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Flexibility in active distribution systems

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Flexibility in active distribution systems

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Contents

Summary

Flexibility is related to the capabilities to manage changes. The word has been used for very different concepts across the literature. Therefore, it is important to specify our vision. This working group has focused on the **flexibility provided by the resources that are connected to the distribution network** and not on the flexibility of the assets of the distribution network. In the same way, we have also given priority to the flexibility referred to the active power, as it is considered the most valuable to the network.

The work was addressed through **different topics** such as Usage and Value, Market Structures, Flexibility Agreements, Tariff Structures, Aggregation, Information Exchange, Platforms and Recommendations for Regulators.

In the first topic, **Usage and Value**, the different ways of approaching flexibility are studied with the intention of seeking value for the distribution network: Stochastic, Centralized (grid restrictions not considered) and Decentralized approach (flexibility is needed at a certain location). Afterwards, the different values are assessed, especially **Hosting Capacity** enhancement. Investments can be avoided or delayed, reliability can be improved, and some costs can be avoided (redispatch, losses, curtailments). In our report, some specific examples for these values are given.

Regarding **market structures**, we have studied possible timeframes, concluding that discrete markets are more appropriate for cases of low liquidity, obtaining long term commitments that can compensate investment signals for flexibility providers and incentives to postpone investments by the DSO. Discrete markets can have a very different periodicity. If they are very frequent, they won´t be very different from continuous markets. Continuous markets, which are better known in the sector for the TSOs, are common global markets with obvious competition, but not useful for local needs. Also, TSO-DSO coordination schemes are addressed in this topic.

The study of **flexibility agreements** is not simple, since they are like tailor-made suits. Therefore, interests and risks of each stakeholder faces are studied. TSO and DSO look for the satisfaction of short term and long-term needs, grid liability, communications liability or the risk of gaming. TSO needs quicker responses to manage its responsibilities, and the DSO also has the concern of the local market in which all the resources connected at the low and medium voltage levels participate. The aggregator and the DER will have different interests too, while one has the concerns of market participation and competition, the other will be more concerned with giving value to his assets and with performing its main functions or processes under the limitations imposed by the flexibility service.

In the next topic, about **tariffs**, we have studied the case of five countries, the current possibility of implementing flexible tariffs that can be adapted to the needs of the network and some suggestions. The case of Germany is remarkable because a fee for flexible charges is possible. We suggest fees on the time of usage and peak shaving as a permanent solution (not only for once). Some pilots are being deployed in Portugal and Switzerland that may bring new conclusions on this topic. In any case, tariff solutions can be complementary to flexibility mechanisms and dynamic tariffs should be tested.

Aggregation was not an initial objective of the working group. But it has its value when it comes to unlocking the flexibility of small flexibility providers. The sole act of aggregation is not enough, as it can be handled in a regulated manner by the TSO or the DSO. It is clear that aggregators have their space to assume their responsibility and provide their value.

The topic of **platforms and information exchange** is so relevant that it could be the only topic of a working group. In fact, since it is the only way to make all possible flexibility schemes feasible, it is one of the most demanding points for the members of existing demonstration projects. After all, they are the tools of

flexibility. The information exchanges between are studied considering the stage at which these exchanges of information must take place.

Finally, regulatory recommendations are given to enable flexibility solutions to become a reality.

Introduction

Flexibility is not a new concept in electrical power systems. Traditionally, flexibility was provided mainly by flexible thermal generation and hydro plants. However, the electricity system is evolving towards a paradigm shift with a high penetration of intermittent renewable generation (solar and wind) connected to transmission and distribution networks, and an increasing electrification of mobility, transport, heating, air conditioning and industrial consumption. This new scenario requires new flexibility mechanisms to safely and efficiently integrate these resources and operate the electricity system as efficiently as possible. This potentially results in lower costs for consumers, lower emissions and better levels of quality and security of supply.

Flexibility, in the context of this report, relates mainly to the flexible provision of active power. This includes variation of generation, reduction or increase of load, moving load in time and operation of storages. The flexibility can be offered by different sources at different markets and controlled by different entities. A compilation and evaluation of the different sources of flexibility is given in the following sections.

The active participation of consumers and generators in network operation can evolve and can help to a more efficient use of the grids. Even if only partially, if the perception of infinite availability and capacity is replaced by a real interest of the customer in adapting to an efficient use of the grid aimed at avoiding fixed costs of sporadic use, the electricity grid can be more efficient and sustainable.

Flexibility always has two sides: flexibility providers and flexibility users. In turn, both users and suppliers can be regulated subjects (network operators) or subjects in free competition (final customers, flexibility suppliers or flexibility service providers (FSPs)). The actions of regulated subjects can impact on subjects operating in free competition. Therefore, a clear and transparent limitation of the functionalities and roles between them is essential and the coordination of the different flexibility options together with the markets and the technical operation are fundamental.

Flexibility can offer solutions to the grid in two different but closely related areas. On the one hand, in relation to the energy balance, in the decentralisation of electricity generation. The TSOs not only face the challenge of managing electricity systems with a decentralized generation and low inertia, but also the need to find service providers that maintain the reliability of the system. DSOs, on the other hand, have the challenge of maintaining the quality and reliability standards of the networks in a system that is increasingly moving away from the distribution function and becoming an energy exchange space, as it is intertwined with the generation function and whose consumers will have more different and more unpredictable profiles. The challenge is very different, but the resources are the same. Hence the importance of having good coordination between agents who can operate in the same flexibility market.

In the European Union, the Article 32 of the Directive 2019/944 on common rules for the internal market for electricity sets that “Member States shall provide the necessary regulatory framework to allow and provide incentives to distribution system operators to procure flexibility services”. And that DSOs “shall procure such services in accordance with transparent, non-discriminatory and market-based procedures unless the regulatory authorities have established that the procurement of such services is not economically efficient or that such procurement would lead to severe market distortions or to higher congestion".

Therefore, for the flexibility procurement, the market-based solution is the one chosen by default, although the regulator may circumstantially choose other solutions for efficiency reasons.

Following the line of the above-mentioned Article 32, different scenarios are proposed in which other non-market-based solutions can be used to access flexible resources and make more efficient use of the network, although it again emphasizes that the market solution is the preferred option.

This work about "Flexibility in active distribution systems" aims to address the following items:

- How DSOs can evaluate network hosting capacity and the value of flexibilities
- Possible structure of markets relevant to flexibilities provided by DER (Distributed Generation Storage Systems and Active Demand) to DSOs and TSOs
- Possible options for information exchange at the different timescales among DER and System Operators (DSOs and TSOs, for the definition of the set of flexibility offers to select and for service activation
- Possible options for some key items to be included in contractual agreements (rights and obligations of parties, duration, penalties in case of failure to deliver the service, performance level evaluation and control, …)
- What the need and the design of data platforms managed by DSOs to enable flexibility are
- Which distribution network tariff structures are most appropriate to allow the development of flexibilities
- Which regulatory approaches encourage DSOs innovation and flexibility.

This report summarizes the work carried out by the CIRED working group, addressing the topics proposed by the Technical Committee.

Usage and value of flexibility

Focus of this section

This section focuses on the evaluation of possible usages and values of flexibilities. It also considers the effects of flexibility on the hosting capacity of a distribution grid. Flexibility services will contribute to balance supply and demand, manage congestions in transmission and distribution networks, control reactive power, regulate voltage and shave peaks. The focus in the working group is put onto flexibility of active power (that means particularly balancing, peak shaving and congestions management). Flexible provision of reactive power and other ancillary services are not the focus of this report.

Sources of flexibility

Flexibility in the sense of the "ability of the power system to manage changes" can have various sources. Even the distribution network itself could be a source of flexibility in this respect. However, in our study we considered only that flexibility that can be provided by the users of the network. The following sources of flexibility are considered:

- Flexible load

    - Can be shifted in time ('controllable load')
    - Can be curtailed (or increased in some cases like power-to-X applications) ('switchable load')
- Flexible generation
    - Can be curtailed
    - Can be shifted in time (especially for conventional generation, consider sector coupling with heat demand and gas availability)
- Flexible storage
    - Can act as flexible load or as flexible generation.

For completeness, though not considered in this report, external grid connections can be understood as sources of flexibility, too.

All of these flexibilities can act in an energy system in a similar way. As from a systems point of view the operation 'reducing a load' has the same effect as 'increasing a generation' all of these sources of flexibility can be modelled similarly taking some special characteristics of each of them into consideration (like probabilistic availability of renewable generation or limited storage capacity). In addition to previous flexibility types, there are discussions of flexibility related to the reliability of supply. In this type of flexibility, DSO can agree with customers about lower reliability expectations (in major storms) and this way avoid unnecessary investments in rural areas where risk of customer loss is high (immigration from countryside to urban areas). This case is discussed in the case study later in the report.

Usage scenarios

Flexibilities can be used in different scenarios. Depending on the control instance they can be divided into the following approaches:

Stochastic approach

> This is the way that unmanaged loads and small generators are handled currently. They are used solely according to the demand of the customer. There is no dependence on prices at energy markets or congestions in the grids. There is no outside control instance. Flexibilities are unmanaged and thus unexplored, as if they were non-flexible loads. They show a stochastic behaviour. Tools of the probability theory (e.g. diversity factor) can be used to estimate the total load in a given area at a certain instant.

Centralized approach

> Flexibilities are controlled by the price signal of the market they take part. These markets usually are global markets (at least within one control zone). They can be named as zonal markets. Anyone can bid on the market no matter where he is located. There are markets for energy, balancing power and other global services. Therefore, all flexibilities in this zonal market operate in a synchronized way. As grid restrictions usually are neglected (grid as 'copper plate') such an operation causes high peaks and therefore can lead to contingencies.

Decentralized approach (Localized)

> The flexibility is needed at a certain location in the energy network. Only participants that are situated in that location can take part in the market. These are markets for congestion management, redispatch, reactive power and other local services.

> Flexibilities are controlled by the responsible system operator (TSO or DSO) in such a way that contingencies or the violation of other grid restrictions are avoided and network elements are utilized in the best way. In general, the load curve is levelled. This control strategy operates with a local focus.

We decided to use the terms “centralized” and “decentralized” approach to distinguish if the usage of the flexibility is determined by a central price signal or if it is determined by local requirements like congestions, which also can be expressed by a price signal but there is the additional restriction that the flexibility needs to be at a certain location in the network to bid at the market. In literature for this distinction also other terms are used. The “centralized approach” is also called “global market” or “market-oriented approach” while the “decentralized approach” is also called “local market” or “network-oriented approach”. We avoided these terms because they are not unique; “local market” sometimes refers to regional peer-to-peer-markets and “market oriented” in the sense that the use of the flexibility is determined by a market is valid also for the “decentralized” approach.

Usually the demands of the centralized approach and the decentralized approach cannot be fulfilled both at the same time. As there is one price signal for all flexibilities in the centralized approach, it leads to maximum synchronisation as all flexibilities react on this same price signal. To avoid congestions a minimal synchronisation is required to level out the loading best.

A possible compromise can be to operate the flexibilities generally oriented according to the centralized approach. Only if grid restrictions are in danger to be violated the use of the flexibilities is limited by the network operator. In typical network structures this is a reasonable strategy as most of the time the network has sufficient capacity to allow an operation according to a centralized approach. Only in few instances, when the network loading reaches its limits the network operator has to interfere into the operation of the centralized approach. For these cases the decentralized approach has to override the centralized approach to ensure system stability. In emergency cases the network operator needs to control flexibilities directly without considering market rules to avoid a blackout. This right is essential for a stable system operation but is not the focus of this report as it is seen as a last resort and not a usual operation.

Such a strategy can be the base of a ‘grid traffic light’ concept. In such a concept for each network segment the state is described by a traffic light. During green light no limit is in danger to be violated. Every stakeholder can freely operate. During yellow light there are some operational restrictions. Operation can adapt to these restrictions based on market-based operations (e.g. use of flexibility in decentralized approach, redispatch). During red light the network state is in danger. Based on the priority rule ‘local network stability is more important than global system stability’ (because if the local network section collapses the units connected to this network section cannot contribute to the global system stability) the distribution network operator can control the flexibilities to keep the network in an operational state without having to consider market restrictions.

Centralized approach: usage and value from a system operator’s point of view (TSO and DSO).

In this section possible usages of flexibilities from a system operator’s point of view are discussed. Here the main focus is on balancing the power within a given control zone. This includes the participation of flexibilities in energy markets at different time scales (from primary control up to day ahead market). Network requirements are neglected. The network is considered to be a ‘copper plate’.

In such an approach the following values can be generated from flexibilities:

- **Optimal power purchase**
  Loads are increased as much as possible during time intervals with lowest prices, generation is increased as much as possible during time intervals with highest prices. Such an operational strategy leads to a synchronisation of the use of flexibilities as all react on the same price signal. It allows to make use of daily price spreads. Inherently it might impact on the use of renewable energies as usually prices are low (or even negative) during a high availability of renewable sources. It could be questioned whether this case is part of the flexibility toolbox, but the integration of the different markets leads us to consider it at this point.
- **Balancing power**
  Flexibilities are used to provide frequency containment or frequency restoration reserve to the system. In this case frequency is the reference variable that synchronises the flexibilities taking part in this market.
- **Self-consumption of power**
  Flexibilities are used to maximise the use of self-generated power. The profit is generated by the difference of power consumed from the public network (containing generation cost, network fees, taxes, allocated costs) and power consumed from the own generation (containing generation cost). In systems where most of the power is generated from renewable sources this strategy usually will lead to a levelling of the loading as flexibilities aim to compensate load peaks with generation peaks. If the flexibility is provided by storages high generation gradients can occur when they reach their capacity limit. One can argue, if this is a 'market-oriented approach' as it does not use a 'market' but exploits tax regulation. But it is not 'network-oriented' and does influence the market price.
- **Balancing and congestion management at higher voltage level**
  Flexibilities are used to solve balancing (day ahead market) or congestion management problems at high voltage levels. For lower voltage level this appears as a centralized approach as within the supply area there is no local orientation.

Decentralized approach: usage and value from a system operator's point of view (TSO and DSO).

In this section possible usages of flexibilities from a network operator's point of view are discussed. Here the main focus is on avoiding the **violation of grid restrictions or limits** like contingencies and over-/undervoltages. This includes the right and ability to restrict operations caused by the centralized approach if necessary.

Hosting capacity is remarkable among the values of flexibility for the whole system, in order to accelerate the energy transition by enabling new renewable generation to connect to the grid. As mentioned above in the introduction, this value is specifically expected to be analysed by the workgroup. The term 'hosting capacity' only makes sense in the context of a decentralized approach all topics regarding this term are integrated into this section. For ways to determine the hosting capacity see the section below.

For this study the term 'hosting capacity' is defined as following: 'Amount of load or generation that can be connected to a network without violating or endangering any limits.'

From a network operators' point of view only the power flow at the connection point of a customer with the network is of interest. Although often there is a mixture of conventional non-flexible loads, flexible loads, generation units and storages included in the customers network, the sum of all these devices can be considered either as a 'load' or a 'generation' according to the following definitions:

- Load: drawn power at a certain moment
  - **Flexible load** can be moved in time – can be connected in any size if it does not increase the total load (It has to be considered that the thermal rating of the equipment for network operators usually assumes a load curve with a load factor of 0.7. That means that there has to be sufficient time for the equipment to cool down even if flexible loads are moved in a way that the load curve is flattened.)
  - **Non-flexible load** cannot be curtailed. As it is the main task of an electrical power system to supply customer loads, the curtailment of non-flexible loads usually is punished by the regulator (e.g. financially via a 'quality element' in the regulation). Therefore, the network operator would curtail such loads only in emergency situations – which are not the focus of this report.
- Generation: injected power at a certain moment
  - **Flexible generation** can be moved in time – can be connected in any size if it does not increase the total generation
  - Generation can be curtailed.

Maximum loading of a network is determined by the interplay between load and generation (higher generation can be connected if it can be ensured that during generation peak there is a certain minimum load available and vice versa).

Considering grid restrictions, the limits can be described as follows:

Limits:

- Maximum current loading of lines, transformers and other equipment.
  Usually limitation in urban and industrial networks.
  For some equipment like transformers and cables overloading for a short period of time is permitted. For other equipment like overhead lines and switchgear this is not possible (or only for very short time scales, e.g. during switching operations to handle (n-1)-situations).
  Dynamic rating of overhead lines can gain flexibility for the network operation.
  Before the application of this method, the effects of dynamic equipment rating have to be examined. In some cases, especially in transmission networks and/or during (n-1)-situations, the stability limit might be lower than the thermal limit of lines with dynamic rating.
  Dynamic equipment rating also requires the observance of the time dependency as the higher loading often is allowed only for a limited time.
  Although dynamic line rating is a tool of flexibility in the hand of a grid operator, the focus of this report was put on providing flexibility with the intelligent control of active power from loads and generation.

- Maximum, minimum voltages.
  Depends not only on the size of the load/generation but also on the location. Usually limitation in rural networks. There, the lengths of the lines are large and there is sufficient space for large PV plants or wind parks. In cities space is more limited. Large generation units within cities are usually combined heat and power plants.
- Maximum harmonics.
  Usually in rural networks with high portion of inverters. Harmonics caused by generation and load can add up, even if active power subtracts.

- Voltage stability limit.
  Usually in rural networks. For loads especially if high motor driven load. Investigations shows that under certain circumstances the nose curves reach the stability limit in the voltage range of 100 %, especially in networks with high reactive power flows.
- Voltage angle stability limit.
  This is usually a limit only in transmission networks. In some cases, especially in (n-1)-situations the voltage angle stability limit can be reached.

In a decentralized approach the following **values** can be generated from flexibilities (see the table below for a detailed presentation of all identified values of flexibilities including their risks and challenges):

- **Network reinforcement or extension avoided**
  Cost of network reinforcement or extension and cost that incur until the network is extended. Also valid for easier integration of charging of electric vehicles. More vehicles can be faster integrated in existing networks. Less political problems will be caused due to network reinforcement or extension. Also, valid if the network reinforcement or extension is required due to stability problems and not due to voltage or current problems.
  The mentioned value only can be generated if it is possible to bind the flexibility over a long time as a reliable source (long time means decades).
- **Network reinforcement or extension delayed**
  The value is given by the present value of delay effect of reinforcement or extension. Easier and faster integration of electric vehicles and other loads will be possible.
- **Payment of curtailed generation**
  Cost for redispatch measures to keep the balance and to compensate the generation operators for the lost income.
- **Penalties** for reduced reliability, if load is curtailed or disconnected.
  Reduction of supply interruptions if load can be reduced in case of a fault and such some interruptions could be avoided. Valid only in meshed grids (possibly in overloaded rings but that should count for 'network reinforcement or extension delayed').
  To determine the value of the flexibility a probabilistic reliability investigation is necessary.
  For the network operator the value is the penalty for reduced reliability. For the customers the value is determined by the cost of lost load which usually is much higher than the penalty.
- Cost of **losses**
  Loss reduction due to a more even load could be possible. Additionally, with flexible active power reactive power flows can be reduced.
- **Redispatch** cost
  Redispatch in this or a higher network level is avoided due to the use of the flexibility.

The next chart explains briefly the cases of flexibility values:

Use case	Criteria	Explanation
Deferred Grid reinforcement or extension	Explanation	If load or generation would require a network reinforcement or extension, the flexibility is used to flatten the sum of load and generation curve such that overloading is avoided. Cost of network reinforcement or extension and cost that incur until the network is extended are avoided. This can be also valid for easier integration of charging of electric vehicles. More vehicles can be faster integrated in existing networks. Less political problems due to network reinforcement or extension. Also valid if the network reinforcement or extension is required due to stability problems and not due to voltage or current problems.
	Beneficiary	Network operator
	Source of value	Saved network reinforcement or extension cost
	Typical amount of value	Estimations for Germany and Spain: 60 000 Euro/km cable (MV, LV), 40 000 Euro/km overhead line (MV, LV), 6 000 Euro per transformer MV/LV, 20 000 Euro/ring main unit.
	Applications, Examples, Research projects from literature	Existing flexibility products in the UK as Sustain or Secure could replace new investments.
	Influence on hosting capacity	Increase
	Challenges, Risks	Flexibility must be reliably available during the full lifetime of the network equipment; that means for more than 50 years. If not, network reinforcement or extension is still needed.
Deferred Network reinforcement or extension	Explanation	Flexibility is used to relieve the load on the network. Therefore, network reinforcement or extension can be delayed until there is a stronger load/generation growth. Present value of delay effect of reinforcement or extension.
	Beneficiary	Network operator
	Source of value	Present value of delay effect of reinforcement or extension.
	Typical amount of value	Difference of net present value of delayed network reinforcement or extension. This is more interesting when interest rates are high.
	Applications, Examples, Research projects from literature	Existing flexibility products in the UK as Sustain or Secure could allow new investments to be delayed.
	Influence on hosting capacity	Increase
	Challenges, Risks	If network reinforcement or extension is required due to wind power plants or load, high "storage capacity" of flexibilities is required

Use case	**Criteria**	**Explanation**
Deferred Network reinforcement or extension (2)	Explanation	Urgent loads can be integrated without having to wait until the network reinforcement or extension is realised, including all the time-consuming approval processes. Easier and faster integration of electric vehicles and other loads possible.
	Beneficiary	Owner of load, e-car; politics
	Source of value	New contracts being awarded earlier in time. As in delaying network reinforcement, value comes from the difference of net present value: earlier cashflow with later investment
	Typical amount of value	Reinforcements or new reinforcement or extensions could have various budgets.
	Applications, Examples, Research projects from literature	For electric vehicles see for instance paper 0196 from CIRED 2019. ANM solutions to allow flexible connections are being tested in Spain and the UK.
	Influence on hosting capacity	Increase
	Challenges, Risks	Very useful strategy, if flexible loads are the source of the problem (e.g. electric vehicles)
Curtailment of generation avoided	Explanation	Flexibility is used to synchronise with generation such that curtailment of generation due to overloading of network is avoided.
	Beneficiary	Network operator
	Source of value	Cost for redispatch measures to keep the balance and to compensate the generation operators for the lost income.
	Typical amount of value	Redispatching costs could be a reference.
	Applications, Examples, Research projects from literature	Nice Grid (FR), Grid4EU (EU, FP7)
	Influence on hosting capacity	Increase
	Challenges, Risks	No significant challenges but the costs of technology to monitor and supervising resources.
Reduced outage times	Explanation	Reduction of supply interruptions if load can be reduced in case of a fault and such some interruptions could be avoided. Valid only in meshed grids (possibly in overloaded rings but that should count for 'network reinforcement or extension delayed'). To evaluate the value of this improvement a probability analysis is necessary.
	Beneficiary	Network operator
	Source of value	Cost of quality element in regulation
	Typical amount of value	Germany 2020: 0.22 Euro/(customer*min) In Spain it depends on the tariff, 0.22 €/kWh for a regular LV tariff.

Use case	Criteria	Explanation
	Applications, Examples, Research projects from literature	Nice Grid (FR), Grid4EU (EU, FP7), Dynamic and Restore products in the UK.
	Influence on hosting capacity	Increase
	Challenges, Risks	OPEX remuneration of DSOs
Improvement of reliability of supply (2)	Explanation	Reduction of supply interruptions if load can be reduced in case of a fault and such some interruptions could be avoided. Valid only in meshed grids (possibly in overloaded rings but that should count for ‘network reinforcement or extension delayed’). To evaluate the value of this improvement a probability analysis is necessary.
	Beneficiary	Customer
	Source of value	Improved reliability of supply (benefit for customer usually much higher than quality element)
	Typical amount of value	It will depend on the customer´s process.
	Applications, Examples, Research projects from literature	Many customers need to improve their facilities with generators or Uninterruptible Power Supply (UPS) that could be avoided.
	Influence on hosting capacity	Increase
	Challenges, Risks	Reliability of the different solutions are not comparable.
Cost of losses	Explanation	Reduction due to a more even load could be possible. Additionally, with flexible active power reactive power flows can be reduced. This is improved by the fact that losses goes with the square of the power.
	Beneficiary	Network operator
	Source of value	Energy cost of losses
	Typical amount of value	For the DSO depend on regulation. Losses for the system could reach 40 – 50 Euro/MWh. It also depends on the voltage level, being from 14% to 1,4% of the energy.
	Applications, Examples, Research projects from literature	No significant references but calculation methods in paper 0161 of CIRED 2020 Workshop
	Influence on hosting capacity	Neutral
	Challenges, Risks	Regulated incentives for DSO.
Optimal power purchase	Explanation	Savings in cost of electrical energy due to optimised power purchase. The flexibility is moved such that the purchase of power during minimum prices is maximised.
	Beneficiary	Electricity retailer

Use case	**Criteria**	**Explanation**
	Source of value	Difference between 'normal' electricity prices and minimum electricity prices
	Typical amount of value	Price differences of up to 50 Euro/MWh during one day not unusual
	Applications, Examples, Research projects from literature	SERVING, SENSIBLE (H2020)
	Influence on hosting capacity	Decrease
	Challenges, Risks	Grid limitations must be considered.
Redispatch cost	Explanation	If redispatch in this or a higher network level is avoided due to the use of the flexibility
	Beneficiary	Network operator
	Source of value	Redispatch price
	Typical amount of value	Consider redispatch price as a limit reference.
	Applications, Examples, Research projects from literature	Regions (flexibility from renewable plants, ERA Net Smart grid Plus)
	Influence on hosting capacity	Increase
	Challenges, Risks	TSO-DSO Coordination
Control power	Explanation	Flexibility is used to provide stability to the market
	Beneficiary	Offeror of control power
	Source of value	Price of control power, especially frequency containment reserve and frequency restoration reserve (primary, secondary control power)
	Typical amount of value	Germany: FCR on average 200 Euro/MW, FRR negative app. 60 Euro/MW, 60 Euro/MWh, positive app. 15 Euro/MW, 70 Euro/MWh (www.regelleistung.net). In Spain FRR 55€/MWh positive, 40 €/MWh negative (www.ree.es)
	Applications, Examples, Research projects from literature	REstable (tested at transmission level, flexibility from renewable plants, ERA Net Smart energy systems)
	Influence on hosting capacity	Decrease
	Challenges, Risks	Time response of decentralized system services
Peak load reduction	Explanation	Large customers can use flexibility to reduce their peak load – that means reducing the network technical losses and fees
	Beneficiary	Large customers
	Source of value	capacity part of network fees

Use case	Criteria	Explanation
	Typical amount of value	Germany: network level M: ≈21 Euro/kW<2500h, ≈120 Euro/kW>2500h; network level N (low voltage): ≈24 Euro/kW<2500h, ≈130 Euro/kW>2500h France, ENEDIS 2020, from 1,9 to 11,2 €/kWh, according to the length of the peak infringement. This service does not exist in Spain.
	Applications, Examples, Research projects from literature	Nice Grid (FR), Grid4EU (EU FP7)
	Influence on hosting capacity	Increase
	Challenges, Risks	Customer investment must be affordable.
Load balancing during network restoration	Explanation	Flexibilities can be helpful to balance load and generation during network restoration, especially with a high portion of generation coming from renewable sources, but value is difficult to determine as use case should not happen
	Beneficiary	System operator
	Source of value	Restoration capacities considered as a service could be remunerated.
	Typical amount of value	In Germany 2019, imbalance prices were in average -44 and +66 Eur/MWh respectively for negative and positive imbalances. Near 60€/MWh in Spain
	Applications, Examples, Research projects from literature	Black start is considered as a flexibility service in the literature, but no real applications have been found.
	Influence on hosting capacity	Neutral
	Challenges, Risks	Communication to flexibilities during black out necessary. Restoration service remuneration.
Improve stability of cellular structures	Explanation	Flexibilities can be used in cellular network structures to improve the stability within a certain cell and to realise determined power schedules at the border of the cell
	Beneficiary	Cell system operator
	Source of value	Overprice paid by the cell users to maintain the cell system.
	Typical amount of value	Depends on the customers´ stability needs.
	Applications, Examples, Research projects from literature	No real applications or examples found.
	Influence on hosting capacity	Neutral
	Challenges, Risks	currently only basic research, no markets/price structures exist

Use case	Criteria	Explanation
Promote energy transition	Explanation	Within a private network the flexibility (of load) is used to maximise the consumption of the individually generated energy.
	Beneficiary	House owner
	Source of value	Difference between price of power from public network (containing network fees, taxes, allocated costs) and from own generator (containing only cost of generation)
	Typical amount of value	Germany: app. 23 cent/kWh Spain: 10 cent/kWh
	Applications, Examples, Research projects from literature	Self-consumption is being incentivized across Europe by regulators.
	Influence on hosting capacity	Increase
	Challenges, Risks	Technology cost. The so caused change of the load and generation profile might lead to additional investments in the grid infrastructure.
Controlled Island operation	Explanation	The flexibility is used to balance power and provide control power in a controlled island operation
	Beneficiary	System operator
	Source of value	Saving in other elements to control the load balance like storages
	Typical amount of value	Value of Lost Load must be considered.
	Applications, Examples, Research projects from literature	CoordiNet project
	Influence on hosting capacity	Increase
	Challenges, Risks	Suitable only in small islands

Table 1 Flexibility values

Determination of hosting capacity

To avoid confusion a short explanation of the term ‘hosting capacity’ as it is used within this report shall be given in the following section. The determination of the hosting capacity can be a difficult task, which is subject of many investigations which are not in the focus of this working group. Definition of hosting capacity, see above: “Amount of load or generation that can be connected to a network without violating or endangering any operational limits.”

Determination is simple for a given location and for a real time situation (in general the approach is fit-and-forget, the network capacity is fixed in worst case conditions for the network): If the network state (voltages, power flows) is known the load or generation at a certain location can be increased until the load flow calculation finds a violation of one limit – the then found value for load or generation is the according hosting capacity for this location in the network under the current state. (Calculation is more difficult, if limit is given by harmonics or power quality).

Usually a more general value is required. One value for the total network would be perfect. If the extent of the network is small often location can be neglected as voltages are similar in the whole network and only current is the limiting parameter.

But, even then, there are different ways to determine a value for the hosting capacity.

The **deterministic way** would be to add up all loads (or generation). The difference to the rating of the equipment would then be the hosting capacity. As this approach neglects the diversity effect it will drastically underestimate the hosting capacity.

Applying diversity factors to load and generation will increase the hosting capacity. Now the calculation will not be deterministic but **probabilistic**. Therefore, there is a certain probability that the calculated hosting capacity is not available. But since for the calculations with diversity factors usually peak loads are used, the results tend to be on the safe side. That means in most of the cases the hosting capacity is underestimated.

With the goal of a more market-oriented behaviour of the customers (considering active power markets as well as time variable network tariffs and the market based procurement of ancillary services) it has to be evaluated if the concept of the 'diversity factor' still is a valid concept to estimate the peak load. The calculation of the diversity factor assumes a somewhat stochastic behaviour of the customers. If the behaviour changes from application oriented stochastical operation (as of today) to a price-signal oriented operation a synchronisation of loads probably will be observed. This leads to higher loads than calculated based on the 'diversity factor' approach.

Time series calculations can consider that usually there are certain patterns in the load curves or generation curves. Therefore, the hosting capacity will vary over time. If the pattern of the load/generation that should be connected is known this will increase the calculated hosting capacity compared to the calculation based on diversity factors.

With probabilistic simulations, the 'real' value of hosting capacity can be approached.

The lesser the safety margins for the calculation of the hosting capacity are, the higher is the probability that during operation a violation of any limit will occur. If there is the possibility to measure/estimate the network state online and if there are flexibilities in the network which can be controlled online these violations can be avoided. Such a regime allows the use of the highest hosting capacity values (these with the least safety margins).

Market structures

Objectives and Scope.

Flexibilities can be offered at markets or the control can be carried out via other ways. The Council of European Energy Regulators released a paper in July 2020 (CEER, 2020) where the different ways of accessing flexibility are described, and which are summarized in the following figure:

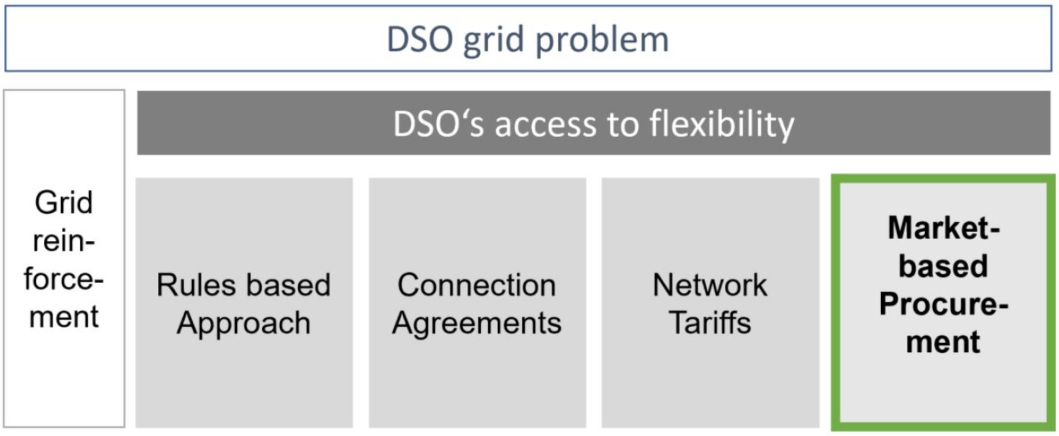


Figure 1 Options of DSO access to flexibility with an emphasis on market-based procurement (CEER, 2020)

Different scenarios are proposed in which other non-market-based solutions can be used to access flexible resources and make more efficient use of the network, although it again emphasizes that the market solution is the preferred option. In this section, all the conditioning factors for the design of the market and the services to be traded in them will be reviewed.

The different possible structures of resources (Distributed Generation, Storage Systems and Active Demand) are relevant to determine which flexibilities provided by DERs are more useful for DSOs or TSOs. Time response, voltage level, availability, quantity and quality of response need to be explored.

The influence of aggregators on market design is important to note in this paper. Indeed, a market where the aggregator assumes the role of flexibility provider assuming the risk and responsibility of delivering a response is not the same as a market where the responsibility is exclusive to the prosumer and the aggregator is limited to aggregation. In any case, the aggregation topic has its section below, so this issue will not be addressed in this section.

TSO/DSO Coordination Schemes.

A coordination scheme is defined as “the relation between TSO and DSO, defining the roles and responsibilities of each system operator, when procuring and using services provided by the distribution grid”. Following this definition, it becomes clear that a coordination scheme is highlighting two important ingredients for increased coordination: (i) the assignment of **responsibilities** and the interaction between system operators, (ii) the focus on specific **market phases** (e.g. pre-qualification, procurement) and how these market phases should be organized through a proper market design.

The SmartNet project (SmartNet Project, s.f.) identified five coordination schemes that could enhance interaction between system operators. In this figure, the customers are grouped according to the voltage level. As in some European countries the HV-level is also operated by the DSO, the HV-customers act as the MV costumers in the figure. For these constellations only the customers directly connected to the TSO-network would act as ‘HV-customers’ (being in reality connected to the EHV). So, in a more general view it should be distinguished between customers connected to DSOs and to TSOs. Also, a cascaded structure of DSOs has to be considered. But these topics were not part of the cited research project.

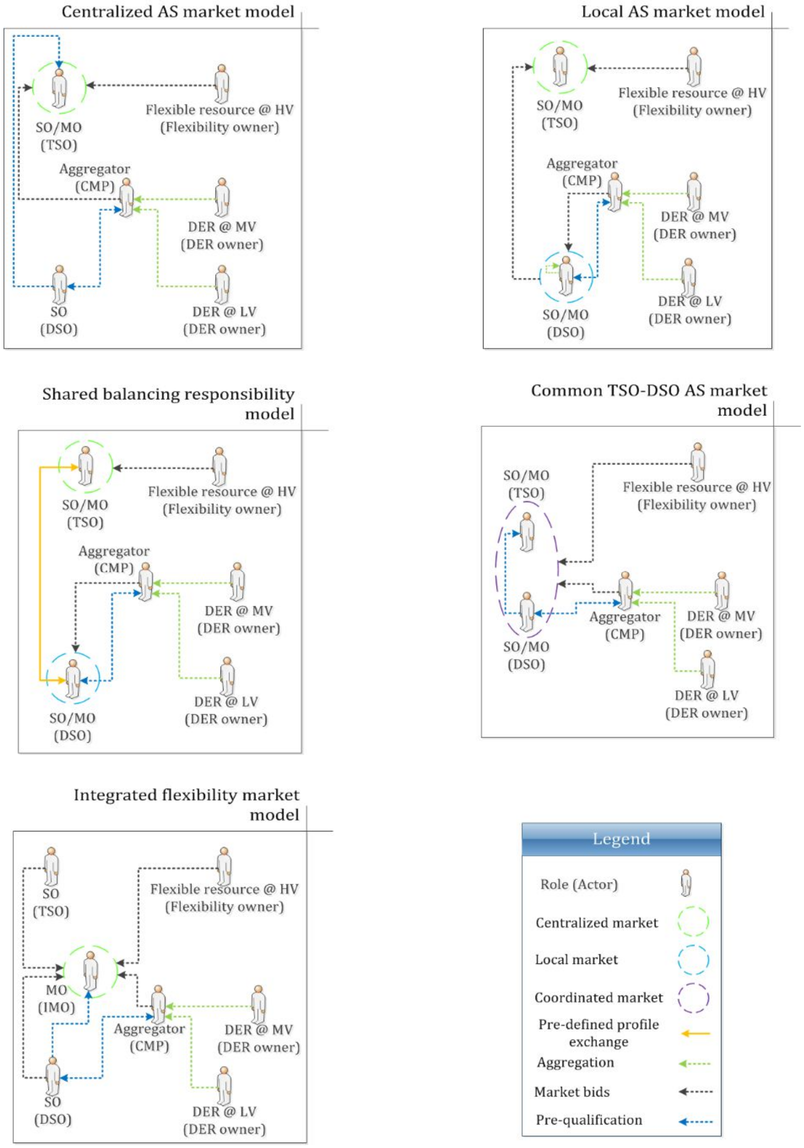


Figure 2: **Smartnet coordination schemes(Gerard et al., 2018)**

Centralized market model – For both resources connected at transmission and at distribution level, there is one centralized, common market for services operated by the system operator. In this scheme the TSO contracts flexibility from DER directly from the DSO grid.

Pros for DSO: None.

Cons for DSO: TSO interferes in DSO operations. DSO grid constraints are not considered. Because all flexibilities react on the same price signal a synchronisation causing higher loading can be expected. The location of flexibilities is out of scope. One could say that it is simpler for FSPs (Flexibility Service Providers), but there are other schemes with the same simplicity.

Local market model – Different markets for DSO and TSO grids. Depending on whether they are connected to the DSO grid or to the TSO grid, FSPs participate in one market or the other.

Pros for DSO: Operates the market. Cleared before TSO market (priority to local flexibility). Better conditions for lower entry barriers. Congestions can be avoided by considering the location of the flexibility.

Cons for DSO: If there are too many small markets, liquidity may be compromised and the risk of market power increases.

Shared balancing responsibility model – This model does not allow resources from the DSO grid to be offered to the TSO grid. Therefore, the DSO is responsible for balancing his own distribution grid according to a pre-defined schedule. The balancing market (redispatch) and the local market are cleared at the same time. This concept also requires the definition of the “new” DSO balancing responsibility, particularly in terms of frequency control. Within the SmartNet project were considered services of Replacement Reserve from 15 min response.

Pros for DSO: FSPs connected to DSO grid only participate in the DSO market. Low entry barriers.

Cons for DSO: Intermediation for balancing services would not be efficient in case of many small markets. Difficulties for real time constraints in TSOs grid. Additional costs are likely as DSOs determine or bill imbalance penalties.

Common TSO-DSO market model – This scheme enables flexible resources connected to both grids. The operation of this market is done by both system operators, with the goal to optimize the outcome of the system as a whole. A single market that does not prioritize TSO nor DSO needs, but the rules of prioritisation must be clear and agreed by all parties. Some European projects are working on this subject, such as CoordiNet.

Pros for DSO: FSPs connected to DSO grid available for both. Optimized costs.

Cons for DSO: Standard products for DSO & TSO may lead to entry barriers for DSO needs solutions. Data sharing needed between SOs may be a con or not.

Integrated flexibility market model – This scheme allows also commercial parties to procure flexibility in a common market. All participants can demand and offer flexibility solutions. The market operator should be an independent market operator to ensure market neutrality.

Pros for DSO: This scheme may provide more liquidity and interactions.

Cons for DSO: The marketplace could cannibalize the solutions for the grid. The point here is who orders needs in the market, not the governance of it. If commercial parties can order services in it, the grid operator needs to check it. SOs would lose control of what is finally delivered in the market. Data sharing also with commercial parties.

The CoordiNet project (CoordiNet Project , s.f.) states that there is not a one-size-fits-all coordination scheme, but a multitude of coordination schemes that propose different solutions to different circumstances. Depending on the categorisation of the need, i.e. the need which is addressed by the provided flexibility, and the potential combination of different needs, a certain coordination scheme could be applicable.

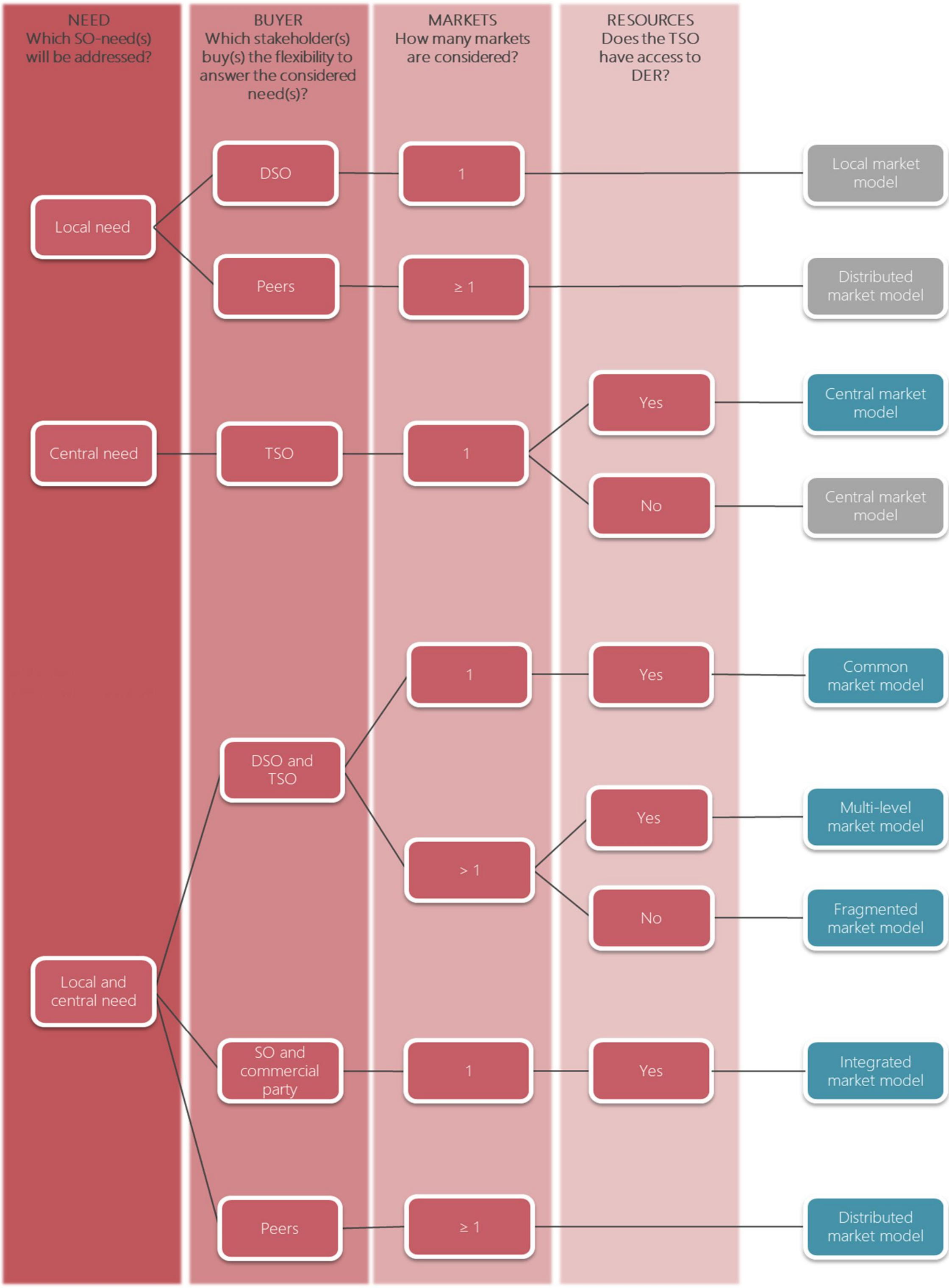


Figure 3 **Categorization structure of coordination schemes considered within the CoordiNet project. Coordination schemes which call for specific market-oriented coordination between TSOs and DSOs are displayed in blue.**

To define the different scenarios, a distinction is made between central and local needs. Central needs refer to the services which can be provided in a control area on a central level regardless local grid necessities, (one interconnected system operated by a single TSO). A local need for flexibility is in fact defined by its location factor. It refers to the services that need to be delivered in a certain location (e.g. congestion management).

The multitude of buyers active on a certain market platform will also engender a different architecture for the coordination between the DSO and TSO. Even other buyers should be considered in order to cover all possibilities. Commercial parties or even peers could take part of the markets. Each of them has their own different role.

A third layer is the number of markets coexisting in a TSO area. If different levels are considered it is supposed that DSO have at least one different market. But there can be different local markets, one for each DSO for example.

And, finally, the accessibility for the TSO to access to DER. This means whether the TSO needs to head to the DSO to access the DERs connected to the DSO grid or whether they can contract them directly.

By a combination of the answers to these questions, seven groups of coordination models are defined. Some of them can be assimilated to those of the Smartnet project, namely the Local Market Model, Central Market Model, Common Market Model, the Integrated Market Model and the Fragmented Market Model (in which we find the shared balancing model). So, within the CoordiNet Project two more models were found considering the four layers:

Multi-Level market model – Somehow this scheme is actually considered in the SmartNet project as long as it is a combination of the Local Market Model and the Central Market Model, enabling a possible coordination between different flexible markets. Therefore, same pros and cons will be considered:

Pros for DSO: Operates the market. Cleared before TSO market (priority to local flexibility). Better conditions for lower entry barriers.

Cons for DSO: FSPs may prefer TSO market if it is more attractive and perhaps do not attend to local market. If there are too many small markets, liquidity may be compromised. Communication and ICT infrastructure would become more extensive as a consequence of having multiple local markets.

Distributed market model – Peers are the sole buyers and providers in the market where peers establish direct (logical) connections to neighbouring peers. So, participants would have more autonomy.

Pros for DSO: This scheme may provide more liquidity and interactions.

Cons for DSO: It may be complex to implement this type of market. The marketplace could jeopardize the solutions for the grid. SOs would need to enable additional control procedures to correct transactions if necessary. Data sharing also with peers.

Other non-market-based alternatives such as bilateral contracts or tariff incentives will be considered, especially for long term needs.

Local Markets

A **local electricity market** is defined as the market in which can or should participate the different entities whose consumption or injection to the grid is located in the distribution networks. These entities, called "Distributed Energy Resources" can be consumers with management capacity, renewable producers, cogenerations, battery installations, hybrid installations (with several of them) and, in general, any installation capable of managing its consumption or injection to the distribution network to which they are connected. Note that the concept differs from the one mentioned for coordination schemes. In this case it is not a coordination scheme, but a type of market. Obviously, when designing local markets, it is necessary to consider the integration of the different markets. In the paper of "Flexibility markets: Q&A with project pioneers"[1] (Tim Schittekatte and Leonardo Meeus, 2019), the integration of flexibility markets with existing markets is being studied, and some pioneering projects (Enera, Piclo, Gopacs and Nodes). This paper also addresses the need for cooperation between TSO and DSO.

The most relevant TSO and DSO associations at European level produced a report called TSO-DSO Report "An Integrated Approach to Active System Management" (E.DSO, ENTSO-E, Eurelectric, Geode, & Cedec). The report lists the advantages and disadvantages of local markets as a separate management option for the TSO and the DSO.

The advantages are:

1) Flexibility to change product requirements and timing congestion management products can be tailored per voltage level specificities without mutual interference.
2) Clear division between the two processes of balancing and congestion management.
3) Separated governance (no agreement is needed between TSO and DSOs).
4) Low entry barriers for small local market parties (aggregators) and technical solutions.
5) 5) Clear congestion management costs.

The disadvantages are:

1) Probably less liquidity in small markets, and probably higher prices: market parties can only participate in the TSO or DSO congestion management market. Participation for aggregators on TSO and other DSO congestion markets is more difficult: participating in the TSO market for congestion management results in other product definitions and interfacing with other IT systems.
2) Market fragmentation: when DSOs build several different local markets that are not interoperable, flexibility resources may be 'locked' in local markets (especially if long-term availability products are agreed), and therefore not available for other market services.
3) Coordination between TSO and DSO is more difficult: coordination between TSO and DSO requires interaction between two Merit Order Lists. Discrepancies such as possible double activation of the same asset bidding in two separated market processes can occur.
4) Possibly extra interfaces (e. g.: IT) for existing market parties (because of different bidding systems).

In addition to the disadvantages reported in the associations' report, other disadvantages could be taken into account concerning the effect that local market flexibility services would have on balance sheet markets. And how a local situation, such as a new customer connection, can affect markets. This certainly opens up a wide range of possibilities that are difficult to predict.

Timeframes

Market clearing can be performed via discrete auctions or a continuous market. If auctions are very frequent, we can have the same effect as in the continuous market. Continuous markets are more appropriate for situations of high liquidity and high competitiveness. In this way, we can obtain greater market efficiency.

[1] EUI Working Papers RSCAS 2019/39 Robert Schuman Centre for Advanced Studies - Florence School of Regulation

Therefore, for global markets (Central, Common, Integrated, Distributed), not restricted to their location, it makes sense to have continuous or often discrete markets. This is the case of the energy market where we have prices every hour or every 15 minutes.

In the flexibility markets, attending to the services required by the DSO, which are preferably local (Fragmented, Local), we must therefore attend to these market liquidity criteria to see the usefulness of going to continuous markets. In these cases, auctions can be held more or less frequently depending on the service and the number of bidders.

However, it is true that needs do not have to be predictable. Therefore, in the case of local markets, availability prices may take centre stage. Thus, other parameters such as the obligation to be available, preparation and recovery times, or other technical parameters may become important when activating the service. Also, adjustments to long-term needs could be made in the short term.

On the other hand, computation needs for continuous markets are bigger and the risk of gaming is higher. The coordination scheme may also interfere in the market configuration as long as coordination for DSO and TSO needs are required (e.g. Common Market Model). A previous agreement is required about if they are cleared in the same time, or DSO needs have priority or not. In normal conditions, Local requirements should be cleared first, in order to enable all the possibilities in the market.

Services and products – overview of research projects.

Flexibility can offer us solutions in two different but closely related areas. On the one hand, in relation to the energy balance, in the decentralization of electricity generation. The TSOs not only face the challenge of managing electricity systems with a pulverized generation and low inertia, but also the need to find service providers that maintain the reliability of the system. DSOs, on the other hand, have the challenge of maintaining the quality and reliability standards of the networks in a system that is increasingly moving away from the distribution function and becoming an energy exchange space, as it is intertwined with the generation function and whose consumers will have more different and more unpredictable profiles.

According to the (USEF, 2018) "Overview of applications of flexibility services" by USEF, the possible applications for DSO are reflected in the following table:

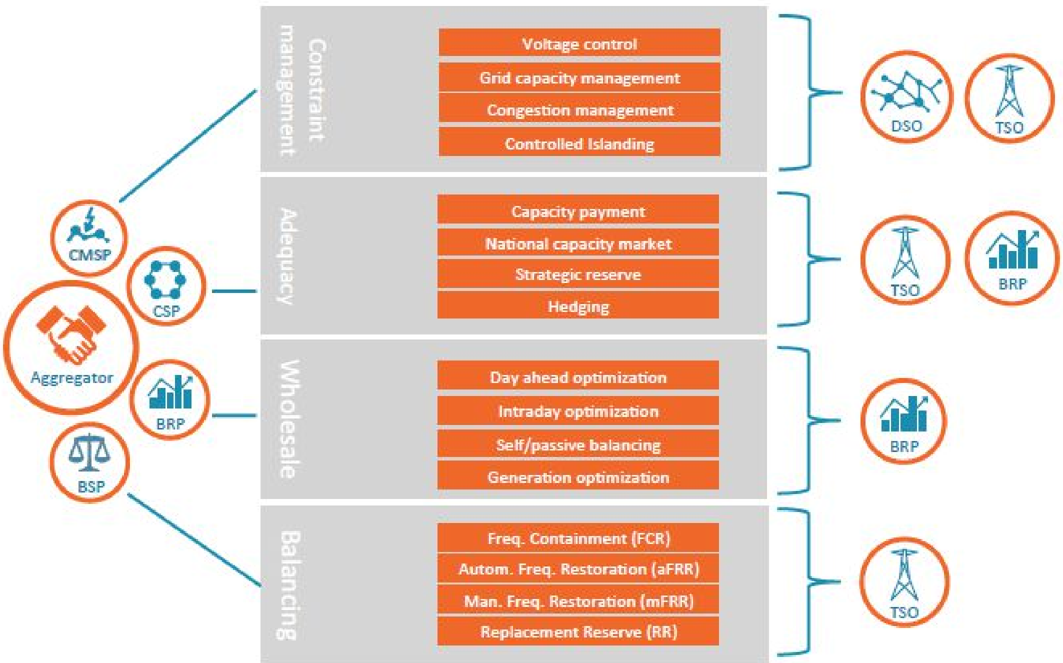


Figure 4 Demand side flexibility services for each stakeholder https://www.usef.energy/app/uploads/2018/11/USEF-White-paper-Flexibility-Value-Chain-2018-version-1.0_Oct18.pdf

Within the range of possibilities offered by the flexibility of a DSO, we will pay special attention to the "Grid capacity management" section for several reasons. Firstly, because voltage control in a radially operated network is usually due to the capacity of the asset. The second reason is that what is called "Congestion Management" is a version that only differs from "Grid capacity management" in the possibility of making predictions. And finally, controlled islanding is applicable to small islands that may arise, after all, due to the inability of the network to keep that piece of network connected to the rest, but advanced self-healing schemes can be applied to wider network areas (e.g., multiple LV grids connected to the same MV grid) in situations with adverse weather regimes. It is true that in the case of real islands it has another use, but these cases, although also local, are a natural situation that we could consider together with the responsibility of the balance sheet.

In the following table, based on the experience from the Horizon 2020 EU Projects SENSIBLE and InteGrid, we present a more detailed list of flexibility use cases and corresponding technical, market and regulatory requirements.

It is important to underline that the use of flexibility from DER is being demonstrated in different projects, e.g. islanding operation of multiple LV microgrids in SENSIBLE project (Santos et al., 2019) or predictive (operational management) pre-book of flexibility from flexible DER located in the MV grid in the framework of the InteGrid project (Bessa, 2017), and the quantification of network resilience is becoming an active area of research (Stankovic, 2018). In particular, the InteGrid project assumed the concept of flexibility tenders and non-firm connection contracts for flexibility activation by the DSO, instead of local flexibility markets with potential low liquidity. The interaction with the DSO and flexibility operators was performed via a grid and market hub (gm-hub) and predictive traffic light system that conducts a technical validation of the flexibility to be activated by the TSO and from resources connected to the MV grid (Matos, 2018).

Finally, the direct provision of flexibility-based services between TSO and DSO was also studied and demonstrated by the FP7 evolvDSO and Horizon 2020 EU-SysFlex project from two perspectives:

- **Provision of information about flexibility** available in the distribution grid
  a) *Steady-state behaviour*: active and reactive power flexibility maps, created and updated by the DSO, that provide information about feasible operating points per primary substation (Silva, 2018). With this information, the TSO can understand the full range of P and Q aggregated flexibility in each distribution grid.
  b) *Transient behaviour*: Aggregated dynamic model for active distribution networks (at the TSO-DSO interface), considering a heterogeneous fleet of generation technologies alongside their expected behaviour when considering the latest European grid codes requirements in terms of voltage support services (Fulgêncio, 2020).
- **Control of active and reactive power in the TSO-DSO interface**, e.g. allowing the DSO to coordinate and supply reactive power services to the TSO (Fonseca, 2016). This use case fits the current regulatory framework in Portugal and France, with penalties as a function of tan φ (Soares, 2020).

Potential Service	Flexibility Type	Control Type	Market/regulatory requirements
Congestion management (short-term)	↑↓ PQ control from DERs, load and storage and DSO resources (OLTC, capacitor banks)	Centralized or hierarchical (Local markets)	• Liquidity is very important to guarantee since most problems are local • The amount of traded flexibility is generally at the kW scale, so interaction with the TSO should not be a fundamental requirement • Consider the possibility of a cap price for flexibility (defined by the planning department) for each network area • A "capacity" price for available flexibility might be necessary, together with an activation price
Voltage control (short-term)	↑↓ PQ control from DERs, load and storage and DSO resources (OLTC, capacitor banks, FACTS) (↑↓ P when R>>X, e.g. LV grid)	Hierarchical (including local control like voltage droop control in power electronic converters)	
Investment deferral in network planning (long-term congestion)	↓ P control from DERs, load and ↑↓ storage	Centralized or hierarchical	• Flexibility tender with standardized products, e.g. availability and activation price, power, number of hours per activation, minimum notification time, etc. • Non-firm connection contracts • Coordination with the TSO is required
Phase balancing	↑↓ PQ control from DERs, load EV and storage. Note: in Europe is mainly relevant for LV grids	Centralized at MV/LV substation, including local control (e.g., droop)	• Should be a regulated activity, i.e. DSO using its own resources (OLTC, FACTS) and prosumers participating with internal phase balancing • Coordination with the TSO not needed
Extend assets lifetime	↓ P control from DERs, load and storage	Centralized	• Preventive asset management strategy. Defined by planning department and recognized in the regulatory framework as avoided costs
Planned and unplanned maintenance operations	↓ P control from DERs and load	Centralized	• Non-firm connection contracts and flexibility tenders for temporary maintenance actions • Coordination with the TSO is required
Resilience in adverse weather events and hazards (self-healing, intentional islanding)	↑↓ PQ control from DERs, load and (mobile) storage Network reconfiguration (or optimisation), which, in some scenarios, might be a cheaper solution that P and Q flexibility	Centralized and local (emergency operation)	• Flexibility tender and non-firm connection contracts for load curtailment under emergency • Interaction with TSO is essential since this will contribute to maximize overall security of supply and system resilience • DSO might own (mobile) storage to operate during these emergency scenarios or network reconfiguration

Table 2 – List of technical issues faced by DSOs and corresponding technical/market requirements

Within each of these services, it is possible to launch different products depending on availability, the time of activation or even the time when the event takes place. The conversion of services into products is an approach to the prosumer so that he can clearly differentiate what is expected from him. Therefore, it also refers to the parameter that will define the payment for the service, i.e. the calculation of the settlement.

An example of this is the definition of the different Congestion Management products launched in the UK:

(https://www.flexiblepower.co.uk/flexibility-services)

	Secure	**Dynamic**	**Restore**
Use Case	Pre-fault mitigation	Post-fault recovery (often under planned outages)	Post-fault network restoration
Availability Payment	Yes, an arming payment for the accepted availability time: £125/MW/h	Yes, an availability payment for the accepted availability time: £5/MW/h	No
Utilisation Payment	£175/MWh	£300/MWh	£600/MWh
Availability Declarations	By midnight every Wednesday for the following week (Mon-Sun)		
Availability acceptance	By noon every Thursday for the following week (Mon-Sun)		
Dispatch Notice	Week Ahead, on acceptance of availability	15 minutes ahead of requirement	15 Minutes ahead of requirement

Table 3 Congestion Management products launched in the UK:

In the context of the CoordiNet project, the products and services have been defined, the general attributes that the products may have, are detailed and each of the products presented in the figure has been assessed individually. Thus, the attributes for each of the services are defined. Some of them are shown by way of example in the section devoted to “Information Exchange”.

In this deliverable D1.3 of the CoordiNet Project (CoordiNet Project , s.f.), the application of product attributes is very interesting. It is a very good approximation of the solutions that the DSO may require for its network needs.

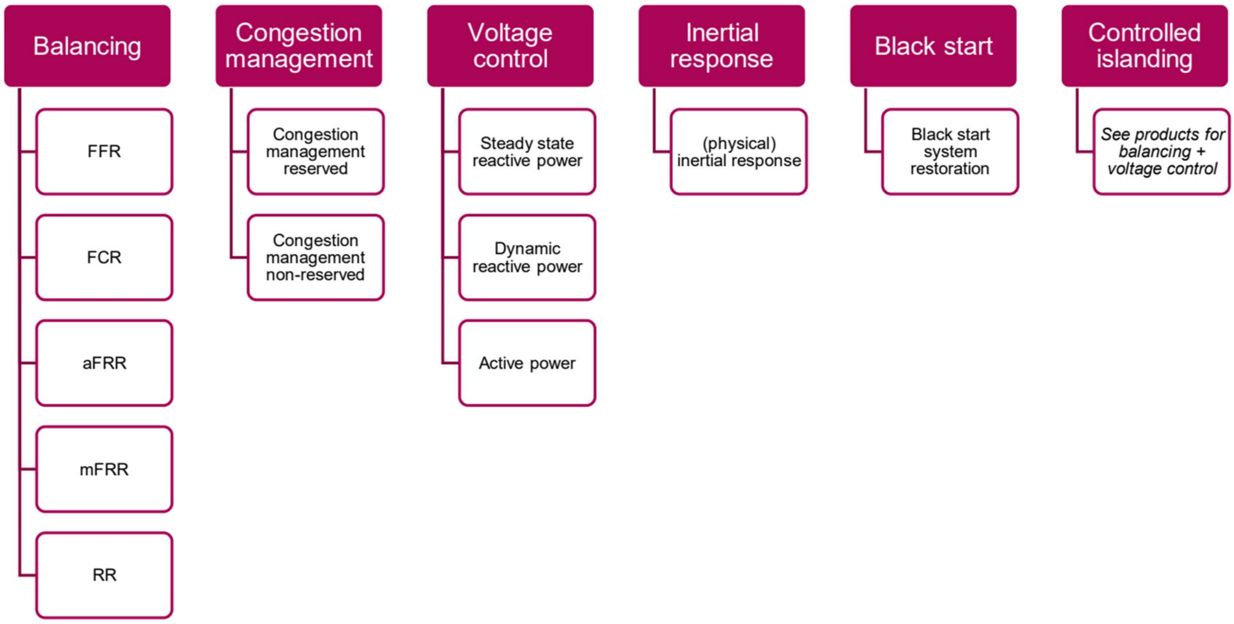


Figure 5 Products for grid services defined in CoordiNet (D1.3)

In deliverable D2.2 of the Interrface project (Interrface Project, s.f.), an analysis of the services and tools that are useful for them is made on the basis of a survey in which countries from all over Europe have participated.

Flexibility Agreements

Focus of this section

This section about flexibility agreements demonstrates current practices and indicates challenges and possibilities from different stakeholder perspectives. Interests and risks are different for each stakeholder; therefore, this section has been addressed from each point of view. Taking into account these risks and perspectives will be easier to come up with agreements.

Contract redaction or contractual clauses are not the aim of this report, since risk mitigation would be addressed in different ways in each country. However, a minimum content of the agreements is proposed within this section.

Background

Overall target of implementing flexibility is to ensure high cost-efficiency, sustainability and reliability in the energy system. To manage all these targets, different kind of agreements between market players are needed to be done. There are several stakeholders such as TSO, DSO, energy retailers who are interested in the flexibility of active users (customers) of electricity. Stakeholders may have different goals for flexibility. To understand what must be finally agreed, technical and economic targets for flexibility as well as present barriers must be studied from all stakeholder's perspectives.

EU legislation

The Clean Energy Package paves the way for aggregation through removing market barriers and giving new rights and opportunities to customers in how they contract aggregation services by allowing aggregators to operate independently of suppliers. (Ministers, 2017)

Viewpoints for flexibility agreement

Need for flexibility depends strongly on stakeholder and operational environment. In city area flexibility needs may concentrate on congestion management (for instance due to simultaneous charging of electric vehicles) whereas in rural area needs are more in reliability of supply and voltage quality oriented. At system level as a whole flexibility needs are more focused on balancing, rather than managing specific network assets.

Transmission System Operator (TSO)

Core tasks:

1. Ensure the operational security of the power system
2. Maintain the momentary balance between demand and supply
3. Ensure and maintain adequacy of the transmission system in the long term
4. Enhance efficient functioning of the electricity market

Need for flexibility:

Interests for flexibility services have been grown strongly among TSOs for instance because of increasing number of renewable sources. TSOs require faster responses than DSO, which need to be coordinated with. And DERs connected to the distribution grids may not be able to give such a fast response. TSOs need to unlock the flexibility sources that is able to deliver balancing services.

TSOs concerns:

- Timing, as mentioned above, to deliver balancing services.
- Short-term perspective – Operation and Maintenance.
- Long-term perspective – network reinforcement or extension can only be avoided, if the flexibility is available with high reliability for decades
- Liability – to what extend the flexibility provider can be held liable? If due to a wrong delivery of flexibility the system collapses (partially) is then the flexibility provider liable or the network operator or the system operator? Who is liable if the flexibility control is done by a system attribute (e.g. frequency or local voltage)?
- Communication connection – who is in charge to make sure the communication connection betweeen TSO/DSO and flexibility provider does work correctly? Who is in charge if it does fail? How can gaming be avoided? - (not actually part of the agreement)

Distribution System Operator (DSO)

For distribution system operators (DSO), the evolution of Distributed Energy Resources (DERs), the Energy Transition and New Client Appliances (e.g. Home Energy Management Smart Systems - HEMS) are a big challenge. Nearly all new DERs are connected to distribution networks. Particularly in areas with low demand, where electricity generation from DERs may easily exceed consumption, distribution systems have to be reinforced and extended. This requires considerable investment in electricity networks and heightens the need for flexibility. It is guaranty that DSOs will procure flexibility services from independent aggregators to manage internal constraints in the local distribution network in a more efficient manner.

DSOs concerns:

- Short-term perspective – Operation and Maintenance. Availability. (Same as TSO)
- Long-term perspective – network reinforcement or extension can only be avoided, if the flexibility is available with high reliability for decades (Same as TSO)
- Liability – to what extend the flexibility provider can be hold liable? What happens when there is a failure? (Same as TSO)
- Monitoring and metering – who provides what information to whom in order to keep all stakeholders updated and concious of their commitments.
- Reliable forecast and baseline design. Data for simulation models are required.
- How can gaming be avoided? - (not actually part of the agreement)
- Real value of flexibility (incentive to implement flexibility).
- Possible conflicts of interest in timing of reducing peak powers (DSO feeder load vs. SPOT price)

Retailer and Aggregator

Challenges: Competition increases. Smart Grids enable more active customer participation with better understanding on how the energy is consumed. There are different ways to increase the energy efficiency which brings new participants in the markets, such as Home Energy Management System (HEMS)-companies and Energy Service COmpanies (ESCOs). Emergence of the new players mean that the competition from customers tightens. Trend is that retailers become more of a service provider, which help customers to save cost through collaboration. (Aalto)

Possibilities: Easier to differentiate from competitors. With more options in possible strategies comes also an advantage. It is easier to differentiate own business from other service providers, by creating services to the certain segment.

Collaboration with other sectors. Retailers have vast experience from electricity markets' behavior. Collaboration with a company which has different core business can create advantages to both players rather than expanding too much to new area. (Aalto)

Benefits for aggregator of DER and flexibility are (Aggregation, 2/2020)

- Creation of new offers for prosumers
- Mitigating commercial risk

By increasing the flexibility in the power system, independent aggregators could therefore play a key role in allowing more intermittent generation onto the system, lowering constraint costs, optimizing market positions and increasing security of supply. (Ministers, 2017)

Aggregators concerns:

- Capability of load control.
- Uncertainty of DER response.
- Aggregation processes and responsibilities.
- Competitors in market environment and technologies associated.
- Data exchange and forecasts liability.
- Cyber security.

End customer (owner of DER)

In the past, electricity end-users have been in passive role in electricity system. Flexibility harvest has reached end-customers by the aggregators. Control of house and water heating units have already a long history in several countries through the different kind of time-of-use tariffs. Now, interest has extended to new DER devices such as charging of electric vehicles, solar PV and battery energy storages. Customers are expected to benefit greatly from this aggregation as it allows them to lower their energy bills when offering flexibility to the system. Benefits for end-customer (prosumer) of DER and flexibility are (Aggregation, 2/2020)

- Capturing the value of flexibility
- Increased value of assets through the markets
- Reduced financial risk through aggregation
- Improved ability to negotiate commercial conditions.

Type of aggregation of customer resources:

- **aggregation is limited to the certain units** (space heating, water heating) (Aaltomaa)
    - Benefit: Technically simple to implement, monitor and control
    - Challenge: The disadvantage of such an arrangement is that the consumer may not have full control of total electricity consumption during periods of high prices since part of the total is controlled by the aggregator. It then becomes difficult to plan the rest optimally.
- **aggregation covers the whole flexible customer load and the aggregator takes full responsibility and risk of demand side flexibility** on behalf of the consumer. (Aaltomaa)
    - Benefits: The consumer can have a fixed price (and better price) contract with the aggregator, removing the stress of monitoring electricity consumption. The aggregator will obtain a better price of flexibility than a consumer acting alone.
    - Challenge: an additional player in the marketplace who takes a cut.

<u>DERs concerns:</u>

- Value of flexibility (incentive to accept load control).
- Uncertainty about the DSO's future flexibility needs and its investment plan for reinforcements that could eliminate these needs.
- Commitment to the agreement. Understanding limitations.
- Uncertainty considering availability.
- Data transfer communication.
- Cyber security.

Agreement minimum contents

The flexibility agreements need to codify the requirements on all the parties involved in offering, using and paying for the flexibility. They also need to codify what happens, if someone does not or is not able to fulfil its obligations. Depending on the use cases the agreements can have different content but they need to have at least the following minimum content.

Define the data flow for master data and flexible data

Who receives when and in which frequency from whom via which connection which data in which format? E.g. all data flow is realized via the connecting network operator and cascading to the TSO. For the amount of data and time of delivery the GLDPM or the SOGL can be used as guidelines.

If data flow is realized via a platform, the structure and the governance of the platform needs to be specified. It has to be agreed on a procedure if the data flow does not work correctly (e.g. because of problems with the communication infrastructure). Procedures and responsible entities for aggregation/disaggregation of data need to be defined.

Define the flow of control commands

Who sends which data to whom via which connection in which format? How long in advance the command has to reach the flexibility? How does the flexibility behave if it does not receive correct commands? Is there a cascading / aggregating structure? Who will aggregate/disaggregate the commands? Is there a priorization of control commands (e.g. the network operator can override market decisions to ensure a stable system operation)?

Product description

What kind of flexibility is offered? What is the characteristic of the product? Are there any limitations (e.g. e-cars can only be controlled if they are connected to the network, some loads (e.g. heating devices) need a certain energy within a defined time scale (e.g. 1 day).

Relevant market

At which market the flexibility is offered? Can flexibility be sold at more than one market at the same time? Under which conditions?

Price determination

How is the price of the flexibility found? E.g. is it a capacity price for providing the flexibility or does it depend on the actual use of the flexibility? Who pays whom (especially important if aggregators are involved)? Is it a market price or is it a determined price?

Risk and liability management

Who is responsible if something goes wrong?

The question what happens if the communication connection does not work and who is responsible if a flexibility cannot be used has to be addressed. What happens, if the flexibility provider does not or cannot deliver the ordered flexibility at the requested location and to the requested time? Who is liable if problems in the grid (e.g. congestions) or in the system (e.g. imbalances) occur because the flexibility does not act as agreed?

If the use of flexibility should avoid network reinforcement or extension: How can it be ensured that the flexibility is available for the next decades?

Monitoring and metering

It must be indicated which values serve as reference for monitoring the service delivery and which meter values are used as reference for the settlement. Technologies required.

Testing and commissioning

It is necessary to undertake and pass a testing and commissioning test, maybe periodically before delivering the service. This test might me done after or before the agreement.

Other

Other common agreement clauses not specially related to flexibility services need to be considered such as confidentiality, termination rights, data protection, etc.

Use-cases

DSO harvesting flexibility of industrial consumer

Use of flexibility for DSO needs in case of increase of power of industrial consumer connected to MV grid

In 2019 in Slovenia the national regulator (Energy Agency) issued a new Regulatory framework in which the DSO can apply pilot projects and gets funding for the pilot. Elektro Ljubljana as one of five DSO's has applied many pilots, including dynamic tariffs in cooperation with energy suppliers, aiming at bigger savings of end customers.

The lasts one is focusing on using flexibility of industrial consumer for DSO needs. The main goal is to enable higher capacity of end customer with the use of its flexibility before high investment of reinforcement of the MV grid. Pilot is done on one part of MV grid which has two main feeders. In case of one is disconnected, required quality of the voltage cannot be ensured if end-customer consumed new higher capacity power. Installation of new 11 km cable line has been started, but it will take a lot of time to get consensus of more than 50 farmers to bury cable line in their fields, and forests. In the pilot, it will be investigated the use of flexibility of (primary) consumer which wants bigger power before new cable line will be build. If another (secondary) consumer which will be willing to lower its consumption is found, it will we rewarded for that. The pilot will be activated in the second half of 2020. In the first phase it is planned to install RTU in the premises of the customer. RTU will be used for sending activation signal from SCADA system (dispatch center) to the end-customer. If end-customer will allow, part of its consumption will be remotely disconnected. For confirming if the customer actually lower its consumption, Iskra -meters which will push 1-minute measurements of active power to the MDM (metering center) will be used. The first challenge will be getting almost real time measurements from MDM to the SCADA system. Currently Elektro Ljubljana is in the process of installing new ADMS from Schneider.

The idea is to establish 'Flexibility server' which will communicate with RTU at the customer and received measurements from MQTT server. At the end, it will be tested usage of main-billing meter as RTU, manning, that SCADA will send activation signal to the meter which will disconnect part of the consumption. The meter won't disconnect whole consumption, digital outputs will be used in the meter or relay output to trigger some disconnector which will disconnect specific load. To achieve that, message exchange between SCADA, flexibility server, MQTT broker, collection module and the meter have to specified in the project.

DSO harvesting flexibility for reliability of supply in rural area

Target

There is high interest among DSOs operating in rural areas to find out if flexibility agreement with end-customer about expected level of reliability of supply (extreme events) could help to optimize network renovation investments in sparsely populated areas (Fig.5). In the best case, flexibility agreement with end-customer could help avoid unnecessary investments in the areas, where there are depopulation (migration) and therefore high risk for loss of customers. So far, the present legislation does not allow this kind of customer-specific agreements. However, techno economic potential of flexibility is high in rural areas and its role in network development have to be studied. Challenges of agreement from end-customer and DSO perspectives are listed in the end of the case study.

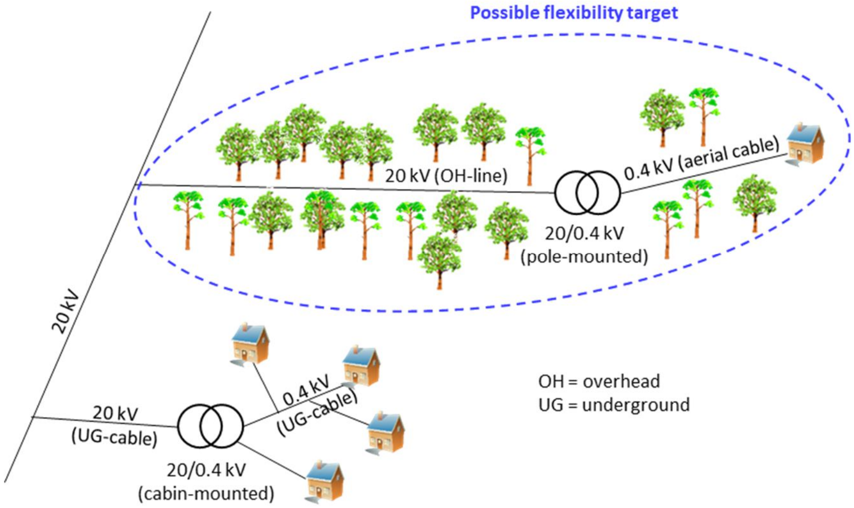


Figure 6. Example of flexibility target for reliability of supply in the distribution network.

Background

One of the main challenges of rural area electricity distribution companies in Finland are the long distances and lines in sparsely populated areas (low customer density) together with decreasing number of populations. Figure 6 illustrates average line lengths vs. interruption time in European countries and the average lengths of medium-voltage overhead lines per customer in rural areas in municipalities. The challenge is significant especially for DSOs operating in the eastern and northern part of Finland.

Even the line lengths per customer are high in Finland, number and duration of interruptions have been in moderate level compared to the many other EU countries. This is for instance due to high integration level of network automation and efficient fault repair organizations. However, several major storm events have affected widely to the electricity distribution in the history. In Finland, electricity market legislation was updated in 2013 enforcing DSOs to renovate infrastructure with 'weather-proof technologies' during ongoing decade. This has created pressure to harvest new cost-effective solutions in addition to traditional network technologies for ensuring required supply security levels in the near future.

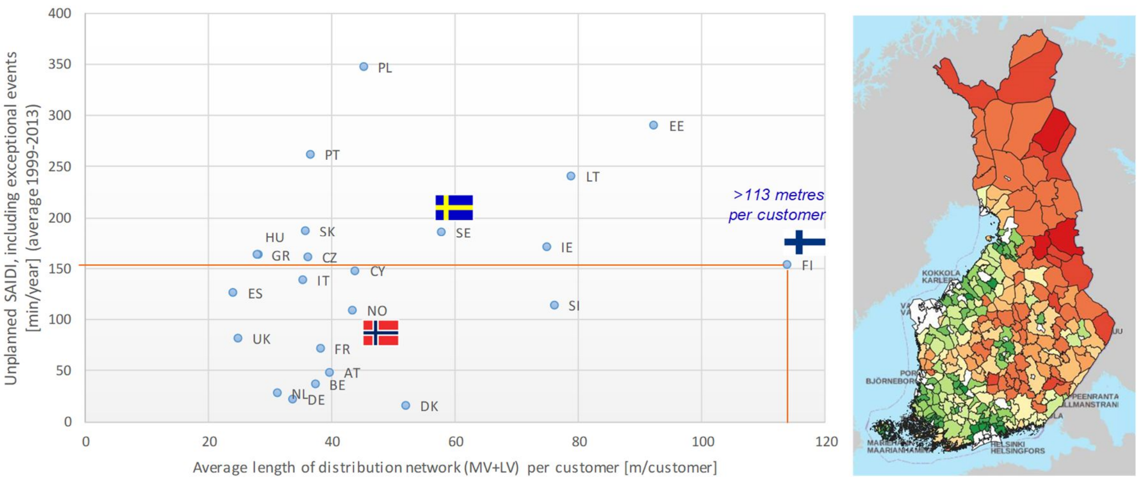


Figure 7 Left side: Average line lengths (m/customer) vs. interruption time in European countries (Lassila). Right side: The lengths of medium-voltage overhead lines per habitant in Finland in rural areas in municipalities.

Figure 8 indicates the same difficulty in the distribution area of a DSO. In the figure, medium voltage feeders are presented on city, urban and rural areas (zones 1, 2 and 3). It can be seen that most of the customers are living in city and urban areas but most of the network infrastructure is located in the rural area. Customer density in the rural area is extremely low, in this case area only 2 customers/km. Risk for unnecessary network investments is high especially when there is no guarantee for customer continuity.

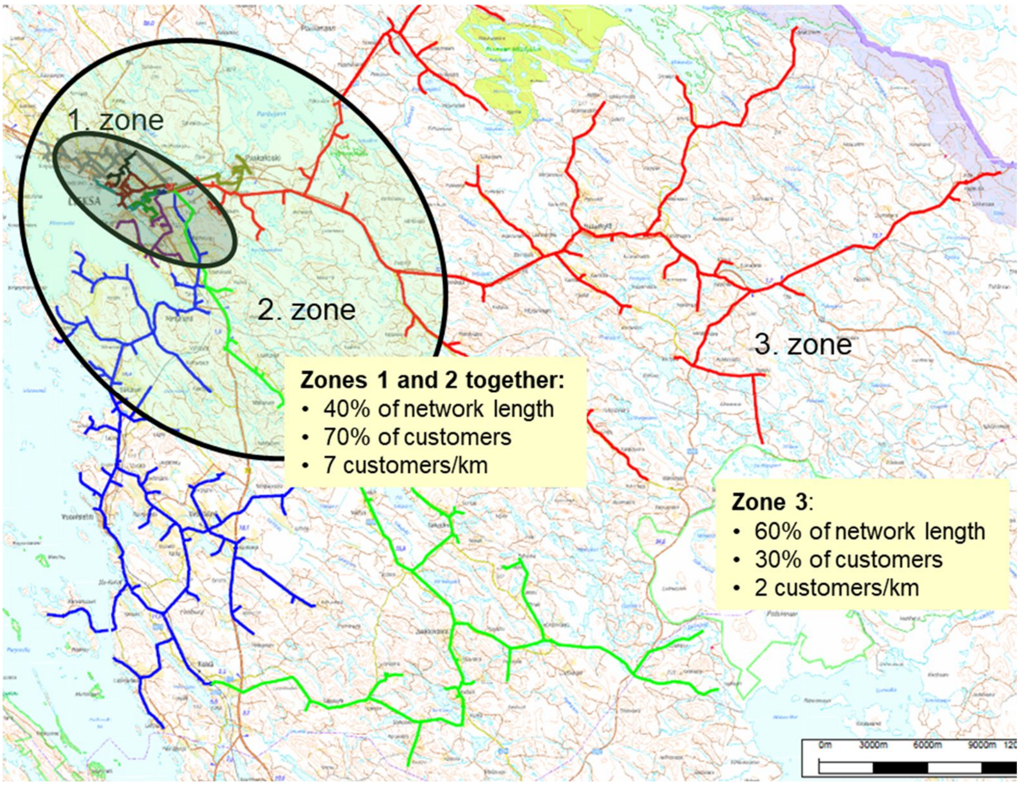


Figure 8. Example of operation environment of rural area distribution company (DSO)

Feasibility for the flexibility

Due to low customer density, depopulation and risk of customer lost, customer flexibility can be more economical and less risky compared to the traditional network renovation technologies.

Feasibility for flexibility for reliability of supply depends strongly on following issues:

1. **Network technology used in existing network:** If existing network is built with overhead line technology, target can be suitable for flexibility. If existing network is built with underground technology, network is already major storm proof and thereby flexibility for reliability of supply is not needed.
2. **Location of the network:** If existing network is located in the forest and built with overhead line technology, network is vulnerable for storms and falling trees. Thereby, target is promising for flexibility.
3. **Age of the network**: If existing network is relatively young but previous issues exists, target is promising for flexibility. With flexibility, ahead of time made renovation investments can be avoided.
4. **Customer density:** If customer density is low (high network length per customer -rate), target is promising for flexibility. With low number of customer agreements, high amount of network included in the agreement.

5. **Technology to be used in network renovations:** If technology planned to be used in network renovations is expensive (for instance underground cabling), with agreements these can be avoided, and thus economic value of flexibility is higher.
6. **Electricity consumption of customer:** If continuity of electricity is crucial for the customer, agreeing of flexibility (of lower reliability level) can be challenging.

Challenges in the agreement

End-customer perspective

- The length of agreement; how long period for agreement (commitment of customer)?
- Constraints of agreement; number of faults (pcs./a) and durations (minutes, hours)?
- Customer change in connection point; how agreement of made by earlier customer (habitant) restrict new customer in the same connection point?
- What is the compensation fee for customer regarding flexibility?

DSO perspective

- By which way flexible customers (reasonable nodes from network) are selected?
    - Economy (value of the network = avoided unnecessary investments)
    - Criticality of use of electricity (permanent housing, leisure, agriculture, …)
    - Continuity of customer (availability, duration, …)
- How the size of group of flexible customers is defined so that it has maximum techno-economic benefits in whole distribution grid
- How to get agreement with all the needed customers in certain area? (nature of the grid; one non-flexible customer leads to the situation where whole grid in the area have to be renovated with expensive way)
- How long agreement have to be that it has positive effect in the long-term development of distribution grids
- Customer change in connection point; how the change in expectations (old customer / new customer) are taken into account in the development of network (network renovation investment schedule, technology selection, etc.)
- How customers (and connection points, network sections) with flexibility agreements are dealt during grid disturbances and fault restoration? (prioritization)
- Compensation principles for the customer; fixed compensation or based on number and duration of interruptions.
- Successful flexibility agreements and savings in investments; which part of savings are 'returned' for flexible customers and how level of compensation is defined?

Tariff structures

Solutions to the generalized local problems could find their place. Market solutions can provide us with the highest efficiency in cases of real competition in which any participant can provide us with the solution to the specific problem. But these market solutions may not be efficient when the needs are very local and there is a lack of competition, in situations of illiquidity. In such a case, if costs allow it and taking care not to generate new inefficiencies, positive or negative incentives can be established to obtain a behavioural response that automatically solves many problems in low and medium voltage networks. These incentives could be reconsidered with a greater capacity to limit the space and time dimensions thanks to the digitalisation of networks, and for this it is necessary that the flow of information is adequate. The paradigm shift that may be implied by modifying tariffs locally could be studied.

Very specific technologies that can be implemented quickly or new electrified activities are appropriate, such as the electrification of transport with electric cars, the electrification of air conditioning or solar production. In all cases the response of the network and the problems generated can be repetitive throughout the medium and low voltage networks.

It is necessary to directly relate the rules-based solutions to be met to the consequences of non-compliance with the rule. In essence, there is a negative economic incentive. So this solution may not be very different from the result that would be obtained from the Network Tariffs based solution.

In this point a short summary of current regulation, grid tariffs, incentives, penalizations will be revised for different European countries.

Tariffs in Switzerland

Current regulation

From 1 January 2009, large-scale consumers (those whose annual electricity consumption exceeds 100'000 kilowatt-hours (kWh)) can freely choose their supplier, i.e. have free access to the electricity network. Consumers with an annual consumption of 50'000 kWh pay a price per peak power (CHF/kW, highest average power consumption during a 15-min-interval in a month, quarter or a year depending on the supply contract). Furthermore, reactive power is penalized if the average power factor (cos Φ) falls below the threshold of 0.9.

For small-scale consumers, who do not have the option of choosing their electricity supplier, the Federal Electricity Commission (ElCom) currently supervises electricity tariffs in their entirety. Electricity supply companies are required to separately indicate the costs for energy, use of the electricity network and any applicable fees and charges on their invoices (ElCom, 2019). Currently a consumption-dependent grid usage tariff is in place, where the consumer pays the grid usage tariff per kWh of electricity consumed. The breakdown of the tariffs charged in Switzerland is according to Swissgrid: 36% for energy procurement, 44% for distribution grids, 5% for transmission grids, 12% for feed- in remuneration (RES subsidies) and 3% duties (Swissgrid, 2020). At voltage levels below 1 kV the DSO must offer end consumers belonging to the base customer group[2] a grid usage tariff with a non-digressive energy component (CHF/kWh) of at least 70 percent (Bundesrat, Stromversorgungsverordnung).

According to the Swiss Federal Energy Act (EnG), electricity producers can directly consume their produced electricity (2016, Art 16), without owing grid fees and taxes. In addition, the utility has to purchase the energy (pay a feed-in tariff for every kWh) that is fed back into the grid (EnG, Art15). Since 1 January 2018, it is possible to merge for own consumption (dt. ZEV=Zusammenschluss zum Eigenverbrauch). Owners of office buildings and apartment blocks can provide all residents with electricity produced in-house for their own consumption. There are certain prerequisites that have to be fulfilled to form a ZEV (e.g. only one grid connection point from ZEV to the grid operated by the utility with one single electricity meter, and the production capacity of the plant or plants must be at least 10 percent of the connected load of the merger) (Art. 15 EnV).

Since 1 January 2018, the introduction of smart meters is a legal requirement (in the Electricity Supply Act and the Electricity Supply Ordinance). The smart meters are part of the Energy Strategy 2050, which was approved by the Swiss electorate in 2017. By the end of 2027, at least 80 percent of the metering equipment must be smart meters. However, as of today, smart meters are still not widely deployed in Switzerland.

[2] End consumers living in properties used all year round with an annual consumption of up to 50 MWh.

Flexible tariffs:

Tariff incentives, with a high tariff during daytime (e.g. 07.00 - 22.00) and low tariff during night-time (e.g. 22.00 - 07.00) and on weekends, are used to incentivise load shifting of consumption into off-peak periods. Furthermore, ripple control is used to control the switch-on procedure of larger appliances such as boilers and heat pumps.

Due to the consumption-dependent grid usage tariff, an increasing number of prosumers is having an impact on the financing of the distribution grids. If less electricity is consumed via the distribution grids due to private plants with high levels of self-consumption, the electricity users who are not self-consumers are forced to bear the share of grid usage costs that are lost due to self-consumption (al., 2016).

In Switzerland, a pilot and demonstration project called "Quartierstrom" exists (German for "district power"). The aim of the project was to implement and evaluate the feasibility of a decentral local P2P energy market in a real-world pilot test with 37 households located in the town of Walenstadt, Switzerland. The decentralised systems (mainly PV) have combined output of 290 kW and supply around 300,000 kWh of electricity annually. The electricity demand of the entire community is around 250,000 kWh per year. To create an incentive for the consumption of locally generated electricity, locational grid pricing[3] could be implemented. Trading within the community involves less grid infrastructure (e.g. the non-use of higher voltage levels) and therefore resulted in a lower grid usage levy (L. Ableitner, 2019).

Recommendations:

There are limited incentives for end customers and prosumers to behave in a grid friendly manner under the current framework conditions. Therefore, such incentives should be created by newly structured grid usage tariffs or other suitable means.

On 17 October 2018, the Federal Council opened a consultation procedure on the revision of the Electricity Supply Act (StromVG). The consultation draft included amendments to the law on full liberalisation of the electricity market, the introduction of a storage reserve and the modernisation of grid regulation. The consultation process lasted until 31 January 2019 and indicated that the majority of respondents supported full market liberalisation (Bundesrat, Revision des Stromversorgungsgesetzes - Bericht über die Ergebnisse der Vernehmlassung, 2019). On 3 April 2020, the Federal Council approved on the key elements for the amendment to the law Strom VG, which the Federal Department of the Environment, Transport, Energy and Communications (DETEC) will draft by the beginning of 2021.

It is planned that the grid usage tariffs for end consumers (grid level 7) will no longer be primarily based on the energy purchased (kilowatt hours) but will include a higher capacity component (centimes per kilowatt). This should provide better incentives for more efficient grid usage (SFOE, 2020). The Federal Council is expecting the reorganisation of the electricity market to strengthen decentralised electricity production. For example, prosumers will be able to sell their surplus electricity in the neighbourhood. Thus, the electricity market liberalisation enables local solutions such as local electricity markets (such as Quartierstrom) and energy communities (SFOE, 2020).

Furthermore, it is planned that producers, end consumers and storage operators (grid connection users) will become owners of their flexibility by law. This enables them to offer their flexibility where it is most beneficial to the system (grid, electricity market, self-optimisation). In particular, own consumers also receive incentives to use their considerable flexibility potential and thus generate additional income. Crucially, for a flexibility business to be established, the DSO cannot be expected to rely on voluntary

[3] Swiss legislation does not currently support such novel location-grid pricing schemes. To test this novel bottom-up tariff model in the absence of regulatory support, the grid costs from higher grid levels were covered with the research-project budget.

provision especially outside a market-based context. Without obligation to provide flexibility the DSO will not request it and could simply revert to conventional practices.

Tariffs in Portugal

Current regulation:

In Portugal, electricity retail tariffs are divided into generation, transmission, distribution, use-of-system (policy costs) and supply charges. The breakdown in Portugal is (CEER A. a., 2017): 28% for electrical energy, 29% for network-use, 21% for RES subsidies, 18% VAT and 4% taxes. Customers pay contracted power (€/kVA), active energy, and higher voltage levels' customers (HV, MV and larger LV customers) pay for the average load in peak hours and also reactive power.

Some groups of consumers can still be offered regulated tariffs. From 2013 to 2017, customers switching from the regulated to the market supplier could not return to the regulated supplier. However, the Portuguese Government has recently allowed the possibility of return to the regulated tariffs.

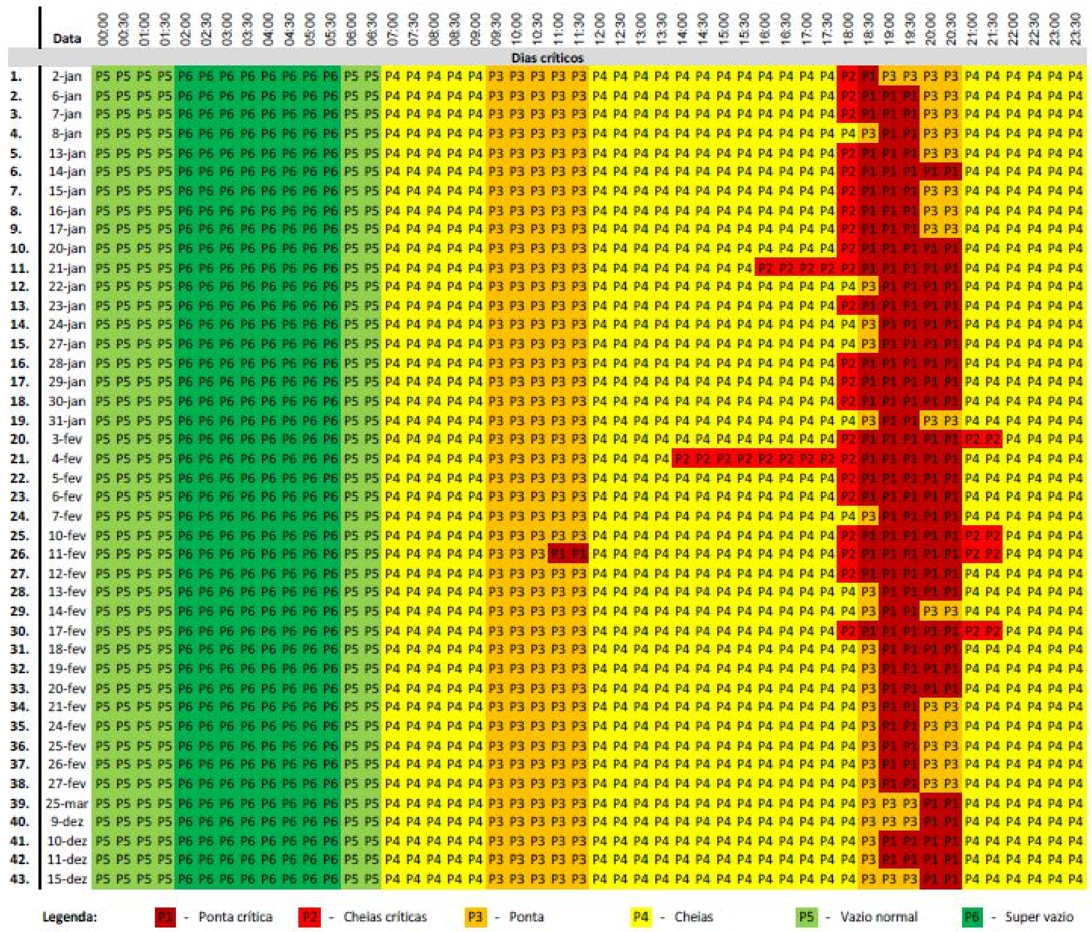
Domestic consumers only have access to time-of-use (ToU) tariffs: single and dual periods. Consumers connected to MV, HV and EHV have more options (or number of periods) in terms of time-of-user tariffs and retailers are already offering dynamic tariffs (e.g., as a function of the MIBEL wholesale price). Finally, it is important to mention that the smart meter deployment is not yet official, which significantly limits the involvement of domestic consumers in demand-side management programs.

Flexible tariffs

In February 2018, ERSE (Portuguese Energy Regulator) approved the rules for implementing, as of 1 June 2018, two pilot-projects, including the introduction of dynamic tariffs for access network access in mainland Portugal.

Participation in the pilot-projects, intended only for industrial consumers, is voluntary and intended to cover 100 consumers per pilot-project, over 12 months. Based on the results of the pilot-projects, ERSE will conduct a cost-benefit analysis to assess the merits for the electricity system and the possible setting of specific targets for installing smart meters.

The dynamic tariff approach was designed as a form of critical peak pricing built on top of a ToU network charging structure. Therefore, in the absence of critical conditions, consumers would be exposed to ToU network charges with four-time blocks: (non-critical) peak, plateau, valley and super-valley. The exact scheduling of these periods changes by region, seasons and day of the week. When critical conditions are detected, a critical period is called (peak periods would be transformed into critical peak periods) and the capacity charge (€/kW) would be increased for those hours. End consumers were notified 48h (weekdays) or 24h (weekends and holidays) in advance.



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12.	22-jan	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
13.	23-jan	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
14.	24-jan	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
15.	27-jan	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
16.	28-jan	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
17.	29-jan	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
18.	30-jan	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
19.	31-jan	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P3	P3	P4	P4	P4	P4	P4	P4
20.	3-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P2	P2	P4	P4	P4	P4
21.	4-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P2	P2	P2	P2	P2	P2	P2	P2	P2	P1	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
22.	5-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
23.	6-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
24.	7-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
25.	10-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P2	P2	P4	P4	P4	P4
26.	11-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P1	P1	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P2	P2	P4	P4	P4	P4
27.	12-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
28.	13-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
29.	14-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P3	P3	P4	P4	P4	P4	P4	P4
30.	17-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P2	P1	P1	P1	P1	P1	P2	P2	P4	P4	P4	P4
31.	18-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
32.	19-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
33.	20-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
34.	21-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P3	P3	P4	P4	P4	P4	P4	P4
35.	24-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P3	P3	P4	P4	P4	P4	P4	P4
36.	25-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P3	P3	P4	P4	P4	P4	P4	P4
37.	26-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P3	P3	P4	P4	P4	P4	P4	P4
38.	27-fev	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P3	P3	P4	P4	P4	P4	P4	P4
39.	25-mar	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P3	P3	P1	P1	P4	P4	P4	P4	P4	P4
40.	9-dez	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P3	P3	P1	P1	P4	P4	P4	P4	P4	P4
41.	10-dez	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
42.	11-dez	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P1	P1	P1	P1	P4	P4	P4	P4	P4	P4
43.	15-dez	P5	P5	P5	P5	P6	P6	P6	P6	P6	P6	P6	P6	P5	P5	P4	P4	P4	P4	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P4	P3	P3	P3	P1	P1	P4	P4	P4	P4	P4	P4

Legenda: P1 - Ponta crítica; P2 - Cheias críticas; P3 - Ponta; P4 - Cheias; P5 - Vazio normal; P6 - Super vazio

Figure 9 Tariffs in Portugal **Source: ERSE (2017). [Online] https://www.erse.pt/media/qs2fovkj/cp-tarifas-din%C3%A2micas-final-mar2017.pdf**

The ToU charging would send long-term signals to adapt to general system conditions, whereas the CPP component would intend to solve problems caused by critical system conditions detected in the short-term. Unfortunately, due to a very low number of consumers interested in this dynamic tariff, the pilot was cancelled by ERSE. Instead, an advanced ToU network tariff (with a geographical differentiation in the definition of the periods) was implemented and the cost-benefit analysis is almost concluded.

A preliminary cost-benefit analysis in (J. T. Saraiva, 2020), conducted by EDP and INESC TEC for dynamic tariffs, suggest that the benefits largely come from the possible deferral of network investments if a small part of peak demand (from EHV, HV and MV consumers) is moved to adjacent hours. Moreover, specific and regional tuning has to be considered given the differences in the location of the critical hours along the year when going from the North to the South of the country.

Recommendations:

The recommendations for the Portuguese regulator are the following (H2020 InteGrid project (L. Lind, 2020)):

- If dynamic tariffs are implemented, unpredictability problems ought to be mitigated. Moreover, the design of dynamic tariffs, e.g. geographical granularity, should be coordinated with local flexibility mechanisms. The former could be more suitable to solve system-wide critical periods, whereas the latter seem more suitable for more localized network constraints.

- Purely volumetric distribution network tariffs should be avoided. Capacity charges and/or fixed charges should be introduced to recover the fixed network costs, provided metering technologies allow to do so.

- Large network areas with consistent utilization rates could be selected to set different network tariffs (J. T. Saraiva, 2020). Local flexibility mechanisms can be used to address network constraints inside these areas or in countries where geographical discrimination is not allowed.

Tariffs in Spain

Current regulation

In Spain, customers pay for energy on the free market and tolls, the regulated part, to the distributors. Therefore, only the tolls are considered regulated tariffs. These tariffs are regulated by the new norm published by the CNMC (National Commission of Markets and Competition). According to it, all customers pay a part for the energy consumed (euros/kWh) called term of energy (Te) and a part for the maximum power they can demand (euros/kW) called term of power (Tp). These parts Tp and Te can vary according to pre-established schedules. Therefore, there are incentives to reduce consumption at times of high load. However, there is no flexible tariff that allows for punctual modification of the customer's behaviour due to a need in the network.

Currently, and since 2018, there are smart meters throughout Spain that allow remote reading and interaction with the meter in real time. This information, however, is difficult to use for flexible solutions due to the risk of network overload for monitoring and the volume of data that would be required to manage.

Flexible tariffs

As mentioned in the previous section, there are no flexible tariffs but there are tariffs that allow a more efficient use of the network as they encourage peak shave. The following figure shows how the winter months and July are more expensive.

Nuevos periodos horarios para BT > 15 kW (3.0TD) y AT (6.XTD) - Sistema peninsular

Mes	Temporada	0 a 8h								8-9	9 a 14h					14 a 18h				18 a 22h				22 a 24	
Enero (laborables)	A. Alta	6	6	6	6	6	6	6	6	2	1	1	1	1	1	2	2	2	2	1	1	1	1	2	2
Febrero (laborables)	A. Alta	6	6	6	6	6	6	6	6	2	1	1	1	1	1	2	2	2	2	1	1	1	1	2	2
Marzo (laborables)	B. Media Alta	6	6	6	6	6	6	6	6	3	2	2	2	2	2	3	3	3	3	2	2	2	2	3	3
Abril (laborables)	C. Baja	6	6	6	6	6	6	6	6	5	4	4	4	4	4	5	5	5	5	4	4	4	4	5	5
Mayo (laborables)	C. Baja	6	6	6	6	6	6	6	6	5	4	4	4	4	4	5	5	5	5	4	4	4	4	5	5
Junio (laborables)	B1. Media	6	6	6	6	6	6	6	6	4	3	3	3	3	3	4	4	4	4	3	3	3	3	4	4
Julio (laborables)	A. Alta	6	6	6	6	6	6	6	6	2	1	1	1	1	1	2	2	2	2	1	1	1	1	2	2
Agosto (laborables)	B1. Media	6	6	6	6	6	6	6	6	4	3	3	3	3	3	4	4	4	4	3	3	3	3	4	4
Septiembre (laborables)	B1. Media	6	6	6	6	6	6	6	6	4	3	3	3	3	3	4	4	4	4	3	3	3	3	4	4
Octubre (laborables)	C. Baja	6	6	6	6	6	6	6	6	5	4	4	4	4	4	5	5	5	5	4	4	4	4	5	5
Noviembre (laborables)	B. Media Alta	6	6	6	6	6	6	6	6	3	2	2	2	2	2	3	3	3	3	2	2	2	2	3	3
Diciembre (laborables)	A. Alta	6	6	6	6	6	6	6	6	2	1	1	1	1	1	2	2	2	2	1	1	1	1	2	2
Fines de semana y festivos nacionales		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Figure 10 Tariffs in Spain

This global solution does not solve the specific problems of the networks but helps in an aggregated way. The only new remarkable feature is the relaxation of the Tp for electric vehicle recharging, which allows for an increase in charging power in periods of low consumption.

Reactive power is not considered for customers below 15kW or for the period 6 of consumption. In the cases considered, a reactive power term and a reactive energy term will be considered as long as the latter exceeds 33% of the active energy consumption in the period considered. Generators of more than 5MW are obliged to regulate reactive energy according to the TSO instructions in a mandatory band. There are penalties for non-compliance with the set point.

Recommendations

The recommendations for the Spanish regulator are no different from those of any other country that has no incentive to obtain the benefit of customer flexibility. In essence, it is proposed to assess:

- Encourage the use of flexibility through bilateral agreements with flexible resources in a standard regulated manner.

- Try to take advantage of existing TSO markets to support the needs of the distribution network.

- Adequately reward active management of resources so that the DSO has an interest in doing dynamic capacity management.

- Allow different tariff solutions according to the needs of the network. (Contingency Te tariff).

- To allow specific modifications of the power limitation (contingency Tp tariff) in a justified manner whenever the needs of the network justify it.

Tariffs in Germany

Current regulation

Small low voltage customers pay only price for the consumed energy (€/kWh).

Large low voltage customers that have a meter for load profiles and customers at other voltage levels pay a price per peak power (€/kW, highest average power consumption during a 15-min-interval in one year) and a price for the consumed energy (€/kWh). The same price structure applies for the consumed energy paid to the retailer as well as for the network usage paid to the network operator.

Additionally, there are a lot of taxes and fees to be paid on top of these prices. They only depend on the amount of consumed energy, not on the load profile or flexibility.

Currently the smart meters are specified in Germany. The first three manufacturer declared that they are able to deliver suitable meters, so the roll out can start. However, up to now there is no advanced metering structure available.

Flexible tariffs

Using a ToU meter, a special tariff can be chosen. This is mainly used for night storage heaters. There is one tariff for the consumption of the night storage heaters. It blocks consumption of the heating devices during the day (6:00 – 14:00 and 16:00 – 22:00) but allows charging during the night and during a short recharging interval during the day (14:00 – 16:00). It requires the installation of an unblocking relay to release the electricity consumption. This tariff can also be used by other flexible loads whose consumption can be moved into the night, like water boiler, church heating, heat pumps. Especially the network usage fee is reduced in this tariff. The price of electric energy is nearly the same than with the standard tariff.

According to §14(a) EnWG (German Energy Industry Act) network operators have to offer flexible loads a reduced network usage fee. There is no further specification in the text of the law. So, it could be used for all kinds of flexibilities. Currently it is used only for time of usage tariffs (at least I do not know of any other application except research and pilot projects.).

According to §19 StromNEV (Electricity Grid Access Ordinance) network operators have to offer reduced network fees if customers consume the energy during off-peak hours. The peak hours are specified for the regions of the network area and for the seasons and weekdays. As the published peak hours are updated only once a year this fee does not really incentivise flexibility.

There is not penalization if a potentially flexible load does not offer their flexibility.

Reactive power is penalized if the inductive reactive power of a load is higher than 50 % of the active power during peak hours and 15 % of the active power during off-peak hours. There is neither a payment for reactive power of generators nor a financial penalization.

Recommendations

Generation units get a power-factor characteristic or a Q=f(U)-characteristic to support voltage control. It would be a recommendation that such characteristics could also be given to loads. For generation units peak shaving and the management of infeed is possible which reduces the congestions caused by generation units. If infeed management is used once, then the network has to be reinforced without delay. So, this is not a permanent solution but helps only until network reinforcement can be conducted. Peak-shaving can be used as permanent solution.

Network usage fees that depend on the time of usage (in 15 min intervals) and the location of the flexibility could support efficient use of flexibility by network operators. But currently there is no discussion in this direction.

Other smart grid measures would be possible and helpful but under the current regulation scheme investment cost are privileged compared to operational cost.

Tariffs in Czech Republic

Current regulation

Low and high tariff (sometimes called day and night tariff) are changed and activated by mass remote control system. Tariff structure for medium voltage customers has one change – the salary for power input according to the main circuit breaker is replaced by the price for the reserved capacity (CZK/MWh)

Unregulated components	Price of power electricity (CZK/MWh, CZK/month)
Regulated components	Distribution low tariff, high tariff (CZK/MWh)
	Salary for power input according to the main circuit breaker (CZK/month)
	Market operator activity (CZK/MWh)
	RES fee (CZK/MWh)
	System services (Ancillary services) (CZK/MWh)
Government (taxis and fees)	Electricity tax (CZK/MWh)
	VAT 21%

RES - renewable energy source
CZK – Czech crown

Figure 11 Tariff structure in Czech Republic for low voltage customers

Distribution low tariff, high tariff (CZK/MWh) - price for the distributed amount of electricity. This is a variable component of the price (CZK / MWh). It depends on the actual consumption of electricity by the customer. Prices for different tariffs and distribution rates vary according to the degree of use of the distribution network. This price includes both the price for distribution and the price for the transmission system. The distributor pays part of the money to the transmission system operator (ČEPS).

Salary for power input according to the main circuit breaker (CZK/month) - Monthly salary for power input according to the value of the main circuit breaker. This fee is created for the reserved power input in the distribution network. The value of the main circuit breaker is installed depending on the needs of household appliances. The higher the value of the circuit breaker in amperes, the higher the fixed price (CZK/month). The Energy Regulatory Office determines the price for each company.

Reactive power penalization is active for medium voltage customer only if the permitted power factor range of 0.95 - 1 is exceeded. In this case, the penalty can also be applied in the LV network but only for business customer type.

Currently a smart measurement system is not implemented in our distribution grid.

Flexible tariffs

A remote-control system is used to activate different distribution rates:

D25d Distribution rate for storage water heating, 8 hours of low tariff.

D26d Distribution rate for storage water heating and heating, 8 hours of low tariff

D27d Distribution rate for electric car charging, 8 hours low tariff

Recommendations

The introduction of dynamic tariffs is now being discussed, together with the deployment of smart metering in the LV network. The market should be opened for support services for the needs of the DSO such that activation of sources of flexibility at the level of LV and MV is possible.

Aggregation value for flexibility

Introduction

Flexibility aggregation is a direct response to the effort to make greater use of flexibility for the needs of the electricity system. It drastically reduces the entrance barrier for small end prosumers to take part in flexibility markets.

The decommission of conventional power plants will have an impact on the amount of flexibility on the production side. On the other hand, with the advancement of technology, flexibility in other areas of the sector - decentralized production resources and consumption - will be expanded.

Aggregation is also the answer to how to maintain the current reliability and scope of power management services. This is mainly because future flexibility will be gain from smaller, non-systemic sources.

For this purpose, a new entity - an aggregator - need to be created according to Article 17º of Directive (EU) 2019/944, not yet transposed to National regulation by all Member States (it should be during 2020 and 2021).

The requirements to establish an aggregator on the electricity market are based on European legislation, the so-called Winter Package. The concept of aggregator has already been introduced by Directive 2012/27/EU of the European Parliament and Energy Efficiency Council. The EU's motivation for highlighting the role of the aggregator now is to harness the flexibility potential even for those flexibility providers (PoFl) who do not have the necessary knowledge and skills for which providing flexibility alone does not make economic sense or is not made possible due to non-compliance with product parameters and requirements.

An incorrect setting of the rules could have a negative impact on other market participants and cause deformation of the electricity market. Therefore, the following points are to be considered:

- the aggregator should operate based on market principles,
- the legislator should maintain non-discriminatory and transparent rules for all market participants - the aggregator is responsible for its commitments in each market,
- the aggregator model should not jeopardize the safe and reliable operation of transmission and distribution systems and the reliable and high-quality supply to customers.

Form and role of aggregator

The role of an aggregator as a market participant that aggregates the flexibility of individual flexibility providers to sell standard products in the electricity and ancillary services markets should be realized as one of the follows:

Integrated aggregator

It combines the role of aggregator and Balance Responsible Party (BRP) taking responsibility for the deviation of its flexibility providers.

Independent aggregator

It concludes a contract to use the flexibility with flexibility providers without assuming responsibility for their deviation. It is therefore not responsible for the deviation of its flexibility providers due to the activation of flexibility. It is directly responsible only for the actual deviation caused by possible non-delivery of the contracted products in individual markets.

The aggregator uses the flexibility of the providers, which it offers in the form of standard products/services to the electricity markets, to the market of balance support services and possibly also to other services, or uses it to adjust its own position (reduction of deviation of contracted flexibility).

Conditions of aggregator operation and impacts

Table 4 shows the main concerns related to the aggregation role that need to be addressed.

Measurement requirements and method of evaluation correct and reliable data	**Specify a default diagram** how to determine the consumption / delivery diagram that would occur if flexibility were not activated	**Settlement methodology BRP-PoFl** method of compensation of SZ-PoFl for deviation and open trading position caused by the aggregator	**Settlement of the rebound effect** compensation for the consequences of the transfer of consumption over time due to the activation of flexibility
Information sharing determining the balance between transparency and discretion	**The relationship between implicit and explicit flexibility** elimination of mutual negative effects of both methods of flexibility management	**Access to devices** adjusting access to facilities providing flexibility	**Enabling the aggregation of flexibility resources** enabling to offer flexibility through a portfolio of controlled devices

Table 4 Areas to be addressed

The aggregator role would have different impacts depending on the market participant perspective. The next chart summarizes the impacts analysis done:

Market Participant	Impacts
Flexibility Service Provider (FSP) or Provider of Flexibility (PoFl) or Reserve Providing Unit (RPU)	• allows trading with own flexibility • method of invoicing based on measured data or schedules
Entity responsible for the deviations caused by Flexibility Service Providers	• the possibility of increasing the complexity of determining each position • activation of flexibility and subsequent settlement of a deviation’

TSO	• enabling the transmission system operator to use flexibility resources that would not otherwise be able to participate independently in the provision of ancillary services and regulatory energy
	  o the possibility of reducing the price of flexibility and ancillary services due to greater competition
	  o the possibility of increasing flexibility
	• motivating the necessary setting of the methods of certification, verification of the availability and quality of supply of every aggregator and flexibility provider.

DSO	• enabling the distribution system operator to use flexibility resources for its needs, which would not otherwise be able to participate independently in the provision of such services • equipping the supply points of Providers of Flexibility with continuous measurement • causes higher demands on the management of distribution systems and the necessary modification of models for the calculation of network operation • provides the possibility of limiting the activation of flexibility to ensure a reliable and high-quality electricity supply and to prevent threats to the safe and reliable operation of the distribution system - it is necessary to design a suitable tool • in countries where applicable, provides the possibility of reducing customer interest in two-tariff rates associated with the mandatory blocking of heat appliances and thus reducing the range of power controlled by centralized ripple control
Market operator	Just in case of independent aggregator implementation • settlement of offers of independent aggregators on the basis of the determined flexibility • adjustment of the position of the entities responsible for the deviation of the flexibility providers and the independent aggregator in the energy transfer between these entities based on the size of the provided flexibility (determined from the measurement data and the estimate of the initial diagram)

Table 5 Aggregator impacts on market functioning

The introduction of the aggregator will also require amendments to legislation that may vary among the different countries, such as the Energy Laws, the Rules of the Electricity Markets, the TSO Codes, DSO Codes, Invoicing or Metering rules, Income Taxes, etc.

For the functioning of the aggregator it will also be necessary to prepare the necessary rules and methodologies, inter alia, for:

- calculation of the forecasts and schedules,

- settlement of the rebound effect,

restrictions on the activation of flexibility by the DSO and a system of penalties for non-compliance with these restrictions, etc.

Information exchange and Platforms

In this chapter the different needs for information exchange between the agents involved will be studied, followed by an analysis of the platforms and their functionalities. The following figure represents these flows for better analysis.

The first point of attention is that DSOs will need direct information from flexibility providers. The information can be real-time or stored information and sometimes the information is useful for the DSO or the TSO, but not necessarily for the market. Especially real-time information.

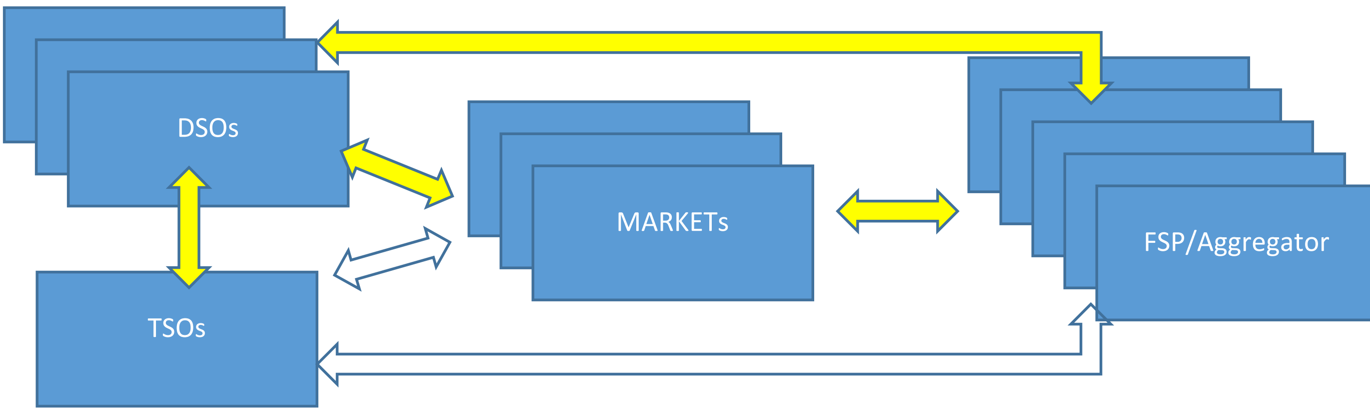

Figure 12 Information exchange among stakeholders

In the same way, DSO and TSO could exchange information via the market or directly between themselves. All this information does not need to flow through the market either, so it makes sense to open the way for direct communication. TSO's information exchanges with the Market or with FSPs are not the purpose of this study.

The USEF white paper about flexibility platforms studied this topic. Although there is an underlying interest throughout the work in highlighting the role of the aggregator, the analysis is comprehensive, and it is inevitable to consider it in this topic. In it, a platform for DSO-TSO coordination is also considered. The question of platforms and data flows is under discussion within the countries across the EU.

This exchange of information will also depend on the stage of the service. To this end, four different stages can be distinguished:

- **Prequalification**: Process where the ability to participate in an service (frequency and non-frequency service) is verified.
- **Service Request**: Specifying of technical requirements, such as: location, measurement requirements, under-delivery consequences, over-delivery consequences, ramp rate. A previous forecast needs to be done for this. Flexibility requesting parties and flexibility service providers need to determine how much flexibility they need to acquire or can deliver.

- **Activation**: Real time commands or set-up points may be needed to be delivered. The compliance with technical requirements of the product may require supervision.
- **Validation and Settlement**: Process to verify that the flexibility service provider has delivered according to his offer and the technical requirements of the product and calculation of financial exchanges between counterparties. A separate settlement process may be needed in case of penalties.

The H2020 project EU-SysFlex proposed a conceptual data exchange model for the pan-European electricity system with descriptions, including functionalities, processes, roles and services. The model does not imply a single data exchange platform but rather allows for interoperability of different platforms across Europe. More details can be found in a public deliverable[4] from Task 5.1.

Information exchange

Market-DSO

The information to be exchanged between the market and the DSO can relate to all stages of the process. In any case, the services must be defined on the basis of attributes that, according to the paper *Aggregation of Demand Side flexibility in a Smart Grid: A review for European Market Design* (Cherrelle Eid) could be defined with direction, duration and capacity.

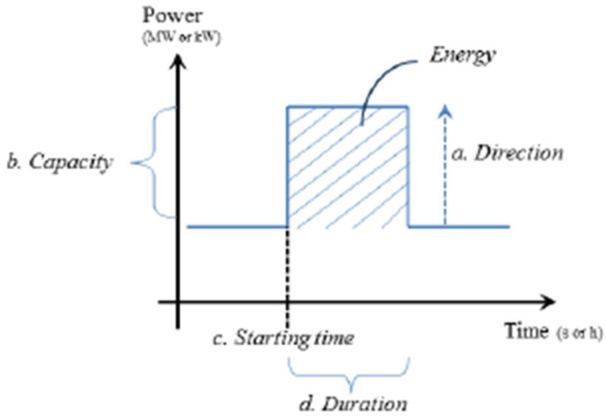

Figure 13 Information to be exchanged for a flexibility service delivery

This simplified definition of attributes was worked on extensively in the CoordiNet Project. The problem was addressed in deliverable 1.3 (CoordiNet Project , s.f.), coming to define attributes for each of the services. (https://private.coordinet-project.eu//files/documentos/5d72415ced279Coordinet_Deliverable_1.3.pdf)

Use the following example for Attributes of the congestion management reserved product:

[4] https://eu-sysflex.com/wp-content/uploads/2020/08/EUSYSFLEX-5.1.9-Data-exchange-role-model-2020.08-FINAL.pdf

Attribute	Value
Preparation period	Defined in terms and conditions for FSPs
Ramping period	Defined in terms and conditions for FSPs[35]
Full activation time	Defined in terms and conditions for FSPs[36]
Minimum quantity	0.1 MW (ETPA, 2019) or 1 MW
Maximum quantity	N.A.
Deactivation period	Defined in terms and conditions for FSPs
Granularity	0.1 or 0.01 MW
Minimum duration of delivery period	Defined in terms and conditions for FSPs[37]
Maximum duration of delivery period	Defined in terms and conditions for FSPs
Mode of activation	Manual
Availability price	Yes
Activation price	Possible, dependent on the procurement process
Divisibility	Divisible and indivisible bids are allowed
Location	Included in the bid [38]
Recovery period	Defined in terms and conditions for FSPs
Aggregation allowed	Yes
Symmetric / asymmetric product	No symmetry required

Table 6 Attributes of the congestion management reserved product

In addition to the attributes and characteristics of the particular services and FSPs enabled, some kind of aggregated information could be part of this information exchange. Depending on the type of service, the delivery of an amount of power, energy or availability could be required to achieve a target. The measurement of that target parameter could also be part of this information exchange.

FSP-Market

The attributes mentioned in the previous section will certainly be part of the requirements to qualify as an FSP in the market and to be recognised as such by the DSO or TSO. They will therefore be part of those information exchange messages between them. Only a small part of them will be part of the next steps. Perhaps the simplified version shown in the figure could be the type of information exchanged in the Request and Activation phases.

To enable the aggregator to function, it will be necessary to ensure the exchange of data between individual market participants and their processing. For this purpose, it will be necessary to introduce new components of data storage. To ensure the exchange of information between aggregators and other market participants, the creation of a data repository is proposed. The main functions of this data store should allow:

1. Create an account for a registered aggregator
2. Evidence of the portfolio of sources of flexibility of individual aggregators
3. Setting restrictive conditions for the activation of flexibility by system operators
4. Verification of the possibilities of activating flexibility by the aggregator
5. Verification of offers (activation programs) of the aggregator

The market will launch a need to be satisfied in one location and FSPs will have the option to access this market. Regardless of how much advertising is given, the way to access will be through the market. In the UK, where a truly flexible solution already exists, the Piclo Flex portal serves as a marketplace platform for FSPs to access.

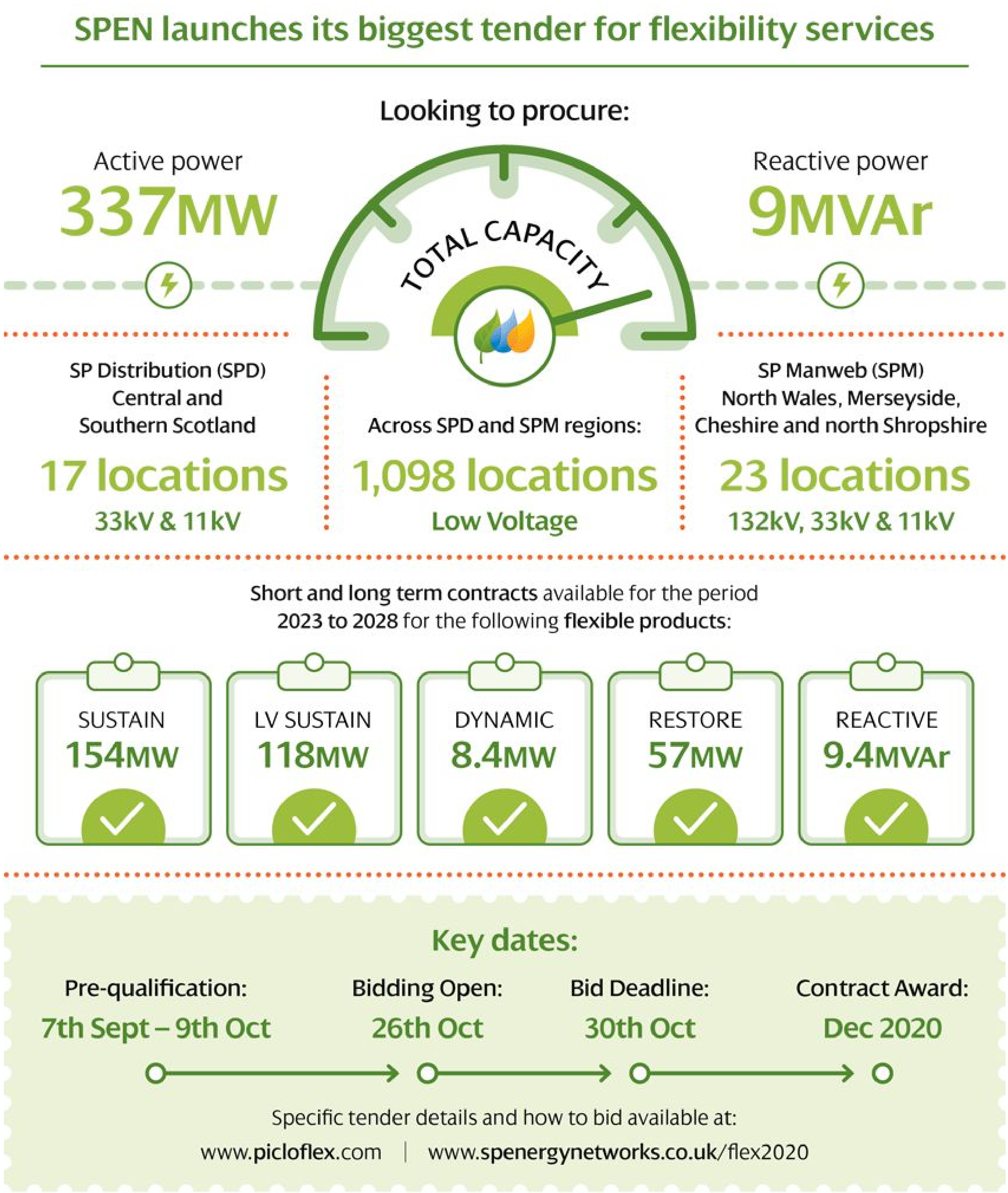

Figure 14 Tender for flexibility services in the UK

TSO-DSO

European Commission Regulation (EU) 2017/1485 of August 2017 establishing a guideline on electricity transmission system operation, includes in its Title 2 the General requirements on data exchange, Data exchange between TSOs and DSOs within the TSO's control area and Data exchange between TSOs, owners of interconnectors or other lines and power generating modules connected to the transmission system. The data are divided in:

- Structural data exchange. Information of the network.
- Scheduled data exchange
- Real-time data exchange

Article 40 addresses the roles and responsibilities. It emphasises the importance of an agreement between TSO and DSO on key organisational requirements, roles and responsibilities in relation to data exchange.

Naturally, all this information concerning the operation of the network is a part of the necessary scheme for flexibility management. Since the exchange of magnitudes active and reactive power, position of the circuit breakers or operational status is the kind of information needed.

The European TSOs defined the key organisational requirements, roles and responsibilities relating to data exchange (referred to as “KORRR”). The KORRR shall be considered the common proposal in accordance with Article 40(6) of the guideline on electricity transmission system operation and shall include organisational requirements, roles and responsibilities for data exchange according to Title II.

FSP-DSO

As mentioned above, regardless of the information exchanges that take place through the market, a given exchange may be needed to obtain information in real time or to send set-points or commands.

This information should not be very different from that referred to in the KORRR. Although it is true that the requirements may be less strict as the time required by the flexibility providers in the distribution network do not have the need for such an immediate response as that required by the TSO to maintain the frequency of the network. It is therefore understood that these requirements for the distribution network with its FSPs will be a simplified version of the existing one for the TSOs.

Platforms

To make an analysis of the platforms to be part of the flexibility scheme, we should analyse the platforms of each of the agents involved. However, as they are not the object of the study, we avoid studying the TSO platforms, as well as the aggregator platforms.

Market platform

It is inevitable to consider global markets separately from local markets. Going back to the references given in the section on market structures, a distinction has to be made between those markets that solve the needs of the TSO and some needs of the DSO from those markets that solve the exclusive problems of the DSO.

With regard to the first group of platforms, the global ones, reference should be made to the existing platforms which, by means of redispatching, make it possible to deliver the flexibility services. These platforms tend to unify, standardise and harmonise the platforms of several TSOs in order to obtain greater efficiency by having a larger market. Obviously, this type of market is possible for balance products. But it does not suit the local needs of the DSO.

An example of it is the new European platform for replacement reserves (TERRE) launched by TSOs from eight countries: Czech Republic (ČEPS a.s), United Kingdom (National Grid ESO), Poland (Polskie Sieci Elektroenergetyczne S.A.), Spain (Red Eléctrica de España S.A.U.), Portugal (REN – Rede Eléctrica Nacional, S.A), France (Réseau de Transport d'Electricité), Switzerland (Swissgrid AG) and Italy (Terna-Rete Elettrica Nazionale SpA).

Market mechanisms of local flexibility are already being implemented in different European countries, such as the United Kingdom, Germany, the Netherlands, Sweden or Norway. Furthermore, several European research projects H2020, Integrid, EUniversal, CoordiNet, INTERRFACE, among others, are also exploring different design alternatives. Some local market platforms in operation, Piclo Flex, Enera, GOPACS and NODES, are demonstrating the possibilities of new business models in this area. While Piclo Flex is a market platform that allows DSOs to obtain long-term flexibility commitments, the last three platforms focus on products with daily flexibility to solve network needs.

DSO platform

The DSO platform needs to manage both short-term and long-term requirements. To do this, it is very necessary to consider the following functionalities:

- Forecast of the load across the grid.
- Forecast of the generation across the grid. May be depending on the generation technology.
- Introduction of grid needs.
- Flexibility activation and monitoring.
- Calculation of power flows.
- Calculation of bus voltages.
- Voltage violations and congestions detection.
- Calculation of required flexibility.

Obviously, these are platforms by and for the distributors that must be integrated with the information systems they must be fed with, such as meters or SCADA. So, it will depend on the starting point of each DSO how to integrate the new needs of flexibility, where forecasts are a fundamental part.

Some of these functionalities may be shared among DSOs. In the UK there are two platforms currently in service: Picloflex; for the publication of requirements and verification of offers. And the FlexiblePower API for automating the dispatch and settlement of services. Different DSOs share the latter in order to give FSPs an easier way to access flexibility.

Regulatory approach

Global Recommendations

These are some recommendations for policymakers and national regulators to adopt the following approach in the implementation of the Clean Energy Package, in particular when considering Art. 32:

• In the spirit of the Clean Energy Package and in order to empower customers and active market participation, market-based solutions for flexibility procurement are to be sought by default. DSOs should act accordingly within their role as neutral market facilitators. To ensure efficient operation and planning of their network, DSOs need a toolbox comprising different types of solutions for congestion management: market-based procurement solutions, as well as incentives through network tariffs or connection agreements. Next to market-based procurement options, tariff incentives are the basis for market parties to adapt to capacity constraints. Therefore, tariffs should be regarded as an integral element in market procurement of flexibility.

• Market-based procurement should promote an efficient use of resources and services. From this perspective, the flexibility procurement mechanisms for distribution grids should be designed so that any contracted resources can offer services to other parties, DSOs or TSOs, and to any available market, as they may be of value for the whole power system, when the DSOs do not need them. This requires proper coordination at least among system operators. Market-based procurement can be applied within different timeframes, for example through implementation of a competitive tender for long-term provisions or a local flexibility market to address short-term needs. Short-term procurement of flexibility should always be open to all resources, including those that have not been subject to long-term contracts.

• The feasibility of market solutions for procuring flexibility is linked to a transparent forecast of the DSO needs. The market solution should be suitable for local specificities in order to avoid potential market failures. Local specificities are defined by the availability, in numbers and volume, of technologies and services to address the local needs in terms of congestion management, which need to be clearly specified.

• In this context, a step-by-step approach carried out in coordination by National Regulatory Authorities (NRAs) and DSOs can help identify use cases where market-based flexibility procurement is not feasible. The outcome of such analysis would help to outline the specificities of the locally applicable market-based solution. In cases where a market-based solution is considered inappropriate, the selected approach should be reconsidered regularly, such as every five years. This continuous reassessment would take into consideration that time is needed for flexibility resources to develop.

• The Member States may start testing market-based flexibility procurement through pilot projects. The pilot projects should test real use cases and consider different forms of procurement considering the abovementioned principles. If not already included in national regulation, regulators should allow regulatory sandboxes outside of the current regulation framework. The incurred costs for the DSOs stemming from these pilot activities shall be publicly disclosed, acknowledged and fully recoverable.

• In addition to traditional grid reinforcements, NRAs should acknowledge that there are alternative solutions to efficient provision of network services, for which more tailored remuneration schemes are required. At the current stage of flexibility market development, flexibility procurement might not provide the same systemic benefits in the long term as grid reinforcements do. Any particular risks of opting for flexibility services should be therefore considered in the contracting and remuneration scheme to make these alternative solutions viable. It is important to understand the risk from the DSO perspective and implement incentives covering that risk properly. Ideally, all stakeholders should strive towards market-based flexibility procurement mechanisms that provide at least comparable systemic and societal benefits as grid reinforcement.

• However, some remuneration models for system operators might not be adequate as incentives to procure flexibility. Different remuneration models can therefore be considered considering local regulatory frameworks, such as TOTEX or output-based incentives for the NRAs to set the DSOs' goals based on parameters that are relevant to a particular distribution task.

• Flexibility remuneration for the procurement of services should be determined by the value it provides in each particular network configuration and ideally be defined by a common high-level methodology agreed nationally. However, a more general approach can also be justified as being a simpler solution. As an example, transparent and open auctions appear to be a possible mechanism to set the appropriate market price in a fair competition framework, provided there is enough liquidity and potential market failures are avoided.

• In particular, it is key to ensure transparency throughout the whole auction process as well as in the selection of technologies and in the selection of activations between service providers and/or technologies.

However, further investigation is required to tackle the challenges that come along with the concept of this auction model.

• The required network development plans for distribution grids at national level shall acknowledge the principles of practicality and visibility. In order to achieve this, these plans should differentiate between different voltage levels DSOs are covering across the EU. Ideally, these asset-based plans cover high voltage level by default and, if achievable in practice, also lower voltage levels.

• The consultation requirement for network development plans will allow DSOs to acknowledge and communicate when new needs are arising and therefore enable discussions with market parties and the TSOs on a level playing field. Furthermore, a more coordinated network development planning for both TSOs and DSOs is feasible and desirable in the mid- to long-term.

Recommendations for the Spanish regulator

According to the Ley 24/2013 the following functions, among others, have been established by regulation for the distribution network managers:

- To carry out their activities in the authorised manner and in accordance with the applicable provisions, providing the distribution service on a regular and continuous basis, and with the quality levels (…), maintaining the electricity distribution networks in the appropriate conditions of conservation and **technical suitability**. (40a)

- To determine, in the exercise of its function as operator of its distribution network, the criteria for the operation and maintenance of the networks, guaranteeing their safety, reliability and **efficiency**, in accordance with the environmental regulations applicable to them. (40r)

For the DSO to carry out these obligations with flexibility solutions:

- There should be economic incentives for Flexibility Service Providers.
- The possibility to do a Regulatory Sandbox to test flexibility solutions.
- DSO responsibility cannot be shared with any other.
- DSOs will need to access data from FSPs for the operations. (Forecasting, Activations, Monitoring). These data need to be as reliable as the whole system.
- DSOs can buy flexibility and facilitate the flexibility market. Which are two different roles that need to be regulated.
- DSOs should be allowed to perform the services themselves if necessary if there is not a non-regulated solution available.
- TSOs and DSOs have different responsibilities. The coordination between them should be the most efficient.

Recommendations for the Portuguese Energy Regulator

The Horizon 2020 project InteGrid produced a set of recommendations to revise the regulatory framework in Portugal, considering flexibility integration in distribution grids (L. Lind, 2020):

- DSOs should be explicitly allowed to procure flexibility services from grid users or aggregators managing a portfolio of flexible DER.
- In the early stages, DSOs and third parties should be allowed to test different flexibility market configurations, under regulatory sandboxes if necessary. Over time, flexibility markets and products may be standardized if deemed required.

- Long-term procurement, years-ahead and with a contract duration of several years, should be encouraged to enable incorporating it in the DSO investment plans. In other words, this recommendation is oriented to include flexibility as an integrated part of the DSO investment plan (e.g., considering a mix between traditional network reinforcements and flexibility resources), which currently is for 3 years in Portugal.
- The activation price of flexibility sources that are contracted under a long-term framework should be determined in the short-term under a market-based mechanism competing against all available sources of flexibility (including those without a long-term contract and flexible connection agreements).
- Long-term contracts may include a cap on the activation price to protect DSOs against opportunistic behaviours from flexibility providers.
- DSOs should submit investment plans as part of the price review process. These plans should reflect fairly the use of flexibility as an alternative to grid reinforcements and make it clear how the different expenditures are related to the outputs that want to be attained.
- Enhanced TSO-DSO coordination (operational planning and real-time operation timeframes) is necessary to ensure seamless participation of aggregators in both local and centralized markets.

Recommendations for the German Regulator

According to §14(a) EnWG (German Energy Industry Act) network operators have to offer flexible loads a reduced network usage fee. There is no further specification in the text of the law. So, it can be used for all kinds of flexibilities. There are currently discussions on changing this paragraph specially to simplify the usage of the flexibilities inherently provided by electric vehicles and heat pumps.

According to §19 StromNEV (Electricity Grid Access Ordinance) network operators have to offer reduced network fees if customers consume the energy during off-peak hours. The peak hours are specified for the regions of the network area and for the seasons and weekdays. As the published peak hours are updated only once a year this fee does not really incentivise flexibility.

To efficiently use these conditions described in the law for the best benefit for society the following recommendations to the regulator are derived:

- The use of flexibilities requires to invest in communication technology and the shift to more operational cost (OPEX). OPEX and other expenses should be valued comparable to CAPEX in regulation.
- To develop and test flexibility solutions it should be possible to run pilot projects in a regulatory sandbox.
- Network usage fees that depend on time and location of the network use should be allowed.
- Smart meters and CLS-boxes need to be specified without further delay. The supply-region wide rollout of smart meters and CLS-boxes is prerequisite to the establishment of use cases. Therefore, it should be realized within a regulated framework.
- The flow of data and the control responsibility need to be organized in a cascaded structure. Each network operator needs to get the data from the flexibilities connected to its network and the responsibility to control them. Each network operator needs to be responsible for its network. He also has to be in the position to exercise this responsibility.
- The provision of the flexibilities needs to be highly reliable, also in long time spans to replace investment in network equipment.
- TSOs and DSOs have different responsibilities. The coordination between them should be the most efficient.

UK RIIO system

In the United Kingdom, distributors are entitled to contract for flexibility services from third parties by means of a contract signed by both parties. The RIIO regulation (Revenue=Incentives+Innovation+Outputs) establishes remuneration for the concept of TOTEX, which encourages the most efficient solution, whether it be investment (CAPEX) or contracting services (OPEX), which would include flexibility services. In this sense it is a reference regulation for the analysis being carried out in this document.

Two philosophies underpin UK regulator OFGEM work on DSO. First, they consider DSO is a set of functions and services that need to happen to run a smart electricity distribution network. This does not focus on a single party as an operator but recognises roles for a range of parties to deliver DSO. Second, optionality is currently valuable given the changing nature of the energy system. They believe that they should not make premature decisions that lock the energy system into path-dependent routes whilst there is still uncertainty about potential developments. Instead, they try to maintain optionality where they think this could be beneficial. This means delivering major progress to DSO now but keeping options open for wider institutional change in future.
https://www.ofgem.gov.uk/system/files/docs/2019/08/position_paper_on_distribution_system_operation.pdf

At the end of 2018, distributors in the United Kingdom jointly launched a project aimed at verifying market availability for offering flexibility services. Since then, a total of six distribution companies have put a total of four flexibility products on the market:

1. Sustain - System support service under normal network conditions.

2. Secure - System support service when security margins have been already used.

3.Dynamic - System support service when an element has failed.

4.Restore - System support service when a service restoration is required.

In order to sign a flexibility contract, the distributors have developed procedures to compare the value contributed by each offer received with the traditional network reinforcement alternative.

The regulator, OFGEM, is expected to incorporate regulatory changes in the next period (RIIO ED2) as a result of the experiences obtained with the flexibility products. The distribution of benefits from the use of flexibility between the distributor and the customers is not yet defined. In the first regulatory period RIIO-ED1 will apply the TOTEX Incentive Mechanism to the TOTEX reductions, i.e. the distributor gets half of the savings. For RIIO-ED2 (starting in 2023) it is still under discussion.

Projects related

This is not an exhaustive list of projects in which flexibility was the main objective but tries to be a list of projects that have inspired the authors of this document. We apologize for all those works that are not listed, either if they also served as inspiration for the authors or not.

SERVING – A project that is currently realised in Germany. There we use night storage heaters and water pumps as flexibility. The SERVING platform then identifies the restrictions of the use of the flexibilities caused by the characteristics of the flexibility itself, the behaviour of other loads/generations and the restrictions from the network. The retailer then can optimally buy the power for the following day. The SERVING platform will take care of the distribution of the bought power in such a way that all customers are satisfied, and no network restrictions are violated. We tested the system successfully on 50 pilot customers. Intermediate results have been published at CIRED 2019 in paper 0044 and final results have been published during the CIRED-workshop this year in paper 0054.

There are many projects regarding possible flexible charging strategies of electric vehicles. I am not sure if it makes sense to mention some of them. From a German prospective I am not really sure, if customers would accept to have their charging regularly controlled by ‘strangers’ like network operator or retailer. In our country the own car is still sacred…

NiceGrid France http://www.nicegrid.fr/en/ distributed residential flexibility with local flexibility market

Sensible https://www.projectsensible.eu/ distributed residential energy storage with local flexibility market. With improvement of operation in islanding mode and combining flexibilities from smart appliances (electric water heaters), small-scale grid and behind-the-meter storage and local photovoltaics the reliability could be improved considerably (SAIFI up to 24 %, SAIDI up to 28 % in Évora, Portugal). Results have been published at CIRED 2019 in paper 1769.The hosting capacity also could be improved.

CoordiNet (https://coordinet-project.eu/projects/project) – Demonstration of a coordination scheme between TSO and DSO to use the same pool of resources without collision.

InteGrid (https://integrid-h2020.eu/, Grant agreement no. 731218): demonstration of predictive grid management tools for flexibility management in MV and LV grids, considering a grid and market hub platform to support information exchange between different stakeholders (TSO, DSO, aggregators) about flexibility. Demonstration of a predictive traffic light concept for TSO-DSO coordination. Comparison between technical and behavioural demand response at the local energy community level.

InterConnect (https://interconnectproject.eu/, Grant agreement no. 857237): contribute for the democratization of efficient energy management, through a flexible and interoperable ecosystem where demand side flexibility can be soundly integrated with effective benefits to end-users. The consortium integrates relevant partners from all the representative stakeholders in this new energy paradigm. To achieve a significant dimension, 7 large scale pilots, in different countries and with different end-users, are foreseen to guarantee representativeness and dimension in terms of number of appliances and services. The overarching objective of these pilots is to demonstrate a real digital market environment over electrical systems with significant amounts of demand-side flexibility, reducing operational and investment costs that will benefit energy end-users and help EU achieve its energy efficiency objectives.

EU-SysFlex (https://eu-sysflex.com/, Grant agreement no. 773505): identify issues and solutions associated with integrating large-scale renewable energy and create a plan to provide practical assistance to power system operators across Europe. This should ultimately lead to identification of a long-term roadmap to facilitate the large-scale integration of renewable energy across Europe.

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