USEF: WORKSTREAM

AN INTRODUCTION TO EU MARKET-BASED CONGESTION MANAGEMENT MODELS

This report describes and evaluates eleven European models that utilise flexibility as a congestion management solution

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USEF

A solid foundation for smart energy futures

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Disclaimer: Although this report is the result of common understanding and consensus of all participants in the workstream, it does not necessarily align with the corporate opinion(s) of the participant's organizations.

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1 Management Summary

USEF's DSO Workstream consists of DSO experts from multiple EU countries. The workstream's initial task was to assess the challenges faced by European DSOs as a result of energy system transition. A key challenge identified was how best to cope with the increasing electrical power volatility resulting from the growth in renewables and energy electrification. These trends have the potential to significantly impact the distribution grid, leading to frequent network congestion and decreased reliability.

The scope of work covered by this report is the identification, description and evaluation of existing market-based congestion management models which incorporate flexibility. The term 'models' refers to any regulatory frameworks, concepts, projects or platforms, or a combination of them. These models give DSOs the capability to perform congestion management in the distribution network. The report aims to share learning across all DSOs and relevant system operators to help improve their own model development. The report does not provide a complete overview of all models in Europe but is a broad snapshot of models that existed in Europe in 2017. The models assessed are listed in Table 1 below.

Model name	Short name	System operator	Country
Flex Groot Verbruik	Flex GV	N.V.Alliander	NL
T-Flex	TFlex	ORES scrl	BE
Red Green	Red Green	Eandis cvba	BE
Das Proaktive Verteilnetz	PaVn	innogy SE	D
grid-control	GridC	Netze BW GmbH	D
Universal Smart Energy Framework	USEF	Stichting USEF	NL
Energy Trading Platform Amsterdam	ETPA	Stedin N.V.	NL
CHP Limiting	CHP-C	Radius	DK
Permissive Construct	PermissiveC	ESB	IRL
NODES Marketplace	NODES Market	Agder Energi	NO
Innovative Concept	InnoCon	Enedis	F

Table 1 Models assessed

Within this report, the term 'flexibility' is defined as the ability and willingness of power consumers and producers to adapt their power demand and production. This flexibility is subsequently used to help solve or avoid specific grid problems within DSOs. There is general consensus in Europe that DSOs should be able to utilise flexibility from market parties for solving congestion.

The workstream selected and evaluated models according to a fixed set of criteria which included:

- Scope & targeted problem
- Number of actors involved
- Type of load
- Customer segmentation
- Type of flex activation
- Regimes of congestion status
- Coordination mechanism

The workstream held open discussions following the assessment and this work was refined to present a set of takeaways, observations, conclusions and recommendations and the most important of these are outlined below.

The takeaways

As the report aimed to share learning across DSOs to assist with further development of their own models, each model owner was asked to define what they felt they would 'takeaway' as a result of participation. Their opinions, which have been left unedited for transparency, can be found in paragraph 5.2.

Observations:

- It was observed that, to be considered sustainable in its purpose, a model must support equal sharing of profits and costs across energy system stakeholders and must not disturb future development of renewables integration. All models aim to deliver a sustainable approach to congestion vs. capacity management. However their approaches differ vastly, from a non-restricted market to regulatory decision in the pre-connection phase.
- The models can be divided into two main categories based on their coordination mechanism:
    - quota- and rule based, with specific or market-oriented remuneration; or
    - market-based, where the flexibility required for congestion management is obtained and priced through a (separate) market mechanism.
- Some of the models provide practical solutions for solving either current or shorter-term problems; others are research projects, focused on identifying solutions to future problems.
- Every model assessed requires some form of load forecasting, if only to be able to predict the global volume of congestion that will occur in the contracted term, up to 15 minutes ahead.
- Because flexibility markets as a whole are not yet mature, DSOs must experiment with the use of flexibility as a congestion management solution. Models will only fully mature as they are adapted in conjunction with a live, fully-functioning market.
- Models must cope with situations where a flexibility market does not (yet) have enough available liquidity of flexibility. Most models handle this situation with a direct technical load or connection control mechanism.
- The model scopes differ significantly with regard to the specific congestion issues they aim to solve and the type of flexibility or customer used to solve it. The models range from 'holistic', where all types of congestion and customer/flexibility type are addressed, to 'case specific', for example, only larger renewables customers. It was observed that European DSOs seemed to mitigate more urgent congestion problems with case-specific models that are mostly already active in regulation in some form (Belgium, Germany, Denmark).
- Holistic models, addressing all types of congestion and customer/flexibility type, are typically more expensive to implement since they involve more market parties and separate flexibility markets and therefore require more time and effort. In theory though, they should then be capable of offering the full range of flexibility sources to solve all types of (future) congestion. This is untested at present as none of the holistic models (USEF, NODES, PaVn, grid-control) have been implemented at full scale yet.
- The total transaction cost for each congestion management model is not considered. While the workstream concluded that transaction cost should be a decisive parameter for selecting a method, it was unable to calculate costs because the diversity of models, and their individual objectives, prevented firm conclusion.
- The workstream considers it mandatory for DSOs to be able to directly control flexibility in any market-based congestion management model as it is required to perform actual congestion management irrespective of flexibility market transactions. Most models in this report do already mandate this option.

Conclusions:

- Effectively managing congestion using flexibility obtained from the market depends significantly on DSO and flexibility (service) provider forecast accuracy. It is essential that they deliver the market parties accurate prognoses of the expected timing and volume of any congestion and the associated request for flexibility.
- In flexibility market-based models, correct settlement poses difficulties as it is not always possible to determine whether the requested flexibility has been activated. Part of this challenge lies in finding the correct baseline for accounting flexibility.
- In general, there is consensus that strong guidelines are required to sustain a balance between congestion and capacity management for the DSO.
- A model's maturity seems to relate to the problem it aims to solve. 'Case-based' models (that address current capacity issues) have a higher implementation ratio. 'Holistic' models (with a much broader focus) are not yet fully implemented and so have not proven their effectiveness for congestion management.

Recommendations:

- The workstream recommends further analysis of the various congestion issues, particularly those resulting from other parties' trade on energy markets, and evaluation of them in accordance with the different solutions.
- There is a need to analyse the legal implications of congestion management models and their impact on national regulatory framework. This work can be done collectively, initially taking a generic approach to define the regulatory rules required and then adapting these as necessary to meet country-specific recommendations.
- There is a need to analyse the total transaction cost for each congestion management model. This is to better evaluate the costs vs. value of congestion management.
- The different definitions and colours used by the models in their respective operating regimes cause confusion. Harmonizing these would promote greater understanding of each other's models and support interoperability within the European energy market.
- When a TSO is not participating in the same market or coordination mechanism (direct or indirectly) as the DSO, the workstream recommends that a TSO-DSO coordination mechanism is introduced to coordinate flexibility activated by the TSO in the DSO domain for balancing purposes that could lead to congestion in the DSO network.
- A market value analysis study should be conducted to provide insight into the value of flexibility for congestion management for the different roles in the energy system.
- The workstream's final conclusion is that it should continue to build on the many lessons that have already been learned from working together, both on this subject and more broadly. Ideas about future subjects to address include:
  - Improving methods to increase prognoses accuracy to support flexibility market transparency and a robust market, network and availability of supply.
  - Gather and share more in depth insight on the technicalities related to matching flexibility requests with actual flexibility delivered for accurate settlement.

2 Introduction

2.1 Energy transition challenges for DSOs

Energy transition poses numerous challenges to the European energy system. One of the challenges for European DSOs is how to manage the increased energy power volatility caused by more renewables and energy electrification in the distribution grid. This volatility has the potential to lead to frequent network congestion on current networks, decreasing reliability. USEF's DSO workstream was created to bring together DSO experts from multiple EU countries to address these challenges and share learning. The workstream's initial kick-off meeting took place on November 8, 2016 and work has been ongoing since then.

2.2 Increasing risk of capacity constraints

Changes in the energy market as a result of energy transition increase the risk of capacity constraints in the distribution grid. DSOs have to adapt the grid and drastically improve operational control and capacity to accommodate this. The three key causes of increased network stress are described below.

Faster increasing demand due to electrification of heating and mobility	A fast growth of sustainable and non controllable production leading to high infeed loads	The use of more and more decentral production and load for portfolio optimization and balancing

2.2.1 Faster increase in demand

DSOs have always been required to accommodate growth in demand. This used to be comparatively easy - a fairly steady year-on-year growth enabled DSOs to plan and budget for work to increase capacity by means of additional cables, lines and transformers. In recent years, new load types have been introduced to the grid such as electric heating, hot water boilers and electric vehicles. These create significant and rapid changes to both load and peak demand patterns on a much more regular basis, increasing the risk of congestion.

2.2.2 More renewables

The sustainable energy transition continues to see the volume of decentralised grid-connected renewables increase. This creates a higher in-feed on the distribution grid at medium and low voltage level and requires that energy flows become bi-directional. In addition, there are synchronicity issues, where generation is high and demand low or vice versa, and this exacerbates congestion problems.

2.2.3 Decentralised load and production used portfolio optimization and balancing

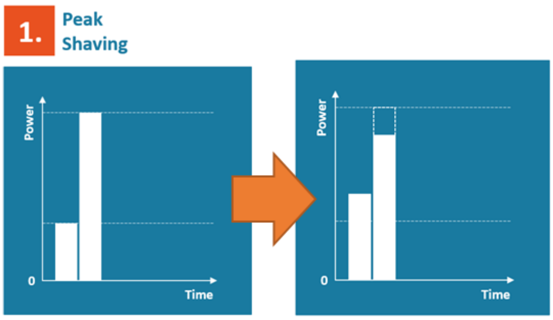
Increasing energy price volatility and a decrease in the ability to optimise and balance portfolios using traditional methods (by adjusting fossil production etc.) means that BRPs and TSOs will increasingly utilize new flexibility sources like decentralised production or load to achieve the same result. This has the potential to drastically increase loads and therefore stress on the distribution grid. The unpredictable nature of this type of usage has the potential to create problems so quickly that it will be almost impossible for DSOs to manage in a traditional way.

2.3 Capacity and congestion management

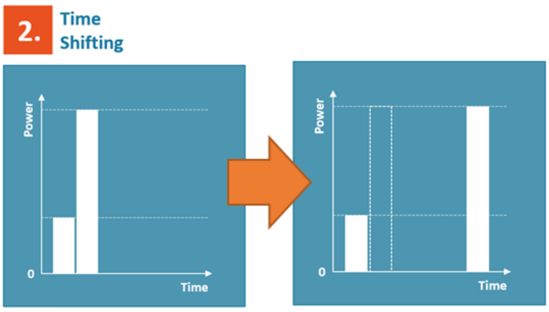
Capacity management involves a system operator performing the planning and realization of network transport capacity, down to individual customer level, according to its business criteria and regulatory framework.
Capacity constraints can result in incidental or frequent temporary overload or congestion (1-2 hours a day/month/year) or even structural and more frequent overload. The term congestion refers to overload of grid components, over- and under voltage and/or forced usage of the local fail-over capacity in the distribution system. The overload deteriorates network performance, power quality and, left unaddressed, would lead to a shutdown by the automatic safety systems installed to prevent a total system collapse. Congestion management aims to limit or avoid exceeding network congestion in accordance with regulatory and/ or the network operator's own rules. Rules are based on broad parameters but are primarily driven by the need to mitigate the risks posed by overload.

2.4 Flexibility

The term 'flexibility' is defined as the ability and willingness of power consumers and producers to adapt their power demand and production. Flexibility can be applied in the following ways:



Peak shaving will reduce demand or production at the critical moment in time and will add this to demand or production at another moment in time when this is more optimal for the portfolio of a BRP or will reduce stress on the network.



Time shifting will postpone the demand or production at the critical moment in time and will activate this demand or production at another moment in time when this is more optimal for the portfolio of a BRP or will reduce stress on the network.

Flexibility in time and amount is a combination of both peak shaving and time shifting.

2.5 Market-based flexibility

Flexibility has a range of purposes within an energy system including system balance, local balance, portfolio optimization and congestion management by the system operator.

In this report, *market-based flexibility* is flexibility that involves all players and roles in the power and energy market i.e. consumers, producers, balance responsible parties, system operators and regulators. We consider all stakeholders that are a source of flexibility, benefit from it, or have a controlling role.

2.6 Flexibility-based congestion management

This report is focused on the use of market-based flexibility to perform congestion management. One method for doing this is to commoditise flexibility and create a market for the exchange of it that offers rewards to all participants. Another method considered viable by DSOs is curtailing prosumers feed-in; this offers benefits to the DSO and, ideally, also the prosumer.

2.7 Traditional congestion management before market based congestion management

The report does not consider congestion management that utilises activation of flexible DSO /TSO grid assets, such as reconfiguration of network parts (topology reconfiguration) or transformers with tap changers (OLTC). While these play an important role in congestion management, the workstream consensus is that they are a default option and applied before or at the same time as considering market-based congestion management. Also the default congestion management options are required for benchmarking the cost of market-based congestion management.

2.8 Status of flexibility-based congestion management in Europe

There is broad consensus in Europe that a DSO should be able to buy flexibility on an open flexibility market as part of its congestion management strategy. The USEF Foundation has been working for several years on market mechanisms to make this possible and these are available in USEF. At the same time, several initiatives and regulatory framework adjustments have been, or are being, developed in European countries. As a result, there are multiple models that incorporate use of flexibility by a DSO to solve its own congestion or capacity management problems.

There are many existing reports that address the need for a flexibility market at European level published by organisations including Smart Energy Europe, Eurelectric, EDSO for Smartgrids, Cedec, Geode, ENTSO-E and the European Commission. The European Commission set up a Smart Grids Task Force in 2009 to advise on issues related to smart grid deployment and development. It consists of five expert groups focused on specific areas. Expert Group 3 (EG3) focuses on regulatory recommendations for smart grid deployment. The group worked through 2014 and 2015 on the subject of flexibility and demand response and its deliverables were published in 2015 (EG 3 report and Annex 'Regulatory Recommendations for the Deployment of Flexibility'). Members of the USEF Foundation were part of this group.

The report included a recommendation that flexibility must be offered by all system participants, through both production and consumption. It also stated that flexibility should be acquired by DSOs and TSOs via a market-based solution as far as possible. The scope for demand response to deliver flexibility was heavily promoted by EG3, as was the need for a new aggregator role to unlock flexibility. The relationship between a new market role aggregator/FSP and existing market roles, like suppliers and balance responsible parties, was heavily discussed in the EG3 group. An important related topic is the payment of flexibility by the independent flexibility aggregator/FSP to the supplier/BRP and the assessment/measuring of the delivered flexibility. EG3 did not work on a market model and so the task was left to the member states.

2.9 Evaluating EU-models for congestion management

DSOs in every European country face congestion and capacity management challenges. As a result, there are multiple initiatives and regulatory framework adjustments, at various stages, which address congestion management at DSO level. Each aims to find a proper mechanism or instrument to manage incidental or short term (< 1-3 years) or even permanent overload in certain parts of the power network. The cause of this overload can be feed-in (production) or loads (consumption).

2.9.1 Congestion management

Where a DSO cannot solve a problem with his own assets (e.g. topology changes, tap changers), the procurement and use of flexibility for congestion management could be the most economical solution. All workstream members consider flexibility for congestion management to be an essential addition to traditional grid reinforcement.

The USEF DSO workstream's aim is to describe and evaluate a set of congestion management models that include interaction between a DSO and the market. The workstream and the report aim to stimulate exchange between DSOs about their specific challenges, and individual congestion management models, and apply the learning in two ways:

- to support the enhancement of country-specific DSO models
- to inform development requirements for future releases of USEF to optimise its relevance and compatibility

2.9.2 Approach

The different country-specific challenges were addressed by the workstream and the respective market-based congestion management models are explained in this report. A set of criteria was defined for initial categorization and evaluation of the models. The evaluation was conducted by, and with, the DSO specialists in workstream sessions and resulted in a set of observations, conclusions and recommendations. The model descriptions were provided by model owners and, after evaluation, each owner was asked to define what they felt they would 'takeaway' as a result of participation.

2.10 Geographical coverage

The map in Figure 1 below shows the selected models' countries of origin. Each model has been created within the context of its country's existing regulatory framework and so is primarily focused on country-specific issues and solutions. Some models have been created as a result of innovation projects and so address the specific challenges of the project.

Figure 1 Countries of origin

2.11 Participating models and organizations

Table 2 includes an overview of the model name, short name, endorsing system operator and country of operation

Model name	Short name	System operator	Country
Flex Groot Verbruik	Flex GV	N.V.Alliander	NL
T-Flex	TFlex	ORES scrl	BE
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Das Proaktive Verteilnetz	PaVn	innogy SE	D
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Table2 Models assessed

2.12 Scope

The scope of this report covers market-based models for congestion management that use flexibility.
Models were selected because they were directly related to the DSOs involved in the USEF workstream. The report is not intended to provide a complete overview of all models in Europe but rather a snapshot of selected models that existed in some form in 2017. The models assessed within the report are evolving over time and, in some cases, they are part of a broader national roadmap.

3 Models overview

3.1 Introduction

This chapter begins by describing model commonalities and references and then summarizes each congestion management model in turn to give an overview of its origin, purpose, congestion management principle, actors/roles and current status.

3.2 Regimes

All the models described in this report make use of temporary regimes or status for predicted or occurring congestion. Most use colour coding to indicate whether congestion is expected or currently occurring and are specific about where in the network this will, or is, taking place. Some models also define a congestion point - a hierarchical point in the network beneath which congestion initially occurs. Often this is a single asset (transformer, cable). Other models use quotas, where a group of customers or a load controlled by a specific aggregator gets a status and matching colour.
Colour codes are an indication of the market interaction regime rather than the state of the network. Paragraph 4.8 details the colour codes used in each model and their individual meanings.

3.3 Loads

The models described in this report have been considered in terms of network control and/or asset loads and often a combination of both. In the report the term 'loads' refers to typical consumption and/ or production (feed-in) unless otherwise stated.

3.4 Roles in the energy system

This report considers energy system roles, except the 'exchange', as those which appear in the USEF roles model as described in *USEF: The Framework Explained* (USEF Foundation, 2015). The individual roles are described below.

Prosumer	A Prosumer can be regarded as an end user that no longer only consumes energy, but also produces energy. USEF does not distinguish between residential end users, small and medium-sized enterprises, or industrial users; they are all referred to as Prosumers. In this text we also use the term Prosumer for end users that have controllable assets (Active Demand & Supply) and are thereby capable of offering flexibility.
ADS	In USEF, Active Demand & Supply (ADS) represents all types of systems that either demand energy or supply energy which can be actively controlled. This enables the ADS device to respond to price and other signals from the Aggregator and to provide flexibility to the energy markets via the Aggregator. The Prosumer owns the device and defers responsibility for controlling its flexibility to the Aggregator. The Prosumer has final control over its assets, which means the Aggregator's control space is limited by the Prosumer's comfort settings. Hence the Prosumer is always in control of its comfort level; if the associated remuneration is high enough however, the Prosumer might be willing to compromise on its comfort levels. In this text we also use the terms units, assets or resources when referring to ADS.
Aggregator	The role of the **Aggregator** or **Flexibility Service Provider** is to accumulate flexibility from Prosumers and their Active Demand & Supply and sell it to the BRP or Supplier, the DSO, or (through the BSP) to the TSO. The Aggregator's goal is to maximize the value of that flexibility by providing it to the service or portfolio of services defined in the USEF flexibility value chain that has the most urgent need for it. The Aggregator must cancel out the uncertainties of non-delivery from a single Prosumer so that the flexibility provided to the market can be guaranteed. This prevents Prosumers from being exposed to the risks involved in participating in the flexibility markets. The Aggregator is also responsible for the invoicing process associated with the delivery of flexibility. The Aggregator and its Prosumers agree on commercial terms and conditions for the procurement and control of flexibility.

BRP	A Balance Responsible Party (BRP) is responsible for actively balancing supply and demand for its portfolio of Producers, Suppliers, Aggregators, and Prosumers. In principle, everyone connected to the grid is responsible for his individual balance position and hence must ensure that at each imbalance settlement period (ISP) the exact amount of energy consumed is somehow sourced in the system, or vice versa in case of energy production. The Prosumer's balance responsibility is generally transferred to the BRP, which is usually contracted by the Supplier. Hence the BRP holds the imbalance risk on each connection in its portfolio of Prosumers.
DSO	The DSO is responsible for the active management of the distribution grid and introduces the system operation services defined in the USEF flexibility value chain (USEF Foundation, 2015). The DSO is responsible for the cost-effective distribution of energy while maintaining grid stability in a given region. To this end the DSO will 1) check whether DR activation within its network can be safely executed without grid congestion and 2) may use flexibility from market participants to execute its system operations tasks.
TSO	The role of the Transmission System Operator (TSO) is to transport energy in a given region from centralized Producers to dispersed industrial Prosumers and Distribution System Operators over its high-voltage grid. The TSO safeguards the system's long-term ability to meet electricity transmission demands. The TSO is responsible for keeping the system in balance by deploying regulating capacity, reserve capacity, and incidental emergency capacity.
Supplier	The role of the Supplier is to supply energy, to buy the energy, hedge its position, manage the energy and the associated risks, and invoice energy to its customers. The Supplier and its customers agree on commercial terms for the supply and procurement of energy.
Exchange	The role of the marketplace is management, facilitation and operation of the marketplace.

3.5 Aggregator / Flexibility Service Provider based models

The recent EU Clean Energy package includes the aggregator role. Some models already have a relatively clear description of the aggregator function or role. In USEF, the aggregator role and responsibilities are crucial for the model to function. Other models do not require an aggregator role but, with the exception of RedGreen, allow for an (independent) aggregator to take a role. The flexibility service provider and aggregator are the same in this report.

3.6 Flex GV – NL

3.6.1 Description

Flex GV, a model developed by DSO Alliander, was trialled until December 2017 in the Netherlands. It is a concept for congestion management based on connection and transport fee incentives. It provides a mechanism between the DSO and customer that uses a 'traffic light' system to announce predicted congestion in the customer's grid area. The contracted applicable regimes (colours) are communicated directly to businesses with a Flex GV contract, enabling network congestion management by communicating temporary local/regional capacity constraints. The target customer group is customers with larger CHP and flexible loads installed.

The model is based upon existing standard connection capacity contracts. Larger customers and SMEs pay a monthly tariff based on capacity and capacity forecast. They are allowed to exceed the contracted capacity in the green phase up to the technical limitation (protected capacity) but are requested to limit this capacity exceedance during red phase. The financial benefit lies in the opportunity for customers to connect with a lower contracted capacity than normal as a result of Flex GV's extra headroom capacity options.

Value drivers:

- Research to offer the customer more flexibility so they can make better use of peaks in energy (e.g. when there is a high volume of renewable energy being produced).
- Lower contracted transmission capacity with the TSO is a driver for the DSO.

3.6.2 DSO role

The DSO has to forecast (up to 15 minutes ahead) the load on congestion points and communicate the regime (green, orange and red) accordingly. The DSO closes a bilateral connection agreement with the prosumer.

3.6.3 Roles and interaction

The roles defined in the model are the DSO and the prosumer. The aggregator role is not explicitly defined. The supplier and BRP retain their existing roles and responsibilities. The model supports an aggregator or services company role but the agreement is between the DSO and prosumer/customer.

The communication of the regime is one directional. There is no response communicated back to the DSO. The prosumer responds to the regime voluntarily. Determining whether the prosumer responded to the regime signal is achieved afterwards, by metering.

The interaction between the actors/roles that are explicitly described in the model are depicted in a standard interaction template in Figure 2.

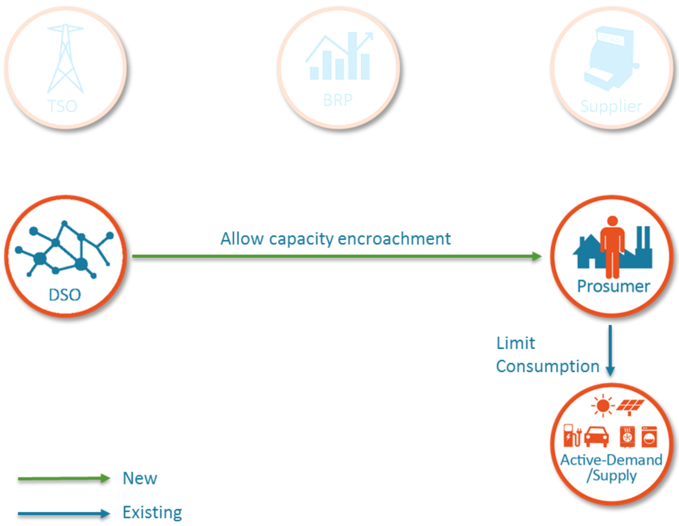

Figure 2 Interaction between actors/roles in the FlexGV model

3.6.4 Congestion management

Congestion management is performed by issuing regimes to customers with Flex GV contracts at least 15 minutes prior to congestion. The DSO defines the congestion point. In the trial project, the congestion point was the primary substation.

Congestion management effectiveness is determined firstly, by the amount of contracted customers and their contracted power and secondly, by their obedience and behaviour with respect to the issued regime.

3.6.5 Status and trial results

The trial was operational between June and December 2017. The total power under Flex GV contract was a maximum of 7 x 2MVA. In the first part of the trial, prosumer participation in the regimes was voluntarily and there were no consequences applied when the red signal was ignored.

In the trial period, the red regime was issued several times but participants did not act on it. Preliminary conclusions suggest the absence of a penalty meant there was no requirement for participants to make a financial choice between paying the penalty and business consequence. It is not yet decided whether there will be a further trial project.

3.7 TFlex – BE

3.7.1 Description

The TFlex model and decree demonstrate the opportunity to connect renewables at DSO level when the requested TSO/DSO network capacity is not available. It is applicable to network areas where new connections, or expanded existing connections, may cause congestion up to the DSO/TSO interconnect.

The decree is based on two main considerations:

- Reasonability of the grid reinforcement by TSO/DSO for accommodation of the renewable source
- Permanent and flexible injection capacity

Reasonability evaluation depends on the network level of the requested connection:

- LV network: Mandatory investment
- MV network: TSO/DSO study (investment cost and increase of energy after investment) and regulatory decision

Initial permanent and flexible injection capacities are defined according to available capacity at the point that a producer requests a new or reinforced connection. The DSO and TSO then evaluate any network investment required to make all the capacity available. The result of this evaluation is compared with the criteria (maximal € network investment per marginal productable MWh as a result of network investment) defined by regulation:

- Network investment is not reasonable: When the network investment costs are not reasonable according to the regulators calculation, the DSO is not obliged to expand the capacity. Nevertheless renewables can be fully connected. When production is exceeding the available capacity, the DSO is allowed to curtail directly. The DSO must compensate loss of revenue within the initial permanent capacity only.
- Network investment is reasonable: The DSO is obliged to expand the capacity. The expansion must be executed in a given period. Final permanent and flexible injection capacities are defined. Renewables can be connected before the expansion but must be curtailable. The DSO must compensate loss of revenue within the initial permanent capacity only. After the convened period for investment, and if curtailment occurs, the DSO must compensate loss of revenue within the final permanent capacity only.

Value drivers:

- DSO: allows connection of more renewables than theoretically possible at a socially acceptable cost.
- Producer: knows the risks of curtailment at the beginning of the renewables project. The flexibility is offered by the producer based on his acceptance of the curtailment and remuneration.
- Pricing rules: price for compensation of revenue loss is defined by the regulator.

3.7.2 DSO role

The DSO has a central role in the whole congestion process, from the initial calculations for the investment to the final loss of revenue payment to the producer.

3.7.3 Roles and interaction

The connection contract describes the requirements between the producer and the DSO. The contract includes general requirements related to the calculation of the permanent and flexible capacity, as well as the calculation of the curtailed volumes. The TSO/DSO collaboration agreement describes the modalities if congestion occurs at TSO/DSO interface level due to renewables at DSO level.

The interactions between the actors/roles that are explicitly described in the model are depicted in a standard interaction template in Figure 3 on the following page.

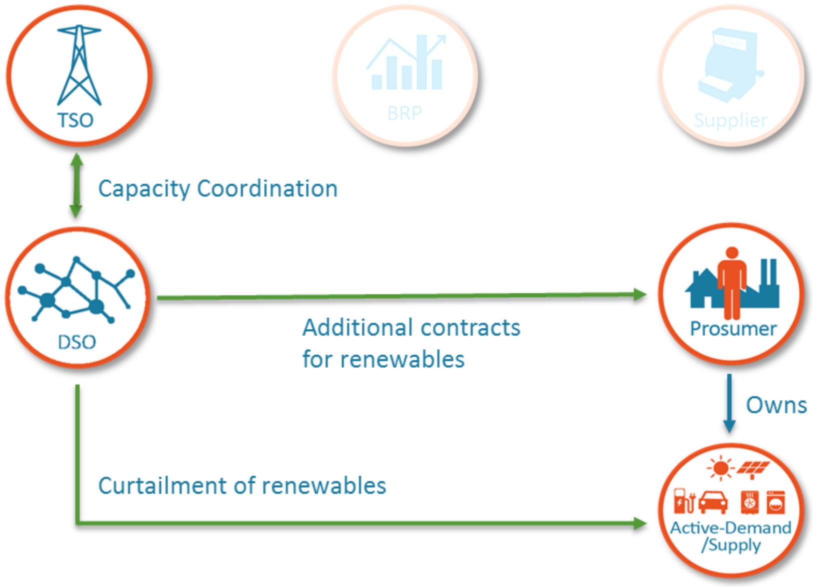

Figure 3 Interaction between actors/roles in the TFlex model

- Operational interaction: The DSO and prosumers interact directly.
- Coordination is required between the TSO and DSO when congestion at TSO level is caused by renewables at DSO level.
- The BRP, aggregator and supplier are not involved directly but are informed through existing processes. There is no BRP perimeter correction or link with the balancing processes at present; this could be an evolution if needed.
- Price of the loss of revenues is defined by the regulator.

3.7.4 Congestion management

Curtailment

When congestion is predicted and occurs, the DSO is allowed to impose individual injection restrictions. In all cases, the renewable source must be technically curtailable.

Congestion management in the model is defined as the process where congestion is predicted and curtailment is effectuated until congestion is relieved.

Congestion management in TFlex includes the following steps:

- The DSO performs load flow calculations and publishes the maximum feed-in profiles for the network area up to day ahead with consideration for network capacity (including maintenance and redundant capacity).
- This also happens close to real time: The DSO then calculates the individual maximum allowed injection and the renewable power to be curtailed. This calculation is refreshed every 5’ until congestion disappears.
- The customer can then choose between renewable curtailment and consumption increase but his actions have to fulfil the injection requirement.
- A technical escalation process is foreseen in cases where the injection requirement is not fulfilled.
- After curtailment occurs, the DSO calculates the curtailed volume in comparison with a baseline. The baseline is derived from real generation profiles of other similar generation. The calculation rules are published.

Local optimization
Local optimization is an alternative to avoid curtailment and optimize the use of renewables.
Limiting curtailment (by increasing local consumption from other customers directly, and/ or via an aggregator, while retaining operational security for the DSO and decreasing curtailment costs) is not yet part of the scope but should be possible in the future.

3.7.5 Status

TFlex has been implemented in regulation decrees since 2016. The first practical cases are expected in 2018.
Regulation can be found here: (F/NL)
http://www.ejustice.just.fgov.be/cgi_loi/change_lg.pl?language=nl&la=N&cn=2016111016&table_name=wet

T-FLEX baseline formulae can be found at http://www.synergrid.be/download.cfm?fileId=C8-04_FR_Final_20171128.pdf

3.8 Red-Green for balancing – BE

3.8.1 Description

The Red-Green model aims to provide technical procedures and model contracts for the delivery of contracted tertiary reserves, specifically manual frequency restoration resource sourced from the distribution grid, as well as a model contract for primary reserves.

In order to guarantee the safety and security of the grid, the DSO performs a network prequalification procedure. This begins with a check to establish whether the connection contract is compatible with the offered services, followed by a check that the offered flexibility does not induce a risk of local congestion (which has not been the case for any participating grid user so far). These checks are referred to as a Network Flexibility Study or NFS. The approval of the DSO is a precondition of participation in the auction (by the TSO) for balancing power.

The DSO is also involved in the calculation of the delivered volumes to the TSO from aggregated DSO resources.

3.8.2 DSO role

The DSO has two main roles:

- Check of the risk of congestion
- Calculate the delivered volumes

3.8.3 Roles and interaction

The interaction between the actors/roles that are explicitly described in the model are depicted in a standard interaction template in Figure 4.

Figure 4 The interaction between actors/roles in the Red-Green model

In the contract phase, information is exchanged between the customers and the DSO about the level of required power and capacity. In operational phase, there is no significant information exchange. In the Settlement phase, the DSO calculates the delivered volumes.

3.8.4 Congestion management

Each NFS study examines the relevant network area access point and contracted flexibility. In each zone, the system operator takes into account all existing pre-qualifications, new pre-qualification requests and any potential new connections and new configurations of the network (for example, as a result of investments).

COLOR CODE ZONES	IMPACT ON THE ZONES
GREEN	No risk to operational security
RED	Operational security risk : Flexibility constraint measures are taken to avoid the risk of congestion

All zones so far have been green. Only a static prequalification process is needed at present. As the process is recurring (quarterly), changes in zones are possible.

The NFS study is carried out on quarterly basis in March, June, September and December of each year. The technical prequalification procedure with the DSO takes 15 days. DSO approval is a precondition of participation in the auction (by the TSO) for balancing power.

When ancillary services are sourced from prequalified distribution grid users (even if related to a service delivered to the TSO e.g. balancing), a contract is created between the DSO and service supplier that, at the least, contains modalities about:

- The DSO prequalification procedure and the information the DSO requires
- Measuring: methods and reporting
- Liabilities between the DSO and the service provider

3.8.5 Status

Red-Green model has been implemented in regulations since 2016 and a red situation has not yet occurred.

The pre-qualification process can be found at:
http://www.synergrid.be/download.cfm?fileId=C8-01_FR_20161020_v4.docx

3.9 PaVn – D

3.9.1 Description

The ‘Das Proaktive Verteilnetz’ (PaVn) is a congestion management model based on the regimes in the ‘Smart Grid Traffic Light Concept’ published by the German Association of Energy and Water Industries (BDEW)[1] and funded by the German Ministry for Economics and Technology (BMWi). The project offers a potential solution for incorporating flexibility into distribution grids. Localised network congestion is managed using distributed flexibility and there is an associated communication process between the market and grid. Figure 5, below, indicates the interaction between Grid Operators and market partners within each phase of the traffic light.

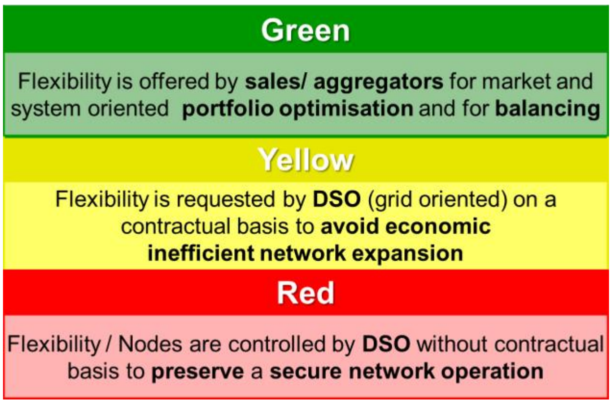

Figure 5 Phases of the traffic light system

The value drivers in this project are as follows:

- Proactive identification of congested areas in the grid
- Introduction of the yellow regime in the German market system
- Identification of the optimal location of measuring points in the grid
- Stochastic state estimation of the grid by means of enviromental and system data, as well as known baseline products without consideration of all system measurements.
- Newly developed grid estimation procedures
- Analysis of the economic efficiency of using flexibity for congestion management

3.9.2 DSO role

The DSO forecasts overload and voltage violations for relevant grid sections up to three days in advance using weather forecasts, baseline products and historical metering data. Where an area is expected to be congested, the DSO publishes the flexibility required to avoid this relative to a list of known local flexibility sources. To be able to perform this task, the DSO has to identify potential congestion areas in his grid planning process and search within markets for guaranteed long-term flexibility (e.g. more than one year with ‘options’). The DSO calculates whether utilization of flexibility or conventional grid extension will be more economically viable and, where it makes sense, contracts the necessary amount of flexibility if available. This leads to contractual relations, like options, between the DSO and aggregators / prosumers.

[1] BDEW Bundesverband für Energie- und Wasserwirtschaft e.V., Smart Grids Ampelkonzept: Ausgestaltung der gelben Phase, Berlin: BDEW, 2015.

3.9.3 Roles and interaction

The interactions between the actors/roles that are explicitly described in the model are depicted in a standard interaction template in Figure 6.

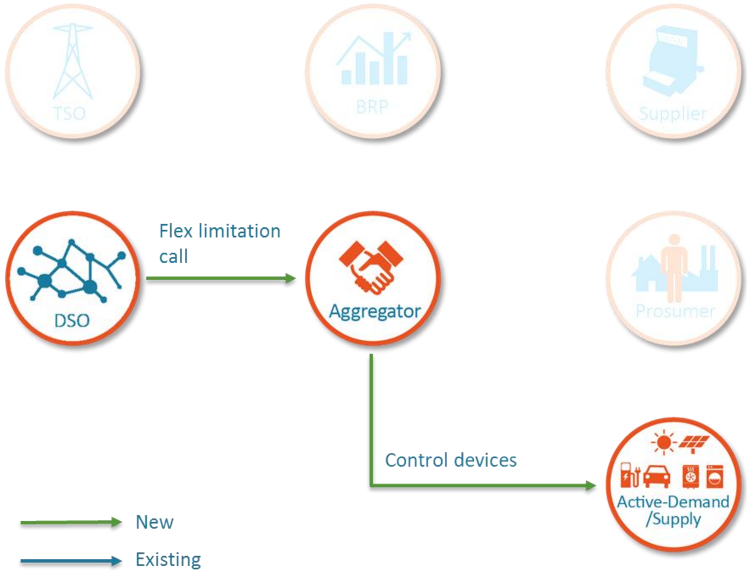

Figure 6 The interaction between actors/roles in the PaVn model

The roles that are actively involved in the model are the DSO, aggregator/retailer. Involvement of the BRP and prosumer is passive in the current market model.

3.9.4 Congestion management

In the rare case where congestion can't be avoided by other means (e.g. topology changes), the DSO provides the aggregator with a list of his total flexibility requirements and types, any related technical demands and the boundary conditions. The influence flexibility has on congestion can change depending on the grid location, topology and predicted power flow. To address this, a congestion-specific sensitivity for each flexibility type is determined which enables the aggregator to individually value elements of his portfolio and optimize assets. As a result, it is easier for him to offer a considerably larger range of freely-selectable flexibility types.

Congestion forecasts are announced via a communication and service platform which coordinates the non-discriminatory selection of flexibility options and manages how the flexibility call (Figure 7) is further processed. Aggregators are subsequently able to determine which assets to use to fulfil the flexibility request while respecting existing contractual SLAs with their customers. Whether there will be an activation fee in addition to the reservation fee, and how this grid-oriented usage is combined with system-oriented usage (TSO), or marketing on the energy spot market (e.g. which market closure procedures etc.) was not part of the original project scope but will be part of future work.

Flex-Limitation Call			
Call-Information			
Call-ID	DSO	Period	
28169132	Westnetz	From→ Until	
Available Power Range			
Pmin	-3,71 MW	Pmax	+5,23 MW
Affected Metering Points			
ID	Metering Point ID	Sensitivity	+Data
1	DE123456...	0,97	ABC
2	DE234567...	0,79	BCD
n	DE987654..	0 → 1	XYZ

1. Boundary Condition			
Pmin	-1,23 MW	Pmax	+0,23 MW
ID	Metering Point ID	Sensitivity	+Data
1	DE123456...	0,93	ABC
n	DE987654...	0 → 1	XYZ

Figure 7 Example of a flexibility limitation call

3.9.5 Status

The model is the result of the project "Das Proaktive Verteilnetz", one of a number of traffic light implementation projects in Germany. The project is currently active and will run until 30th April 2018. The demonstration tests are already complete and the results are being analyzed.

Supported by: Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

3.10 grid-control – D

3.10.1 Concept description

The research project, 'grid-control – Advanced Decentral Grid Control,' began in July 2015 to develop a comprehensive system approach for the successful realization of the German 'Energiewende'. It aims to develop and evaluate innovative concepts and solutions as part of an overall concept for sustainable distribution grids. The project is part of the funding initiative, 'Zukunftsfähige Stromnetz,' of the German Federal Ministry for Economic Affairs and Energy. It is being delivered by a consortium, with Netze BW GmbH as the leader, working alongside industry and research institution partners including: ADS-TEC, Fichtner IT Consulting, FZI Forschungszentrum Informatik, KIT Karlsruhe Institute for Technology, Landis+Gyr, PREdistribuce, Seven2one Informationssysteme and University of Stuttgart. The concepts and implemented system solutions are tested and evaluated with end customers, by field test, at the gridlab (NETZlabor) Freiamt.

Part of the overall concept is the development of an integrated process between the market and the DSO for generating load flow forecasts. A non-discriminatory quota-based approach for congestion management (based on the German traffic light concept published by the German Association of Energy and Water Industries) has also been implemented with role-specific system solutions. Each traffic light phase has associated rules related to interaction between the DSO and market, and usage of flexibilities (see Figure 8). In project grid-control, the yellow phase is realized through a non-discriminatory quota model.

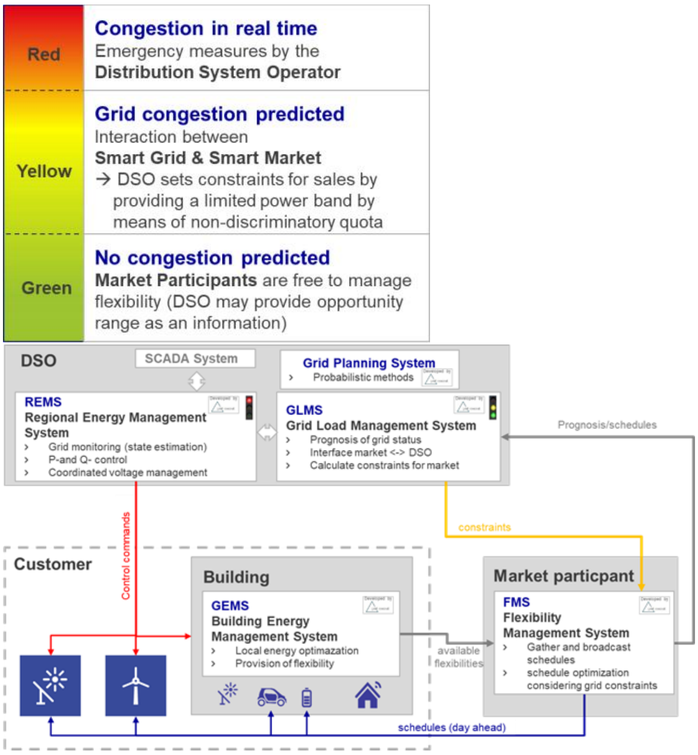

Figure 8 Realization of the Grid Traffic Light Phases and implemented system solutions (project grid-control)

3.10.2 DSO role and coordination mechanism

In principle, the DSO is indifferent about whether action to mitigate predicted grid congestion is taken on the generation or consumption side. The concept applied assumes the DSO provides constraints for the market actions by means of non-discriminatory quota (yellow grid traffic light phase) or opportunity ranges (green grid traffic light phase), so the DSO does not act as a market participant.

The DSO calculates the grid constraints based on the schedules of market participants and prognoses for unflexible loads/generation units on a quarter-hourly, day-ahead basis. These are provided to market participants in the form of quotas. Where congestion is predicted, the market participants consider the constraints as part of their regular, market-oriented optimization and either send final schedules to smart home systems at the prosumer side, or directly control flexibilities.

Grid planning processes, to identify potentially congested areas and contract the flexibilities associated with quota model (e.g. long-term contracts, yearly auctions or regulated by law) are required. While not part of the original scope for the research project, they will be part of future work.

3.10.3 Roles and interaction

The interaction between the actors/roles that are explicitly described in the model are depicted in a standard interaction template in Figure 9.

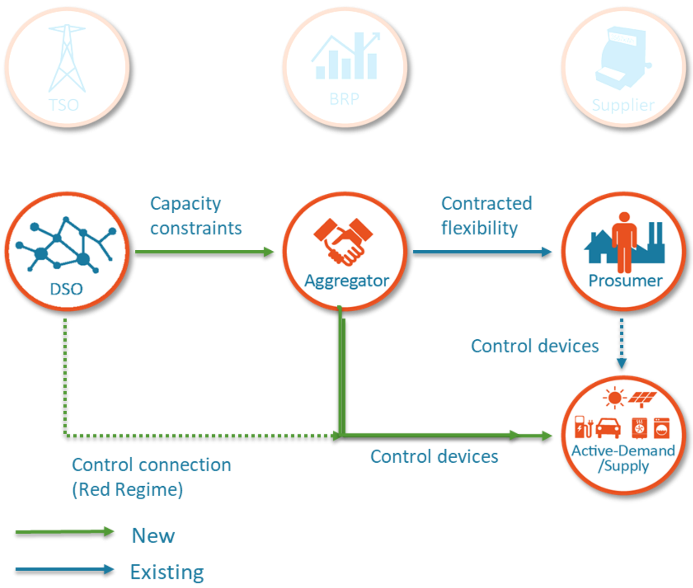

Figure 9 Interaction between actors/roles in the grid-control model (D)

3.10.4 Congestion management

The increase in grid connected renewables and use of flexibility by market parties may make it difficult in future to predict the grid state without any knowledge of the market. To address this, the project includes an integrated process between the market parties and the DSO to enable the generation of power flow forecasts in MV/LV grids.

The DSO determines several grid clusters in the relevant grid section for the calculation of grid constraints (quotas). The cluster levels represent technical restrictions that effect all decentralised energy systems at lower cluster level and are generally based on the network structure and natural congestion. In project grid-control, four grid-oriented regional cluster levels are defined: HV/MV transformer, MV feeder, MV/LV transformer and LV feeder.

Quotas present the share of flexibilities per grid cluster that can be activated at each point in time without causing grid congestion. The ratio is calculated according to the grid capacity, the forecasted power required by unflexible loads/generation units and the installed power of flexibilities in each cluster. The quotas are valid for all flexibilities in the relevant cluster and are non-discriminatory i.e. similar in size for all market participants, with flexibility in the cluster (e.g. 95%). Market parties may act freely within the provided restrictions and optimize amongst themselves e.g. by trading quota in a secondary market. In the red phase, the DSO directly controls flexibilities.

There are several levels of expenditure and complexity in the quota model for step-by-step implementation:

1. Static quota for flexible loads: adapt the current fixed activation times for e.g. power-to-heat systems to a more flexible concept. Calculation e.g. once a year and for typical days. No consideration of decentralised energy production. (approach of the Project 'Flexible-Power-to-Heat' by EnBW and Netze BW)
2. Dynamic quota for flexible loads: consideration of decentralised energy production on the basis of long-term feed-in prognosis or day-ahead calculation.
3. Dynamic quota for flexible loads and generation units: project grid-control concept with day-ahead quota-calculation on the basis of schedules and prognosis for loads and generation units.

Figure 10 shows the realization of quotas compared to the current fixed activation schemes for controllable loads including market trading and physics.

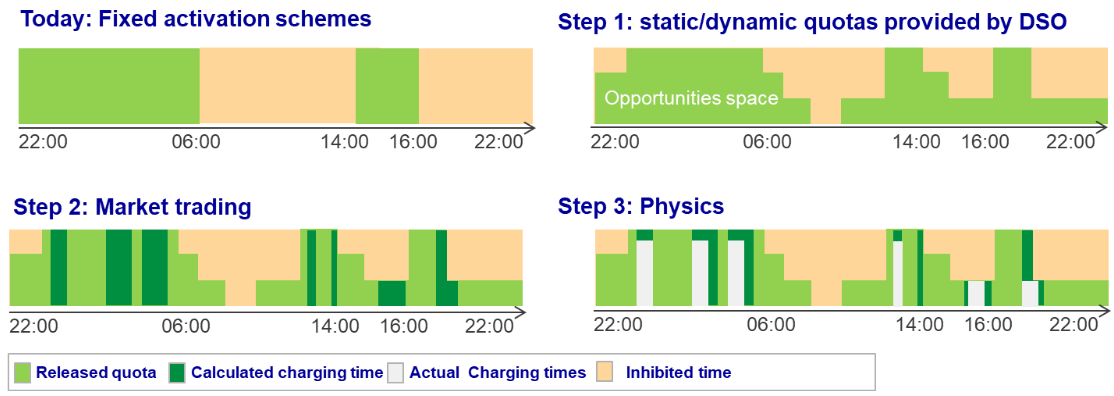

Figure 10 current fixed activation times vs. quotas

3.10.5 Status

The concept and developed system solutions are implemented in test models and integrated in a field test environment in the gridlab (NETZlabor) Freiamt at Netze BW GmbH. Current field tests will run until September 2018, with the project projected to end in December 2018. More information can be found at www.projekt-grid-control.de

3.11 USEF – NL

3.11.1 Description

The Universal Smart Energy Framework (USEF) was established to enable a smart energy market encompassing all players including the DSO and (residential) prosumers. The framework includes a market structure and the associated rules and tools required to integrate flexibility. It fits on top of most energy market models, extending existing processes to offer the integration of both new and existing energy markets.

USEF aims to provide an integral flex market model which includes all stakeholders in the energy system. Flex requirements and offers are traded on a flex market centred on the aggregator role. The BRP and DSO roles have direct access to this market. Aggregated flexibility is available through the market for portfolio optimization, TSO balancing and TSO/DSO congestion management. The TSO has access to the market via the BRP. It aims at sustainability by providing fair market access and benefits to all stakeholders active on the market.

3.11.2 DSO role and coordination process

The DSO begins by communicating the congestion points and underlying connections with the relevant stakeholders (aggregators, meter data companies) via the common reference register.

Next, the DSO receives a day-ahead plan (D-prognoses) from every aggregator in a congested area and determines for which periods and congestion points overload situations are expected. A corresponding flexibility request is then sent to all related aggregators. The DSO assesses all received offers and orders flexibility based on best fit to the need and price. The DSO works through this process for all congestion points.

The actions described above are all executed up front, either day-ahead or intraday. At the time of execution, the DSO monitors the situation to see whether the requested capacity stays within the limits and, where it doesn't, he orders flexibility based on open offers.

Sometimes insufficient flexibility is available to avoid an overload so the regime for that grid part switches to orange. The DSO then directly intervenes in the market, and relations between prosumers and aggregators, by technically limiting connection capacity or using an alternative direct measure to control the load. During this period, the market is overruled by the DSO. As soon as the situation allows it, the regime returns to yellow.

3.11.3 Roles and interaction

The interaction between the actors/roles that are explicitly described in the model are depicted in a standard interaction template in Figure 11.

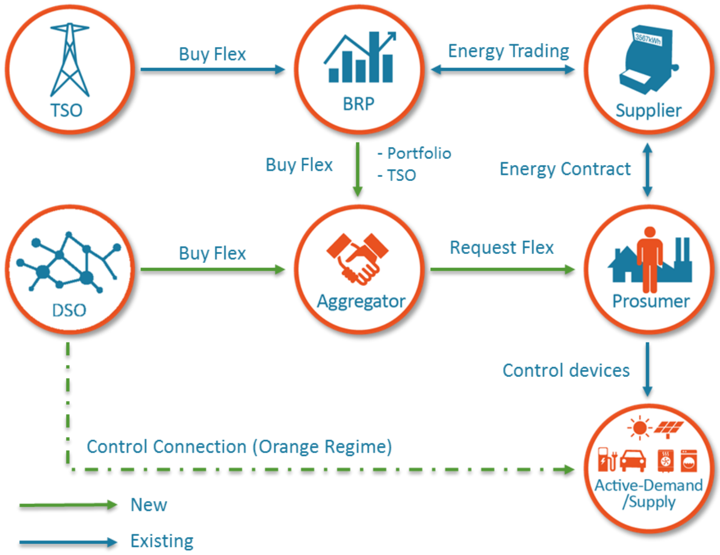

Figure 11 Interaction between actors/roles in the USEF model

The main roles in USEF processes are the aggregator, BRP and DSO. In addition the TSO (via the BRP) and the prosumer (via the aggregator) are involved. Supporting roles are the common reference operator, responsible for linking flexibility sources to specific congestion points, and the meter data company.

3.11.4 DSO Congestion management

The TSO and DSO are responsible for detecting and forecasting congestion, defining the congestion area, receiving load forecast from aggregators and requesting flexibility offers from aggregators. Congestion areas are published in an open access repository and forecasting is mandatory for the published congestion areas. Congestion management is performed by issuing flexibility requests to aggregators active in the congestion areas in advance of expected congestion periods. The volume and price of the flexibility offered by aggregators is negotiated in an iterative process, where the aggregator program is validated and offered to and/ or with the BRP. The DSO is obliged to buy the offered flexibility at the price offered (single buyer must buy). The supported timeframe for this process can vary from year ahead to 15 minutes ahead.

In situations where the requested flex is not, or won't, be delivered, the orange regime is applicable. In the current version of the framework, the DSO is then allowed direct (real time) control of the loads. The technical and contractual requirements and implementation of this direct control depend on the country or distribution grid where the framework is applied. Arranging the orange regime capabilities is the responsibility of the DSO.

In general, for the sake of security of supply and proper business evaluation, the aggregator and DSO agree a long-term flexibility contract and activation well in advance of any expected congestion.

3.11.5 Status

The first version of USEF was published in November 2015. The next version, expected in 2018, will include several new aggregator models and consider recommendations in this report. Focus is on encouraging its adoption in EU as a standard template for national markets that want to integrate flexibility into their energy system and regulatory framework. It has already been applied in multiple projects and by two DSOs and several aggregators in the Netherlands. Further implementations are planned or already in progress in the Netherlands, Scotland and Germany.

3.12 ETPA – NL

3.12.1 Description

The Energy Trading Platform Amsterdam (ETPA) is a trading platform for short-term electricity transactions, geared towards medium and small sized commercial customers. The products offered are: intraday, day-ahead, weekly and weekend contracts. Intraday is the most developed and liquid at the moment.

Normally a customer has a pass-through contract with his BRP which means that all balancing costs (positive and negative) are passed on to the customer. The customer sources his energy up front from the supplier / BRP (month/week/day ahead). If he then decides that he is going to use less energy during a day, he can sell his additional sourced energy on the ETPA platform. Likewise, if he needs more energy, he can try to find an offer from another user/customer of the ETPA platform. A typical example of a customer that may sell energy to other parties on the platform is one with a combined heat and power (CHP) installation. All customer actions have an effect on the associated BRP's portfolio. When a customer makes a bid or request on the ETPA platform, the Dutch TSO Tennet is informed and adjusts the BRP portfolio accordingly.

3.12.2 DSO role

The DSO does not participate in the market so energy bought for congestion management purposes must also be sold at the same time to avoid its transfer to the DSO's portfolio. As a result, the DSO can only buy an offer from a participant if there is a counterbalance action possible outside of the congestion area. The advantage of ETPA is that it promotes a liquid market so the counterbalance action is very likely to be possible. There is an option for participants to specify their location in their bids; this makes it possible for the DSO to select bids in a certain congestion area and find a counterbalancing option outside of the area. The DSO does not know whether a customer is selling energy because he has sourced too much or is willing to use less energy from the grid. For the ETPA platform to be a long-term solution for congestion management, it is likely that the information exchange between the DSO and the customer via the ETPA platform will have to be enhanced.

3.12.3 Roles and interactions

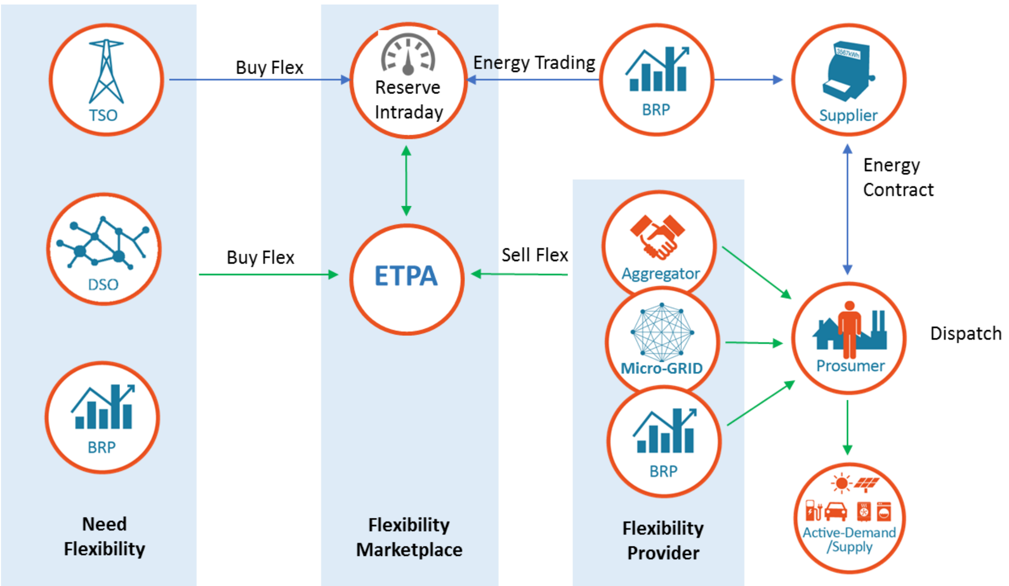

Figure 12 The interaction between the roles in the ETPA (NL) model

The customer plays the central role. The ETPA end result is a transfer of the imbalance risk from the BRP to the customer and so, in essence, the customer becomes a BRP. As a result, the customer must be knowledgeable about how the electricity market works and the risks involved. The aggregator could also adopt the central role but this would require agreement from the customer's BRP and so is dependent on commercial relationships. The DSO procures electricity and looks for counterbalancing actions in another area.

3.12.4 Congestion management

The DSO is responsible for his own monitoring. The ETPA only provides access to customers who are willing to sell their flexibility or sourced energy. The intention is that the DSO can mitigate any congestion by buying electricity in specific congested areas. The customer doesn't know whether he has sold his electricity to his DSO for congestion management purposes, or to another participant on the ETPA platform for portfolio optimisation. At present, the DSO is not entirely sure whether the buying of energy will result in a capacity reduction or not. Ideally, a market restriction is required when the DSO has bought electricity for congestion management purposes. At present this is not the case and so there is limited confidence in delivery; this needs to be addressed going forward.

3.12.5 Status

The ETPA platform was launched on 31st of January 2017.
The Dutch DSO, Stedin, is testing the platform to see if it is suitable for congestion management.

3.13 CHP-C – DK

3.13.1 Description

The product, developed by Radius, has been in operation since 2014. It is a load management system specifically aimed at curtailment of electric kettles in CHP systems. In Denmark, about 75% of housing is heated by district heating and CHP is prevalent in approximately 400 district heating companies. CHP system electric kettles or boilers are also being used either to absorb excess wind energy (buffering and conversion), or provide back-up during peak demand. There are 400 MW of installed CHP kettles/boilers in Denmark.

Participating CHP owners receive a discounted connection charge so only pay the actual cost of connection which is usually considerably lower. In return, the CHP installation must be made controllable at their expense. The CHP provides all data communication, control systems and monitoring. The electric kettle must be equipped with online energy consumption measurements.

The DSO and the CHP make an agreement on power limitations (this must not be 100% of the power) and expected interruptions. The CHP owner may, in parallel, offer the electrical kettle's capacity to the reserve market (primary and secondary frequency market) but is then responsible for ensuring he does not offer more capacity than he has available. The DSOs interruption of the CHP kettle takes priority over other services.

3.13.2 DSO role

The DSO is responsible for load management and contracting. The coordination mechanism is a peer-to-peer (DSO-prosumer) contract with load management by the DSO.

3.13.3 Roles and interaction

The DSO controls the load in conjunction with the contract and interacts only with the customer. The customer can provide services to third parties (TSO) as long as the DSO contract is respected.

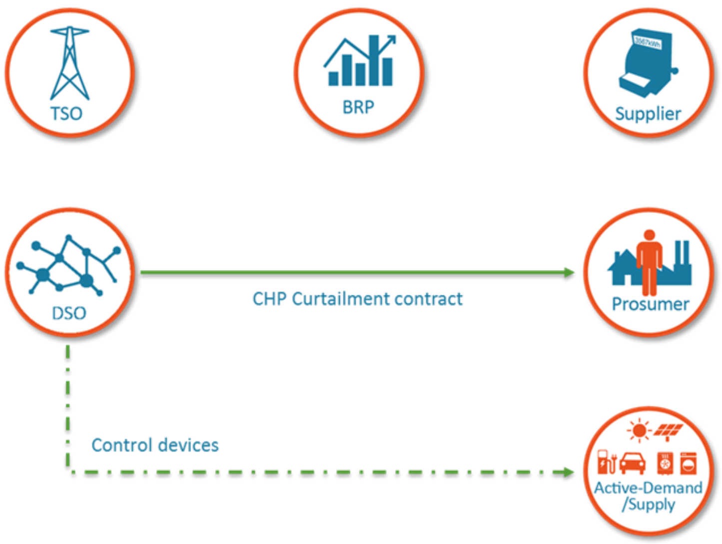

Figure 13 Interaction between roles in the CHP-C model

3.13.4 Congestion management

The DSO performs congestion management by direct (real time) control of flexible resources based on a one-to-one relationship with the customer. No regimes are defined or communicated.

The DSO decides which loads are limited/shed and when.

3.13.5 Status

The product is developed by Radius and has been in operation since 2014. It is approved by regulatory authorities for use by all DSOs in Denmark but is seldom used.
Radius is in the process of applying to the regulatory authorities for 'generalization' of the product as appropriate for all types of flexibility asset. The minimum power limits and connection charges are modified according to asset type.

3.14 NODES Market – NO

3.14.1 Description

The NODES model, which is in development, aims to develop a transparent flexibility marketplace within a distribution grid that can be integrated with existing power markets. Making distribution level flexibility available to an integrated market this way will demonstrate the real value and utilization of flexibility at all levels of the power system. DSOs must be able to make use of flexibility resources, supervise flexibility operations and make it easier, and cost-effective, for customers. This must be done while assuring quality of service and security of supply in a challenging environment. A flexibility marketplace can provide scalable and optimal use of flexibility and provide a transparent view using multiple technological solutions. Several flexible loads can be activated including smart homes with solar panels and batteries, electric vehicles and commercial and residential demand response customers.

3.14.2 DSO role

DSOs participate in the flexibility marketplace, placing offers to buy flexibility and providing grid-related topological/geographical information. They can filter and choose the grid level at which the flexibility is required. Bids below that grid level will be aggregated in the marketplace. The system operator acquires load forecast and decision support data from internal grid systems and the marketplace. He then runs or obtains results from decision support data analytics to reveal any locations with potential overload forecast issues. This optimization results in potential offers to be made in the marketplace.

3.14.3 Roles and interaction

The model's distributed flexibility market can be accessed by DSOs and TSOs to exchange flexibility with the market operator. The market operator is responsible for management, facilitation and operation of the marketplace.

The market operator's main role is to ensure that the market is available. He also acts as a counterpart for all market participants. To ensure market transparency, information about the volume and price of offered bids is available to all market participants. The market operator will facilitate buyers and sellers in placing/accepting bids and offers. The market operator matches the bids and offers and then orders the associated volumes of flexibility. T

he interaction between the actors/roles that are explicitly described in the model are depicted in the interaction template in figure 14.

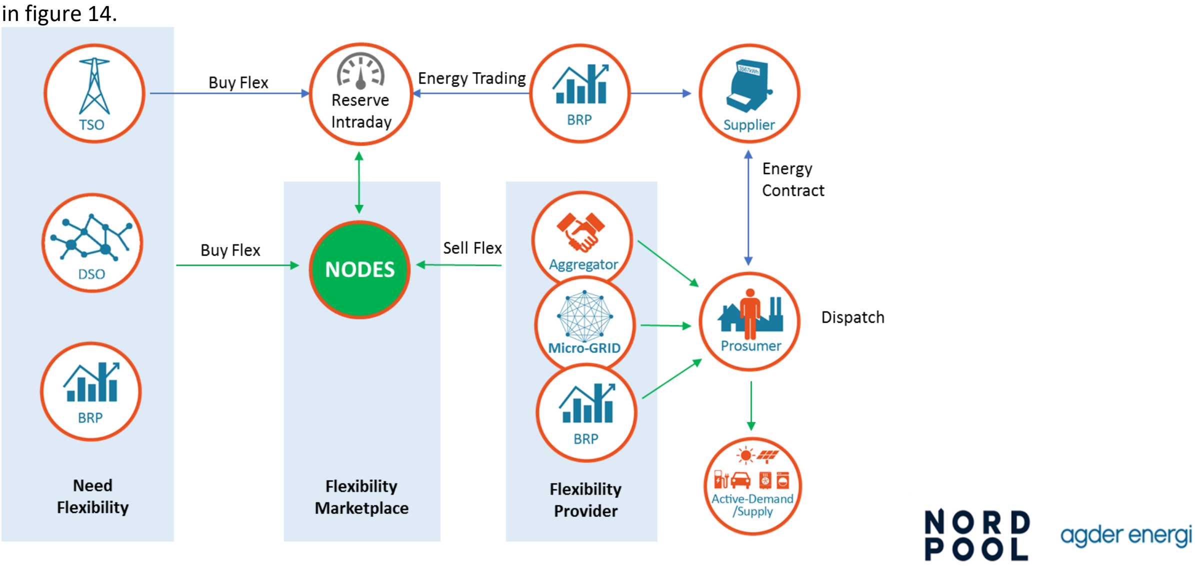

Figure 14 Defined roles and interaction in the NODES model

Congestion management

The solution will always use the most economical alternative first i.e. the least expensive of DR assets, battery assets or a combination thereof. In normal operational situations, the economic optimization takes place without capacity constraints. Every hour, a new optimization process evaluates whether DR assets can be used without causing congestion. This allows the DSO to mitigate congestion by buying electricity in a congested area based on the topological/geographical information in any flexibility offers.

3.14.4 Status

The NODES market aims to make flexibility in the form of production, consumption and storage available to DSOs, BRPs and TSOs.

For DSOs, a new flexibility market can help alleviate congestion, offer an alternative to grid investment or potentially allow them to defer investment. TSOs will also have an increasing need for flexibility from the distribution grid as many of their traditional flexible sources disappear from the high voltage grid. NODES aims to fill this gap by offering a fully integrated marketplace for flexibility. The main difference between NODES and other existing organized markets is NODES' inherent knowledge about local grid topologies and the congestion challenges within them. This information makes it possible to locate the required resources in the grid and decide which are best to mitigate current grid challenges. It is envisaged that NODES will exist alongside current markets, creating value for flexibility providers and incentivizing investment in flexibility.

The main principles of the marketplace in relation to the distribution grid have been defined as follows:

- Allow the DSO to export information about the physical distribution grid to the marketplace.
- Allow the DSO to continually update the marketplace with information about congestion in the local grid.
- Allow all market participants to trade flexibility in accordance with congestion information provided by the DSO.

This approach is variable and staged but the base assumption is that that there is a copper plate offer from the DSO and with abundant capacity.

NODES’ flexibility offer will be compatible with familiar energy products but, as a modular system with broad parameters, it will also be capable of offering more flexible combinations to better match buyer/seller needs.

At present, NODES is in pilot phase with Agder Energi. The ambition is to expand the pilot into other DSO areas in Norway and Europe, to prove it works in other geographical locations and identify any requirements for additional functionality. Ultimately, the hope is that it will contribute to the development of a fully integrated European marketplace for distributed flexibility.

The main barriers to realizing the project aims are the current market model and regulations. It is considered that a new integrated market, designed using a bottom-up approach, will offer a better solution for solving future challenges.

3.15 PermissiveC – IRL

3.15.1 Description

The "Permissive Construct" model is proposed in the context of ongoing issues in Ireland, where the activation of flexibility by the TSO can create congestion on distribution networks. Flexibility Service Providers [FSP's] in Ireland are currently called Demand Side Units [DSU's]. In common with many other countries, they would comprise a portfolio of what are called Individual Demand Sites [IDS']. When called upon by a DSU, demand reduction at the IDS achieved through demand reduction and / or bringing on of on-site generation.

The reason such demand reduction can cause congestion lies in the way in which distributed generator connections have been planned to date. In order to maximise distribution generator connection capacity, account of minimum load is taken at substations. Activation of IDS' in a given location can reduce the load to less than the assumed minimum load; this means more MWs flow up through network elements, for example a transformer, than was originally planned. Hence the activation of DSU's causing Congestion in Distribution Networks.

This proposed model represents the DSOs' preferred method of dealing with this issue. It could equally be applied to the more obvious case of 'turn-up' demand response.

3.15.2 DSO role

Each IDS is an ESBN customer with a Connection Agreement

- DSU has contractual relationship with TSO / MO
- ESBN has no contractual relationship with DSU

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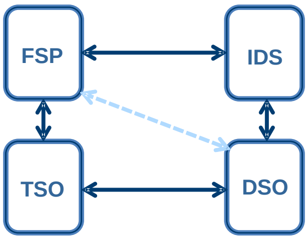


3.15.3 Roles and interaction

In this proposed model, the market actors effectively test the state of the network and ask permission for the activation to go ahead. Where an activation is deemed not to cause problems, the actor is allocated a chunk of network capacity [a ticket] for a defined time slot. This could be day-ahead. The actor is then free to take this ticket to the market operator. The market operator rejects any bids not accompanied by a valid ticket. The operation of the ticketing is on a first-come, first-served basis – or any other rule-set stipulated by the regulatory authority
Crucially, the DSO can say 'no' or, more specifically, 'the network cannot facilitate the proposed action for the next [defined] period of time' or 'capacity has already been allocated'.

The model assumes the following as pre-requisites:

- The DSO has sufficient observation of its own network
- There is a portal or other means via which the actors can make their proposed intentions known
- The DSO has means in place to make a determination on, and can quantify any congestion that would occur.

3.15.4 Congestion management

Under this model, the DSO 'Red Light' interventions are only made when local congestion is predicted to occur. An alternative view is that the network capacity is being fully utilised and made available to market actors most of the time. As this process takes place before the market actions, it could be argued that it does not distort it.

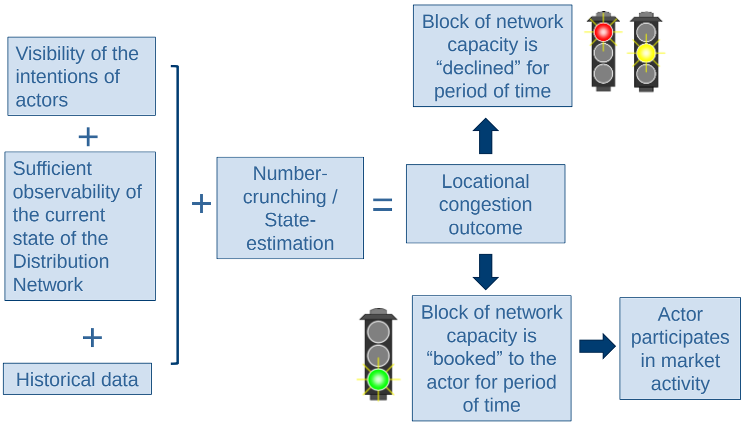


Figure 15 Congestion management process of Permissive Construct

3.15.5 Status

At present, the regulatory authority in Ireland has given the DSO the right to issue 'Instruction sets', these are effectively 'Red Light' signals on the basis of studies carried out by the DSO. In the absence of visibility of the flexibility activation and sufficient visibility of the distribution network, this is currently being done in very crude timeframes. There is an understanding with regulatory authorities that there will be an increase in the granularity of these instruction sets over time.

This is driving an active program of work by the DSOs to achieve objectives and work towards the model depicted in figure 15.

3.16 InnoCon – F

3.16.1 Description

In France, DSOs are not allowed to refuse connection of any MV power plant to the network as the prosumer pays most of the connection costs. The innovative connection offer (InnoCon) aims to give renewables power plants an alternative to the reference connection offer, making it possible to connect them more quickly and cheaply. One can also consider this offer as a connection contract plus an opportunity for the producer to produce more than contracted most of the time. In return, the DSO is able to curtail their power generation at certain times of the year when network constraints are likely to occur.

As a rule, the innovative connections involve connecting a wind power plant using an existing MV distribution network feeder rather than a new dedicated feeder.

While connection rules state that a MV generator must be able to generate all of its power at all times, making the capacity dependent on the state of the network allows for an increase in the network's overall connected power, with limited energy curtailment. As a result, reinforcements that would have been required in accordance with current connection rules can be postponed or even avoided.

3.16.2 DSO role and coordination mechanism

Before connecting any new power plant to the network, the DSO carries out a two-part study. The first part assesses the possible impact on the quality of supply (fluctuations of power (flicker), harmonic distortion, etc.). The second assesses the network's capabilities (short-circuit protection plan, voltage plan and thermal resistance) and the connection mode to be applied (connection to the existing network or creation of a new dedicated feeder).

On receiving a request for a renewable power plant connection to the MV network, the DSO establishes a reference scenario and prices it according to the applicable connection rules. In this scenario, the network can cope with the total electricity generation at every moment, both in normal and some backup operation schemes.

When the reference scenario includes the creation of a new dedicated feeder, the DSO endeavours to build and price an alternative scenario where the renewables power plant is connected to a part of the existing network where the quality of supply criteria allows it. To do so, the DSO calculates the maximum power that can be delivered at all times while respecting the rules related to network's capabilities.

3.16.3 Roles and interaction

The DSO provides the producer with both the reference connection and the innovative connection offers. A non-contractual estimate of the average number of hours per year during which power limitations may occur is included as part of the innovative offer. This gives the producer the opportunity to choose between the reference connection offer, at reference prices and conditions, and the innovative connection offer including limitations. The renewables plant's maximum permanent power limitation and maximum delivered power are stated in the connection contract.

The terms and conditions of the contract state that the DSO does not compensate the producer for energy not produced during required limitation, even if the latter exceeds the non-contractual volume initially estimated. Any related losses are considered to be covered by the benefits received from reduced connection costs.

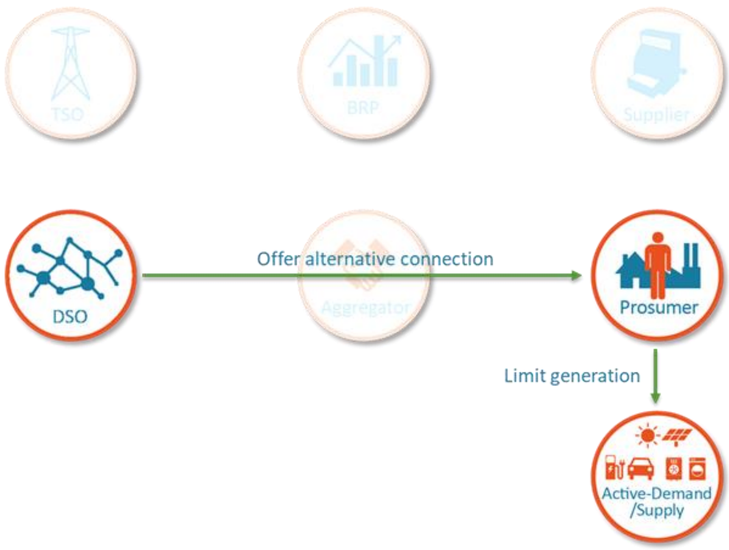


Figure 16 Roles and interaction in the InnoCon model

3.16.4 DSO Congestion management

The DSO builds its own load and generation forecasts from weather data and complementary information provided by market participants e.g. generation schedules from conventional power plants and maintenance schedules from non-conventional plants. The DSO crosschecks these forecasts with real time physical measures.

Where an innovative offer is contracted and the DSO forecasts a situation where the load flows are likely to exceed the network's capabilities, its SCADA automatically sends a limitation signal to the producers SCADA. It is then the producer's responsibility to apply the limitation required by the DSO. The signal is sent in real time without prior notice.

3.16.5 Status

The innovative connection offer for renewables power plants has been implemented as part of a demonstrator. Work is underway to adapt the DSOs procedures and the current regulation to allow its industrialisation.

The effectiveness of the generation drop down to the maximum permanent power when required by the DSO is monitored. Assessment will be undertaken to identify whether a penalty should be introduced when a producer fails to respond to a DSO's limitation request.

4 Evaluation of models

4.1 Introduction

In order to compare the different models, the workstream evaluated each model against a fixed set of criteria. This made it easier to distinguish which model was best suited to which goal, how they fit within their current national regulatory context, and which mechanisms were most effective in dealing with certain challenges.

The assessment criteria included:

- Model categorization
- Scope & targeted problem
- Number of actors involved
- Type of load
- Customer segmentation
- Type of flex activation
- Regimes of congestion status
- Coordination mechanism

The criteria and attributes were developed by the workstream and further refined during the assessment workshops. They are described further in the following paragraphs.

4.2 Model categorization

The reviewed models were categorized according to their principal coordination mechanism. There were two categories - flexibility market-based or rule-based. Some models use both e.g. when a market is enabled within certain predefined quota. Some models are based on a local or regional capacity limit or quota set by the DSO/TSO.

These quota are communicated to all relevant actors in the local or regional market e.g. aggregators and/or customers. Coordination is then based on the quota, or multiple quota, within the capacity limits. The remuneration or price can be based on a secondary market in which, for example, redispatch is possible (such as PaVn and grid-control), or based upon preliminary calculations by the regulator or DSO/TSO. The models using hybrid quota and market-based coordination (PaVn, Permissive Conduct, Grid-control) are placed in the middle of the diagram. See Figure 17.

Coördination mechanism	"Quota"			"Open market "
Tflex	Δ			
FlexGV	Δ			
RedGreen	Δ			
Grid-control		Δ		
USEF				Δ
ETPA				Δ
PaVN		Δ		
PermissiveC			Δ	
NODES Marketplace				Δ
CHP-C	Δ			
InnoCon	Δ			

Figure 17 Models and their dominant coordination system

4.3 Model target and scope

The models differ in terms of scope and target. Some deal predominantly with potential congestion in a bi- or trilateral contract; others claim to be a new (market) model offering value from flexibility to all possible stakeholders in the energy system, from residential customer to BRP.

Solution scope of model	"Bilateral"		"Systemwide" Holistic design, all systemroles involved	
Tflex		Δ		
FlexGV	Δ			
RedGreen			Δ	
Grid-control			Δ	
USEF				Δ
ETPA				Δ
PaVN				Δ
PermissiveC			Δ	
NODES Marketplace				Δ
CHP-C	Δ			
InnoCon	Δ			

Figure 18 Model scope and target

4.4 Number of actors involved

The models differ in the number of actors and stakeholders involved. In each case, they take an active role based on contractual or regulatory/legislative relations.
In some models (TFlex & FlexGV), the customer and the DSO and/or TSO have an active role. Other stakeholders, such as the BRP are not (yet) explicitly part of the model and retain their current role. Most market-based mechanism models do consider additional roles & responsibilities.

Relative number of active roles in model	"limited"		"multiple"
Tflex		Δ	
FlexGV		Δ	
RedGreen	Δ		
Grid-control			Δ
USEF			Δ
ETPA			Δ
PaVN			Δ
PermissiveC			Δ
NODES Marketplace			Δ
CHP-C		Δ	
InnoCon		Δ	

Figure 19 Model scope by relative number of actors

4.5 Targeted customers / type of load

The models provide a solution for different load types and customer segments. Some are designed mainly to focus on congestion management as a result of large renewables feed-in, or to guarantee TSO reserve products in the DSO grid. The more 'holistic' designs are typically indifferent about load type and customer segment.
Since congestion management of larger loads in existing areas is the most urgent problem in many countries, the models that solve these issues are already active.

Congestion caused by residential loads is relatively new and a less urgent problem overall. It introduces the need for new roles and actors, with new responsibilities, such as the aggregator, who makes it possible to create value from smaller amounts of flexibility, for smaller customers. This aggregated flexibility then becomes part of the larger potential for market-based flexibility. Introducing new roles and actors this way is more complex and so takes longer to implement.

Targeted customer segment	large (MV)	large(MV)& Residential(LV)	residential (LV)
Tflex	Δ		
FlexGV	Δ		
RedGreen	Δ		
Grid-control		Δ	
USEF		Δ	
ETPA		Δ	
PaVN		Δ	
PermissiveC	Δ		
NODES Marketplace		Δ	
CHP-C	Δ		
InnoCon	Δ		

Figure 20 Model scope by dominant targeted customer/connection type and related flex volume

4.6 Coordination mechanism and customer segmentation

Figure 21 shows the models and their dominant coordination mechanism plotted against their (current) customer segmentation target. The cusomter segmentation is very much related to the type of congestion. Models that are purely based on prequalification are targeted at larger renewables and primarily industrial customers. Most do not explicitly cater for aggregators and so are not, at present, well suited to residential and SME customers and their flexibility potential. There is usually an implicit suggestion that this will change as they evolve and this is likely to be when there is greater urgency for congestion management of residential customers. With the exception of the Norwegian and German models, current and near future congestion problems are not primarily caused by residential customers. They would be unable to assist with congestion management in most places anyway at present due to a lack of both flexibility volume and control.

By contrast, the German and Norwegian models very much consider residential customers because those customers cause, and can solve, many congestion issues in the short-term. As a result, there is a fairly urgent requirement for a solution that supports that.

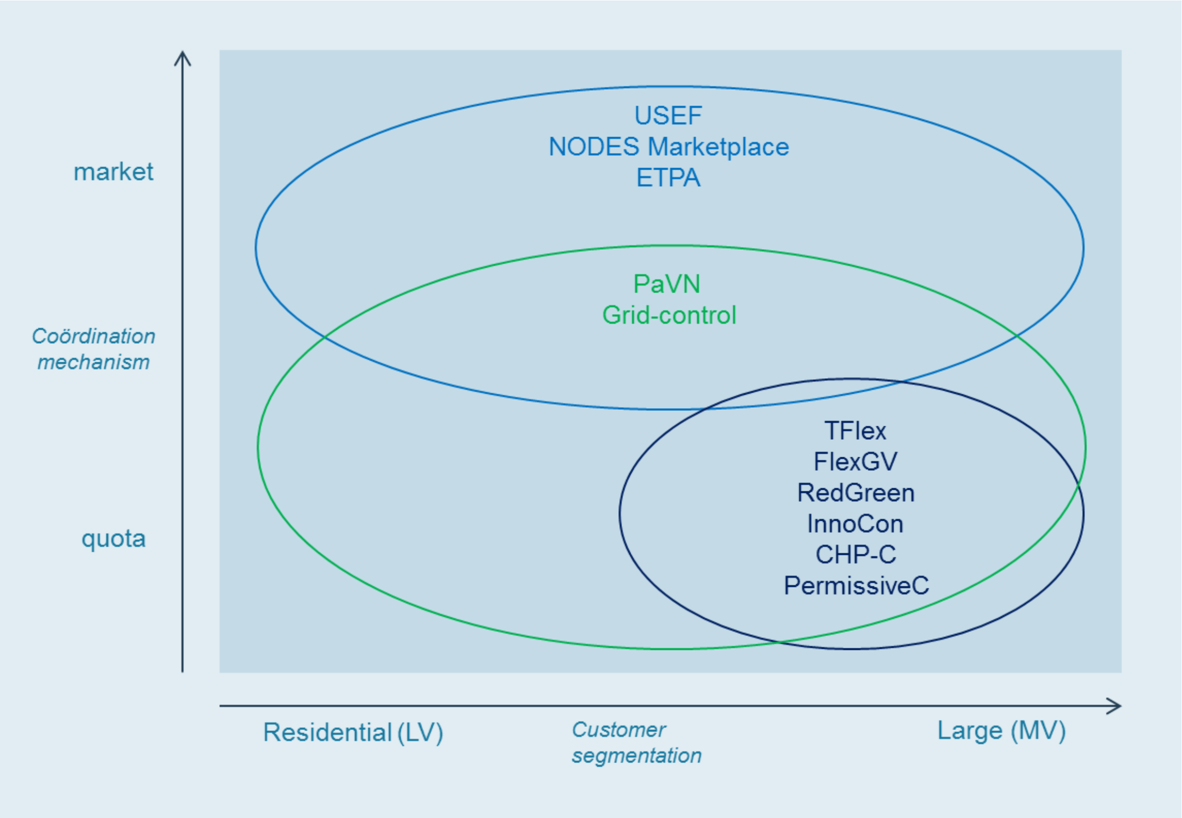


Figure 21 Coordination mechanism versus customer and load type

4.7 Technical flexibility activation

Most models require flexible energy sources to be controllable. A technical infrastructure or signalling system to the owner of the flexibility source is mandatory to be able to activate the amount of flexibility required at the right time.
Some models are also based on a mandatory or regulatory infrastructure or control mechanism (Germany, Belgium, Denmark).

4.8 Regimes or congestion status

To indicate the (expected) amount of congestion in a network section, most models describe the status of the network section in relation to the load with colour codes. These colours are used to communicate the regime/network state in models that rely on an operational monitoring or forecast system. The colour indicates whether congestion (will) occur for each section.
Although the definition of the colour is not the same for each model, we see that three main grid congestion statuses are common:

- green: no congestion expected
- yellow: congestion management by market interaction
- red/black: for congestion management by DSO/TSO

In Figure 22 the models and their colour schemes and definitions are summarized.

.

Model					
TFlex	No congestion	na	na	Congestion, load control	Grid safety switch off
FlexGV	No congestion	Return to green announcement	Congestion announcement	Congestion	Grid safety switch off
RedGreen	No congestion	na	na	Congestion	Grid safety switch off
Grid-control	No congestion,	Congestion; Quota active	na	Curtailment/load control	Grid safety switch off
USEF	No congestion	Flex trading for DSO	Graceful degradation/ direct load control	Grid safety switch off	na
ETPA	na	na	na	na	na
PaVN	No congestion	Congestion; Quota active	na	Curtailment/load control	na
PermissiveC	No congestion	na	Congestion announcement	Congestion	Grid safety switch off
NODES Marketplace	No congestion	Flex trading for DSO	Graceful degradation/ direct load control	Grid safety switch off	na
CHP-C	na	na	na	na	na
InnoCon	na	na	na	na	na

Figure 22 The models and their colour schemes

4.8.1 Green

In the *green* status, all models indicate that no risk of congestion is expected so there is no need for congestion management by the DSO.

4.8.2 Yellow

Yellow is commonly where the 'soft' congestion management through a quotum or market-based coordination takes place. The actual congestion is announced and the available flexibility is supposed to avoid the congestion.

Congestion control mechanism Yellow	Activation by direct load control	Quota / market / contract based activation
Tflex		Δ
FlexGV		Δ
RedGreen		Δ
Grid-control		Δ
USEF		Δ
ETPA		Δ
PaVN		Δ
PermissiveC		Δ
NODES Marketplace		Δ
CHP-C		Δ
InnoCon		Δ

Figure 23 Congestion control mechanism in Yellow

4.8.3 Red

In some models, the *red* regime is where direct load control is performed. A (tele-) control infrastructure or a code red mechanism that forces the load to switch off or reduce is a prerequisite. Some models (USEF/Nodes) use the colour orange for the direct control option. Note that the loads, rather than the connection(s) are controlled. Black is the common colour for 'black out' or a grid safety-based grid state, where all the connections in the congestion area are disconnected for grid safety reasons.

Congestion control mechanism Red regime	Activation by direct load control	Quota / market / contract based activation
Tflex	Δ	
FlexGV		Δ
RedGreen		Δ
Grid-control	Δ	
USEF	Δ	
ETPA		Δ
PaVN	Δ	
PermissiveC		Δ
NODES Marketplace		Δ
CHP-C	Δ	
InnoCon		Δ

Figure 24 Congestion control mechanism in Red

4.9 Coordination mechanisms

We searched for the principal distinctive coordination mechanisms in all models.
In Figure 25, these characteristics are depicted together with the models that fall into that category.

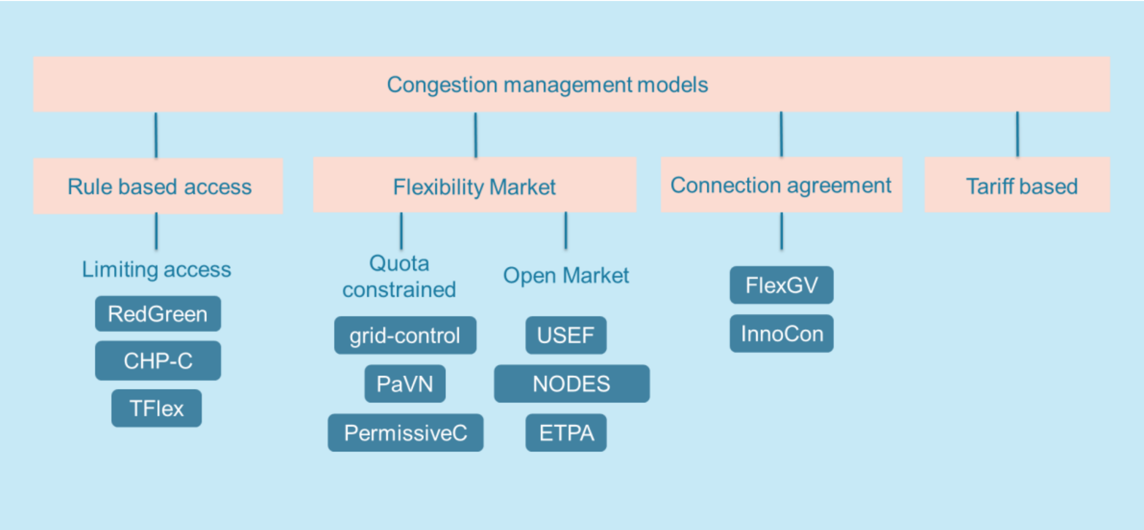


Figure 25 Categorization by congestion management principle

The workstream found 4 categories, of which 3 are applicable to the models evaluated.

Rule based access
The rule-based access category is based on a prequalification method (rule) and operationally, the measures taken when capacity is exceeded. As shown in Figure , these models are suitable for larger individual congestion issues and, within that segment, mostly for renewable production or limitation of peak demand.

Market based
The second category is market-based flexibility. These models contain or allow a marketplace/mechanism where flexibility for congestion puposes is traded and allocated. The market is constrained by a preliminary announced quotum (quota models) or a non pre announced market boundary. These models mostly allow aggregators or flexibility service providers to aggregate flexibility from multiple providers, and areas, and are therefore are also suited to use of aggregated smaller amounts of residential flexibility.

Connection agreement
The third category, connection agreement-based models, currently target larger connections and flex resources and are financial incentive based. They are implicit flexibility models. The amount of flexibility is less deterministic but the low implementation and operational costs made them interesting to workstream members.

Tarrif based
Tarrif based category is empty. This implicit form of flexibility activation based on energy pricing based on f.i. Time of Use or other is not used explicitly in any congestion management model.

5 Observations and takeaways

5.1 Observations

The workstream's observations are summed up below:

- It was observed that, for a model to be considered sustainable, it must support equal sharing of profits and costs across energy system stakeholders and must not disturb future development of renewables integration. Techno-economical evaluation of (incidental) overload costs vs network expansion costs is challenging. All models aim to deliver a sustainable approach to congestion vs. capacity management but their approaches differ vastly, from a non-restricted market to regulatory decision in the pre-connection phase.
- The evaluated models can be divided in two main categories based on their coordination mechanism:
    - quota-based, with specific or market-oriented remuneration; or
    - market-based, where the flexibility required for congestion management is obtained and priced through a (separate) market mechanism.
- Some of the models provide practical solutions for solving either current or shorter-term problems; others are research projects, focused on identifying solutions to future problems.
- Every model assessed uses some form of load forecasting, if only to be able to predict the global volume of congestion that will occur. The forecasting of load on short term and lower grid levels is a new discipline for DSOs.
- Because flexibility markets as a whole are not mature, DSOs must experiment with the use of flexibility as a congestion management solution. Models will only fully mature as they are adapted in conjunction with a live, fully-functioning market.
- Models must cope with situations where a flexibility market does not (yet) have enough available liquidity. Most models handle this situation with a direct technical control mechanism.
- The model scopes differ vastly with regard to the specific congestion issues they aim to solve and the type of flexibility or customer used to solve it. The models range from 'holistic', where all types of congestion and customer/flexibility type are addressed, to 'case specific', for example, only larger renewables customers. It was observed that European DSOs seemed to mitigate more urgent congestion problems with case-specific models that are mostly already active in regulation in some form (Belgium, Germany, Denmark).
- Holistic models, where all types of congestion and customer/flexibility type are addressed, are typically more expensive to implement' since they involve more market parties and separate flexibility markets and therefore require more time and effort. In theory though, they should then be capable of offering the full range of flexibility sources to solve all types of (future) congestion. This is untested at present as none of the holistic models (USEF, NODES, PaVn,grid-control) have been implemented at full scale.
- The total transaction cost for each congestion management model is not considered. While the workstream concluded that transaction cost should be a decisive parameter for selecting a method, it was unable to calculate costs because the diversity of models, and their individual objectives, prevented firm conclusion.
- The workstream considers a DSO direct control option as mandatory for any market-based congestion management model. It is required to perform the actual congestion management irrespective of flex market transactions. Most models in this report already mandate this option.
- As the centralized flexibility used by the TSOs for balancing gradually reduces, they will have to look for flexibility provided by prosumers in the distribution grid. In some models, the potential congestion caused by the TSO services is specifically addressed. In other models, the TSO does not take part directly in the flexibility market.

There four key overall observations can be summarised as follows:

1 Range of challenges

- Every model has specific strong points. Not all models solve the same problem. Each model is designed to solve one or more specific challenges

2 Now vs later

- Some models are designed to solve current actual congestion problems while others are designed to solve future challenges

3 Technical vs market solution

- Some models are specifically oriented to provide a technical solution only while other models are more oriented on providing a market based solution or a combination

4 Key topics

- Key topics for market based solution models are:
  - It is crucial to address the price of the flexibility
  - Capacity reduction can be achieved by providing a certain bandwidth to the market or by buying enough flexibility from market players until the congestion is relieved

5.2 Takeaways

An important objective of this work was to give all participants insight into both their own model and those of other DSOs. Doing so provides an opportunity to use any learning to improve / further develop their own model. As part of the overall process, participants were asked to define what they had learned about their own model as a result of participation and any other useful information they would be taking away as the result of the process. Their responses are below and left unedited for transparency.

5.2.1 FlexGV (NL)

Takeaways, remarks and recommendations from FlexGV perspective:

FlexGV is a connection agreement concept and therefore an *implicit* and non-deterministic demand response concept, where flexibility is delivered voluntarily. As such, it falls in to a different category than the other models reviewed. Although an implicit model, FlexGV is seen as an interesting model because of the low implementation efforts, therefore the members are curious about its effectiveness for congestion management.

The results from its first trial showed a low effectiveness; this was very probably due to a lack of penalty or financial consequence as a result of failure to respond to a red signal. Research is planned to determine whether effectiveness will increase when consequences are implemented for neglecting the red regime. Recommendations for improvement of the model are under construction by the Alliander project board.

Given the outcome of the trial, the recommendation is to prolong the trial with the full concept implemented (with financial or contractual consequences). This will also enable customers to better consider flex requests in response to a red signal. Adding a better forecast mechanism (through an aggregator ?) might also help to activate more flex at the right time.
From a USEF perspective, it is suggested that the model is positioned as a demand response concept between the aggregator and the customer, making the aggregator responsible for providing forecasts to the BRP and DSO. Tradeoff for the aggregator could be the spread of the forecast errors over multiple customers.

5.2.2 TFlex (B)

Takeaways, remarks and recommendations from TFlex perspective:

The most important take-away for T-Flex is from Flex GV: with proper DSO tariffs it becomes easier to complete the TFlex model with commercial flexibility from an FSP/aggregator.

5.2.3 Red-Green (B)

Takeaways, remarks and recommendations from Red-Green perspective:

The most important take-away for Red-Green is the use of quota in other models, especially when congestion management requires a more dynamic form than the current yearly evaluation.

5.2.4 PaVn (D)

Takeaways, remarks from PaVn perspective:

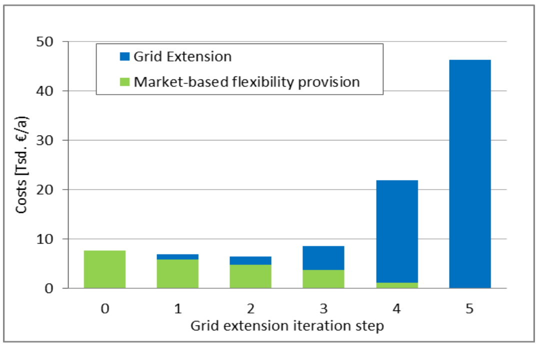
For the PaVn model, we see a number of actions to take to create an operational grid v. market interaction model within a demanding environment.

- Optimize grid operation especially within areas of high DER-share to resolve network bottlenecks.
- Design grid v. market interactions within the orange regime.
- Development of generic requirements for a mediating communication and service platform.
- Develop and use flexibility for the distribution grid to minimize grid expansions
- Deliver recommendations for a future market design.

Conclusions drawn for cost-efficient grid expansion with market-based provision of flexibility are:

- The determination of an individual, non-discriminatory power range per retail company is facilitating an optimal congestion management as each retailer is able to select suitable schedules of flexibility within his portfolio
- Flexibility calls will be distributed non-discriminatory among all retail companies owning / operating flexibility within the involved grid topology
- Due to unique call IDs, retail companies could perform secondary trading on their flexibility calls, to e.g. hold SLAs with customers

- Market-based flexibility provision for congestion management increases the amount of electricity from renewables integrated into the system and avoids cost-intensive grid extension measures.
- Congestion management costs could be reduced significantly by using market-based flexibility compared to reducing RES power generation.



5.2.5 grid-control (D)

In general in the grid-control model there are missing topics that were not part of the research project but would be necessary to implement the grid-control mechanism.
Some missing elements are ‘prequalification’/‘contracting of flexibilities’ / ‘incentives for participation’. This is part of other models e.g.:

- Flex GV: connection capacity contracts (regulation)
- USEF: (market) prices

Battery storage unit in gridlab Freiamt

Controller of a Building Energy Management System

Furthermore, there are some interesting elements/observations in the coordination process in other models that lead to questions to be answered for a further development of the grid-control model:

- Prognosis for non-flexible loads/generation units by the DSO (USEF) for an easier power flow prognosis for a short-term implementation?
- Is there a possibility for non-optimum (unused grid capacity) (provided that there is no liquid secondary ‘quota market’)? USEF: allocation of flexibility that is required and not too much (but what about liquidity?). How to procure the flexibility for the grid-control model?
- Calculation of sensitivity/ impact on congestion for each flexibility (PaVn) in order to use the best flexibilities? Or is this too much information for the market?
- Usage of congestion points (USEF) and intraday coordination? Is there an added value through intraday coordination?
- Will there be new technologies like locally optimizing grid cells or swarm grids so that the discussed models may be outdated?

The grid-control model and the PaVn have independently worked out a very similar approach which is remarkable.
If there is a liquid market, the USEF model (a flex market) may be a possible solution for high voltage grids (or maybe middle voltage grids) as a further development of the grid-control model or as an addition to a quota model.

5.2.6 USEF

Takeaways and remarks from USEF perspective:

Overall, workstream participants were positive about USEF. There were a number of ideas and recommendations about potential enhancements to the framework that were considered to provide the opportunity for a big leap forward and that have helped for our takeaways below:

- Consider developing USEF as a set of modules that can be implemented more-or-less independently of each other based on individual needs and as market development dictates.
- Currently in USEF, the DSO is a single and ‘must buyer’ of flex for congestion management. When orange is not implemented, this is seen as a vulnerable way to perform congestion management. Care has to be taken to ensure enough flexibility is available and can be contracted in advance.
- Consider describing how a DSO should or could take direct control of prosumer loads or connections in orange regime.
- Consider investigating whether USEF should include an option for the DSO to implement technical and regulatory elements in orange regime.
- From a USEF perspective, most quota and rules-based models could potentially serve as country-specific implementations for ***orange*** as defined by USEF, except for Flex GV. All the models have a prequalification method or a quotum issued to provide a mandatory or voluntary amount of flex when congestion might occur. With some changes, USEF can ‘host’ most of the models because they are complimentary to the framework and, in most cases, do not conflict with the USEF coordination mechanism.

- In addition, most rule and quota-based models could introduce the USEF proposed market mechanism for trading flexibility options within the boundaries and rules set by the model. An example is the 'secondary' market between aggregators/FSP's in the grid-control model.
- TSO role: Allowing TSOs direct but coordinated access could help stimulate the flexibility market. Increasing TSO activity in the distribution grid would create congestion in it and therefore DSOs and/or aggregators would need to adopt solutions to cope with it. USEF does currently not allow the TSO direct access to flexibility offered by the aggregator and the general consensus was that this should be addressed.

5.2.7 ETPA (NL)

Takeaways and remarks from ETPA perspective:

- To use the ETPA for congestion management by the DSO, the DSO needs to be able to forecast when and where the congestion will occur and flex providers need to be labeled to congestion points.
- It is important for Stedin that the relation between ETPA and USEF is made clear, so that ETPA and USEF can work together in the integrated energy system.
- The discussion on the interaction between TSO and DSO underlines the importance of a flex market mechanism and an interaction model ETPA can play a role in.
- As with other models, ETPA also needs to prove its value by piloting.

5.2.8 CHP-C (DK)

Takeaways and remarks from CHP-C perspective:

- There is large diversity in the solutions across Europe which mainly reflects the various reasons for the different pilot projects.
- A traffic light model appears to be a general acceptable explanation template for categorization of congestion management solutions, although a clear definition of what the various lights mean is lacking.

5.2.9 NODES Market (NO)

Takeaways and remarks from NODES perspective:

The NODES concept is under development and is taking away the following considerations and recommendations from the workstream sessions:

- Introducing the NODES market for flexibility trading requires a more active role for the DSOs. DSOs need to be active in information exchange to all market parties.
- The DSO needs to be able to forecast when and where the congestion will occur.
- NODES will connect to current markets exposing the value of flexible assets to all potential buyers, also when there is no local congestion.
- NODES will provide a way to offer flexibility that is compatible with existing energy products.
- A product in NODES is made up of building blocks and a set of parameters. By offering this flexible product design, NODES can give buyers and sellers the exact desired properties that they are looking for.

5.2.10 PermissiveC (IRL)

Take aways and recommendations for Permissive Construct:

- DSO interventions, [where they arise], should take place before the actors make their bids into the market
- Actors submit a list of locations and proposed MW reductions
- On this basis, distribution network capacity allocated for time slots
- Allocation should be done in a transparent first-come, first-served [or other agreed]manner
- ESBN as DSO believes that this would achieve the objectives of:
    - Granularity of congestion management implementation
    - Efficient use of finite network capacity

5.2.11 InnoCon (F)

Takeaways, remarks from InnoCon perspective:

Implementation of an “Announcement of limitation” signal.
The InnoCon offer is a connection agreement that doesn’t provide the customer with any announcement before the limitation signal is issued. Indeed, when designing the mechanism, it was assumed that such an announcement could only be helpful if the customer or his BRP could use it to balance his position, which involved at least a Hour-2 or even a Day-1 announcement. Such timelines are not compatible for attaining sufficient accuracy of the forecasts required to minimize the limitations and the decision was made to issue only a real time limitation signal. However, the 15 minutes announcement provided by the Flex GV model seems to be interesting. Indeed, a short notice warning signal could improve the quality of the response of the customer to the real time signal. The possibility to issue such a warning signal will be assessed in the framework of InnoCon.

6 Conclusions and recommendations

6.1 Conclusions

The conclusions below are drawn from both the model assessment and the discussions in workstream meetings. Some are based on general shared characteristics of models. Others are directly related to the takeaways identified by individual model owners.

- A model's maturity seems to relate to the problem it aims to solve. 'Case-based' models (that address current capacity issues) have a higher implementation ratio. 'Holistic' models (aggregator based and with more roles directly involved) are not yet fully implemented and so have not been able to prove their effectiveness for congestion management. This leads to the preliminary conclusion that rule based models are easier to implement and seem effective and efficient in mitigating specific congestion risks caused by larger connections occurring today.
- The models that also focus on congestion caused by residential loads ('the aggregator based models') involve more system roles and are much harder to implement in a regulatory framework and in the national energy system. Also the effectiveness and efficiency (especially the flex market based) for congestion management has yet to be proven. A third missing incentive is that in most countries residential loads do not yet pose congestion risks. However the members see the necessity of arranging a regulatory framework to be able to cope with these congestion risks
- Effectively managing congestion using flexibility obtained from the market depends significantly on DSO and flexibility (service) provider forecast accuracy. It is essential that they deliver the market parties accurate prognoses of the expected timing and volume of any congestion and the associated request for flexibility.
- In flexibility market-based models, correct settlement poses difficulties as it is not always possible to determine whether the requested flexibility has been activated. Part of this challenge lies in finding the correct baseline for accounting flexibility.

6.2 Recommendations

Recommendations are based on assessments and the discussions in the workstream meetings.

- The workstream recommends further analysis of the various congestion issues, particularly those resulting from other parties' trade on energy markets, and evaluation of them in accordance with the solutions methods.
- There is a need to analyse the legal implications of congestion management models and their impact on national regulatory framework. This work can be done collectively, initially taking a generic approach to define the regulatory rules required and then adapting these as necessary to meet country-specific recommendations.
- There is a need to analyse the total transaction cost for each congestion management model. This is to better evaluate the costs vs. value of congestion management.
- The different definitions and colours used by the models in their respective operating regimes cause confusion. Harmonizing these would promote greater understanding of each other's models and support interoperability within the European Energy Market.
- When a TSO is not participating in the same market or coordination mechanism (direct or indirectly) as the DSO, the workstream recommends that a TSO-DSO coordination mechanism is introduced to coordinate flexibility activated in the DSO domain that could lead to congestion in the DSO network.
- Market value analysis; Performing analysis of (market) value of flexibility for congestion management is recommended to be able to evaluate market based congestion management economically
- The workstream's final conclusion was that it should continue to build on the many lessons that have already been learned from working together, both on this subject and more broadly. Ideas about future subjects to address included:

- Improving methods to increase prognoses accuracy to support flexibility market transparency and a robust market, network and availability of supply.
- Gather and share more in depth insight on the technicalities related to matching flexibility requests with actual flexibility delivered for settlement.