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Technical Report 1: Flexibility

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

Comprehensive Technical-Regulatory Advisory to enhance RE-based share in electricity grids of Western Balkans

July 2024

Western Balkans

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ACRONYMS

aFRR	Automatic Frequency Restoration Reserve
CIM	Common Information Model
CM	Congestion Management
DER	Distributed Energy Resource
DERMS	Data Energy Resource Management System
DSO	Distribution System Operator
DSM	Demand Side Management
ENTSO-E	European Network of TSOs for Electricity
ERPS	Enhanced Reactive Power Service
ESMP	European Style Market Profile
EU	European Union
EV	Electric Vehicle
FCR	Frequency Containment Reserve
FFR	Fast Frequency Reserves
FSP	Flexibility Service Provider
FRR	Frequency Restoration Reserve
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HV	High Voltage
LFC	Load-frequency Control
mFRR	manual Frequency Resto-ration Reserve
MV	Medium Voltage
MW	Megawatt
ORPS	Obligatory reactive power service
PV	Photovoltaic
RE	Renewable Energy

RES	Renewable Energy Sources
RR	Replacement reserves
SCADA/EMS	Supervisory Control and Data Acquisition / Energy Management System
TSO	Transmission System Operator
WB	Western Balkans

EXECUTIVE SUMMARY

This report was prepared as part of the GIZ project for the Western Balkans region: "Green Agenda - Comprehensive Technical-Regulatory Advisory to enhance RE-based share in the electricity grids of the Western Balkans". The project deals with capacity building of stakeholders in the WB region on the topic of flexibility of distribution grids through expert presentations in the regional meetings, technical working group meetings and the webinar dedicated only to the topic of flexibility. This technical report complements all previous activities.

GIZ and project partners recognised flexibility as an important topic that facilitates better utilisation of electricity grids, contributes system balancing and postpones necessary investments in the distribution grids. It is stated in the EC Mandate 943/2013 that "*the future electricity system should make use of all available sources of flexibility*" and foresees "*investments in digitalisation of the grid infrastructure and in services that increase flexibility*"[1]. Furthermore, Article 32 in Mandate 944/2019 determines the incentives for the use of flexibility in distribution networks[2]. The recent proposal of Network codes on demand response by ENTSO-E and EU DSO Entity is just a confirmation that TSOs and DSOs must consider flexibility services: "*The accelerated deployment of renewables necessitates a growing availability of flexibility solutions to ensure their integration to the grid and to enable the electricity system and grid to adjust to the variability of electricity generation and consumption across different time horizons*"[3].

This report briefly describes all aspects of the use of flexibility services. At the beginning, the reasons for using flexibility services are explained and a definition is given: *Grid flexibility refers to the ability of the electricity grid to respond efficiently and reliably to changes in electricity demand and supply*. The flexibility services for TSOs and DSOs were further evaluated in detail, with basic instructions for the development of harmonised products. An overview of the processes in the flexibility chain is presented and different flexibility market mechanisms are described.

In the end, it will be understood that although grid flexibility brings numerous advantages, it also entails certain costs. We recommend that distribution system operators in the WB region approach flexibility services by "learning by doing" and develop these new, unavoidable processes through simple, cost-effective solutions, such as the definition of simple flexibility products and bilateral agreements. These processes should be included in their plans and roadmaps.

[1] REGULATION (EU) 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity.

[2] DIRECTIVE (EU) 2019/944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU.

[3] EU DSO Entity and ENTSO-E, Proposal for a Network Code on Demand Response, V 1.0, 8 May 2024

1 Introduction

The decarbonization process of European grids has driven the rapid scale-up of renewable energy sources (RES), predominantly connected to the distribution grid, alongside an increase in electricity consumption due to the electrification of heating and mobility. Current projections indicate that by 2050, electricity consumption will double, and intermittent renewable generation will increase fivefold compared to 2020 levels[4].

Globally, RES are anticipated to provide a substantial share of electricity generation. By 2030, RES are expected to account for 45 to 50 percent of global generation, and this share is projected to rise to between 65 and 85 percent by 2050. Solar energy is predicted to be the largest source of this growth, with wind energy following closely behind[5]. Electric vehicles and heat pumps are becoming increasingly affordable, making their adoption a low-risk investment.

With a such trend of increase of intermittent renewable generation and electricity consumption, DSOs are commonly facing with a **network inadequacy**, that is the inability of the existing power grid infrastructure to effectively support the growing demands and complexities of modern electricity generation and consumption.

This issue can manifest in several ways[6]:

- *Capacity limitations*: The current grid might lack the capacity to handle increased electricity loads, especially with the rise in electric vehicles, heating systems, and other electrified technologies. This leads to congestion of the network elements in the distribution gird, such as transformers and lines.
- *Integration of renewables*: Renewable energy sources, such as solar and wind, are inherently intermittent and distributed. The existing distribution grid may struggle to integrate and manage these variable energy sources efficiently. For instance, increased solar generation can significantly raise voltage levels if this generation is not matched by local consumption. Grid with long lines will experience more voltage fluctuations and voltage rise (in comparison with systems with shorter lines).
- *Aging infrastructure*: Many distribution grids are burdened with outdated infrastructure, such as a significant number of MV/LV transformers nearing the end of their lifespan. This aging infrastructure lacks the capacity to manage new energy demands or integrate large-scale RES(RES) effectively.
- *Limited grid reinforcement and lack of new capacity development*: The construction of new network elements and the reinforcement of the existing grid are both costly and time-consuming processes. Numerous barriers hinder these efforts, including:

[4] McKinsey, “Global Energy Perspective 2022”, 2022.
[5] McKinsey, “Global Energy Perspective 2022”, 2023.
[6] E.DSO Technology Paper, “Experiences for Optimising Renewables' Integration in the Distribution Grid September”, 2023

- Property acquisition: Navigating property rights and obtaining necessary land for new infrastructure can be complex and prolonged.
- Procurement procedures: The procurement process for new equipment and services is often slow and bureaucratic, delaying project timelines.
- Financial Constraints: Securing sufficient financial resources for large-scale grid projects is challenging.
- Community Opposition: Public resistance to new infrastructure projects can lead to additional delays and increased costs.
- Environmental Considerations: Ensuring projects meet environmental standards and mitigate impacts requires thorough planning and can extend project timelines.

As a result of network inadequacies, Distribution System Operators (DSOs) are currently experiencing longer delays in connecting new RES and additional consumption to the grid.

Impact on Transmission System

High penetration of renewables makes a significant impact on the **transmission system operation**. Some of the major challenges that TSOs are facing with are:

- *System balancing*: Due to intermittence and variability of RES, balancing process is becoming a more challenge. The generation profile of RES often does not align with the demand profile. For example, solar power peaks during midday when demand might be lower and drops in the evening when demand typically rises. Wind power can generate large amounts of electricity during low demand periods, such as at night, creating surpluses that need to be managed. Consequently, advanced forecasting and real-time balancing mechanisms to ensure supply always meets demand.
- *Frequency control*: Conventional power plants provide inertia that helps stabilize grid frequency. High penetration of RES, which typically lack inertia, can make frequency control more challenging. Nowadays, TSOs are introducing new ancillary services such as **"*fast frequency response*",** to counteract the variability introduced by RES.
- *Distribution grids are becoming sources for the transmission system*: Due to RES production connected onto the distribution grid, changes of power flow direction at the TSO-DSO boundary can occur, potentially transforming consumption nodes into generation nodes within the transmission grid.
- *Geographic disparities*: RES are sometimes located far from major consumption centers. The existing grid may not have the necessary transmission lines to transport electricity efficiently from these renewable-rich areas to where it is needed most.

The grid needs to become more flexible to handle the rapid changes in generation from RES and increased electricity consumption. Seasonal variations pose specific challenges: during summer, there is often an excess of electricity due to high solar generation, while in winter, the grid is stressed by the increased consumption for heating. Addressing these issues requires the implementation of energy storage solutions, demand response programs, smart grid technologies, and infrastructure upgrades to ensure a stable and reliable electricity supply throughout the year.

All possible actions and new technologies that enable system operators to address the challenges posed by RES integration and the electrification of mobility and heating should be systematically introduced under the comprehensive concept of grid flexibility.

Grid flexibility refers to the ability of the power grid to efficiently and reliably respond to changes in electricity demand and supply.

From the TSO perspective, flexibility is defined as the capability of the power system to maintain a balance between generation and load under conditions of uncertainty. For DSOs, flexibility refers to the ability of an active consumer to deviate from their usual electricity consumption or generation profile in response to price signals or market incentives, encompassing consumption, generation, and storage of electricity. In both cases, flexibility is a crucial asset for addressing the new challenges brought by the deployment of RES and widespread electrification.

Grid flexibility can be achieved through implicit or explicit mechanisms. Implicit flexibility involves dynamic pricing and network tariffs designed to encourage consumers to adjust their energy usage. For instance, electricity prices can vary throughout the day to prompt consumers to use energy when the grid is not congested or when there is an excess of renewable energy, such as from solar power. An example is incentivizing electric vehicle (EV) users to charge their vehicles during the day when there is a surplus of energy. Additionally, wholesale markets may introduce negative prices to stimulate increased consumption when there is an oversupply.

Explicit flexibility, on the other hand, involves dispatchable services that can be activated when the system needs them. These services are procured through dedicated markets. Flexibility products are designed to meet various needs of system operators during stress periods and are traded on these markets. For example, in the balancing market, TSO procures ancillary services to maintain frequency and system stability. Explicit flexibility is thus procured and dispatched based on market mechanisms to address specific system requirements, complementing the consumer-driven approach of implicit flexibility.

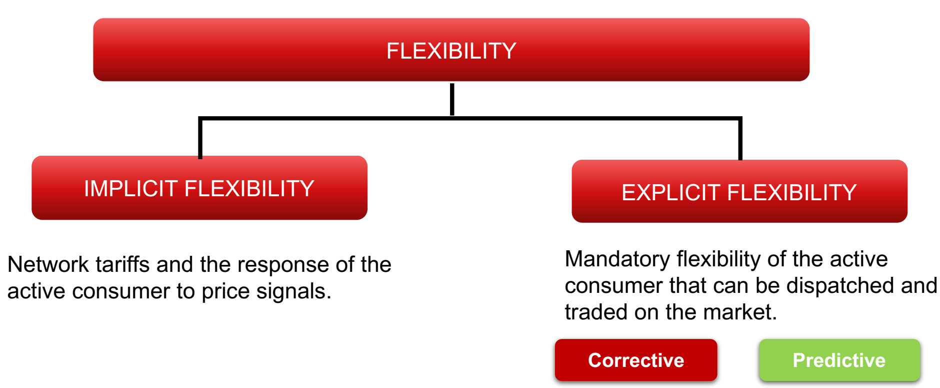

Figure 1-1 Grid flexibility classification

2 Harmonization of flexibility products

2.1 Definition of the grid flexibility product

A **grid flexibility product** is a market-based service or resource that provides the ability to adjust electricity generation, consumption, or storage in response to grid needs.

These products are designed to improve the stability, reliability and efficiency of the electricity grid, especially in times of stress or imbalance. They can be categorized as follows:

- Corrective and predictive products.
- Positive and negative products.
- Capacitive and energy products.

Predictive flexibility product is a flexibility product for the implementation of measures to improve the predicted or expected operating state of the distribution network. This product is aimed to meet system needs which can be predicted a day ahead or hours ahead.

Corrective flexibility product is a flexibility product for implementing corrective actions to improve an unexpected operational condition of a distribution network that requires rapid (near real-time) activation. This product arises as the result of unexpected circumstances.

Positive flexibility product denotes upward delivery of energy, that is increase in generation or decrease in consumption.

Negative flexibility product denotes downward delivery of energy, that is increase in consumption or decrease in generation.

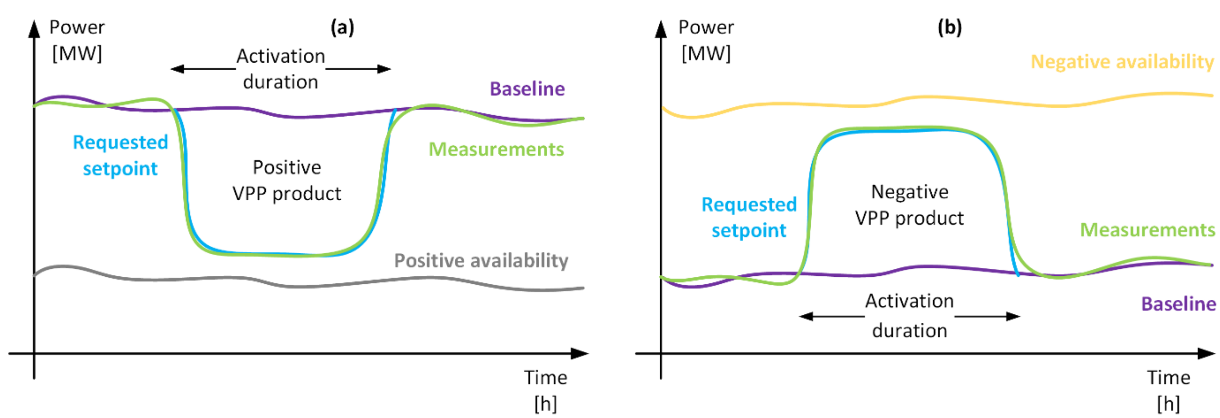

Figure 2-1 Positive and negative flexibility products[7]

[7] M. Kolenc, "COMMUNICATION SYSTEMS FOR DATA MONITORING OF DISTRIBUTED ENERGY RESOURCES", PhD thesis, Ljubljana, 2019.

A **capacity product** is a medium to long-term solution for providing power capacity or reserving flexibility resources. These resources are often reserved in advance, such as for an entire season when network issues are anticipated. They are secured at a fixed price per available capacity unit (EUR/MW) and can be activated by system operators when flexibility services are needed.

This product is designed to address structural constraints, encourage adequate investment in resource options within the network, and enhance the liquidity of the local flexibility market over the long term. Once a contract is signed, the flexibility service provider must also submit bids for energy products.

An **energy product** is a short-term flexibility product designed to provide energy by adjusting generation and consumption when the system needs it. It is procured at an energy price (EUR/MWh) and represents an activated flexibility service.

In order to harmonize the flexibility products, a general product is defined that serves as the basis for the definition of the individual flexibility products. **Flexibility products are defined by attribute-value pairs.** A total of 25 product attributes are defined to describe it (Figure 2-2)[8].

	Objective of the product				
	Technical dimensions			Bid related dimensions	
	The network operator aims to operate the network efficiently and reduce the overall cost of network operation and planning. To achieve this, the network operator will define technical requirements for the traded products and the market mechanism.			The bid related dimension of a flexibility product reflects the rules introduced in the bid as part of the procurement process.	
	Definition of the good traded	Timing for delivery	Communication	Technical rules for the bid	Settlement rules
	Characteristics of the "good" being acquired by the SO	Description of the timing in the delivery of the product	Methodology used to communicate between SO an FSP	Limitations in the structure of the product	Measures linked with the way that companies will be paid
Choices SO/MO do in attributes	Capacity / energy	Maximum preparation period	Required mode of activation	Minimum quantity	Baseline methodology
	Active/reactive energy	Maximum ramping period		Divisibility (Y/N)	Measurement requirements
	Location information required (Y/N)	Maximum full activation time		Granularity	Penalty for non-delivery
	Certificate of origin (Y/N)	Duration of delivery period		Maximum and minimum price	
	Minimum level of availability	Maximum deactivation period		Availability price (Y/N)	
	Symmetric/asymmetric product (Y/N)	Maximum recovery period		Activation price (Y/N)	
	Validity period of the bid	Maximum number of activations		Aggregation allowed (Y/N)	

Figure 2-2 Attributes of a generic flexibility product[9]

The attributes are divided into two classes: the '*technical dimensions'* and the '*bid-related dimensions*'. The attributes of the technical dimensions are further subdivided into the attributes that

[8] F. Domingez et al, „A set of standardised products for system services in the TSO-DSO-consumer value chain". Horizon OneNet project, deliverable D2.2, 2022

[9] A. Snjab et al, „Recommendations for a Consumer-Centric Products and Efficient Market Design". Horizon OneNet project, deliverable D3.3, 2023.

define “the service traded” (seven attributes), the attributes that define the “timing for delivery” (seven attributes), and an attribute that defines how the “communication” between the system operator and the flexibility service provider is established. The second class is divided into the attributes that define the “technical rules for the bids” (seven attributes) and the attributes that define the “settlement rules” (three attributes).

2.2 Flexibility products for TSO

Flexibility products provide TSOs with the tools to manage the variability and uncertainty associated with electricity generation and consumption, particularly with the increasing integration of renewable energy sources.

2.2.1 Balancing services

In order to maintain the system frequency as close as possible to the nominal 50 Hz value, TSO needs to balance generation and demand in the real time. In guidelines on the system balancing[10], the process of “balancing” is defined as “all actions and processes, on all timelines, through which TSOs ensure, in a continuous way, the maintenance of system frequency within a predefined stability range as set out in Article 127 of Regulation (EU) 2017/1485”. These actions with the “balancing process” are provided by the balancing services procured at the balancing market. These services belong to the operational timeframe.

Frequency control services are in EU documents denoted as frequency restoration reserves. System operation guideline by ENTSO-E define “frequency restoration reserves” or “FRR” as the “active power reserves available to restore system frequency to the nominal frequency and, for a synchronous area consisting of more than one LFC (load-frequency control) area, to restore power balance to the scheduled value”[11].

In general, they are classified regarding the amount of time that the SO has to address the system need, which can range from real-time to hours ahead of the actual consumption of energy.

Balancing services are well analyzed and overviewed in the deliverable D3.1 of Horizon project INTERRFACE[12], and we will use this description in this report. The detailed description of these products is given in the ENTSO-E explanatory document of standard products for balancing capacity for frequency restoration reserves[13].

[10] COMMISSION REGULATION (EU) 2017/2195, A guideline on electricity balancing, 23 November 2017.
[11] COMMISSION REGULATION (EU) 2017/1485, A guideline on electricity transmission system operation, 2 August 2017.
[12] INTERRFACE deliverable 3.1, Definition of new/changing requirements for services, 2020.
[13] ENTSO-E, Explanatory Document to all TSOs' proposal on a list of standard products for balancing capacity for frequency restoration reserves and replacement reserves in accordance with Article 25(2) of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing, 2019.

Table 2-1 Overview of the products for balancing services[8]

Balancing service product	Description
Frequency Containment Reserves (FCR)	Frequency containment is an automatic function which aims at stabilising the frequency at a steady-state value within the permissible maximum steady-state frequency deviation after disturbances in the high-voltage grid. By the joint action of all automatic devices, the process ensures the operational reliability in the synchronous area.
Automatic Frequency Restoration Reserve (aFRR)	This service is a centralized automatic function intended to replace FCR and restore the frequency to the target frequency – usually 50.00Hz. In contrast to mFRR, aFRR 'can be activated by an automatic control device'. This control device shall be an automatic control device designed to reduce the Frequency Restoration Control Error (FRCE) to zero. The activation delay must not exceed 30 seconds.
Manual Frequency Restoration Reserve (mFRR)	Manual Frequency Restoration is a manual change in the operation set-points of the reserve (mainly by re-scheduling), in order to restore system frequency to the set point value frequency and, for a synchronous area consisting of more than one load-frequency control area, to restore power balance to the scheduled value. Full activation time is set at maximum 12.5 minutes.
Replacement reserves (RR)	The reserve replacement process replaces the activated FRR and/or complements the FRR activation by activation of RR. The replacement reserve process is activated in the disturbed LFC area. Activation is semi-automatic or manual. The full activation time of the RR standard product is 30 minutes.
Fast frequency reserves (FFR)	Fast Frequency Response (FFR) is defined as any type of rapid active power increase or decrease by generation or load, in a timeframe of less than 2 seconds, to correct supply-demand imbalances and assist with managing frequency.
Ramp control	Ramp control or ramping margin is a **new service** that is intended to ensure system stability by responding to variations in demand, variable weather forecast errors and plant outages. Its timeframe is longer than a traditional FRR reserves - up to 8-hour ramping period with 8 hours of maintaining level of production.

The common characteristic of these products is that they don't require the location component.

2.2.2 Congestion management

In 2015, European Commission established a guideline on capacity allocation and congestion management[14]. Within this document, "physical congestion" is explained as any network situation where 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. Congestion management (CM) involves implementing remedial actions to ensure the power grid operates within established security limits. This process is essential for maintaining grid stability and preventing overloads on transmission and distribution lines. Remedial actions can include **re-dispatching generation**,

[14] COMMISSION REGULATION (EU) 2015/1222, A guideline on capacity allocation and congestion management, 24 July 2015.

adjusting load, reconfiguring the network, and deploying flexibility services. Please note that also DSOs use CM services.

Unlike balancing services, **CM products include a location component.** Table 2-2 gives an overview of CM products, provided in INTERRFACE deliverable 3.1.

Table 2-2 Congestion management products for TSO[8]

Congestion management product	Description
Congestion management operational	Congestion management means handling of the situation when the network is physically congested so that operational limits of the elements of the grid and voltage stability or the angle stability limits of the power system are violated. Operational congestion management operates during the market time unit (hour/15minutes). Activation in operational hour (or market time unit). Procuring options (to have sufficient capacity) could be done day-ahead.
Congestion management short-term planning	Congestion management short term planning considers the physical congestion that might occur in the timeframe of D-1 (meaning the day before) up to M-1 (month before). Default service criteria same could be the as mFRR, but used internally by TSOs for congestion management in short-term planning timeframe (not for balancing markets). Activation decision will be done D-1 (grid calculations and congestion check one day in advance for every market time unit) by a short-term planner.
Congestion management Long Term Planning	An envisaged service that may serve network reinforcement deferral, network support during construction and planned maintenance, where location-specific flexibility assets are being activated for shaving or shifting peak demand and production in order to compensate for the lack of network connections, loads or production units mainly in the distribution network.
Cross-border Redispatch	Re-dispatching is a remedial action, including curtailment, that is activated by one or more TSOs by altering the generation, load pattern, or both, in order to change physical flows in the electricity system and relieve a physical congestion or otherwise ensure system security. This product is in the operational time frame.
Cross-border Countertrading	Countertrading means a cross-zonal exchange initiated by system operators between two bidding zones to relieve physical congestion, where the precise generation or load pattern alteration is not predefined. This measure is a market based-solution, where the cheapest bid is selected independently of the geographical location within the bidding zone.

2.2.3 Non-frequency ancillary services

Non-frequency ancillary services for TSOs are essential support services that maintain the reliability, stability, and efficiency of the power grid, but are not directly related to the frequency control. These services address various operational needs to ensure the smooth functioning of the grid.

Table 2-3 overviews some key products for provision of non-frequency ancillary services. In the general aspect, CM service could be considered to fall in this category.

Table 2-3 Non-frequency ancillary services[8]

Non-frequency product	Description
Obligatory reactive power service (ORPS)	The main function is to maintain the voltage profile within the acceptable range and within the tolerance margins. This will allow a minimization of power losses and keep a steady state security. Time frame is on monthly basis.
Enhanced reactive power service (ERPS)	Enhanced reactive power services (ERPS or a like) is voluntary service organised for any service provider that can absorb or inject reactive power, hence providing ERPS. Usually this ancillary service is connected with the obligatory system reactive power services, provided by the TSO.
Black Start	The black start capability is the ability of a power source to support the system restoration after a blackout, through a dedicated auxiliary power source without any electrical energy supply external to the power generating facility.
Damping of power system oscillations	Damping of power system oscillations is one of the main concerns in the power system operation mainly dealing with the angle stability of power systems. These oscillations, when not well damped, may keep growing until loss of synchronism. These low-frequency oscillations affect the stability and efficiency of the power system.
Cross-border Countertrading	Countertrading means a cross-zonal exchange initiated by system operators between two bidding zones to relieve physical congestion, where the precise generation or load pattern alteration is not predefined. This measure is a market-based solution, where the cheapest bid is selected independently of the geographical location within the bidding zone.

2.3 Flexibility products for DSO

Distribution system operators (DSOs) need flexibility services to effectively manage the dynamic and complex nature of modern power grids, particularly with the integration of intermittent RES and the increasing demand from electrification trends like electric vehicles and heat pumps. Flexibility services help alleviate congestion in the grid, resolve voltage increase problem and optimize existing infrastructure, thereby deferring costly upgrades.

Flexibility services for DSOs are not yet fully mature or widely integrated into everyday operations. The incorporation of these products into grid codes across EU countries is still an ongoing process. As a result, the current understanding of these services is largely based on insights from Horizon projects (such as INTERRFACE, EUniversal and OneNet) addressing this topic and the best practices observed in pilot deployments.

DSOs in WB region should use these principles described in this report to define flexibility products, tailoring these products to meet their specific needs.

2.3.1 Congestion management

The congestion definition provided in the section 2.2.2 is also valid for DSO. The most common problem in the congestion domain that DSO faces with is the overload of the distribution MV/LV transformer. However, the congestion can be also related to the other grid elements, such as power lines. The overload of assets in the network can be triggered by various factors, each with different detection time frames and associated response services. Faults like short circuits typically require a rapid, automated response, whereas network planning is utilized to analyze future scenarios and implement measures to reduce and prevent bottlenecks over the long term[15].

Table 2-4 CM services for DSO[11]

Congestion management service	Description
Corrective active power for Congestion Management	For the targeted congestions caused by grid outages and subsequent corrective measures (e.g. switching status changes, ad hoc active power interventions) by activating active power generation sources. As these services are caused by an unexpected situation, they can only occur in our operational timeframe. Products with fast activation are required for this service and their duration should be adapted to the thermal limits of the overloaded equipment.
Predictive active power Congestion Management	Predictive active power management is a service that is used to eliminate foreseeable congestions (e.g. congestions that arise due to forecast maintenance work or long-term grid reinforcement). These needs can occur in all three time periods considered in our framework. However, the reasons for these needs could be different, which could lead to different products to fulfil them. For example, at the operational level, the DSO could forecast congestion due to a change in the weather forecast affecting the availability of some FSPs, while in the long-term timeframe this service can be considered either as a complement or even as an alternative to traditional grid investments.

2.3.2 Voltage control

The voltage level is a crucial parameter determining the quality of electricity supplied by power grids. Deviations from the permissible supply voltage can adversely affect the operation of various types of loads and distributed energy resources (DER), including electronic loads, induction machines, and inverter-based DER. Given the specific nature of voltage fluctuations, it is essential to have appropriate procedures and approaches for voltage control. Identifying when corrective action is needed is vital to prevent risks to grid operation.

Voltage control in low-voltage grids presents unique challenges. The typically low X/R ratio of low-voltage cables, the connection of single-phase loads and generators, and the integration of generation and load through EVs charging all increase the likelihood of over- and under-voltage issues. Voltage control capabilities in low-voltage grids are generally limited to medium voltage/low voltage (MV/LV) substations, which usually rely on MV/LV power transformers with manual regulation set from the line[11].

[15] J. Falcao et al, Grid flexibility services definition, EUnivesal Deliverable D2.1, 2021.

Table 2-5 presents an overview of flexibility services for voltage control, defined with the OneNet project.

Table 2-5 Voltage control service[11]

Voltage control service	Description
Corrective active power management for Voltage Control	To address voltage control needs caused by network failures and implement corrective actions, the activation of active power sources can be utilized. During activation, active energy is either increased or decreased to stabilize the voltage. This service is particularly useful for resolving local voltage issues in low-voltage (LV) grids and must be available for rapid activation.
Predictive active power management for Voltage Control	Predictive active power management is a service that is used to eliminate foreseeable congestions (e.g. congestions that arise due to forecast maintenance work or long-term grid reinforcement). These needs can occur in all three time periods considered in our framework. However, the reasons for these needs could be different, which could lead to different products to fulfil them. For example, at the operational level, the DSO could forecast congestion due to a change in the weather forecast affecting the availability of some FSPs, while in the long-term timeframe this service can be considered either as a complement or even as an alternative to traditional grid investments.
Corrective reactive power management for Voltage Control	To address voltage control needs arising from network failures and subsequent corrective actions, near real-time activation of reactive power sources is employed. Reactive power consumption or injection can be used to decrease or increase voltage levels in high-voltage (HV) and medium-voltage (MV) grids. This service must be available for rapid activation, with the duration of activation heavily dependent on the specific voltage level of the grid (HV, MV).
Predictive reactive power management for Voltage Control	To address forecastable reactive power needs and solve voltage problems in HV and MV networks, this service aims to acquire resources capable of injecting or absorbing reactive power for predictable grid voltage fluctuation scenarios in the short term.

2.3.3 Support to islanding operation

Islanding can facilitate planned maintenance and upgrades by allowing parts of the grid to be taken offline without disrupting the entire network, thereby improving operational efficiency.

Islanding operation is defined within INTERRFACE project as a flexibility product. Island operation can be implemented in a customer's network by utilizing standby generation units, uninterruptible power supplies, and load prioritization during controlled islanding, leveraging the micro-grid concept to enhance distribution network reliability. DSOs can balance the islanded network, initiate a black start after an outage, or automatically disconnect the island from the faulted network. They can then resynchronize the islanded network with the main grid, once the fault is cleared.

2.4 Harmonized flexibility products

The harmonization of flexibility products enables flexibility service providers to understand the requirements of flexibility service markets and to integrate their own systems more easily in order to offer and provide these services. In general, the harmonization of flexibility services will reduce their differences. However, this is still an ongoing process in Europe and our observations are based on the results of the two EU Horizon projects, OneNet and Coordinet.

Harmonization can be achieved by defining general standard products with attributes that can be customized for specific needs. The inclusion or exclusion of certain attributes in these products can impact the technologies eligible to provide them. For example, specific attribute values might render certain technologies unsuitable, thereby excluding them from potential revenue streams.

A notable example of harmonization efforts is the work of ENTSO-E, which has developed an implementation framework for the exchange of balancing energy from mFRR and aFRR.

Some important benefits that flexibility product harmonization brings are:

- **Cost reduction**. Defined flexibility product can be used by TSO across the Europe allows them to conduct a joint balancing capacity sizing exercise and contract less total balancing capacity, resulting in cost savings. ICT integration costs are reduced for FSP, when there are required significant changes in software to integrate with different market platforms.
- **Reduced complexity**. Harmonization of product between TSO and DSO will make easier for FSP to offer their services across different markets and increase market liquidity.
- **FSP entrance to new markets**. FSP can enter new markets across Europe faster and in a simpler way.

The full list of all benefits is available in the OneNet deliverable D2.2[16]. This document also provides a comprehensive methodology on the development of harmonized flexibility products. In this report we are listing only harmonized non-frequency products that can be used by TSO and DSO:

- ***Corrective local active product***: This product use change of active power as a fast response (within an hour) to unexpected incident and includes location attribute.
- ***Predictive short term local active product***: This active power product to reach on predicted event in the operational planning time frame and includes location attribute.
- ***Predictive long-term local active product***: Product to contract capacity to mitigate the need for traditional grid reinforcements using active energy. Includes location attribute.
- ***Corrective local reactive product***: This product use reactive power as a response to unexpected incident and includes location attribute.
- ***Predictive short term local reactive product***: This product is designed to respond to forecasted system needs within the operational planning timeframe by utilizing reactive power. Includes location attribute.
- ***Predictive long-term local reactive product***: This product utilizes reactive power to mitigate and/or delay the need for additional grid reinforcements, with a duration that can extend over a month or multiple years.

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[16] F. Domguez et all A set of standardised products for system services in the TSO-DSO-consumer value chain, OneNet deliverable D2.2, June 2021.

3 Processes in the flexibility utilisation chain

The full utilisation of flexibility services by system operators requires the implementation of a series of processes. We can say that these processes need to be implemented by both TSOs and DSOs, although there are some differences. While these processes are clearly defined in the implementation documents for frequency services by ENTSO-E, they are not yet well established for flexibility services provided to DSOs. This report provides only a brief overview of these processes that DSOs should keep in mind when developing a system for the utilisation of flexibility services. These processes are included in the organised local flexibility market. Detailed explanation of these processes is available in the project INTERRFACE deliverable 3.2[17].

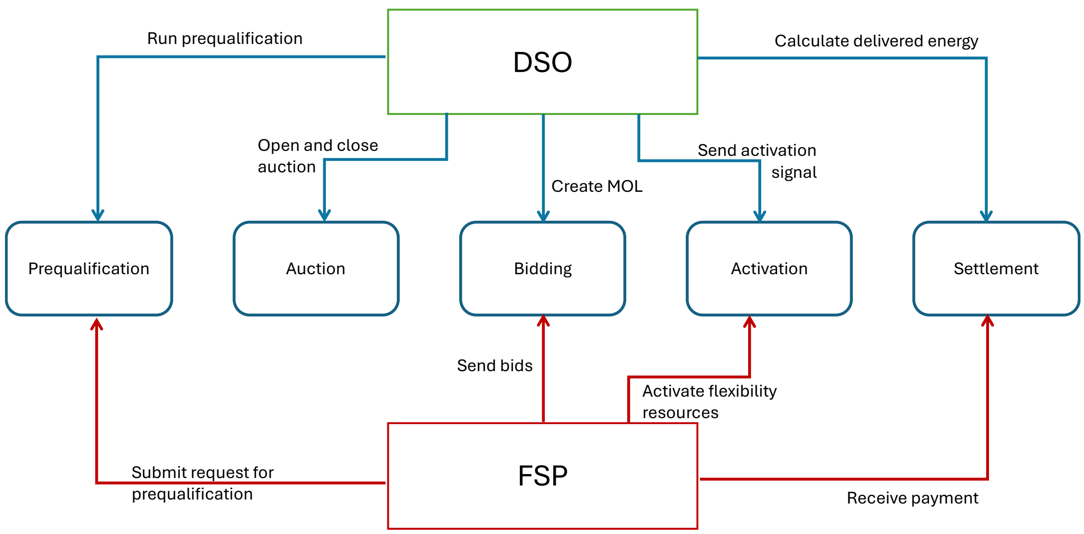

Figure 3-1 Flexibility service processes

3.1 Prequalification

Grid prequalification is essential for the proper and effective functioning of flexibility markets. It ensures that the flexibility offered by a particular service provider can be delivered properly, without causing any adverse effects on the involved grids.

Flexibility service providers (FSPs) must go through a prequalification process to verify that their resources meet the technical and operational requirements. This includes both product prequalification and grid prequalification:

- ***Product Prequalification***: This process verifies that the flexibility resource is technically capable of supplying the flexibility product it intends to offer on the market.

[17] INTERRFACE deliverable D3.2. Definition of new/changing requirements for Market Designs.

- ***Grid Prequalification***: This process assesses whether the flexibility resources connected to the distribution grid can provide flexibility services to the DSO, based on the technical characteristics of the source and the current grid capacities.

3.2 Auction

An auction on the flexibility market is a competitive process in which flexibility service providers (FSPs) submit bids to offer their services. The auctioneer announces the demand for flexibility and prequalified FSPs submit bids stating how much flexibility they can offer and at what price. Different auction mechanisms can be used, including sealed-bid auctions, pay-as-bid, descending clock auctions and uniform price auctions. The DSO evaluates the bids based on cost efficiency and reliability and awards the contracts to the winning FSPs. The auction can be held for capacity (reservation of flexibility resources) and energy (for the service actually activated).

3.3 Bidding

When auction is open, prequalified FSPs submit bids specifying the amount of flexibility they can provide and the price they are willing to accept. The DSO ranks these bids in a Merit Order List (MOL), sorted from lowest to highest price, to prioritize cost-effective solutions. The DSO then selects the most economical bids to meet their flexibility needs, awards contracts, and activates the services as required. For the accepted capacity bids, FSP must submit bids for the energy.

3.4 Activation

Activation is initiated by the DSO sending an activation signal to the FSP. Upon receiving this signal, the FSP activates its flexibility resources as defined by the contract and sends an acknowledgment signal back to the DSO. For automatic activations between IT systems, the activation signal is typically an XML document aligned with the CIM ESMP profile. In the case of manual activation, the signal is sent via SMS or email.

3.5 Settlement

Settlement is the process of calculating and distributing payments to FSPs based on the flexibility services they delivered. A crucial element in this process is the baseline, which is a predefined standard or reference level of power consumption or generation established before the activation of flexibility services. The role of the baseline is to measure the actual change in power usage or generation compared to what would have occurred without the flexibility intervention. After the flexibility event, the DSO compares the FSP's performance against the baseline to determine the amount of flexibility provided. Payments are then calculated based on the agreed-upon contract terms and the verified delivery of services.

4 Market aspects of flexibility

4.1 Market mechanism for DSO to procure flexibility

Flexibility is a service that can be procured through bilateral agreements or an organised local flexibility market.

In a bilateral agreement for the procurement of flexibility services, a DSO negotiates directly with flexibility providers, such as large industrial consumers or aggregators, and concludes a contract with them to adapt their electricity consumption or generation to the needs of the DSO. This contract defines the service requirements, payment terms, performance metrics and penalties/incentives. This enables low-cost customised solutions and faster implementation compared to organised market mechanisms.

An organised local flexibility market is a structured platform that facilitates the trading of flexibility services between distribution system operators and various flexibility providers, such as industrial consumers, renewable energy producers and aggregators, in order to manage local grid conditions. In this market, standardised processes, rules and regulations govern the submission of bids and offers, pricing mechanisms and the settlement of transactions. It includes all the flexibility procurement processes, described in the previous chapter.

An **organised flexibility market** needs market operator and ICT trading platform to automate the trading process. When DSOs start introducing flexibility services in planning and operation, it is recommended to use bilateral agreements to reduce the start-up costs and tackle non-liquidity of the local flexibility market.

One example of an organised flexibility market is the Nordic Flexibility trading platform Nodesmarket[18]. **NODES** is a market platform to facilitate the trading of flexibility services within the electricity grid, enabling DSOs and TSOs to efficiently manage grid constraints and balance supply and demand in real time. In Norway, for example, almost 8000 MWh of flexibility was traded via this market in 2023.

4.2 Role of aggregators in offering flexibility resources connected to the distribution grid to TSO

Aggregators play a vital role in offering flexibility resources connected to the distribution grid to TSOs by pooling small-scale distributed energy resources (DERs) like hydro, demand response, residential solar panels, batteries, and industrial load management systems into a significant, manageable capacity. This **aggregated flexibility** can then be bid into energy markets to respond to TSO needs for balancing, managing congestion, and maintaining grid stability.

[18] [Available] Online: https://nodesmarket.com/nodes-platform/

To provide balancing service, an asset must have a minimum capacity of 1 MW. Multiple assets can be aggregated to meet this requirement. Consequently, the cluster of assets collectively responds to the balancing reserve controls issued by the TSO, and the profits are shared among all asset operators.

Network code on demand response define aggregation models, that is “how service providers that aggregate controllable units may participate in balancing, local services, or contribute to the provision of transfer of energy services”[19]. It is expected that the aggregation of smaller flexibility units will reduce the costs of balancing services in the long term.

4.3 Flexibility register as a tool to visibility of flexibility resources in the distribution grid

The **local flexibility market model** introduces a new role - the flexibility register. The role of the flexibility register is described in the document "TSO - DSO report - integrated approach to active system management" prepared by ENTSO-E. **The flexibility register contains structural information on the location of usage points that can offer flexibility services to system and distribution operators.** The purpose of the register could be to include new sources of flexibility in the prequalification process for FSPs and the settlement of flexibility services between market participants. This register would provide all the information that TSOs and DSOs need for the utilisation of flexibility services. The flexibility register offers a possible solution to ensure seamless data exchange between TSOs and DSOs and to make the flexibility potential visible. The flexibility resource will be visible to all grid operators to whom flexibility can be made available.

> The main task of the **flexibility register** is to collect and disseminate relevant information about the flexibility resources available on the flexibility markets.

In one scenario, the DSO to whose network the resource is connected registers prequalified flexibility resources. The same DSO is responsible for maintaining up-to-date data on the flexibility resource (connected to its network). In this way, the TSO and DSO are aware of all flexibility resources at all voltage levels (which resources are connected to specific grids, their technical characteristics and whether they are available in a given period).

The flexibility register is the database which contains at least information from the prequalification procedure. This is technical information about the flexibility resource, such as location, validated capacity limits, activation duration, response speed, activation method, associated FSP and the specific flexibility service it can provide (voltage control, network congestion management, etc.).

[19] DSO Entity and ENTSO-E submit Joint Network Code on Demand Response, May 8, 2024 [available] Online: https://www.entsoe.eu/news/2024/05/08/dso-entity-and-entso-e-submit-joint-network-code-on-demand-response/

5 Conclusions

Transmission system operators (TSOs) and distribution system operators (DSOs) must utilize flexibility services in their operations and incorporate these services into their planning processes. It is important to recognize that not all investments should be eligible for flexibility alternatives, necessitating a careful and strategic approach to planning.

Flexibility services are well-established within the balancing market, and TSOs need to introduce new **non-frequency products** to enhance grid stability and efficiency. In contrast, flexibility services for DSOs, which involve creating **local flexibility markets**, are still in the developmental stages.

Flexibility services entail certain costs, and allowing value stacking is crucial to **incentivize investment**. Value stacking enables flexibility providers to offer their resources to multiple bidders, including both DSOs and TSOs, thereby maximizing the economic benefits and encouraging greater participation.

Furthermore, DSOs should engage in learning and sharing best practices to improve their implementation of flexibility services, fostering a collaborative environment that enhances overall grid resilience and efficiency.