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Use of Flexibility in Distribution Networks: an Overview of EU and Croatian Legal Framework and Trends

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***Summary* — The new Croatian Electricity Market Act (in force since October 22, 2021 [1]) stipulates that the distribution system operator is encouraged to use flexibility, including participation in congestion management in distribution network in coordination with transmission system operator, to increase efficiency, develop the distribution system and promote energy efficiency measures. DSO can access flexibility in one or more of the following ways: market-based procurement of flexibility services, distribution network tariffs, flexible (non-firm) connection agreements, rules based (regulated) approach, in combination or separately. The categories are not necessarily mutually exclusive and the inherent regulatory incentives and implemented measures may overlap. Member States and national regulatory authorities should, therefore, carefully evaluate the interactions when implementing new forms of access to flexibilities or when enhancing existing ones. The paper reviews the mentioned possibilities of using flexibility in the distribution network.**

***Keywords* — flexibility, distribution networks, network tariffs, active system management, efficient network development**

I. Introduction

An increase in the share of renewables has created and will continue to create challenges for the energy system. These challenges include frequency variation, insufficient capacity in the networks, excessive voltage swells/drops, overloading of network equipment, outages and inefficient resource handling. Increasing and promoting flexibility in the grid could be a cost-effective way to minimize the challenges that come with renewable energy production and new forms of consumption.

The main aim of distribution system operators (DSO) and regulatory authorities (RA) is to maximize the efficiency of the distribution network, by utilizing the existing and future infrastructure to its full capacity. The use of flexibility to maximize the efficiency of the grid could provide socio-economic benefits by utilizing existing resources that could decrease or defer the need for new investments in grid infrastructure.

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On an individual level flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) to provide a service within the energy system. The parameters used to characterize flexibility include the amount of power modulation, the duration, the rate of change, the response time, the location etc.

Flexibility is of particular importance to the DSOs because most of the distributed generation and new loads are connected directly at the distribution level. In essence, if the DSO use of flexibility would make the current grid last longer by requiring less infrastructure upgrades or reinforcements, while at the same time achieving better voltage quality and continuity of supply, there is the potential to better utilize and efficiently develop the distribution system. The utilization of flexibility in the distribution system can fulfil several purposes, such as:

- Reduce or defer required network reinforcements;
- Active congestion management, allowing alternatives to curtailment;
- Reduce or shift demand or generation profiles to smoothen the load shape;
- Better management of power quality issues, such as those relating to voltage swells/drops, harmonics, flicker, and asymmetry.

The flexibility can be acquired from the planning stage, and later be used during the system operation. As given in 2020 CEER Paper on 'DSO Procedures of Procurement of Flexibility' [2], management of the distribution network constraints/limits can be divided into the following categories:

- Grid capacity management;
- Congestion management;
- Voltage control.

Grid capacity management involves planning and realization of network investments according to predefined criteria and the respective regulatory framework. Capacity constraints can result in incidental or frequent temporary overload or congestion, but in contradistinction to *congestion management* (which usually provides temporary solutions), it should in the future be considered business as usual. DSOs may use the explicit, or even some forms of implicit, demand-side flexibility to increase their operational efficiency without any impact on the freedom of dispatch, trade and connections (copper plate principle).

Flexibility mechanisms are divided into (Figure 1):

- Implicit, where actors respond to fixed price signal, e.g. spot price in wholesale market or tariff set by DSO;
- Explicit, where the actors themselves bid in their price and actively contribute to the price formation.

Explicit Flexibility
is committed, dispatchable flexibility that can be traded on the different energy markets (wholesale, balancing, non-frequency ancillary services markets).
This is usually facilitated and managed by an aggregator or on an individual basis (larger businesses and industrial sites). This form of flexibility is often referred to as "incentive driven".

Implicit Flexibility
is the consumer's reaction to price signals.
Where consumers have the possibility to choose hourly or shorter-term market pricing, reflecting variability on the market and the network, they can adapt their behaviour (through automation or personal choices) to save on energy expenses.
This type of flexibility is often referred to as "price-based".

Fig. 1. Types of flexibility

The main purposes of flexibilities within distribution system are deferral of grid reinforcements (especially relevant for (but not limited to) grid areas where n-1 obligations apply), optimization of operational performance of assets (e.g. extending the lifetime of the component) and reducing grid losses by influencing the peak load.

Congestion management refers to avoiding the overload of system components by reducing peak loads to avoid failure situations or outages. This process addresses, contrary to *grid capacity management*, the overload situations that have not been anticipated during the long-term grid planning process, or situations where grid reinforcements cannot cope with the load/ generation increase. Such measures provide a temporary solution, where the long-term solution (in general) is grid reinforcement. In the future, to fully harness the potential of flexibility, *grid capacity management* should be considered as business as usual for the DSO, contrary to *congestion management*. Both services, when designed as an explicit, market-oriented mechanism, could have different tailored products (short term – energy products or long term – capacity products that may be combined with energy products), but are aimed at solving or preventing active power overloads.

Voltage control (mostly depending on active power in lower voltage levels) addresses problems with power quality, e.g. occurring when production (mostly generated by distributed renewable energy sources (RES)) significantly exceeds the demand in the observed time interval with the result of an increased voltage level in the (local) grid. Using demand-side flexibility to impact the load/ generation can avoid exceeding any voltage limits and consequently reduce the need for grid investment (such as automatic tap changers) or prevent generation curtailment.

Article 32 of the Directive (2019/944) [3] on common rules for the internal market of electricity sets new requirements on the use of flexibility in distribution networks. For the procurement of flexibility services, the way that the DSOs describe their needs and how this is signaled to relevant market parties and other actors are of particular importance because this has a significant influence on the market outcome. The specifications of network needs might differ substantially depending on grid topology, customer basis and locational cause of congestions. The different needs in the grid could require different solutions and various types of access to and use of flexibility.

Several technologies can provide flexibility, including centralized or de-centralized generation, demand side participation and energy storage. However, only very large customers, e.g. industrial customers, find it easy to sell their flexibility on an individual basis and participate in the flexibility market today. Smaller residential and commercial customers may face high barriers in accessing these markets. Transaction costs of such participation are too high if managed at individual level. Aggregation is a commercial function of pooling de-centralized generation and/or consumption to provide energy and services to actors within the system. It offers the opportunity for smaller residential and commercial customers to exploit their flexibility potential. Aggregators can be retailers or third parties. They may act as an intermediary between customers who provide flexibility (both demand and generation) and procurers of this flexibility. They would identify and gather customer flexibilities and intermediate their joint market participation. This could be done via flexibility products or simply by selling and buying aggregated energy (kilowatt-hours) at optimal points in time.

The provision of ancillary services including services for congestion management by grid users connected to the distribution system has been the core of numerous research and development projects as well as recent regulatory developments in some European Member States. There has been a significant number of research initiatives over the past years. In late 2021 Joint Research Centre (European Commission) – JRC, has published report "Smart Grids and Beyond: An EU research and innovation perspective" [5] in which an analysis of investments in (realized or ongoing) smart grid R&I projects has been made. Projects relevant to flexibility are categorized as "smart network management" and "demand side management". They focus on increasing the operational flexibility of the electricity grid through enhanced grid monitoring and control capabilities and on facilitation of demand flexibility (demand response) respectively, and which, according to [5], gather 40% of the total funding. As observed in [4], local flexibility markets and flexibility in general are not so far from the infancy stage in the real-life. On the other hand, both academia and R&D oriented departments in the commercial sector are active in exploring various high-RES penetration models, flexibility provision, TSO-DSO coordination schemes and distribution level market models. Among surveyed papers, we single out the following works that provide overview of the most advanced and promising projects and platforms: [4, 5, 7, 8]. Even though the literature provides insights on current state, what lacks is the pilot project and research on applicability in different markets around Europe. Local and national pilot projects are good steps forward as they allow testing of different strategies within a fast-evolving framework.

II. The Croatian Law on Electricity Market (2021) – Flexibility and Ancillary Services at the Distribution System

The market-based approach, meaning DSO procurement of explicit flexibility, is a relatively new field despite regulations in many EU countries neither disincentivizing nor explicitly forbidding such access. Recently adopted Croatian Law on Electricity Market [1] stipulates that the regulatory agency should provide incentives to DSO to procure flexibility services, including congestion management in coordination with the transmission system operator (TSO), in order to improve efficiencies in the operation and development of the distribution system, and to promote the uptake of energy efficiency measures (Article 75, paragraph 1).

The Law prescribes that in the Distribution network code DSO shall prescribe the technical criteria for the provision of ancillary and flexibility services (Article 75, paragraph 3).

In line with the CEER Conclusions Paper "Flexibility Use at Distribution Level" [9], the Croatian Law recognizes four different mechanisms for DSO's access to flexibility (Figure 2): Rule based approach, Connection agreements, Network tariffs, and Market based procurement.

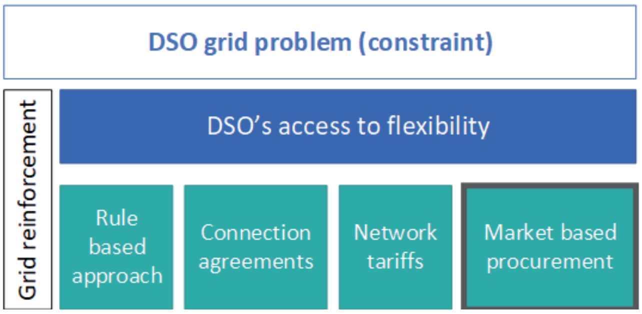

Fig. 2. Different ways of accessing flexibility for DSO - the Croatian Law on Electricity Market, Article 75

Constraint management consists of several methods to handle challenging grid situations (Figure 2). As a starting point, DSOs can manage constraint issues with the activation of their own flexible grid assets. Such actions are a default option and applied before or at the same time as considering market-based management. If a DSO cannot solve a problem with its own assets (e.g. topology changes, tap changers, voltage boosters, etc.) it may need to invest in new assets (grid reinforcement); the procurement and use of flexibility for constraint management could be the better solution economically.

The regulatory framework ensures that DSO can procure services from providers where such services cost-effectively alleviate the need to upgrade or replace assets in the grid and support the efficient and secure operation of the distribution system (Figure 3). DSO shall procure such services in accordance with transparent, non-discriminatory and market-based procedures unless the regulatory authorities have established that the procurement of such services is not economically efficient or that such procurement would lead to severe market distortions or to higher congestion. In other words, the EU Electricity Directive states with an "*argumentum e contrario*" that the flexibility procurement must be economically efficient and must not lead to severe market distortions or to higher congestion. Consequently, this inverse conclusion shows that market-based flexibility procurement presents the base-case to be implemented, but also must not come at any price, e.g. if congestions are increased as a result. Thus, there may be cases where it is decided at national level to not implement the market-based approach. In this regard, the Croatian Law (Article 75, paragraph 4) obliges DSO to perform the cost/benefit analysis based on which the regulatory agency shall decide on the exemption from the market-based procedures.

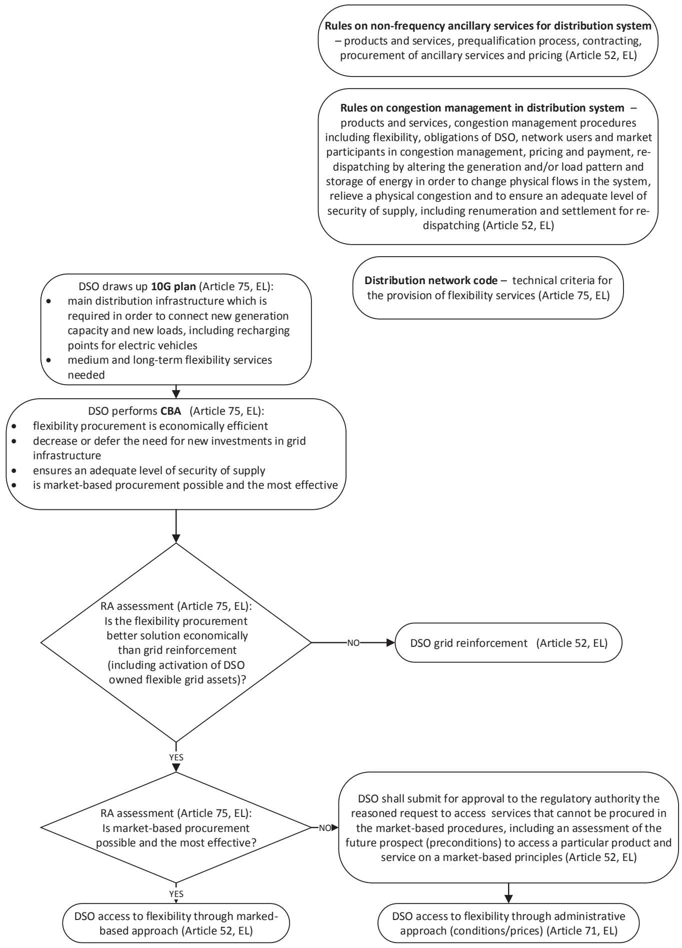

Fig. 3. The Croatian Law on Electricity Market (EL) – DSO access to flexibility

By September 30 each year DSO shall submit for approval to the regulatory authority the reasoned request to access flexibility and non-frequency ancillary services that cannot be procured in the market-based procedures, including an assessment of the future prospect (preconditions) to access a particular product and service on a market-based principles.

The Law (Article 75, paragraph 8) states that every year the DSO shall draw up and publish a transparent network development plan (10G plan) and shall submit it to the regulatory authority which may request amendments. The 10G shall provide transparency on the medium and long-term flexibility services needed and shall set out the planned investments for the next ten years, with particular emphasis on the main distribution infrastructure which is required in order to connect new generation capacity and new loads, including recharging points for electric vehicles. The network development plan shall also include the use of demand response, energy efficiency, energy storage facilities or other resources that the DSO is to use as an alternative to system expansion.

The Law (Article 52, paragraphs 22-26) also prescribes that the DSO shall procure the non-frequency ancillary services needed for its system in accordance with transparent, non-discriminatory and market-based procedures, unless the regulatory authority has assessed that the market-based provision of non-frequency ancillary services is economically not efficient and has granted a derogation. Subject to the regulatory approval, by the end of the October 2022 DSO should have adopted rules on non-frequency ancillary services for distribution system in which at least the following shall be provided: products and services, prequalification process, contracting, procurement of ancillary services and pricing.

The Law (Article 52, paragraphs 31-35) prescribes that the DSO shall engage in flexibility services, including congestion management. The DSO congestion management rules shall prescribe at least the following: products and services, congestion management procedures including flexibility, obligations of DSO, network users and market participants in congestion management, pricing and payment, re-dispatching by altering the generation and/or load pattern and storage of energy in order to change physical flows in the system, relieve a physical congestion and to ensure an adequate level of security of supply, including renumeration and settlement for re-dispatching.

III. Implicit Flexibility through Network Tariffs

Network tariffs typically have three main components, used either alone or in combination: fixed (€/point of delivery); capacity (€/kW); and volume (€/kWh). Common charging bases include flat rate and non-linear rates varying with volume or time of use. The advantages and disadvantages of each tariff component and each charging basis are discussed in [10] and are summarized in Table I.

Table I. Tariff components and charging bases [10]

Tariff component	Fixed	Capacity		Volume
		ex ante	ex post	
Advantage	• Simple • Stable • Predictable	• Signals that capacity has a price	• Signals that capacity has a price • Cost-reflective	• Acceptable to consumers
Disadvantage	• Does not signal long term costs and so does little to encourage energy efficiency and system flexibility	• Reflect capacity costs to a limited extent	• Requires smart metering • Complex • Less predictable • Less acceptable to consumers	• Does not reflect capacity costs • Can raise revenue uncertainty for DSOs
Tariff charging basis for capacity and volume components	Flat rate	Non-linear	Time-of-Use	
			static	dynamic
Advantage	• Simple • Acceptable to consumers	• Can be designed to balance multiple objectives of affordability, conservation, efficiency and cost recovery	• Mitigates congestion • Reflects capacity costs • Signals the value of flexibility • Benefits engaged consumers financially	• Mitigates congestion • Reflects capacity costs • Signals the value of flexibility • Benefits engaged consumers financially • Can target specific system events on short notice
Disadvantage	• Less cost-reflective • Can over-incentivize self-generation which does not always synchronize with system peaks	• Complex • Potential adverse consequences due to poor design or consumer understanding	• Predicted peak times may not coincide with actual system peak • Does not allow for variability when peak conditions occur	• Requires advanced metering • The risk of all consumers responding simultaneously to a single price signal • Traditional consumers who cannot change consumption pattern may face higher prices

Power consumption is not the only determinant of the level of network costs. As the network requires enough capacity for peak consumption, the time-of-use is also important to consider. Time-differentiated "static" tariffs (TOU, Figure 4) are characterized by offering different price signals for energy and power, based on discrete time periods (or "time-bands") that are fixed in advance, possibly differing between relevant locations on the network. Generally, with time-differentiated static tariffs the time periods and the price signals themselves do not change for several years. Time-differentiated static tariffs offer a reasonable balance between efficiency and complexity, but lack the most desirable advantage of dynamic ToU tariffs, i.e. short-term changes in prices, reflecting the actual network conditions. This is especially true when actual critical peak hours are highly volatile.

Time-of-use, whether energy, power or any mixture are generally considered to be more cost-reflective than time independent tariffs, as they are aligned to predicted peak times. However, static time-of-use differentiated tariffs could also pose a challenge if they lead to large loads being shifted in and out of the network simultaneously (e.g. at the change of hours). For example, such shifts could happen when the price variation in the energy charge is high between two hours and an increasing degree of home automation results in a large number of users responding at once. Tariffs giving such signals could lead to new network peaks. The aforementioned situation could be solved by using automation and gradual consumption management.

A dynamic ToU tariff means that the price signal is defined at shorter notice, possibly close to real-time. This contrasts with static ToU tariffs, where the price signals are associated with predetermined time periods. Dynamic ToU network tariffs are one way that DSOs could (implicitly) make use of flexibility to avoid or defer reinforcement. The objective of a dynamic ToU network tariff is to promote more efficient network use under a scenario where network use has become more uncertain (e.g. due to intermittent production or new consumption patterns) and where new technological solutions are enabling demand response (smart meters, automation, storage). Being dynamic, the price signals can be sent closer to real time, increasing the cost-reflectiveness of the network tariff, which should result with a more cost-efficient system, benefitting all network users.

A first step for a more dynamic ToU network tariff is providing price signals that reflect the critical periods that need to have significantly higher prices. Critical peak pricing (CPP, Figure 5) is a dynamic form of a time-varying tariff, where the peak price would be significantly higher on a limited number of days (typically 10 to 15) or hours per year, when the capacity of the system is most likely to be constrained (i.e. critical events), and lower for the rest of the year. The dynamic nature of a CPP rate allows the utility to respond with short notice of an upcoming "critical peak period", during which tariffs will be significantly above normal. Peak time rebates (PTR, Figure 6) are in some ways the mirror image of a CPP rate.

Studies [11] have shown that CPP tariffs provide incentives for customers to change their consumption pattern. Results from France, Great Britain, Slovenia and Japan show that customers react on CPP pricing, which means that the peak load can be reduced. Plans to introduce or actual implementation of CPP tariffs can be found in countries including Slovenia, China, USA, Japan and France. For example, in France, time-of-use and variable-peak signals have been used for 50 years.

A PTR provides consumers with a payment for reductions in consumption below a predetermined customer level baseline during peak events. PTR is popular since it is a "no-lose" tariff for customers (in the short-term at least). However, accurately forecasting customer baseline usage is not trivial.

Real-time pricing (RTP, Figure 7) provides consumers with an hourly or sub-hourly price. While RTP is typically used to capture hourly variation in wholesale energy prices, theoretically, real time pricing of the network (under which the tariff is dynamically set) may be possible, although it has not been implemented anywhere on the distribution network. As the amount of intermittent generation capacity from wind and solar generating sources increases, distribution system capacity constraints may become less predictable and hence rate designs that can respond to actual system conditions (such as RTP or CPP) rather than reflect stable patterns (such as TOU) may become more valuable.

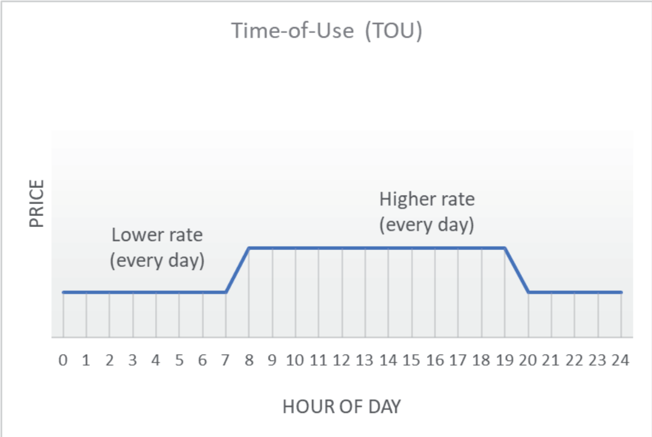

Fig. 4. Illustrations of alternative time–varying rates – Time-of-Use (TOU)

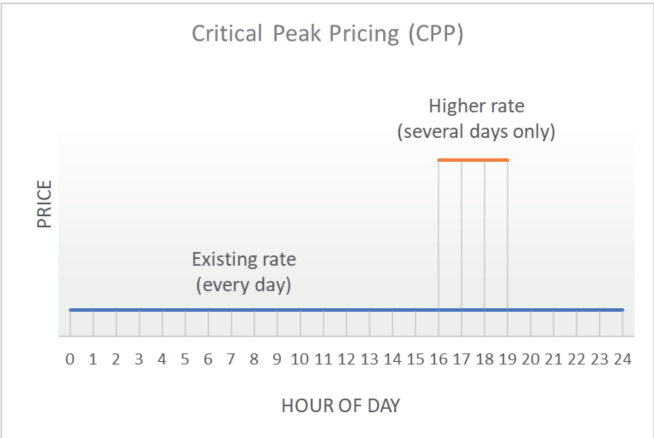

Fig. 5. Illustrations of alternative time–varying rates – Critical Peak Pricing (CPP)

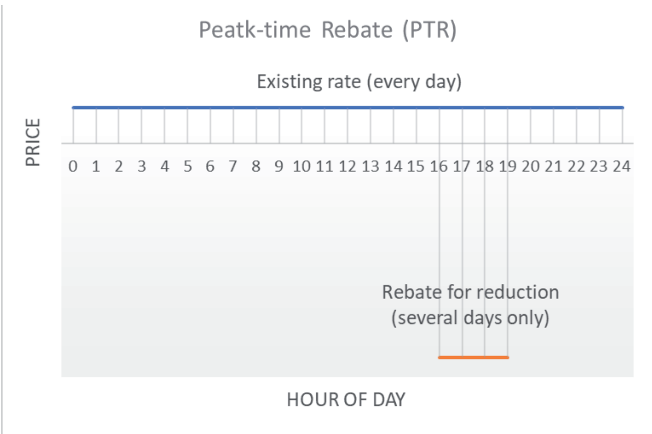

Fig. 6. Illustrations of alternative time–varying rates – Peak-time Rebate (PTR)

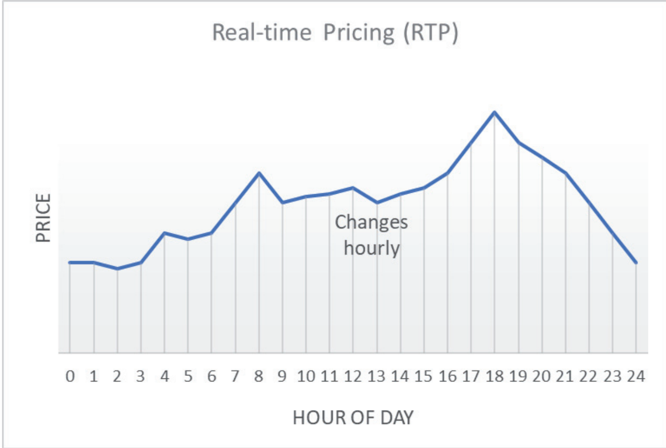

Fig. 7. Illustrations of alternative time–varying rates – Real-time Pricing (RTP)

The introduction of dynamic ToU network tariffs shares the same pre-requisites as (envisaged by the Electricity Directive [3]) dynamic retail prices, namely:

- Introduction of smart meters in order to measure consumption in short time intervals, according to the time unit, as determined by the imbalance settlement period. This is on track across Europe with the widescale roll-out of smart meters. For the status of the rollout of electricity smart meters at the end of 2021 see the ACER/CEER report [12] and for the progress on national smart meter roll-outs see article published in January, 2022 [13];
- Feedback about metering data to enable a user to control their energy use (e.g. through an app or a technical device). This is the stated intention of the Clean Energy Package [14];
- Technological solutions for flexible use and power reduction within property, housing and industry (e.g. automation and storage);
- A detailed forecasting model, which would be used by the DSOs to determine the critical periods by network area/point. Notably, DSOs need to become increasingly engaged in active grid management, and this includes modelling of future congestions;
- IT infrastructure to send price signals to network users, possibly differentiated by network area/point, in order to ensure users are able to predict charges and respond to them;
- Robust estimates about long-term avoided costs.

In general, dynamic ToU network tariffs would be far more complex in comparison to static ToU network tariffs. In [11] CEER emphasizes that principles such as simplicity and predictability are especially important for small customers, while other principles have more weight for larger customers at the DSO level. Besides, the introduction of dynamic ToU network tariffs raises numerous regulatory questions. These issues include how customers should be informed of tariffs, how regulators should regulate tariff setting, and how they should be integrated into the system of tariff or revenue cap incentive regulation (when applied). Finally, through the resulting tariffs it should be ensured that a reasonable distribution of costs among all network users is achieved, especially between customers with and without automation. If a high degree of cost recovery is done through the dynamic tariff signal, costumers who are unable to respond through technology are likely to pay higher network costs. This depends on a number of aspects, e.g. on whether the dynamics ToU network tariffs are voluntary for customers and how the costs would be distributed between dynamic and static tariff users.

For the beneficial network behavior of network users important is the interaction between both static and dynamic ToU network tariffs and the procurement of flexibility. Combined with static ToU network tariffs, the impact of flexibility procurement should be easy to identify. Provided the procured flexibility is contracted for a sufficient period of time, the procuring network operator will be able to avoid network expansion. This leads to an overall reduction of the DSO's costs in most cases in the long run. Thus, network users will be charged lower tariffs than would have been the case without the procured flexibility. Where tariff static time signals do not prompt the desired demand response, the procurement of flexibility forms a beneficial instrument for avoiding costs. This creates the potential to use flexibility, while allowing network tariffs to fulfil the tariff principles of simplicity, predictability and non-discrimination.

More complex is when flexibility procurement is considered alongside dynamic ToU network tariffs. Dynamic ToU network tariffs and flexibility procurement differ in that under the procurement of flexibility, the DSO explicitly contracts for it with the customer or their intermediary, while with dynamic ToU network tariffs, the flexibility provided by customers is implicit. Thus, the effectiveness of the latter firstly depends on the actual existence of customer flexibility and, secondly, on the interaction between the network tariff signals and other behavior-influencing factors.

CEER [11] emphasizes that worldwide there is limited experience of full dynamic ToU network tariffs at the distribution level. Nonetheless, there are a couple of observations that can be made, when they are compared with the procurement of flexibility. First of all, the effectiveness of both instruments might currently be limited at the DSO level, as it depends on the potential for flexible behavior. For small customers, such as private households and small businesses that are mostly connected to the low voltage level, it might be questionable whether there are currently available sufficient (technological) possibilities for providing flexibility. The complexity of dynamic ToU network tariff calculation is also an important factor when discussing the potential effects of dynamic tariffs and flexibility procurement being applied simultaneously. Realizing the benefits of dynamic ToU network tariffs is even more complex when explicit flexibility is applied, because the interaction between both instruments makes the effects of any behavior change in response to tariffs harder to predict. Under a system of continuously changing tariffs and network load situations, it will be very difficult to effectively allocate and (subsequently) apply explicit flexibility. This again might lead to problems regarding location decisions, e.g. for new storage facilities.

As observed by CEER [11], for now a combination of procurement of flexibility and maintaining static time-of-use tariffs where needed would be more suitable, at least until the level of automation for customers at lower voltage levels has reached sufficient maturity.

IV. Congestion Management

According to the definition [15], congestion management is activating a remedial action to respect operational security limits. Congestion is a condition (forecasted or realized) where one or more constraints (thermal limits, voltage limits, stability limits) restrict the physical power flow through the network. Network congestion occurs because the hosting capacity of a given grid is limited by the inherent characteristics of physical assets (i.e. lines, cables, transformers). Congestion in the distribution network is caused by voltages exceeding the allowed limits or overloading of the network components. Thus, congestion management is mitigated by voltage control or by load/generation control. In the context of DSO congestion management, the focus of this paper is on physical congestions. These are defined by EU Directive [15] as "any network situation where the forecasted or realized power flows violate the thermal limits of the elements of the grid and voltage stability or the angle stability limits of the power system".

Furthermore, there is a distinction between two types of physical congestion:

- Structural congestion, which is defined as congestion in the distribution or transmission system that can be unambiguously defined, is predictable, is geographically stable over time and is frequently reoccurring under normal power system conditions; and
- Sporadic congestion, which can be defined as an unpredictable congestion that is not stable over time and can occur under any system condition.

Higher utilization of the distribution grid increases the risk of more frequent congestion and leads to an overall system operation with lower capacity margins. This constitutes an increased need for local system services to handle constraints at specific locations in both meshed and radial networks. Key prerequisites are sufficient observability (meaning the DSO's information regarding the known and forecasted state of its own grid) and controllability (to assure correct activation of flexibility from network users).

In short, the term observability describes DSOs' abilities to determine the current and coming state of their networks through models comprised by static data on components and topology, planned changes, prognostics and real-time measurements. With a sufficient level of observability, DSOs can detect where congestions might occur in short or longer terms, based on calculations and observations. Hence, determining within a variable time frame where they need to reinforce the grid and/or how to procure flexibility.

Controllability refers to DSOs' ability to control their own and other assets remotely or manually, either individually or in combination with the actions of network users and system operators at their interface. This activation can be performed directly or through indirect (intermediary) measures. DSOs usually coordinate the operation of their networks from a control center.

Congestion management measures in the distribution network can be divided into preventive ones – non-costly measures and remedial (curative) - costly measures. Using calculation tools and data collected by SCADA, DSO can predict congestion (thermal and voltage) in network components in different time frames, year, month, week or day in advance. Such predictions are more reliable with the availability of information, such as weather forecast and measured values (loads and voltages). As a starting point DSO will try to prevent expected congestion by network reconfiguration and voltage regulation on transformers. If a DSO cannot solve a problem with its own assets it will rely on the curative/remedial measure of congestion management: the use of flexibility and re-dispatching.

The vital part in real-time operation, after forecasting the capacity margin and setting the expected congestion size on particular nodes, is the actual activation of a given resource while ensuring that the delivery is sufficient to handle the congestion. It is important that the controllability of flexible resources is thoroughly tested going through an agreed product prequalification process. Control centers can thereby gain sufficient experience before wide-spread deployment. To ease the transition towards more active system management, DSOs might, as a starting point, prefer the possibility to access and activate flexible resources directly from their control centers instead of being dependent on intermediaries. A more advanced (and necessary) step would be activation through intermediaries, for instance flexibility market platforms and aggregators, which is for some DSOs already business as usual and state of the art in TSO grids.

V. Energy Storage Facilities

A significant penetration of energy storage will be one of the crucial factors for integrating more renewable energy into the power system, because it enables a combination of intermittent RES with rather inelastic demand, while meeting the technical requirement that power supply matches demand at all times.

Regulation (EU) 2019/943 [16] establishes that "network charges shall not discriminate either positively or negatively against energy storage". Since a storage facility may withdraw energy from or inject energy into the distribution network, it can be regarded as both a consumer and a producer located at the same network connection point. As such, non-discrimination would suggest that energy storage should be subject to distribution tariffs applicable to both energy withdrawals and, where applicable, energy injections. Notwithstanding this, the cumulative charges for withdrawal and injection must reflect the value of storage to the system. A storage facility operated with the purpose of improving network utilization can decrease the need for future network investment, while a storage unit operated inefficiently from a network perspective can increase future distribution costs. The distribution tariff design should be able to reflect the positive or negative impact that storage facilities might have.

In practice, there will not only be standalone storage facilities, but also storage that could be combined with withdrawal or injection (or both) behind a single point of connection. In the short run, behind-the-meter storage will probably increase more than network-scale storage solutions. Also, energy storage is likely to develop further where there are explicit instruments of flexibility procurement for them.

Regulatory authorities should review whether their current tariff design, with special attention to volumetric charges, is providing adequate incentives for storage equipment or equivalent network utilization, such as self-consumption or energy communities. CEER recommended [11] that net metering for self-generators and storage facilities should be avoided.

VI. Ownership of Storage for DSO

By the Croatian Law on Electricity Market (Article 79, paragraph 1) [1], DSO shall not own, develop, manage or operate energy storage facilities.

This prohibition, however, comes with a double derogation possibility; DSO may own, develop, manage or operate energy storage facilities:

- where they are fully integrated network components and the regulatory authority has granted its approval or,
- where a series of (cumulative) conditions is fulfilled including a tendering procedure as well as ex-ante review and approval by the regulatory authority. Decisions to grant a derogation also must be notified to ACER and the EC.

Fully integrated network components can include energy storage facilities such as capacitors or flywheels which provide important services for network security and reliability of the transmission or distribution system, and not for balancing or congestion management.

The conditions for the second derogation are threefold:

- other parties, following a tendering procedure (subject to review and approval by the regulatory authority) have not been awarded with a right to own, develop, control, manage or operate such facilities or could not deliver these services at a reasonable cost and in a timely manner;
- such facilities are necessary for the DSO to fulfil their obligations under the Croatian Law on Electricity Market for the efficient, reliable and secure operation of the distribution system and they are not used to buy or sell electricity in the electricity markets; and
- the regulatory authority has assessed the necessity of such derogation, has carried out an ex-ante review of the applicability of a tendering procedure, including the conditions of the tendering procedure, and granted its approval.

Figure 8 outlines authors view of the approval process of DSO request to own, develop, manage or operate energy storage facilities in Croatia.

Here is worth to add that the drafting of new EU network code on demand side flexibility is in the process which will aim at enabling market access for demand response, including load, storage and distributed generation (aggregated or not), as well at facilitating the market-based procurement of services by distribution and transmission system operators. In this regard in the ACER draft framework guidelines on demand response [17] the novelty is explicit possibility of shared ownership with a third party (i.e. the storage facility may be owned and operated partly by system operator, partly by a third party). Besides storage facilities owned and operated by a third party, shared ownership is to be defined as a mandatory option for system operator to consider, as part of the tendering process.

The Croatian Law on Electricity Market also includes an obligation for regulatory authority to perform at regular intervals (at least every five years) a public consultation to assess for existing storage facilities the potential availability and interest of market parties to invest in such facilities, in view of a phase-out of DSO energy storage activities (in which case the regulatory authority also must ensure phase-out within 18 months). Hence the Law entails several new duties for regulatory authority, including approval (Figure 8), assessment and phase-out tasks.

Based on JRC survey [18], eight out of thirty-nine (20 %) EU DSOs have mentioned about the ownership of a storage system. In terms of size of these systems, apart from some systems which have been installed during pilot projects in which the DSO was involved (500kW, 2MW, 2,5MW), DSOs which have a storage system in place indicate a capacity size below 100kWh and usually are distributed through substations for powering transformers equipment during outages or for customer powering during critical situation, which is in line with the provisions specified in the EU Directive 2019/944.

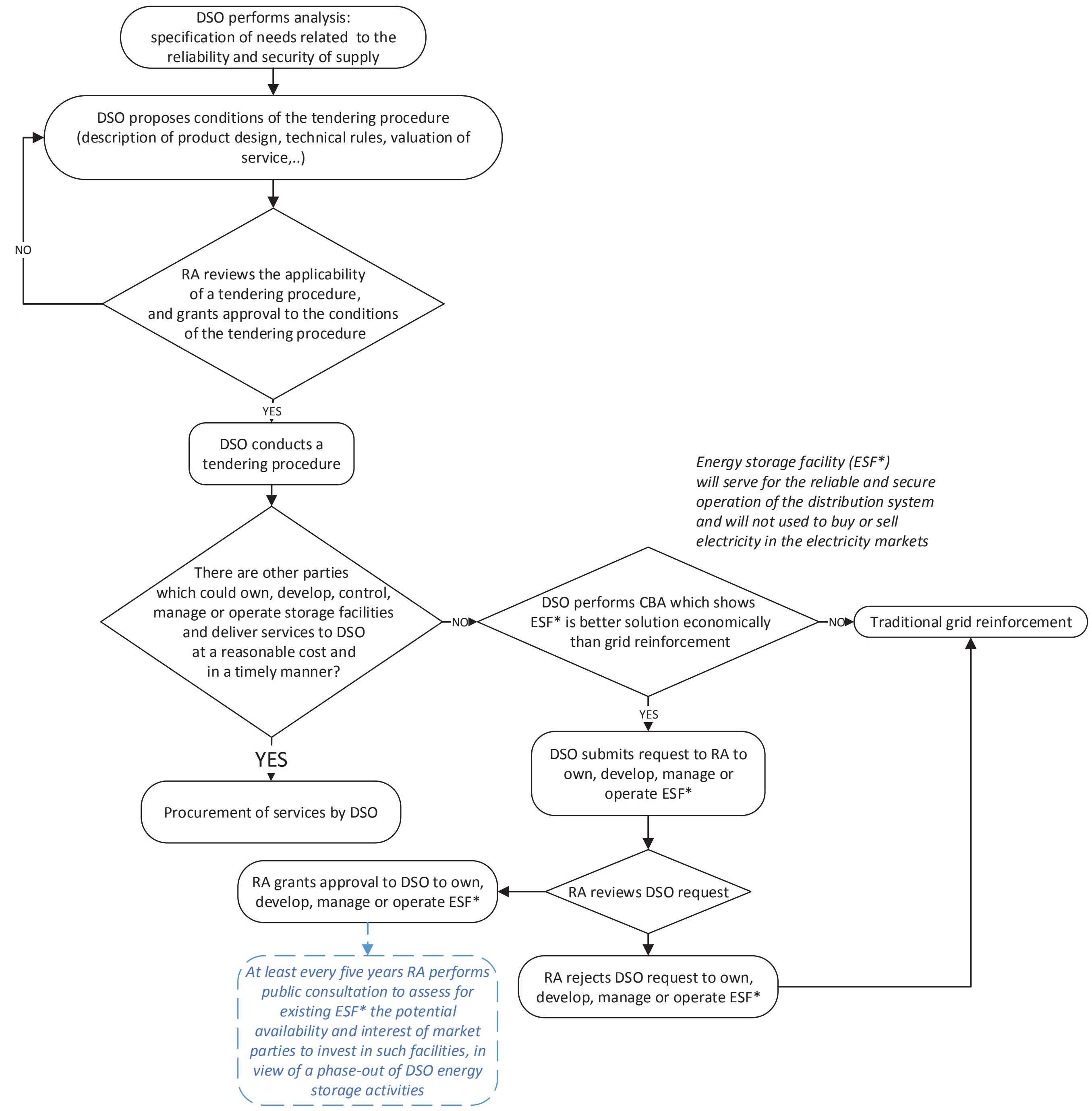

Fig. 8. DSO request to own, develop, manage or operate energy storage facilities approval process – derogation from Article 79, paragraph 1 of the Croatian Law on Electricity Market [1]

In most cases (81%) no specific connection and access rules are in place for energy storage systems. Based on connection charging methodology adopted in August 2022 [19], energy storage facilities (ESF) in Croatia are subject to specific shallow policy; i.e. applicant ESF is not charged for reinforcements to the existing system but only for the immediate connection assets. Also, ESF in Croatia is subject only to withdrawal charge [21], which is the approach applied in 50% of EU jurisdictions (in 30% of EU jurisdictions ESF are subject to both injection and withdrawal charges and in 20% are fully exempted from network charges).

VII. Flexible Connection Agreements

Connection agreements that DSOs need to offer to system users across the EU have generally concerned agreements with firm capacity rights. This implies that system users should be able to access their contracted capacity for the full 100% all of the time. The gap between available network capacity and connection requests has recently widened significantly and is expected to grow on a larger and larger scale. As a result, in more and more instances, third-party access to the transmission or distribution network cannot be granted (be it for demand or generation or a mixture thereof) because of a lack of network capacity (calculated at present grid standards and based on present grid connection rules).

Flexible connection agreements can generally be thought of as a deviation of this firm capacity right on different dimensions: they may vary from firm capacity rights that are valid part of the time (i.e. time-specific) to non-firm capacity rights all of the time.

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https://doi.org/10.37798/2022711343

Until recently, flexible connections, non-firm access or interruptible capacity contracts - all of these terms referring to a connection capacity agreement where the rights granted are in some aspect (time or capacity or other) limited - were rather an experimental, exceptional solution to this problem and could not be considered the norm. Flexible connection agreements are a possible way to fit new users into a network where there is not full capacity available at all times. They might be applied either as an interim solution to defer grid reinforcement or under certain specific conditions as a long term remedy.

The first approach increases grid use efficiency until grid development. In order to solve the capacity problem, grid operators have to reinforce their grids. Network reinforcements generally take quite some time causing long waiting times for parties that are seeking access to the grid. Until the grid is reinforced, it is desirable that the existing grid capacity is used as efficiently as possible. For example, grid capacity is often still available outside peak times. However, this requires a certain degree of flexibility from system users, and might not be an interesting or viable option for all system users as their supply and/or demand is inflexible; e.g. Ofgem (UK) did not consider flexible connections suitable for small, domestic households.

What makes flexible connection agreement increasingly popular is that as opposed to the extremity of having or not having a firm capacity agreement, it introduces a scale in between. Each grid user can therefore decide, whether it prefers a quicker or cheaper connection with certain limitations, or pays and waits for a firm connection.

EU Directive 2019/944 (Article 42) [3], with regard to the decision-making powers regarding the connection of new generating installations and energy storage facilities to the transmission system, stipulates that the TSO shall not be entitled to refuse the connection on the grounds of possible future limitations to available network capacities, such as congestion in distant parts of the transmission system.

The Croatian Law on Electricity Market [1] the aforementioned obligation stipulates not only to TSO (Article 12), but also to DSO (Article 72). This shall be without prejudice to the possibility for DSO to limit the guaranteed connection capacity or to offer connections subject to operational limitations, in order to ensure economic efficiency regarding new generating installations or energy storage facilities, provided that such limitations have been approved by the regulatory authority.

The newly adopted Rules on general conditions for network use and electricity supply [20] (in force since October 2022) allow that the use of network agreement may comprise provisions regulating operational limitations as an interim solution, with a clearly defined duration and the mutual rights and obligations of the system operator and network user. The conditions of the operational limitations shall be determined in the process of connecting and shall be comprised in distribution connection agreement. New Rules on connection to the distribution network shall prescribe determining the conditions for operational limitations.

In addition to the Rules on connection to the distribution network, the new Rules on congestion management in the distribution system (should have been adopted by the end of October 2022) shall provide implementation details, while ensuring that any limitations in guaranteed connection capacity or operational limitations are introduced on the basis of transparent and non-discriminatory procedures.

VIII. Incentives for the use of flexibility in distribution networks

As observed by CEER [2], when planning, expanding and managing their networks DSO may either opt for the use of greater network expansion with less need of flexibility or less network expansion with a greater need of flexibility. The level of security of supply and other criteria (e.g. unrestrained interconnection of RES) must be guaranteed according to national obligations. The details of the regulation and the lawmakers' provision to necessary grid expansions, including potential degrees of freedom for the DSO on network dimensioning, determine the direction of the system operator's approach.

If a DSO decides to design the network with scarce capacity, meaning lower capacity margins, there is a greater need to carry out congestion management procedures. In this case, the DSO incurs the cost of payments to third parties for their contribution to relieving congestion. Congestion management costs are classified as operational expenditures (OPEX), whereas network expansion costs are classified as capital expenditures (CAPEX), Figure 9.

Of relevance here is how these costs are treated and remunerated in the regulatory scheme comprising the total cost of expenditures (TOTEX), Figure 10. In Croatia, the recognized costs method is currently applied with a regulation period of one year. A high weighted average cost of capital (WACC) will encourage DSO to increase investments since it will be reflected in justified expenditures in the form of a higher return on equity (refund). On the other hand, in the case of a multi-year regulatory period, the increased OPEX (due to the expenditures for services) will occur in the revenue allowance with a certain lag.

In addition to traditional grid reinforcements, regulatory authority should acknowledge that there are alternative solutions to efficient provision of network services, for which more tailored remuneration schemes are needed. Through a risk incentive, the regulatory authority should recognize that there could be different levels of risk for DSO to opt for a service like flexibility rather than traditional grid reinforcement, which is a safer option. Indeed, traditional grid reinforcement has well-known outcomes such as lower losses, greater reliability, ability to quickly connect new loads, provision of rapid increase in capacity, higher short circuit levels and greater voltage regulation. The regulatory authority should consider the transfer from a solution with known expense (CAPEX) to one comprising both capital and operational expenditure with a highly variable expense (flexibility as OPEX) and that penalties for non-delivery of contracted flexibility may not fully cover the incurred costs in case the provision of flexibility fails.

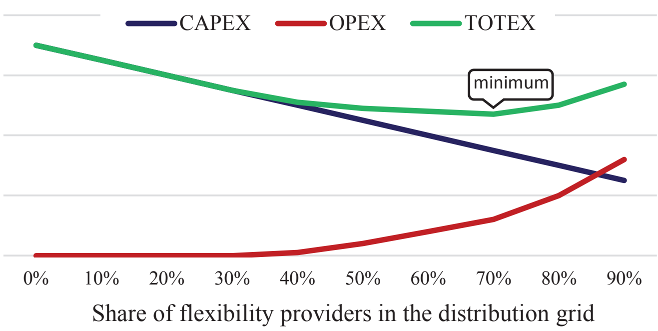


Fig. 9. Treatment of congestion management expenditures in regulatory scheme

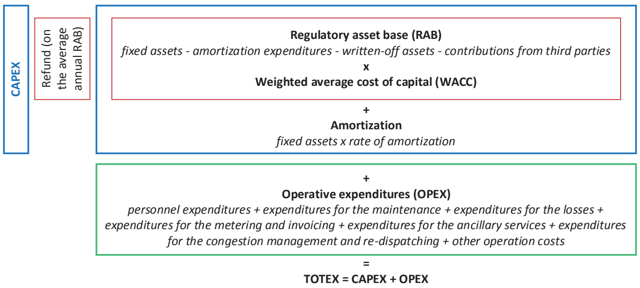


Fig. 10. Determination of the justifiable level of total expenditures - Croatian regulatory scheme for DSO [21]

Due to the complexity of the use of flexibility or any other innovation projects, Eurelectric recommends [22] to adopt the following approach in the implementation of the Clean Energy Package [14]:

- Member States may start testing market-based flexibility procurement with pilot projects. These pilot projects should test real use cases and consider different forms of procurement;
- If not already included in the regulation, regulators should allow regulatory sandboxes outside the current regulation framework to test those pilot projects. Given that it entails high technical and regulatory risks for the DSOs, the incurred costs stemming from these pilot activities for the DSOs shall be publicly disclosed, acknowledged and fully recoverable;
- In the event of already mature, economically and technically feasible solutions, to go straight to the deployment and implementation phase.

At the current stage of flexibility market development, market-based flexibility procurement might not provide the same systemic benefits in the long term as grid reinforcements do. Ideally, all stakeholders should strive towards market-based flexibility procurement mechanisms that provide at least comparable systemic and societal benefits as grid reinforcement.

IX. DSO Network Development Plans

Network development plans (10G plan) are an important tool to inform potentially interested parties where a demand of flexibility is or will be needed. In 10G plans the scenarios are fundamental to the result. They should at least cover a broad range of assumptions, including a scenario with the highest degree of probability, based on available information.

In the development plan, it is challenging to define the scope and breadth of how the DSOs should signal their medium- and long-term flexibility needs. In CEER's view [2], while providing information on foreseeable capacity issues and estimates of how much flexible capacity they might need in order to avoid grid expansion, DSO signaling could be very broad; i.e. covering characteristic grids, if not the entire distribution network. As a result, within the 10G plan the DSO would need and expect a certain number of MW of flexible assets within the ten-year horizon to be a viable solution within the defined area. If there are not enough flexible assets available currently or in the future, the DSO may need to make an investment decision at a given date upfront or potentially rely on other measures such as curtailment. Signaling the need goes beyond network development plans but this will be one way of doing it. The most important part is that network users and flexibility service providers (FSPs) know that the need is there in order for them to anticipate providing the flexibility, hence, seeing the opportunity for business and potential profits in the long run.

A significant component of how flexibility needs are signaled are the definitions of congested points or congested areas. A growing number of jurisdictions are taking an active role to require that operators make some amount of information about the grid available to developers or to the public. Information about available hosting capacity can be critical to evaluating the viability of a particular project. Figure 11 shows practice of the Netbeheer Nederland - the Dutch association of national and regional network operators. Starting from the December 2021, the Netbeheer Nederland provides congestion map (see [23]) for the high-voltage and medium-voltage grid, which shows which areas in the Netherlands are seeing increasing constraints for connection of demand and generation respectively.

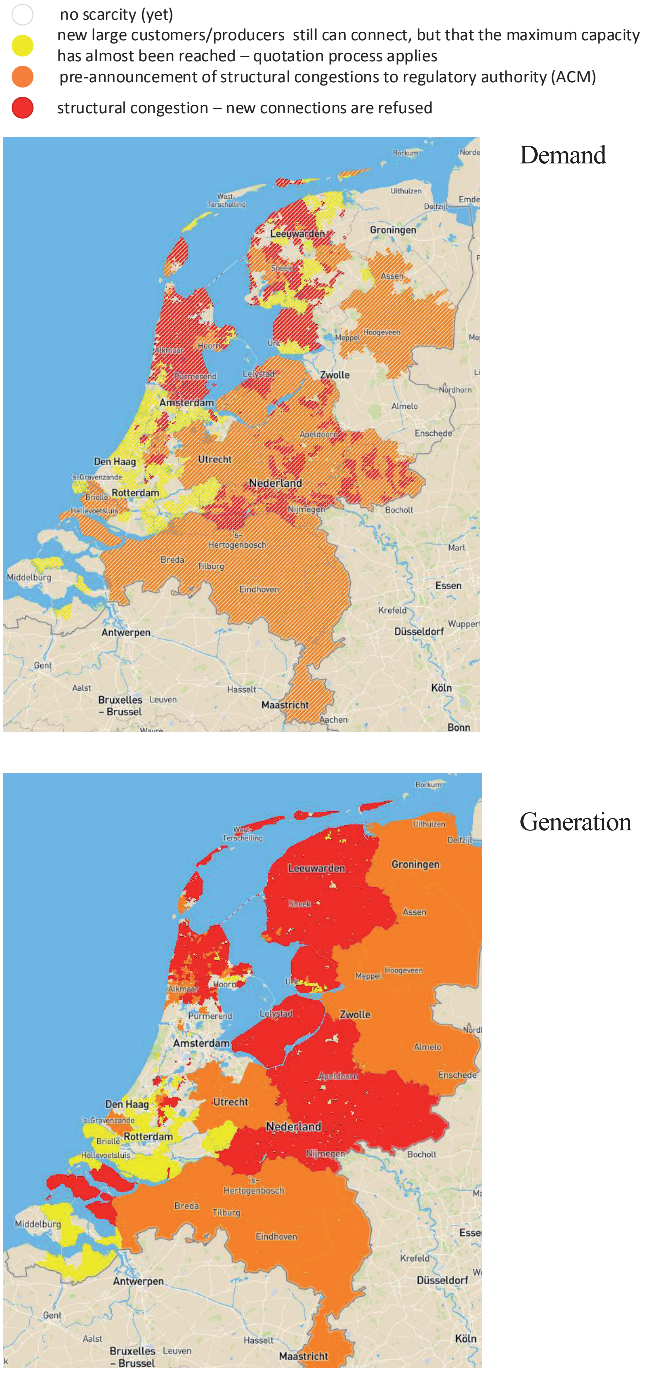


Fig. 11. Congestion map of the Netherlands [24] – state on December 22, 2022

When there is no scarcity in the observed area (transparent), new request for connection receives a quote with a limited validity period which cannot be extended (due to high interest to connect, operator wants to know whether and when new installation will actually be built).

When capacity of the grid in the observed area is limited (yellow), and the total requested capacity of requests exceeds the available hosting capacity in the observed area, adapted quotation process applies. Quotations are then valid for one month, instead of three months. For applications with a capacity equal to or smaller than 1750 kVA, the normal quotation process applies and also the existing agreements with current projects continue as usual.

When there is almost no (minimum) capacity available in the grid (orange), this is reported to the regulatory authority (ACM). The possibilities of congestion management are being analyzed. As long as the assessment is ongoing, operator does not know whether it can connect new request. Therefore, the connection request receives a provisional rejection. If the assessment shows that there is capacity for connection to the grid, operator issues a quote.

If the connection request exceeds the hosting capacity of the grid (red), even with the use of congestion management, then the quote will not be issued, and the request is placed on a waiting list. Even though there is no hosting capacity in the grid, request for quotation should be submitted because this way the operators know what the interest to connect is and also the investors will be informed as soon as there is free capacity in the grid. Have investor not paid the quotation 45 days after signing, the order and the connection capacity claim will lapse. All applications that are "rejected" (quote is not issued) are reported to the regulatory authority.

The Croatian Law on Electricity Market (Article 12, paragraph 7) obliges transmission and distribution system operators to review and make publicly available the information on the hosting capacity of the existing grid to safely and reliably integrate additional network users. Accordingly, on their website Croatian transmission system operator (HOPS) has recently published data which reflect the situation in 2022 (see [25]).

X. DSO Flexibility Procurement Components and Methods

DSOs should be able to identify relevant locations in their grids to engage in congestion management. Summarized, this includes determining where congestions are expected to occur, their cause, size, duration and time frame. Depending on the granularity, this information could be very sensitive and if made completely public could be to the detriment of the market functioning. The DSOs should consider the relative sensitivity, and thereby only to a limited extent publish their needs for flexibility, signaling it in as broad a way as possible, whilst still providing enough information to support the market.

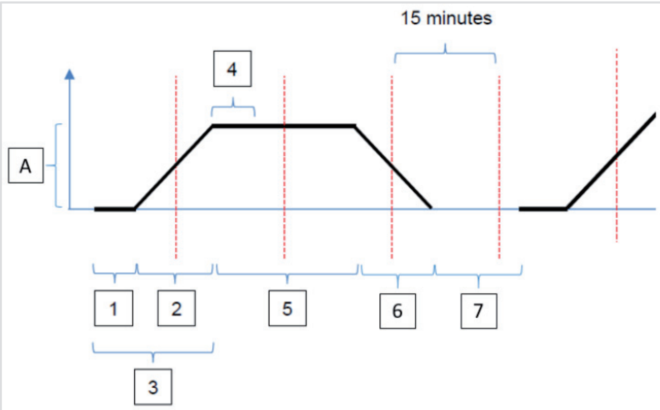
When a potential congestion has been identified, and the expected size and duration are forecasted, important assessments include selecting one or several resources to relieve the congestion, the method of activation and how the activation should be validated. Accordingly, an appropriate procurement procedure needs to take place. Within this frame of considerations there are various approaches to flexibility mechanisms that could reach an efficient outcome.

A vital part of DSOs signaling their needs, is establishing the product specification. In the Electricity Balancing Guideline (EBGL) [26] a list has been set up containing parameters that could be necessary to define a product, Figure 12. A description of all the attributes in such products and how they might look like in practice could be very comprehensive.

As observed by CEER [2], it is not a goal to parameterize everything, but in the long run, product specifications should primarily be set with reference to these key parameters. In the starting phase, through demonstrations and piloting, it might be a good idea to study and utilize the different characteristic of flexible resources, rather than defining specific products. As there is a vast variety of flexibility service providers characteristics, and in theory also DSO needs, it is important to be technology-neutral when setting up the specifications. In other words, defining them in an agnostic way to ensure a level playing field.

Characteristics of standard product for balancing capacity:

1. Balancing capacity validity period;
2. Minimum duration between the end of deactivation period and the following activation (or "minimum duration" in short;
3. Direction of the capacity: upward or downward.



Characteristics of standard product for balancing capacity bid:

1. Price characteristics;
2. Volume characteristics
   (minimum bid quantity and granularity);
3. Bid divisibility;
4. Location;
5. Other as defined by TSO.

A – requested power;
1 – preparation time;
2 – ramping (up) period;
3 – full activation time;
4 – delivery period due to scheduled activation;
5 – delivery period;
6 – ramping (down) period;
7 – minimum duration between the end of deactivation period and the following activation

Fig. 12. Standard product characteristics for balancing capacity for frequency restoration reserves and replacement reserves, all TSOs' proposal (ENTSO-E) [27]

As an alternative to referring to the comprehensive list in the EBGL, CEER [2] proposes another way of addressing the designs of products; i.e. they mainly need to balance three considerations:

1. 1As specific as necessary to solve the congestion;
2. As broad as possible to facilitate liquidity; and
3. Standardized (on a national or regional level), e.g. it could be a similar approach as for balancing products.

Going back to the EBGL list, most of the parameters are related to time, availability and bid size. DSOs and FSPs should aim to experiment with the different attributes to see which of the considerations are most relevant in their specific use cases.

As a step further, the April 2019 TSO-DSO report [28] introduced the concept of a flexibility resource register. A flexibility resources register will allow system operators (TSO and DSO) to have visibility of which flexibility resources are connected to their grid and to their connected grids, so they know what resources they potentially have available when solving congestion. The objective of the flexibility resources register is to gather and share relevant information on potential sources of flexibility. The qualified connections would be registered in the flexibility resources register by the connecting system operator. This connection is visible to all relevant system operators. In this way, if a DSO or TSO has a congestion, they have visibility of all potential flexibility resources at all voltage levels. Several H2020 projects and national initiatives are now planning to look more into and develop some of the concepts of such a register. These outcomes should be taken into account in further design of the framework if they are deemed to be viable solutions to address or potentially implement at the national level.

The EU has put emphasis on active role of DSO and distribution grid and efficient TSO-DSO coordination to successfully accommodate high penetration of RES and achieve EU climate goals [3]. Cooperation and coordination between system operators in network planning phase in already business as usual (see [29]).

Flexibility can only be used efficiently if the right coordination mechanisms are put in place and the appropriate data and information are exchanged between DSOs, TSOs, customers and market players. As electricity flows are set to change significantly, without proper coordination mechanism, fixing a problem on the distribution level may cause additional problems on a transmission level and vice-versa. As observed in [4], all the TSO-DSO coordination mechanisms share similar prequalification, activation and settlement of flexibility resources, and in all mechanisms it is noticeable the evolution of the DSO role as it becomes more and more active participant. The review article [4] provides short overview of different TSO-DSO coordination mechanisms for procuring ancillary services in Europe.

Baselines are also a crucial aspect of flexibility procurement. In short, the offered flexibility for congestion management equals the deviation from a given baseline, Figure 13. Baseline methodologies are in most cases based on individual load profiles and historical data, although these are not legally binding at this point. In the establishment of baselines, it is important that all relevant actors are involved, preferably with regulatory overview, when categorizing and agreeing on the different terms of such a framework.

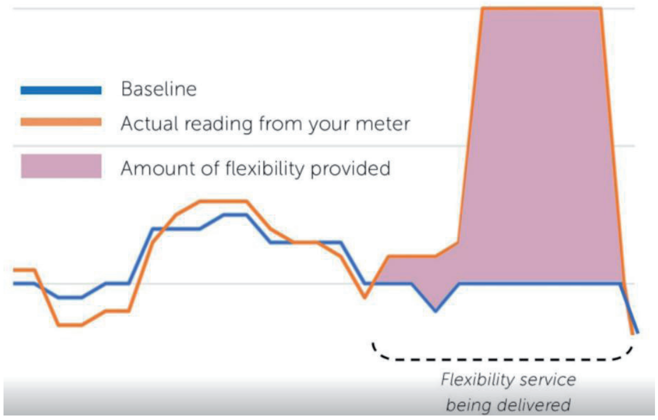


Fig. 13. Baseline - approach to measure the amount of flexibility delivered to the network operators

Article 32 of the Electricity Directive (2019/944) [3] clearly states that the preferred option for DSO procurement of service should be market-based. Based on a former consultation, in conclusion paper [9] CEER agreed with many respondents that market-based procurement is the preferred option because the procurement of flexibility on a competitive basis would be efficient as long as markets are liquid, overall costs are lower than in alternative solutions, DSOs comply with unbundling rules and market distortion/misuse potential is acceptable. In a market-based setting, the DSO could negotiate bilaterally or participate in an organized marketplace with network users offering their flexibility (producers, demand response, active customers), or interact with service providers acting on their behalf (aggregators). Essential parts of a well-functioning market with free competition are:

- Full information;
- Rational actors;
- Standardized products;
- Liquidity;
- Low entry and exit costs; and
- Low transaction costs.

However, it should be noted that Article 32 provides also for a situation where the market is restricted under certain conditions, stating that flexibility procurement has to be economically efficient and must not lead to severe market distortions or to higher congestion. Therefore, DSOs and regulatory authorities should carefully assess which model (see Figure 2) is appropriate in which context and what the impact of the combination of several categories can be. In other words, when evaluating the categories, the type of congestion to solve shall be considered, taking into account that a combination of the categories could be beneficial.

The DSO's access to market-based procurement of flexibility is a new phenomenon, thus there is a lack of empirical data and experiences in this context (see Eurelectric [22] recommendation in paragraph 8). At this point, there are numerous pilots and demonstration projects being undertaken to get deeper insights into the subject and to explore the benefits of this access: [4,7,8,30]. These are mostly still in the starting phase and the scope of the projects seems to vary significantly. However, on the other end of the spectrum is the UK, where all DSOs are tendering for flexibility as business as usual, inviting bids according to a (predefined) specification of needs (see [31]).

XI. Advanced Metering Infrastructure

Advanced Metering Infrastructure (AMI) is the collective term to describe the whole infrastructure from smart meter to two way-communication network to control center equipment and all the applications that enable the gathering and transfer of energy usage information in near real-time. AMI makes two-way communications with customers possible and is the backbone of smart grid. The objectives of AMI can be remote meter reading for data, network problem identification, load profiling, energy audit and partial load curtailment in place of load shedding. Smart grids and advanced metering systems are key enablers of flexibility. The advent and wider adoption of smart home technology and smart metering systems will further the possibilities regarding demand response; this in turn will help consumers to be more price-responsive and will increase the value of implicit flexibility.

According to the Croatian Law on Electricity Market [1], the minister responsible for energy is obliged to make decision on the introduction of an AMI in the Republic of Croatia based on an economic assessment of all long-term costs and benefits of such a system prepared by the regulatory authority (HERA). The input data for the economic assessment, including main features of the proposed AMI and the time frame for its introduction shall be provided by the DSO.

Regardless that the minister has not made an official decision on national plan for smart meters roll-out, there is certain action concerning smart metering installation taking place in Croatia.

Around 50% of total low voltage (LV) commercial customers metering points (Figure 14) and 13% of total households metering points (Figure 14) have been equipped with smart meters. More precisely, all connection points of medium voltage (MV) and LV commercial customers >22 kW have been equipped with smart meters and remote reading. 36% of LV single tariff and 44% of LV dual tariff commercial customers already have smart meters, as well as 45% of public lighting connection points. Summarized, at the end of 2021 17% penetration rate of smart meters was achieved in Croatia.

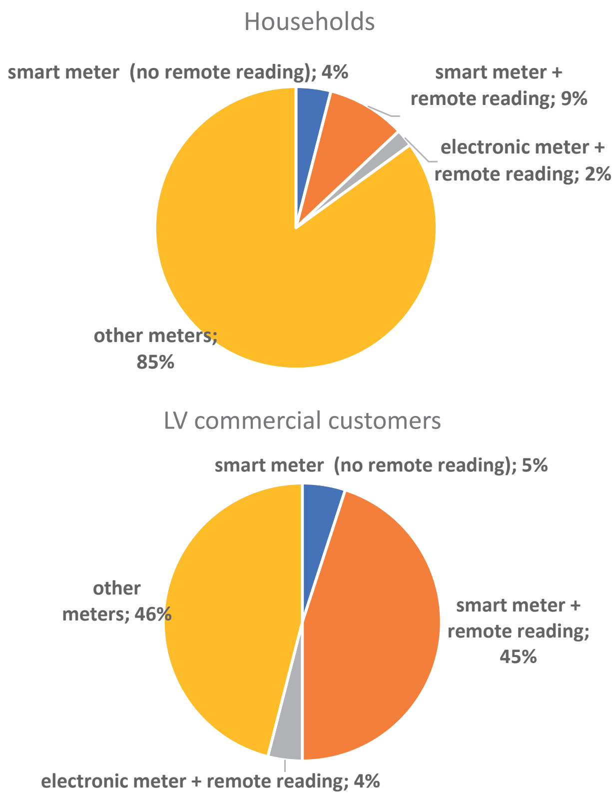


Fig. 14. Types of electricity meters at LV customers - Croatia, end of 2021 [32]

For flexibility to be traded and responsibility for imbalances to be accounted for, we need means for verifying that the flexibility took place, and a its volume. Two elements of measurement are necessary for the other regulatory aspects to work:

a) A 'baseline' of consumption for a flexible resource had flexibility not been delivered. That is, a mathematical model or an estimate of how much energy the resource would have used in the absence of an action (see section 10);

b) A measurement of real-time usage of the flexible resource, as distinct from the rest of a customer's load.

Flexibility delivered is therefore simply the difference between the baseline and the metered real usage of the flexible resource.

To distinguishing the real-time usage of the flexible resource there are two options:

a) Sub-metered model: two (or more) separate metered data variables, one for the customer's normal consumption and one for the new flexible unit(s),

b) Single-meter model: use one data variable for the whole customer's consumption, and then use a mathematical model to split this data between load and flexibility delivered. This is what we have today in practice, where there is only one consumption input submitted by the DSO-owned smart-meter.

Flexibility service providers have the option to use either flexibility asset sub-meters or metering data from the connection meters of network operators [33].

The consumption of flexible resource in most instances is metered by the service provider (aggregator). If a service provider wants the ability to control (or just observe) the consumption of the flexibility resource or check that the consumer is doing what they said, then the consumption on the flexible resource needs to be metered. What this means in practice is that the sub-meters required for offering and metering the consumption of a specific flexible unit should be installed and paid by the service provider.

XII. Conclusion

The main aim of DSOs and regulatory authorities is to maximize the efficiency of the distribution network, by utilizing the existing and future infrastructure to its full capacity. Constraint management consists of several methods to handle challenging grid situations. As a starting point, DSOs can manage constraint issues with the activation of their own flexible grid assets. Such actions are a default option and applied before or at the same time as considering other options. If a DSO cannot solve a problem with its own assets (e.g. topology changes, tap changers, voltage boosters, etc.) it may need to invest in new assets (grid reinforcement); the procurement and use of flexibility for constraint management could be the better solution economically. The use of flexibility to maximize the efficiency of the grid could provide socio-economic benefits by utilizing existing resources that could decrease or defer the need for new investments in grid infrastructure.

With regard to the procurement of flexibility services DSOs should be able to identify relevant locations in their grids to engage in congestion management. This includes determining where congestions are expected to occur, their cause, size, duration and time frame. Flexibility mechanisms are divided into implicit (actors respond to fixed price signal) and explicit (actors themselves bid in their price and actively contribute to the price formation). The Croatian Law [1] recognizes the four different mechanisms for DSO's access to flexibility: Rule based approach, Connection agreements, Network tariffs, and Market based procurement.

Network tariffs can be designed to provide incentives to system users to change their behavior in such a way that it benefits efficient distribution system operations by the DSO. However, the actual impact of a particular tariff structure on actual behavior of system users inherently has a degree of uncertainty regarding its actual impact because system users may show different behavior than expected or may not be able to shift or reduce their demand. Dynamic network tariffs and flexibility procurement differ in that under the procurement of flexibility, the DSO explicitly contracts for it with the customer or their intermediary, while with dynamic tariffs, the flexibility provided by customers is implicit. Thus, the effectiveness of the latter firstly depends on the actual existence of customer flexibility and, secondly, on the interaction between the network tariff signals and other behavior-influencing factors. Realizing the benefits of dynamic network tariffs is more complex when explicit flexibility is applied, because the interaction between both instruments makes the effects of any behavior change in response to tariffs harder to predict. Under a system of continuously changing tariffs and network load situations, it will be very difficult to effectively allocate and (subsequently) apply explicit flexibility. Therefore, the combination of static network tariffs and procured explicit flexibility might be the most reliable way to reduce network costs.

When planning, expanding and managing their networks DSO may either opt for the use of greater network expansion (CAPEX) with less need of flexibility or less network expansion with a greater need of flexibility (OPEX). The details of the regulation and the lawmakers' provision to necessary grid expansions, including potential degrees of freedom for the DSO on network dimensioning, determine the direction of the system operator's approach. If a DSO decides to design the network with scarce capacity, meaning lower capacity margins, there is a greater need to carry out congestion management procedures.

Due to the complexity of the use of flexibility or any other innovation projects, pilot projects should test real use cases and consider different forms of flexibility procurement. Regulatory authority should allow regulatory sandboxes outside the current regulation framework to test those pilot projects. Given that it entails high technical and regulatory risks for the DSOs, the incurred costs stemming from these pilot activities for the DSOs shall be publicly disclosed, acknowledged and fully recoverable.

Network development plans (10G plan) are an important tool to inform potentially interested parties where a demand of flexibility is or will be needed. In 10G plans the scenarios are fundamental to the result. They should at least cover a broad range of assumptions, including a scenario with the highest degree of probability, based on available information. As a result, within the 10G plan the DSO would need and expect a certain number of MW of flexible assets within the observed horizon to be a viable solution within the defined area. Signaling the need goes beyond network development plans but this will be one way of doing it. The most important part is that network users and flexibility service providers know that the need is there in order for them to anticipate providing the flexibility, hence, seeing the opportunity for business and potential profits in the long run.

When a potential congestion has been identified, and the expected size and duration are forecasted, important assessments include selecting one or several resources to relieve the congestion, the method of activation and how the activation should be validated. Accordingly, an appropriate procurement procedure needs to take place. Within this frame of considerations there are various approaches to flexibility mechanisms that could reach an efficient outcome. A vital part of DSOs signaling their needs, is establishing the product specification. Crucial aspect of flexibility procurement is also baseline - approach to measure the amount of flexibility delivered.

This paper proposes the process of DSO request to own, develop, manage or operate energy storage facilities, and DSO access to flexibility, in accordance with the Article 79 and Article 75 of the Croatian Law on Electricity Market [1] respectively.

It is worth considering the possible additional role of the Croatian Power Exchange (CROPEX) as a local electricity flexibility market platform in Croatia.

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