Power
Transmission
& Distribution
Systems

Single Marketplace for Flexibility

Discussion Paper

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ISGAN Annex 6

Task 5.2

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Disclaimer

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Acronyms and Abbreviations

AG	Aktiengesellschaft
AGG	Aggregator
APCS	Austrian Power Clearing and Settlement
APG	Austrian Power Grid
BRP	Balance Responsible Party
BSP	Balancing Service Provider
D	Day
DER	Distributed Energy Resources
DSO	Distribution system operator
DSR	Demand Side Response
EC	European Commission
FCR	Frequency Containment Reserve
FSP	Flexibility Service Provider
aFRR	Automatic Frequency Restoration Reserve
mFRR	Manual Frequency Restoration Reserve
h	Hour
ICT	Information and communication technology
IEA	International Energy Agency
ISGAN	International Smart Grid Action Network
MHz	Megahertz
min	Minimum
MW	Megawatt
n	Number of e.g. bids
RES	Renewable energy sources
SWOT	Strengths, Weaknesses, Opportunities, Threats
TSO	Transmission system operator

Abstract

Evolutions in the electricity sector, such as the increasing integration of renewables and the electrification of loads, will result in an increased use of flexibility from distributed generation and consumption in the distribution network to support grid operation of the transmission and distribution grid.

To use this flexibility in a coordinated way, an ever closer cooperation between System Operators will be required.

Several approaches for the coordinated use of flexibility for system balancing and congestion management are imaginable. In this work, the concept of a single marketplace for flexibility is introduced. Based on the requirements for TSO-DSO interaction, the concept of a single marketplace for flexibility has been assessed. This assessment does not provide a comparison with other ways to ensure a coordinated use of flexibility, but it shows the strengths and weaknesses of a single marketplace for flexibility.

The single marketplace is a lean and transparent concept to deal with the procurement of flexibility, which could theoretically lead to an economical optimum for the entire system, while respecting technical boundary conditions. On the other hand, the marketplace will not function properly without sufficient flexibility offers, there is no practical experience with this concept and the ICT requirements for its implementation are challenging.

Executive Summary

This discussion paper is part of task 5 within ISGAN Annex 6, which focuses on Power Transmission & Distribution Systems. The main objective is to assess the requirements of the coordinated use of flexibility by the TSO and the DSOs of one control area and to draw a concept for a Single Marketplace for Flexibility, which meets these requirements.

The report is mainly aimed at network operators and decision makers in restructured electricity markets, where a clear distinction between Transmission System Operators (TSO) and Distribution System Operators (DSO) exists, but may also be useful for decision makers considering the re-design of vertically integrated utilities.

A number of emerging trends indicate that the interaction between Transmission System Operators (TSO) and Distribution System Operators (DSO) will evolve in the coming years. One of these trends is the increasing amount of distributed (intermittent) generation being connected to the distribution grid, which contributes to reducing CO_2-emissions and reaching climate goals. However, these generation units change the behavior of the entire system, making it more challenging, for example, to balance generation and demand at every single point in time. At the same time distributed generation and new electric loads (e.g. electric cars, heat pumps) impact the loading of the distribution grid. To avoid network reinforcements and maintain high levels of grid stability and security of supply, flexibility is expected to be used to cope with grid operation challenges such as local congestion, voltage management and system balancing.

This flexibility will partly be found on the distribution grid level. TSOs and DSOs will have to coordinate the use of this flexibility to make optimal use of this scarce resource. Several approaches are imaginable for the coordinated use of flexibility. One concept introduced in this work is a single marketplace of flexibility.

The idea is to use one market platform designed by the TSO and the DSOs in which bids from flexible resources, connected to the distribution and the transmission grid, are collected. Both TSO and DSO have full visibility on all bids. From the available flexibility, the involved TSO and DSOs can acquire the flexibility they need. Thanks to its transparency, this acquisition process enables grid operators to avoid that the activation of procured flexibility by one operator would harm grid operation of others. The use of a well-functioning single market for flexibility could result in an economic optimum for the entire system, while respecting technical boundary conditions.

The goal of this paper is to provide a basis for discussion on the value of a single marketplace for flexibility and the potential challenges for its implementation. To this end, this paper proposes a possible design of a single marketplace for flexibility, meeting the requirements for the coordinated use of flexibility by TSOs and DSOs.

To investigate the requirements for such a coordinated use of flexibility, several use cases have been identified and assessed. Each of the use cases refers to flexibility services to support distribution or transmission grid operation. Based on the use case assessment, the main requirements for the coordinated use of flexibility through a single marketplace for flexibility have been identified:

1. Ensure effective market access for all market participants to valorise their flexibility, directly or through an intermediary.
2. Generate sufficient liquidity ensuring the procurement of all required capacities.
3. Enable information flows between TSO, DSOs, Flexibility Service Providers and BRPs to allow network operators to coordinate their actions.
4. Meet high standards of data security and privacy

A first evaluation of the opportunities and challenges for a single marketplace for flexibility is summarized in the table below.

Internal analyses	**Strengths** • Lean concept: one marketplace for various use cases • Cost optimization due to maximal market liquidity • Building on well-established balancing market • Acceptable need to change existing regulations	**Opportunities** • Clear trend towards an increasing need for the coordinated use of flexibility • The use of distribution connected flexibility is supported by EU and by different stakeholders of the electricity industry • Development successes in the field of ICT components for smart grids • Use of a common tool designed by the TSO and the DSOs	**External analyses**
	Weaknesses • The concept does not work in case of low liquidity of the flexibility market • No practical experience with such a concept, further investigations indispensable • Challenging ICT requirements • Cost of control and communication equipment is a critical factor	**Threats** • Creation of a level-playing field for all sources of flexibility is required first • Slow pace of change for electricity systems • Danger for data safety and security	

The single marketplace is a lean and transparent concept to deal with the procurement of flexibility, which could theoretically lead to an economic optimum for the entire system, while respecting technical boundary conditions. On the other hand, the marketplace will not function properly without sufficient flexibility offers, there is no practical experience with this concept and the ICT requirements for its implementation are challenging.

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1 Introduction

This discussion paper is part of task 5 within IEA ISGAN Annex 6 on Power Transmission & Distribution. The main objective of this task is to assess the future technical and market based interaction of distribution and transmission networks and to develop recommendations for this future interaction. Figure 1 positions this work in the ISGAN context.

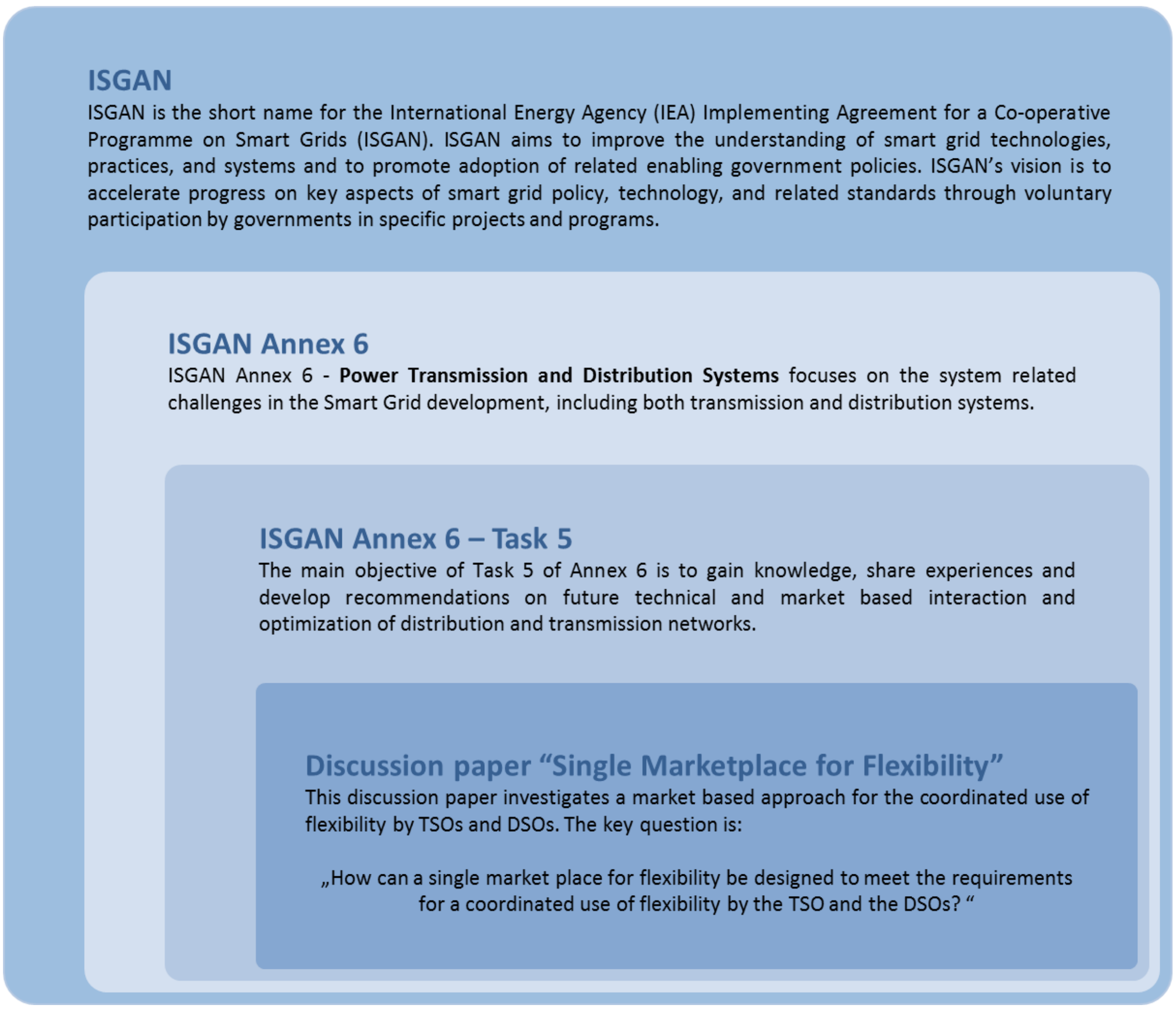

Figure 1: Position of this discussion paper in ISGAN context

A number of emerging trends indicate that the interaction between Transmission System Operators (TSO) and Distribution System Operators (DSO) will evolve in the coming years. The increasing integration of intermittent renewables, the electrification of energy consumption and the ongoing decentralization of energy generation, will require an increased use of flexibility, both on the generation as well as on the demand side:

1. Due to replacement of conventional power plants by distributed energy resources (DER), Transmission System Operators are expected to use flexibility from DER for system balancing.
2. Due to local increase of grid loading, caused by volatile renewables and new electrical applications, Distribution System Operators (DSO) are expected to use flexibility from DER to deal with voltage problems and congestions.

While today the TSO is the main actor procuring flexibility from flexible units to ensure system stability, in future, DSOs are expected to procure flexibility as well to solve issues in their networks. As DSOs might use the same sources of flexibility as the TSO, this flexibility has to be used in a coordinated way.

Different market based and non-market based approaches for the coordination of flexibility used by the TSO and the DSOs are possible. In recent publications [1][2], the concept of a single marketplace for flexibility has been introduced. The idea is to install one market platform in which bids from flexible resources, connected to the distribution and the transmission grid, are collected. Both TSO and DSO have full visibility on all bids. From the available flexibility, the involved TSO and DSOs can acquire the flexibility they need. Thanks to its transparency, this acquisition process would enable grid operators to make sure that the activation of procured flexibility by one operator would not harm grid operation of others. The use of a well-functioning single market for flexibility could result in an economic optimum for the entire system.

The goal of this paper is to provide a basis for discussion on the value of a single marketplace for flexibility and the potential challenges for its implementation. To this end, this paper proposes a possible design of a single marketplace for flexibility, meeting the requirements for the coordinated use of flexibility by TSOs and DSOs. To investigate the requirements for such a coordinated use of flexibility, several use cases have been identified and assessed.

Although this paper has been written from an Austrian perspective, the results are applicable to most other European countries. It is important to note that this paper focusses solely on the use of flexibility for grid operation support. Other uses of flexibility are not in scope of this work. Further, it is assumed that technical requirements for the use of flexibility (e.g. grid monitoring) are met.

2 Use case assessment

2.1 Definition of use cases

When using flexibility to cope with one grid operation challenge, this might have an impact on other grid operation aspects. For example, the activation of distribution-connected flexibility for system balancing might cause congestion on the distribution grid. Theoretically, the activation of distribution-connected flexibility to mitigate congestion on the distribution grid may also affect system balancing. In practice, this impact can be expected to be small when assuming that the activation for distribution grid purposes would not be simultaneous for different parts of a distribution grid. Nonetheless, a mutual impact exists.

To investigate this impact, use cases related to the coordinated use of tradable flexibility services can be defined. These use cases can be assessed in terms of required information flows and required actions to cope with interdependencies.

The use cases refer to flexibility services provided by flexible generation or consumption units connected to distribution networks. Each use case represents a flexibility service, which might have interdependencies with other use cases or actions and therefore requires information flows between and actions by the TSO and the DSOs in order to avoid interferences. The use cases listed below are based on the ISGAN Annex 6 discussion paper on technical aspects of TSO-DSO interaction [3].

Use of distribution connected flexibility by the TSO

T1 - Balancing (FCR, aFRR and mFRR)
In this use case, the TSO uses flexibility for system balancing purposes: frequency containment reserve (FCR), automatic frequency restoration reserve (aFRR) and manual frequency restoration reserve (mFRR). The involved actors are the TSO and Flexibility Service Providers.

T2 - Reactive Power Management in Transmission Networks
Currently, the TSO only controls the reactive power flows of the conventional power plants connected to the transmission network. In future, the TSO may benefit from reactive power control from distribution-connected flexibility. In this use case, flexible units are used for reactive power management to minimize grid losses or support the voltage on the transmission network. The involved actors are the TSO and Flexibility Service Providers.

Use of distribution connected flexibility by the DSO

D1 - Local Congestion Management in Distribution Network
Assuming increasing integration of RES and new electrical applications, congestions due to thermal capacity limitations of lines are more likely to occur. This use case refers to the use of flexibility to relieve one or more congested lines. The involved actors are the DSO and Flexibility Service Providers.

D2 - Congestion Avoidance at TSO-DSO Interface
For countries in which the transformers at the TSO-DSO interface are owned and operated by the DSOs, transformer congestions can be avoided using flexibility from the distribution grid. The involved actors are the DSO operating the transformer and Flexibility Service Providers.

D3 - Voltage Control in Distribution Network (active power)
Especially in rural low voltage grids RES feed-in, e.g. from photovoltaic systems, might violate the upper voltage limit. In contrast, powerful consumers, e.g. electric cars, have the potential to violate the lower voltage limit. In this use case the DSO uses flexibility to control the voltage via active power management. If the voltage in a certain point in the network is too high, reduced flexible generation, electricity storage charging or augmented flexible load may decrease the voltage. If the voltage in a certain point in the network is too low, electricity storage discharging or flexible load reduction may increase the voltage. The involved actors are the DSO and Flexibility Service Providers.

D4 - Voltage Control in Distribution Network (reactive power)
In this use case the DSO activates one or several flexible units connected to its distribution network to perform voltage control in its network via reactive power flows provided by flexible resources. The involved actors are the DSO of the affected network and Flexibility Service Providers.

Note: Congestion management via redispatch in transmission networks was not considered as it is a domain of large power plants (> 50 MW) and not the main focus of this work.

From the perspective of TSO-DSO interaction, the interesting question is how the use of flexibility for one use case impacts other use cases.

2.2 Assessment

Based on the presented use cases, an assessment concerning general technical requirements for the coordinated use of flexibility can be made.

Table 1 illustrates the results of this assessment, focusing on some important interdependencies, required information flows and actions to cope with these interdependencies. Due to the complexity of the topic, and to stay within the scope of this work, the assessment is restricted to some obvious interdependencies and is not aiming to be complete. Moreover, different solutions could be proposed to deal with the interdependencies of which only one is mentioned in the table below.

Table 1: Outcome of use case assessment

Use case	Possible interdependencies	Required information flows	Required actions
T1	DSO blocks activation of flexible units, activated by the TSO because of local congestion issues DSO activates flexible units for voltage or congestion management, impacting the need for balancing capacities BRP unintentionally counteracts balancing efforts to perform portfolio optimization (avoiding imbalance costs)	DSO → FSP: which units are blocked, or activated for voltage control FSP → TSO: inability to deliver certain amount of flexibility if compensation of blocked reserves by alternative flexibility of aggregator is not possible TSO → BRP: changes in generation and consumption patterns due to balancing actions to prevent BRP from counter-acting balancing measures	Adequate treatment of balancing capacities which are unavailable due to DSO blocking FSP (if possible) compensation by available, alternative capacities or reduction of offered capacity TSO: compensation of unavailable capacity via procurement process (if information of blocking or curtailment is given before gate-closure)
T2	DSO blocks activation of flexible units, activated by the TSO because of local congestion issues, inhibiting the supply of reactive power to TSO DSO requires reactive power from same units like TSO	DSO → TSO: which units are needed for voltage control by DSO DSO/FSP → TSO: communicate reactive power reserves which are available for TSO	TSO & DSO: coordinate reactive power optimization resulting in a trade-off between the needs of TSO and DSO (e.g. through a coordinated activation assessment and/or a common procurement platform)

D1	TSO needs the same flexibility, which is required for congestion management or voltage control in distribution network, for balancing purposes TSO activates flexibility for system balancing, resulting in local congestion Local congestion management impacts system balance Local congestion management impacts the balance of the BRP portfolio, which would result in imbalance settlement costs	TSO/FSP → DSO: communicate which units are required for system balancing TSO/FSP → DSO: communicate which units will be activated for system balancing DSO → TSO: communicate which units will be activated for local congestion management FSP → BRP: communication of activated flexibility for local grid congestion management	DSO: one possible action is the procurement of additional flexibility to solve local congestion. However, liquidity on DSO level might be low. DSO: Overrule procurement or activation of flexibility for TSO use cases TSO: procurement and activation of additional compensation capacities might be necessary
D2	Same interdependencies like in use case D1	Same requirements concerning information flows like in use case D1	Same requirements concerning actions like in use case D1
D3	The use of distribution connected flexibility by the TSO leads to violations of voltage range on the distribution grid Local voltage management impacts the balance of the BRP portfolio, which would result in imbalance settlement costs	Same requirements concerning information flows as in use case D1	Same requirements concerning actions as in use case D1
D4	Reactive power based voltage management performed by the DSO could interfere with the needs in terms of reactive power of the TSO.	TSO/FSP → DSO: communicate the need of reactive power capacities for transmission purposes	DSO: identify negative impacts of the use of reactive power capacities in distribution networks by TSO TSO & DSO: coordinate reactive power optimization creating a trade-off between the needs of TSO and DSO (e.g. through a common procurement platform, see T2)

From this preliminary analysis, it can be seen that quite some interaction between the different stakeholders is needed when flexibility connected to the distribution grid is used for distribution and transmission system support. As mentioned above, there are often several options to ensure a proper interaction between different stakeholders. The assessment shows that it is especially important for TSOs and DSOs to know, as early as possible, which flexibility would be used for which purpose. It allows them to assess the impact of a possible activation of this flexibility on the respective grids and to take measures if necessary.

One option to insure the interaction between TSOs and DSOs in terms of coordinated use of flexibility, is proposed in the following paragraph, which introduces the concept of a single marketplace for flexibility.

3 Single Marketplace for Flexibility concept

3.1 Definition of a Single Marketplace for Flexibility

The term "Single Marketplace for Flexibility" refers to a trading platform on which flexibility bids are collected. The idea is to install one market platform in which bids from flexible resources, connected to the distribution and the transmission grid, are collected. Both TSO and DSO have full visibility on all bids. From the available flexibility, the involved TSO and DSOs can acquire the flexibility they need.

> Thanks to its transparency, the proposed acquisition process enables grid operators to make sure that the activation of procured flexibility by one operator would not harm grid operation of others.

In this work, the Single Marketplace for Flexibility is described for the Austrian control area but the concept could be adapted to fit for other control areas or even for larger areas as well. An introduction to the current Austrian balancing market design is given in Annex 1.

3.2 Marketplace requirements

The requirements for a Single Marketplace for Flexibility, as defined above, have been investigated based on the outcome of the use case assessment, recent literature concerning the use of flexibility in distribution networks and the applying regulatory framework:

1. The marketplace should ensure effective market access for all market participants and provide non-discriminatory and cost-reflective services, in accordance with Directive 2009/72/EC [4].
2. The market mechanisms should be able to generate sufficient liquidity to procure all ancillary services, both for system stability and congestion management.
3. Information flows between TSO, DSOs, FSPs and BRPs should be enabled through an independent data manager to allow network operators to coordinate their actions. This includes:
    a. Allowing the TSO to procure alternative flexibility when flexibility that was intended for system balancing, is procured by the DSO.
    b. Avoiding that system imbalances in the control area are caused by the activation of flexibility for distribution grid operation.
    c. Dealing with imbalances in the BRPs' portfolio resulting from the activation of flexibility for grid operation support in the imbalance settlement.
4. Meet high standards of data security and privacy.

3.3 Products and market structure

The products which would be offered to the TSO would basically be the same as in current balancing markets: Frequency Containment Reserve, automated Frequency Restoration Reserve and manual Frequency Restoration Reserve. Moreover, there would be a product for reactive power provision to the TSO.

The products offered to the DSO would be for congestion and voltage management purposes and would consist of active and reactive power flexibility. For products for DSO purposes, the geographical aspect is particularly important. Therefore, the products must be tagged e.g. with the metering point reference number allocating them to the respective network node.

A general comment is that in order to have a liquid platform, standardised products, with requirements that can be met as easily as possible, are preferred. Aggregation of e.g. smaller flexibilities might further increase the liquidity of the market. In this case, the return on the flexibility offered will (have to) be shared between the Flexibility Service Provider and aggregator.

One challenge when dealing with flexibility provided to the DSO is the potential impact the activation of this flexibility has on the system balancing. If this applies, one option is to give the DSO the responsibility to compensate the use of flexibility for distribution grid operation support with other flexibility, mitigating the impact on the system balance. Another (probably less cost-effective) option would be that the TSO procures additional flexibility for a possible increase of the system imbalance.

Another particular challenge is the impact of the activation of distribution connected flexibility on the balance of the portfolio of BRPs. To cope with the potential impact on the balance of the BRPs´ portfolio, a practical solution is to handle the resulting deviation from the nomination in the imbalance settlement. Another solution would be to give BRPs the responsibility to deal with the uncertainty of their customers who offer flexibility by, for example, charging them higher premiums.

According to market design theory, marketplaces are institutions, where non-cooperative games take place assuming that the participants act rationally. In real marketplaces the participants’ behavior can be more complex. Therefore, information flows, market rules and organizational structures are crucial for the design of resilient market mechanisms. How a market works is strongly related to its market structure, which can be described by the following parameters: market participants, the market type and the product differentiation.

As for the market participants, network operators, Flexibility Service Providers and BRPs can be identified. TSO and DSOs are responsible for safe and reliable grid operation. They have a specific need for flexibility. FSPs are heterogeneous: smaller and larger enterprises and a multitude of private people owning e.g. photovoltaic systems. Their needs and motivations to buy or sell flexibility are different.

The market type is related to this number of market participants. The main market types are polypoly, oligopoly and monopoly which can refer to both the seller and buyer side. Due to a large number of participants, polypoly markets provide dynamic market processes as there is more competition compared to market types with only few participants. Nevertheless, the degree of competition not only depends on the number of participants but also on their values (e.g. ethos of competition) and not all monopolists behave in a monopolistic way [5]. The market type is also characterized by the relation between the number of sellers and buyers, the degree of market access, spatial, personal or time-related preferences, the degree of transparency, etc.

The market type of a single marketplace of flexibility would vary depending on the type of service. For balancing, the number of competing sellers might be high: as only the TSO and maximum one DSO might compete for the same flexibility offer, there might be a polypoly on the seller side and a monopoly respectively oligopoly on the buyer side. On the other hand, products with geographical properties, required by a DSO, might be provided by only one or a few sellers. In this case, the market is a monopoly or an oligopoly on both sides. Regulatory measures may become necessary in order to prevent the sellers from taking advantage and demanding high prices [6]. Such measures are already in place in some countries (e.g. in Belgium).

An important aspect of a market for flexibility is the timeframe in which services are procured. The procurement of balancing reserves currently differs strongly between different TSOs. The procurement can take place week-ahead, monthly or even annually. This works well for conventional power plants as their dispatch can be planned long time in advance. In contrast, the availability of flexibility from DER, especially from RES and from Demand Side Flexibility may be known only days or hours in advance. Therefore, the gate-closure might have to be closer to real-time, e.g. day-ahead. On the other hand, shorter timeframes are more demanding for Flexibility Service Providers (in terms of people, IT…) which could lead to less liquid markets. A trade-off has to be made.

3.4 Market process

In the following paragraph, important parts of the market process of the single marketplace for flexibility are described: the information collection and negotiation.

Information collection is required due to information asymmetries between market participants. Information collection at a flexibility marketplace is the collection of flexibility offers and purchase bids. The offers may include a minimum power price and a fixed energy price similar to common secondary and tertiary energy trading platforms today, in order to reflect the fixed and variable costs of flexibility provision.

The negotiation process coordinates the economic plans of sellers and buyers. In order to enable effective negotiating, communication between buyers and sellers must be facilitated, but communication between market participants of the same market level, which can occur e.g. at open auctions, should be avoided to avoid collusion. This is an argument for the marketplace to be operated by an independent data manager, which could be a TSO or DSO as long as they are not participating as Flexibility Service Provider.

Due to the locality of issues in distribution grids, DSOs need flexibility from specific resources, in contrast to the TSO who has less geographical restrictions to acquire flexibility. In most cases, the price is the main reason why the TSO may want flexibility from the same source as the DSO. If the price for a particular flexible resource would increase, the TSO would prefer to procure flexibility from an alternative, cheaper source, which is assumed to be available in a liquid market. In that case, the TSO could leave the specific flexibility offer to the DSO, who will often have few alternatives.

> In a single marketplace for flexibility, the coordinated procurement of flexibility can be the result of an auction: the market buyers reply to offers by placing purchase bids.

In a single marketplace for flexibility, the coordinated procurement of flexibility can be the result of an auction: the market buyers reply to offers by placing purchase bids. The stated purchase price must be equal or superior to the offer's minimum price. During the auction process, the TSO and the affected DSO may overbid each other several (n) times until the last ("n^{th} bid") is placed.

There might be a risk of high prices when both TSO and DSO overbid each other several times. However, in a liquid market, it can be assumed that the TSO would have the opportunity to procure alternative offers of the same quality and at a lower price. In contrast, the DSO has high interest in procuring specific bids located at those points in the grid where congestion might occur.

The result of the negotiation is hedged by an agreement between the seller and the buyer. In the proposed single marketplace for flexibility, these agreements are made through the clearing process. After the clearing, the obligations between the market participants are determined.

3.5 Exemplary processes in the single marketplace for flexibility

To provide a better understanding of how a Single Marketplace for Flexibility could be designed, an exemplary marketplace has been drafted. The market processes and the chronological order are visualized in Figure 2.

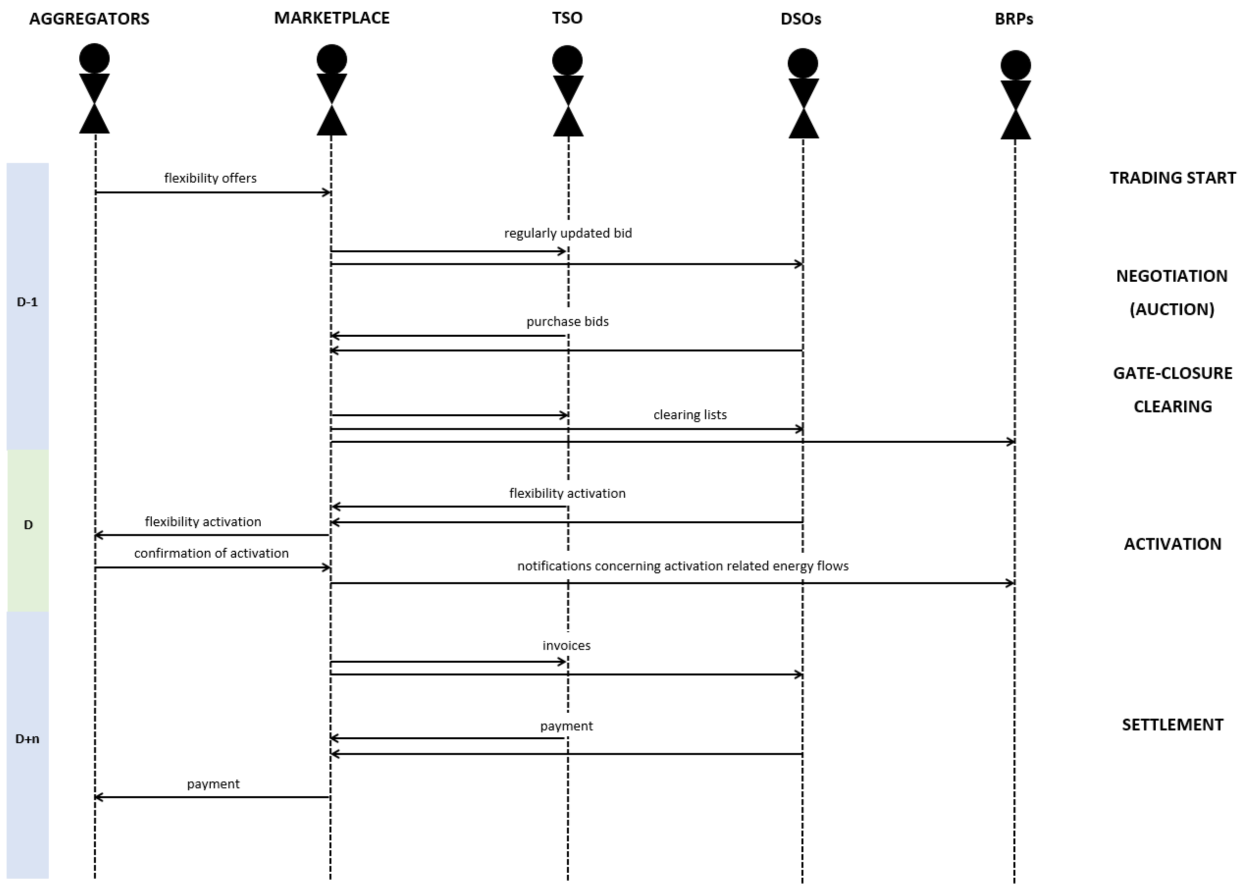

Figure 2: Market processes

After trading start, the information collection is performed day-ahead, receiving and registering flexibility offers. Then, the prices are negotiated by means of an auction. After gate-closure, the clearing determines all trades. In this example, the trading platform provides additional functionalities related to flexibility activation and the registration of related energy flows.

All flexibility offers are registered in a common order book, like the example shown in Table 2. In this order book, all relevant product information and all purchase bids placed by the TSO and the DSOs are registered. The information is processed and then provided to all market participants.

Table 2: Extract of an exemplary order book

Offer	time	power	min. price	fix energy price	meter point ID	product	FSP	1st bid		2nd bid		nth bid
[-]	[h]	[MW]	[€/MW]	[€/MWh]	[-]	[-]	[-]	[€/MW]	Bidder	[€/MW]	Bidder	[€/MW]
1	0-1	0.01	10	100	DSOzip1x1	aFRR	FSP1	10	TSO			
2	0-1	-0.01	10	-80	DSOzip1x1	aFRR	FSP1	10	TSO			
3	0-1	-50	20	-40	DSOzip1x2	aFRR	FSP1	20	TSO			
4	0-1	1	50	0	DSOzip1x3	FCR	FSP1	50	TSO	55	DSO1	
5	0-1	-1	50	0	DSOzip1x3	FCR	FSP1	50	APG	55	DSO1	
6	0-1	-0.8	30	-10	DSOzip2x1	aFRR	FSP1					
7	0-1	0.01	10	110	DSOzip2x2	aFRR	FSP1	10	TSO			
8	0-1	-0.01	10	-70	DSOzip2x2	aFRR	FSP1	10	TSO			
9	0-1	-50	20	-30	DSOzip2x3	aFRR	FSP1	20	TSO			
10	0-1	5	60	0	DSOzip2x4	FCR	FSP1	60	TSO			
11	0-1	-5	60	0	DSOzip2x4	FCR	FSP1	60	TSO			
12	0-1	-0.8	30	-15	DSOzip3x1	aFRR	FSP1					
13	0-1	0.01	10	120	DSOzip3x2	aFRR	FSP1	10	TSO			
14	0-1	-0.01	10	-90	DSOzip3x2	aFRR	FSP1	10	TSO			
15	0-1	-50	20	-50	DSOzip3x3	aFRR	FSP1	20	TSO			
16	0-1	1	60	0	DSOzip4x1	FCR	FSP1					
17	0-1	-1	60	0	DSOzip4x1	FCR	FSP1					
18	0-1	-0.8	30	-20	DSOzip4x2	aFRR	FSP1					
19	0-1	100	10	20	DSOzip5x3	aFRR	FSP2	10	TSO			
20	0-1	-100	10	-10	DSOzip5x3	aFRR	FSP2	10	TSO			
21	0-1	450	20	0	DSOzip5x4	FCR	FSP2					
22	0-1	-450	20	0	DSOzip5x4	FCR	FSP2					

The purchasing market participants place their purchasing bids according to these continuously updated lists. This provides indirect communication between the market participants. Conflicting flexibility needs are indicated easily and are solved quickly by placing a higher bid. It can be assumed that the TSO will place a new purchase bid to an alternative offer, which will be more expensive than the original conflicting bid but cheaper than overbidding the DSO to get the original bid. Following this logic, in most cases there will not be more than two bids for one offer. An exception could be flexibility offers concerning reactive power, where the TSO may also need geographically determined products.

4 SWOT analysis and assessment of impacts

A SWOT analysis and an impact analysis have been carried out to assess the concept of a single marketplace for flexibility. The strengths and weaknesses are related to the characteristics and the performance of the trading platform, the opportunities and threats refer to the external boundaries. The outcome of the SWOT analysis is shown in Table 3 and explained in more detail below.

Table 3: SWOT analysis

Internal analyses	**Strengths** • Lean concept: one marketplace for various use cases • Cost optimization due to maximal market liquidity • Building on well-established balancing market • Acceptable need to change existing regulations	**Opportunities** • Clear trend towards an increasing need for the coordinated use of flexibility • The use of distribution connected flexibility is supported by EU and by different stakeholders of the electricity industry • Development successes in the field of ICT components for smart grids • Use of a common tool designed by the TSO and the DSOs	**External analyses**
	Weaknesses • The concept does not work in case of low liquidity of the flexibility market • No practical experience with the concept, further investigations indispensable • Challenging ICT requirements • Cost of control and communication equipment is a critical factor	**Threats** • Creation of a level-playing field for all sources of flexibility is required first • Slow pace of change for electricity systems • Danger for data safety and security	

Strengths

- The Single Marketplace for Flexibility provides a solution for the coordinated procurement of flexibility for various use-cases, bringing together the flexibility trade for TSO and DSO needs in one platform.
- Markets have the potential to minimize costs as the prices are achieved by competition.
- The presented marketplace concept is expected to facilitate the communication between sellers and buyers.
- The concept builds on the well-established balancing market and settlement process. Therefore, the need to change existing regulations is reasonable compared to other approaches, which may imply more severe changes.

Weaknesses

- For the single marketplace to work, the flexibility market has to be liquid. Enough offers of flexibility have to be available. If this is not the case, flexibility prices will be high or even worse: the demand for flexibility to support grid operation can not be met.
- The Single Marketplace for Flexibility is a new approach. The underlying research has to be validated. One pressing issue is that the market clearing algorithm could result in a very complex model that would be difficult to solve in the required time. Further investigations are indispensable.
- The ICT requirements to put the single marketplace into practice might be challenging.

Opportunities

- A clear trend towards an increasing need for distribution connected flexibility in the next years and decades is anticipated. Opportunities for concepts like the Single Marketplace for Flexibility can be expected.
- The use of distribution connected flexibility is supported by the EU, by different stakeholders in the electricity industry and (industrial) customers themselves.
- Recent developments in the ICT field are promising: recently developed standards may increase the efficiency of ICT systems and lead to cost reductions.

Threats

- The creation of a level-playing field for all sources of flexibility, both generation and demand, is required first [7].
- The electricity system in Europe evolved historically. Its planning and operation is characterized by a high degree of caution. The process of introducing a concept like the Single Marketplace for Flexibility is expected to be complex and time-consuming.
- Due to the important role of ICT, data safety and security require particular attention.

The introduction of a Single Marketplace for Flexibility will have an impact on the electricity industry, especially the stakeholder roles.

The tasks and roles of a TSO might not change much, as the principles of the marketplace can be based on those of the present balancing market. The TSO could still be marketplace operator. Only in cases where the market fails, additional responsibilities related to the communication with other stakeholders may arise.

> The DSO's roles would shift towards an active system operator. New tasks might be the procurement and activation of flexibility in order to avoid congestions or voltage problems.

The role of Flexibility Service Provider is currently developing in different European countries. DER are aggregated to sell electricity on the wholesale electricity market and flexibility on the balancing market. This role would be extended in order to provide flexibility to DSOs. This implies that flexibility offers will have to be provided together with additional information like the point of connection of the provided flexibility. The data detail will increase. These new requirements can be met by means of ICT, already used by Flexibility Service Providers today. Due to further decentralization of electricity generation and increasing use of DSM, the importance of the role of Flexibility Service Provider will further increase. A comprehensive consideration of the roles of a Flexibility Service Provider in the regulatory framework will be important.

The role of a BRP is key in Europe's present electricity system. Due to the use of flexibility for distribution grid support, the BRP might have to cope with undesired imbalances. These imbalances should not result in financial consequences (penalties) for the BRPs. Some administrative mechanism will be necessary to make sure that imbalances due to the activation of flexibility do not result in imbalance costs for the BRPs.

5 Closing discussion

There is a clear trend towards the use of flexibility connected to the transmission and distribution grid to support grid operation. The single marketplace for flexibility, discussed in this paper, is one amongst several options to facilitate the use of distribution-connected flexibility for system operation support.

The implementation of such a market would allow matchmaking between supply and demand of flexibility for distribution and transmission grid support. The products are sold at the highest price a buyer is willing to pay, reflecting the product's value. This way, the marketplace could theoretically lead to an economical optimum for the entire system while respecting technical boundary conditions.

The most important challenges are that the marketplace as presented in this work will not function properly without sufficient flexibility offers and that the ICT requirements for its implementation are challenging. A level-playing field for all sources of flexibility would increase the market's liquidity. Nevertheless, for local issues on the distribution grid, it is more difficult to have a liquid market, with sufficient flexibility offers.

Further investigations will have to prove whether the assumptions made in this work are realistic. Market simulation tools, which take into account different future scenarios for the development of DER and the participation of flexibility, could be very useful to investigate the proper functioning of such a marketplace.

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Appendix – Introduction to current balancing market in Austria

Balancing reserves are procured differently across the European control areas. The most common form of procurement are tenders in which Balancing Service Providers (BSP) submit proposals for balancing capacity and are activated according to system needs and the offered balancing energy prices. The tender for balancing capacity is carried out on a mid to long term basis, e.g. yearly, trimonthly, monthly, etc. In Austria's control area, the required balancing reserves are procured at an electronic tendering platform, operated by the control area manager Austrian Power Grid (APG). The BSPs must meet specific technical pre-qualification and contractual requirements in order to be allowed to participate.

For technical and economic reasons, a distinction is made between frequency containment reserve (FCR), automatic frequency restoration reserve (aFRR) and manual frequency restoration reserve (mFRR). The TSO is responsible to procure the balancing reserves for each control area.

The activation of FCR is performed automatically via turbine control equipment. The maximum activation, achieved at a frequency deviation of 200 mHz, must be reached within 30 seconds and must remain available for at least 30 minutes. The proportional control characteristic of FCR causes a permanent control offset which leads to a permanent frequency deviation from the 50 Hz nominal frequency. In Austria's control area, FCR is traded at the FCR tendering platform of APG. The FCR product is a weekly power reservation product. When the bid is accepted, the total volume of primary control power must be available without interruption. The bids refer to equal positive and negative power. The minimum bid is +/-1 MW, all bids must be placed in full MW increments. The bids are ranked according to the balancing capacity price and are compensated pay-as-bid. Austria's control area manager must procure a total frequency containment reserve of +/-65 MW (2016). Balancing energy is not compensated separately. The costs of primary control (capacity provision) are charged via system charges to all generators with a power of equal or superior to 5 MW.

Automatic frequency restoration reserve is performed by a superordinate frequency controller which continuously compares the actual frequency with the 50 Hz nominal frequency and adapts the set point of certain generators. Hence, the frequency gets restored and the generators glide back to their original operating point, relieving the activated FCR [8]. aFRR is activated when the system is affected for longer than 30 seconds or it is assumed that the system will be affected for a period longer than 30 seconds [9]. In Austria's control area, aFRR is traded at the aFRR tendering platform of Austrian Power Grid. There are three aFRR products:

- Peak week: Monday to Friday from 8:00 to 20:00
- Off-peak week: Monday to Friday from 0:00 to 8:00 and from 20:00 to 24:00 and on weekends

Positive and negative aFRR are tendered separately. The minimum bid is +/-5 MW, all bids must be placed in 1 MW increments. In contrast to FCR, the aFRR balancing energy is compensated. The reserves are activated in the order of the energy price. Austria's control area manager hast to procure a total frequency restoration reserve of +/-200 MW (2016). The bids are ranked according to the capacity price and are compensated pay-as-bid. The balancing energy is activated based on the merit order list. The main share of 78 % of the costs for aFRR is charged to the electricity producers (> 5 MW) via system charges. The remaining 22 % are charged to the Balance Responsible Parties (BRPs) via imbalance settlement [10].

Manual frequency restoration reserve refers to the manual allocation of control power to certain generators in order to optimize the costs for generation and transmission replacing aFRR. mFRR is activated when the deviation in the control area lasts for longer than 15 minutes [9]. Procured mFRR must be of at least the same capacity as the capacity of the largest power plant in the control area [11]. The replacement of aFRR by mFRR can take up to 15 minutes [9]. When activated, mFRR must be provided for a minimum of 15 minutes. In Austria's control area, aFRR is traded at the aFRR tendering platform of APG in two different ways:

1. Market maker tenders: the products include a power price for reserved capacities and an energy price. The products refer to 4 hour blocks of one week and of one weekend. Therefore, this tenders count with 12 different products. The bids are ranked according to the power price and are compensated with pay-as-bid pricing.
2. Day-ahead tender: short-term tender without compensation of provision of balancing capacity, the bid for balancing energy can be placed or adjusted[1] for each product on each day. The balancing energy price of the bids can be adjusted until the end of the day-ahead tender.

Positive and negative mFRR are tendered separately. The minimum bid is +/-5 MW, all bids must be placed in full MW increments. The maximum bid per supplier and time interval is 50 MW. Austria's control area manager has to procure a total manual frequency restoration reserve of +280/-125 MW (2016). The activation of the units is performed manually by the APG based on the merit order list. The costs of mFRR are charged to the BRPs via imbalance settlement.

Imbalance settlement is performed by the balance group coordinator „APCS Power Clearing and Settlement AG" (APCS) and is based on measurement data and schedules: DSOs provide their customers' consumption values, which are quarter-hourly measured or generated via standard load profiles from annual consumption values. These measurement data are aggregated and allocated to the BRPs. In addition, the TSO provides external and internal schedules from BRPs [12]. Then, the technical clearing is carried out in two stages: The first clearing is carried out every month and determines the quarter-hour imbalance energy per balancing group ($V_{BRP,t}$), netting for each quarter-hour (t) the energy

[1] The accepted bids from the market maker tender can be adjusted in the day-ahead auction, but only in favor of the TSO.

consumption ($E_{BRP,t}$), the energy generation ($G_{BRP,t}$), the purchase schedule ($PS_{BRP,t}$) and the sale schedule ($SS_{BRP,t}$) [14].

$$V_{BRP,t} = (E_{BRP,t} - G_{BRP,t}) + (PS_{BRP,t} - SS_{BRP,t})$$

The first clearing price ($P_{C,t}$) is determined using a base price (wholesale market price, $P_{B,t}$) and the allocation function T.

$$P_{C,t} = P_{B,t} + sgn(V_t)\, T$$

$$T = \min\left(U_{Min} + \frac{U_{Max} - U_{Min}}{V_{Max}^2} V_t^2;\ U_{Max}\right)$$

The minimal value of the allocation function (U_{Min}) and the value of the control area's imbalance (V_{Max}) at which the allocation maximum is reached are determined by the regulator. The actual delta of the control area (V_t) is provided by the TSO. Figure 3 shows the first clearing price as a function of the total control area imbalance.

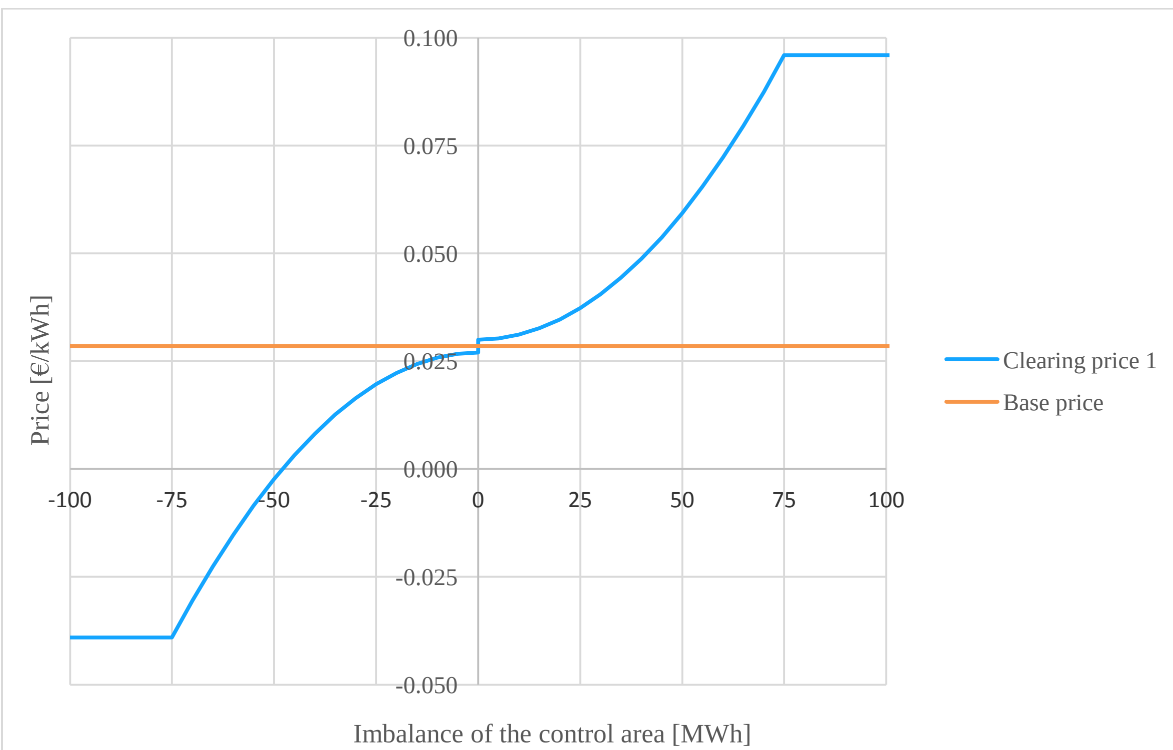

Figure 3: First clearing price vs. the imbalance of the control area[2]

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The second clearing is also carried out every month but referring to the month, 15 months in the past. The second clearing considers the actual energy amounts based on the annual meter reading data and corrections concerning the first clearing.

Every month the financial clearing is carried out by Oesterreichische Kontrollbank AG (OeKB) on behalf of APCS. The imbalance is then invoiced to the BRPs.