✓	✓	✓	✓	-	-	-	-	✓	✓
[26]	LFM	✓	✓	✓	✓	-	5, 15, or 30 min	- Welfare max. - Multi-period cost min.	Single-sided auction	-	-	✓
[27]	LFM	✓	✓	✓	✓	-		- Operation cost min.	-	-	-	-
[28]	LFM+TSO AS	-	-	-	-	-	15 min	-	-	MIP problem[c]	-	-
[29]	LFM	✓	-	-	✓	-	30 min	- DSO operation cost min. - Prosumer cost min. - Aggregator profit max.	-	Agent-to-agent negotiation between DSO, aggregators, prosumers	-	-
[30]	LFM with price negotiation	✓	-	-	✓	-	1 h	Social welfare max.	-	Pay-as-cleared	-	-
[31]	LFM	-	-	-	✓	-	-	- Social welfare max. - Operational cost min.	-	- Centralized optimization - Decomposition methods - Bi-level optimization - Game theory-based - Auction theory-based - Simulation	✓	-
[32]	VPP+ TSO AS	✓	✓	✓	✓	-	-	-	-		-	-
[33]	LFM	-	✓	-	-	✓	1 h	-	-	Pay-as-bid	-	-
[34]	LFM	-	✓	-	-	-	-	-	-		✓	-
[35]	LFM	✓	-	-	✓	-	-	- DSO energy, penalty and flexibility procurement cost min. - Aggregator energy cost min.	-	DSO optimization is solved through KKT[d] conditions relaxation	-	-
[36]	LFM	✓	✓	✓	✓	-	1 h	DSO portfolio investment risk min.	- single-sided aggregator auction - "super market"	Pay-as-cleared	-	-
[37]	LEM+LFM	✓	✓	✓	✓	-	-	Overall cost min.		Grid tariff or price decided by market operator	✓	✓

a) RT: Real Time; b) TLS: Traffic Light System; c) MIP: Mixed Integer Programming; d) KKT: Karush–Kuhn–Tucker.