REPORT

DSO Role in Market conflicts

Workshop Report on Analysis of the DSO role in Market Conflicts

Project: DSOs' Role in the Electricity Market
Delivery 2.2, 3.1 and 3.2

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1. Executive Summary

The innovation project DSO[1]s' Role in the Electricity Market was initiated July 2017 and funded by EUDP (ForskEL application).

The project target specific problems faced by DSOs in the future energy system, where power system balancing is provided by flexibility assets in the distribution grid. The objectives of the project are to define the DSO's role where market conflicts occur in the wholesale and ancillary markets.

This delivery reports the results of the workshops and work groups on identifying the market conflicts that involve the DSO regarding trade on the wholesale and system markets, and the corresponding solutions. The term Trade Permission System is not a concrete digital platform but a conceptual term describing the communication flow and roles of the participating agent.

In total 8 use cases were identified each containing various numbers of scenarios. The work group task was to refine the use cases and cluster the DSO action pattern into a small number.

The work has been conducted by pouL Brath, Radius Elnet, Oliver Gehrke and Daniel Esteban Morales Bondy, both from DTU CEE.

The project is supported by EUDP[2].

Disclaimer: The work herein has been produced through collaboration with several partners from the industry, yet the work reflects only the opinions of the abovementioned authors.

[1] Distribution System Operator
[2] Energiteknologisk Udviklings- og Demonstrationsprogram administrated by The Danish Energy Agency

2. Content

This is a workshop report. The report partly refers to intermediate results from the process that the participants went through and is not only restricted to the final result.

The major part of customer[3] flexibility is traded on the wholesale or the system market. But in some cases the trade can produce conflicts between the TSO[4], BRP[5] and DSO. When the TSO or BRPs activate flexibility installed at the distribution grid level and for instance the full grid capacity is not available for some reasons, the DSO can react to unwanted effects of trades in a number of ways and, if unregulated and uninformed, the reaction could be counterproductive to the purpose of the trade. This would lead to a more expensive operation of the power system, since it could cause imbalances or cause the activated flexibility services to not be delivered.

The solutions reported here focus therefore on improved communication between market parties.

The report initially presents eight market conflict cases which were identified during a series of workshops. The conflict cases can be distinguished by the prescribed DSO response. Some of the conflict cases are further subdivided into sub-cases, depending on the set of actors and the relations between them. This means that some conflict types appear similar but are still different between individual sub-cases in terms of DSO response. Thereafter, the complex interrelations between the cases are described. A traffic light model is used for gathering solutions into solution regimes. The traffic light model is then used to analyse which solutions could be viable. The analysis showed that the traffic light solution regimes are consistent throughout the sub-cases, which means that the number of practical solutions is reduced considerably.

Based on the above set of solution regimes, a solution design is proposed. The design is based on a combination of interventions in the regulatory, market and communication/operation domains. The proposed design includes communication sequences for responses to two general classes of events.

The report contains several references to the term “flexibility assets” which may appear ambiguous since in principle, all consumption could be flexible. In this case, we use the USEF definition[6] of flexibility as deliberate, time limited changes to the normal energy profile of a consumer.

The EU commission has established a Network Code on Demand Connection (Commission Regulation 2016/1188, 17th of August 2016) which prescribes a notification procedure for flexibility assets. This regulation is not yet fully implemented in Denmark and the content of the flexibility asset notifications is not determined. However, the regulation is an important step towards better coordination since the DSO’s ability to identify the flexibility assets in the network is a precondition for being able to integrate them into network operation. The DREM project is approaching a number of rather complex issues because grid constraints are not usually caused by the operation of a single flexibility asset, but by the simultaneous (fleet) control of a portfolio of assets.

[3] We are not distinguishing between customers and prosumers. The customers could consume and produce energy.
[4] Transmission System Operator
[5] Balance Responsible Party
[6] USEF White Paper. ‘Energy and Flexibility Services for Citizens Energy Communities’, February 2019

3. Approach

The DREM project aims to suggest market-based solutions to the extent possible. However, DSO congestion is always a local problem which relates to a specific feeder on the low voltage or medium voltage level. Within the foreseeable future, it will be difficult to operate local markets at the level of a single feeder due to the lack of liquidity, except in few, very specific cases. In some cases, constraints on response time may not allow for open market solutions using current technology.

Therefore, the DSO may have to simply limit the activation of flexibility assets in certain cases. The newly approved EU electricity regulation permits this solution if no market-based solutions are available (Article 12).

Solving congestion issues is complex since it involves conflicting interests of several parties that may not have an incentive to share information. Furthermore, since not all relevant players in the power system necessarily share the same objectives, it is difficult to reach consensus on how to solve the stated problem. The approach taken in this project has been to involve representatives from all parties in the energy sector in a series of workshops in order to secure that all interests were covered.

Representatives from the energy sector have participated in identifying the conflict cases. The work was initiated by a larger workshop, which allowed all representatives in the energy sector to participate. After the workshop a smaller working group was formed that concluded the identification of the conflict cases.

The working group had two meetings in autumn 2017 between the initial workshop and the final reporting workshop (in January 2018), all related to conflict identification. The work group continued during spring 2018 in order to identify corresponding solutions which were presented at a workshop in September 2018.

The Workshops and Workgroups were arranged and hosted by Intelligent Energy.

3.1 The Process

The first step in the approach was to identify the possible sources of conflicts between market participants when accessing flexibility through aggregators. Throughout the first workshops, special emphasis was put on separating the conflict identification phase from the later solution design phase.

The second step was to propose a series of solutions that could either be of a regulatory, market, structural, or technological nature. These solutions were then arranged in clusters, reducing the possible solutions to as few as possible.

Finally, based upon the initial clustering, specific solutions were formulated, addressing the different sources of conflicts.

3.2 Workshop participants

The following companies, institutions and authorities have participated in the workgroups designing the solutions. However, not all of them were represented in all the workgroups:

- Syddansk Universitet
- Balslev Rådgivende Ingeniører A/S
- INSERO
- Neogrid Aps
- Bornholms Energi og Forsyning
- Energinet
- NEAS Energy A/S
- SEAS-NVE A.m.b.a
- GEV A/S
- EWII A/S
- Schneider Electric Denmark A/S
- Dinel
- Energistyrelsen
- Eniig Holding A/S
- EURISCO
- Mogens Balslev A/S
- SK Forsyning A/S
- Energi Danmark
- Ørsted
- Markedskraft
- DTU
- Radius Elnet

4. Conflict cases

4.1 Introduction

In a well-functioning market, different and opposing interests meet to find a market optimal solution. The markets considered here are the wholesale electricity market and the ancillary services market, where North Pool and the TSO on one side and the BRPs/AGRs on the other side make market based agreements. The DSO does not play a role in this process as it is not involved in the procurement of electricity or the balancing of the grid. As a result, some instances of flexibility activation as agreed by the market participants may be against the interests of the DSO; for example, because the activation causes network congestion.

The term 'conflict case' refers to this situation. Usually, the market works without problems for the DSO as the distribution grid is dimensioned to allow the customers to operate their assets without restrictions. But under certain circumstances, faults in the grid or an abnormal operation situation may reduce grid capacity, or fleet control of the assets may increase the concurrency factor to an unexpected level (at the wrong time and place). It is in these situations that we refer to a 'market conflict' because the DSO is in conflict with the market solution.

The project has identified eight market conflicts. Some of these are further subdivided into various scenarios depending on the legal relations between actors, the nature of the problems caused for the grid (thermal overload, voltage issues) and other factors.

As it will appear, the cases are not independent; instead, some may occur as a result of resolving, or trying to resolve, another conflict. However, all the identified cases are discussed below to make the analytic process more transparent.

Within each case, a table is provided below for each of its scenarios, explaining the details of the conflict. In addition, six main grid operation characteristics that separate the cases are presented. These are the following:

Multiple or single customers – we identified whether the sub-case arises due to a single large customer, or due to the simultaneity of response of multiple customers.

Day ahead or momentarily – the sub-cases were further classified depending on when they arise. They can either be a product of a day-ahead trade, e.g. due to a trade on the energy markets; or they can occur due to a sudden, and unexpected, activation, e.g. due to activation of an ancillary service.

Normal or alert/emergency situation – ENTSO-E defines a set of situations for TSOs, where normal operation allows for trade on the energy markets, alert situation allows for trade but the operation centre is monitoring closely and may intervene in operations, and emergency situation where the markets are suspended and the TSO, in collaboration with the DSOs, decouple or activate the necessary resources in order to maintain the stability of the grid. In this work we further define a DSO-alert situation, where the DSO may force flexibility assets to turn on or off in order to protect parts of the network and avoid a brown-out. The table identifies if the sub-case can occur at all situations or only during some of the situations.

4.2 General Assumptions for Conflict Analysis and Solution Design

Many of the conflict cases cannot be observed yet in today's grid due to a lack of volume or demand, i.e. the penetration of flexibility assets is not high enough to cause serious grid impact. A central assumption behind all cases is a future energy system where the installed capacity of flexibility assets is significant, seen from the perspective of the entire power system as well as when considering a single feeder. This does not mean that the presented problems are only applicable at a single feeder level, but that they can appear at different levels of the distribution system.

For all cases it is assumed that customers are exposed to an incentive signal reflecting the spot price variations. The incentive signal may also contain other components, such as e.g. the CO2 footprint.

The general market setup for flexibility trade is assumed to follow the model shown in Figure 1. In this model, the traditional way of operating the energy markets is expanded to include a new role (the aggregator) as well as opening up for the distribution system operator (DSO) acquiring services through a localized flexibility market. Such a flexibility market would offer services so that the DSO can solve congestion problems or voltage issues.

The traditional setup with balancing responsible parties (BRP) interacting with the wholesale energy markets and the ancillary service markets is kept as it is today, but in this expansion, they also act as intermediaries between flexibility aggregators and the wholesale energy and ancillary service markets. It is assumed that BRPs trading flexibility do not have direct access to individual flexibility assets; instead, assets are pooled and managed through an aggregator (AGR). The flexibility BRP and the AGR (and energy retailer/supplier for that matter) are not necessarily separate entities. The transmission system operator (TSO) purchases ancillary services through a market where the BRPs offer their services. At the same time, the BRPs interact with the wholesale energy markets in order to purchase energy for their customers or sell energy from their production plants (if they are producing BRPs). It is assumed that the aggregator does not need to bid into the DSO flexibility market through a BRP, since the energy volumes traded in flexibility markets are small.

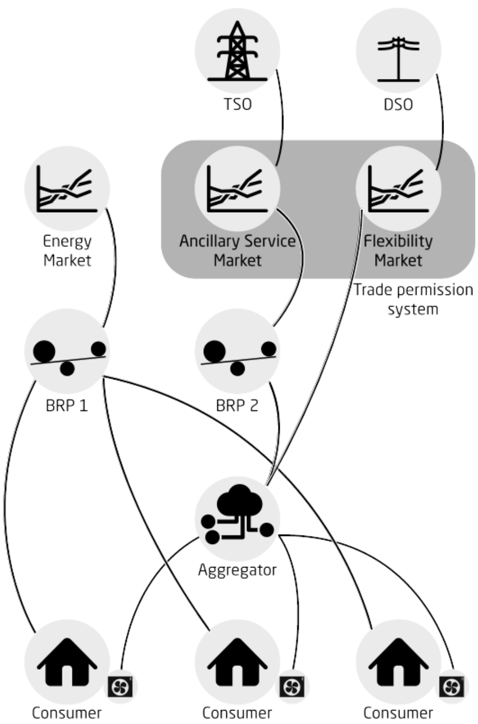


Figure 1: Assumed market setup for flexibility trade

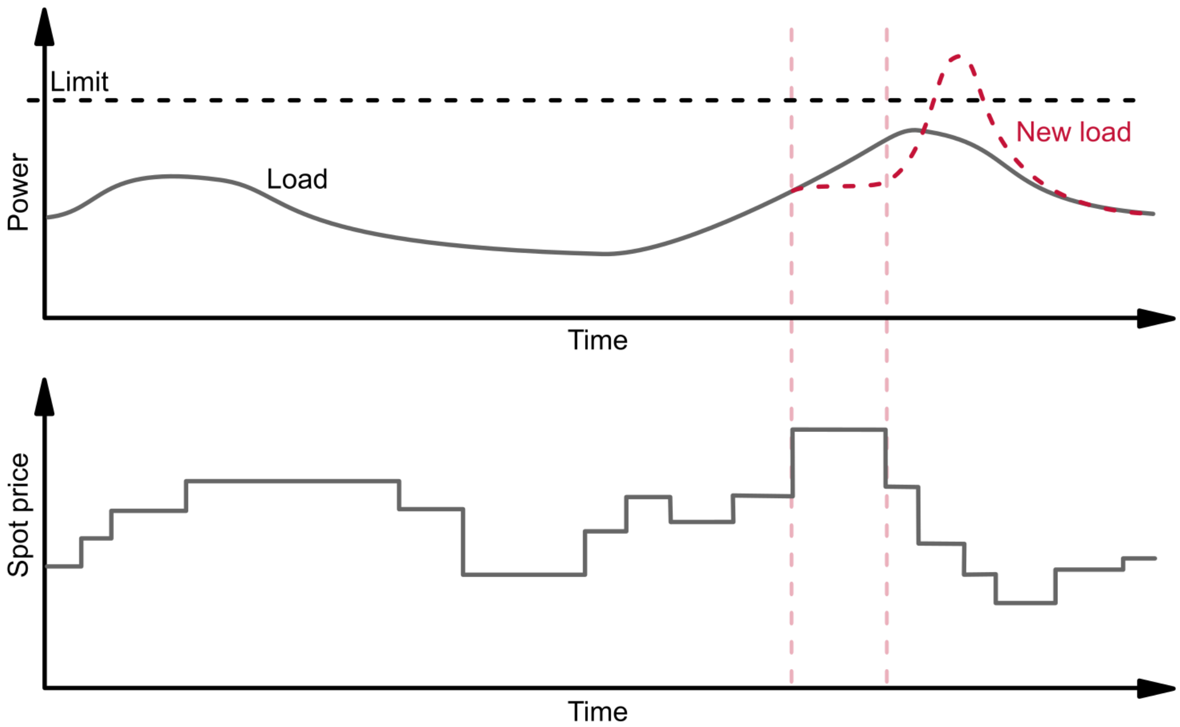
In addition, we assume that remote submeters are installed such that all flexibility assets can be individually metered (either through parallel, serial, or virtual metering) such that a BRP is associated to the general uncontrollable household load and a second BRP can be associated with the flexible load. Furthermore, it assumed that the DSO has a sufficient number of remote meters in the low-voltage grid to enable load flow analyses and to predict congestion points.

4.3 Conflict case 1: Implicit Demand Response

The situation occurs when several household customers simultaneously respond to an external stimulus such as variations in the energy price or tariff. For instance, a fleet of heat pumps with automatic control units might respond to a decrease in spot market price by switching on and charging a hot water storage unit. In this situation, the concurrency factor raises to (close to) one. The distribution grid planning procedures relies on the assumption that energy use by customers incorporates a random element and would typically set the concurrency factor to approximately 0.3 – 0.5.

The same effect could occur as a response to a variation in the end consumer price charged by the energy supplier as well as on the basis of other parameters than price. Furthermore, automatic control of the flexibility assets is not a necessary precondition; however, it is very unlikely that customers would closely monitor spot price variations on a daily basis.

A graphical representation of the case is shown below.



The situation is not a conflict between market actors, although it can be claimed that the spot market could work against the DSO’s interest, as can be seen by the red dashed line above.

	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope
1.1 Main case	Spot price variations	Customers react to a stimulus in a simultaneous but uncoordinated fashion. The concurrency factor increases significantly when re-engaging flexibility assets.	X		X		X	X

The situation could occur under normal operating conditions as well as during an alert and/or emergency grid condition, but only when a sufficient number of customers act simultaneously to represent a threat to the grid. It must be noted that in emergency grid operation, the market is suspended. However, customers could react to other signals, such as CO2 emissions.

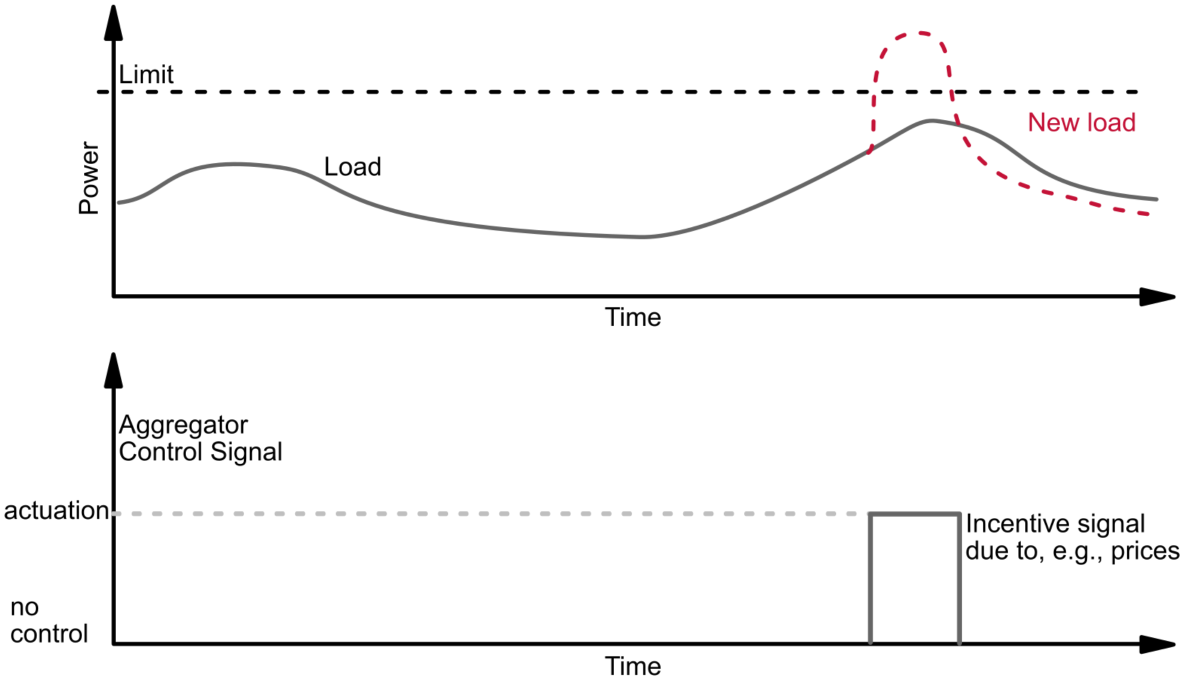
The problem could be mitigated if the DSO introduced a specially designed variable tariff encouraging the load peak to occur at predictable points in time when capacity is sufficient. Or an aggregator could be contracted to control and phase in the heat pumps in a more gradual way. The case is not further considered as there is no other organised party involved besides the DSO.

4.4 Conflict case 2: Explicit Demand Response

In this case, an aggregator activates a portfolio of flexibility assets simultaneously. As in conflict case 1, only flexibility assets in private households are considered.

This case is similar to conflict case 1, but it differs in that the concurrency problem is caused by at least a single legal entity (AGR) which manipulates the load on the DSO feeder for its own economic gain.

A graphical representation of the case is shown below.



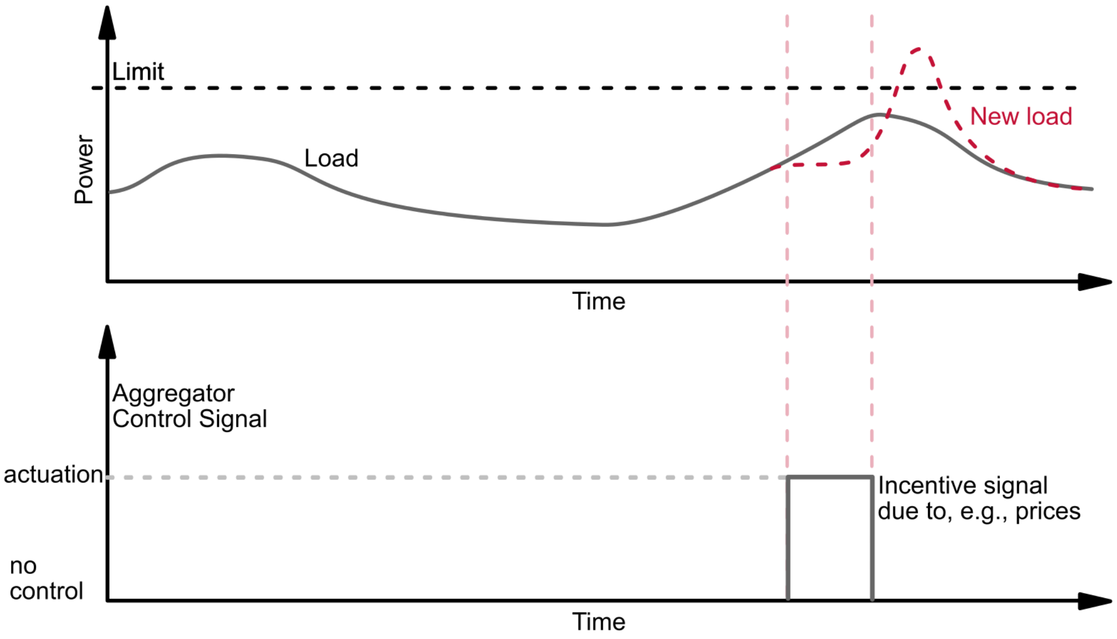
	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope
2.1 Main case	AGR control of several customers	Customers are controlled simultaneously by AGR on basis of a long term contract regarding energy management. The concurrency factor increases significantly when re-engaging flexibility assets.	X		X		X	X

4.5 Conflict case 3: Rebound effect

The situation occurs when an AGR controls a portfolio of flexibility assets which are connected to the same distribution feeder. Under most conditions, simultaneous interruption of the flexibility assets does not represent a problem for the DSO as this only reduces the load (although consider conflict case 8 as a counterexample). However, if the assets are simultaneously released at the end of the flexible period, they may all reactivate at the same time, raising the concurrency factor to 1 and causing a high peak load.

This so-called rebound effect occurs in various situations. For the analysis, we assume the worst case in which the flexibility assets reactivate at full power in order to regain the lost energy supply (e.g. heat pumps for space heating).

A graphical representation of the case is shown below.



Rebound does not always cause problems for the DSO, but if it occurs near the daily load peak, the total load may exceed the design capacity of the distribution feeder.
A special variant of this case exists in which the rebound effect is caused by an aggregator delivering a flexibility service to the DSO itself. This scenario is not listed below because it can be trivially avoided through contractual agreements, for example if a rebound limit is made part of the DSO service definition.

	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope
3.1 Main case	AGR offer energy management for customers	Unless the AGR portfolio is registered with the DSO, the Rebound Effect may occur without the DSO knowledge	X		X		X	X
3.2	TSO activated customers	The fleet of flexibility assets could be traded on system markets in which case the flexibility asset is known to the DSO and relative easier to find solutions for (this is use case 4)	X			X	X	X
3.3	BRP Self balancing through AGR	Unless the AGR portfolio is registered with the DSO, the Rebound Effect may occur without the DSO knowledge	X			X	X	X

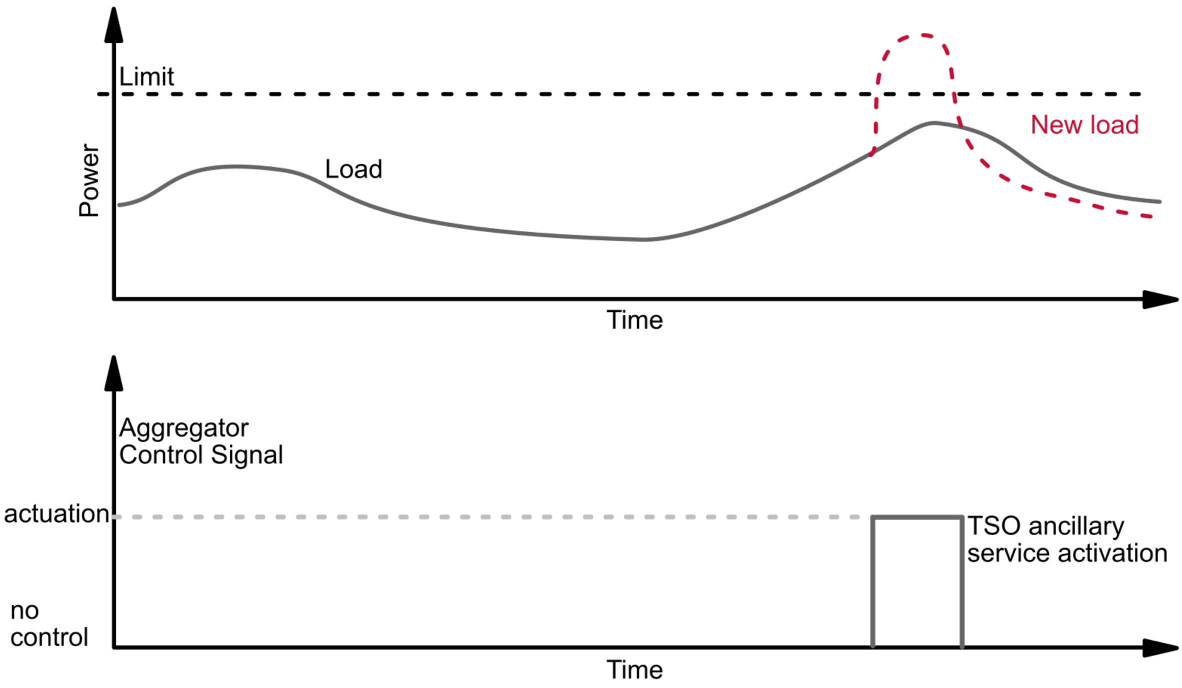
4.6 Conflict case 4: TSO-DSO Conflict

This conflict case occurs when an AGR activates a large portfolio of flexibility assets in order to provide a downward regulation service (regulating power) to the TSO. The problem results from an increase of the concurrency factor but is different from explicit demand response (case 2), since the activation is due to trading on the ancillary services market.

This conflict is usually not caused by only one large flexibility asset because its regular operation would cause distribution grid issues on a daily basis, and the DSO would already have taken preventive measures before installation of the asset, for example as part of the connection agreement/permission. However, under emergency situations, a single large flexibility asset used for downward regulation could be interrupted against the interests of the TSO.

Before connecting new customers, the design capacity of the grid at the connection point is compared to the expected load in order to determine if sufficient capacity is available. If a customer is only using e.g. 50% of the rated load during normal operation, the analysis of available grid capacity will take this load factor into account. However, if the customer decides to enter the remaining 50% into the ancillary services market, an overload situation may occur when the unit is operated at 100% of the rated load due to a market request.

A graphical representation of the case is shown below.



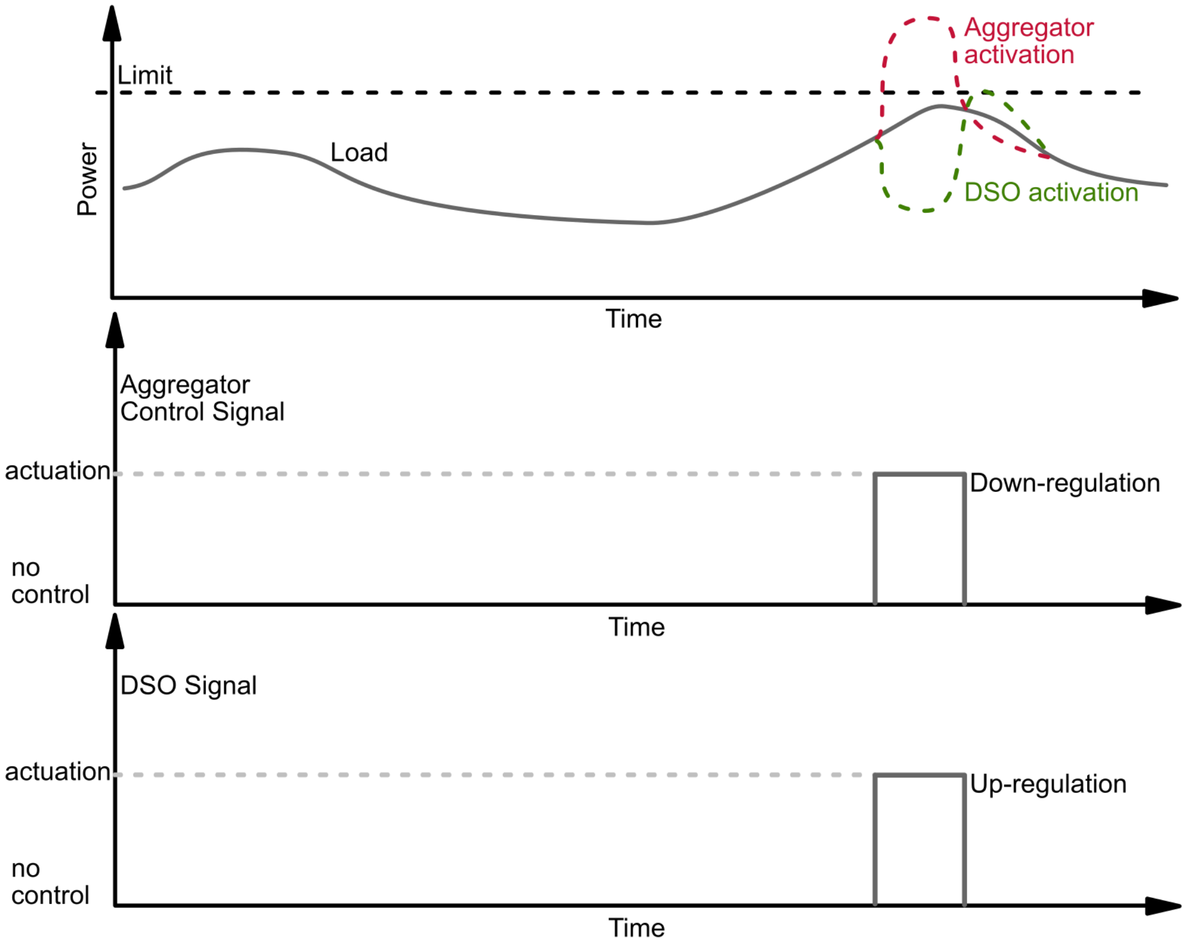
	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope
4.1 Main case	TSO activated; several flexibility assets.	The flexibility assets are traded on system markets, but the flexibility asset is known to the DSO, through the flexibility assets prequalification for market trading.	X			X	X	X
4.2	TSO activated; one single flexibility asset but Alert/Emergency Grid Operation	The flexibility assets are traded on system markets, but the flexibility asset is known to the DSO, through the flexibility assets prequalification for market trading.		X		X		X

4.7 Conflict case 5: DSO Counteracts Flex Activation

This conflict case extends case 4 in which one or more large flexibility assets are used to provide a service at the transmission level. Following the previously made assumptions, the DSO is aware of the presence of the flexibility assets on each feeder but does not know when, nor why, they are being activated. Upon observing a sudden load increase, the DSO activates a number of flexibility assets under contract on the same feeder in order to provide load relief. The two activations counteract each other, reducing the effectiveness of the system level service.

At first glance, this may appear to be just market forces at work. However, the market itself is formed by the opposing interests of the TSO on the one side and the BRP/AGR on the other side, leading to the eventual discovery of prices and delivery contracts. The DSO is not part of this market mechanism. The two activations counteract each other, neutralizing the balancing effect at the transmission level while both assets owners are remunerated for their service.

A graphical representation of the case is shown below.



The case arises because the TSO has no information about the grid constraints of the DSO, and because the DSO does not know about ancillary service reserves that may exist on its network. Although counteracting an activation at a radial level does not necessarily cause a problem for the TSO, it still increases the overall cost of operating the system.

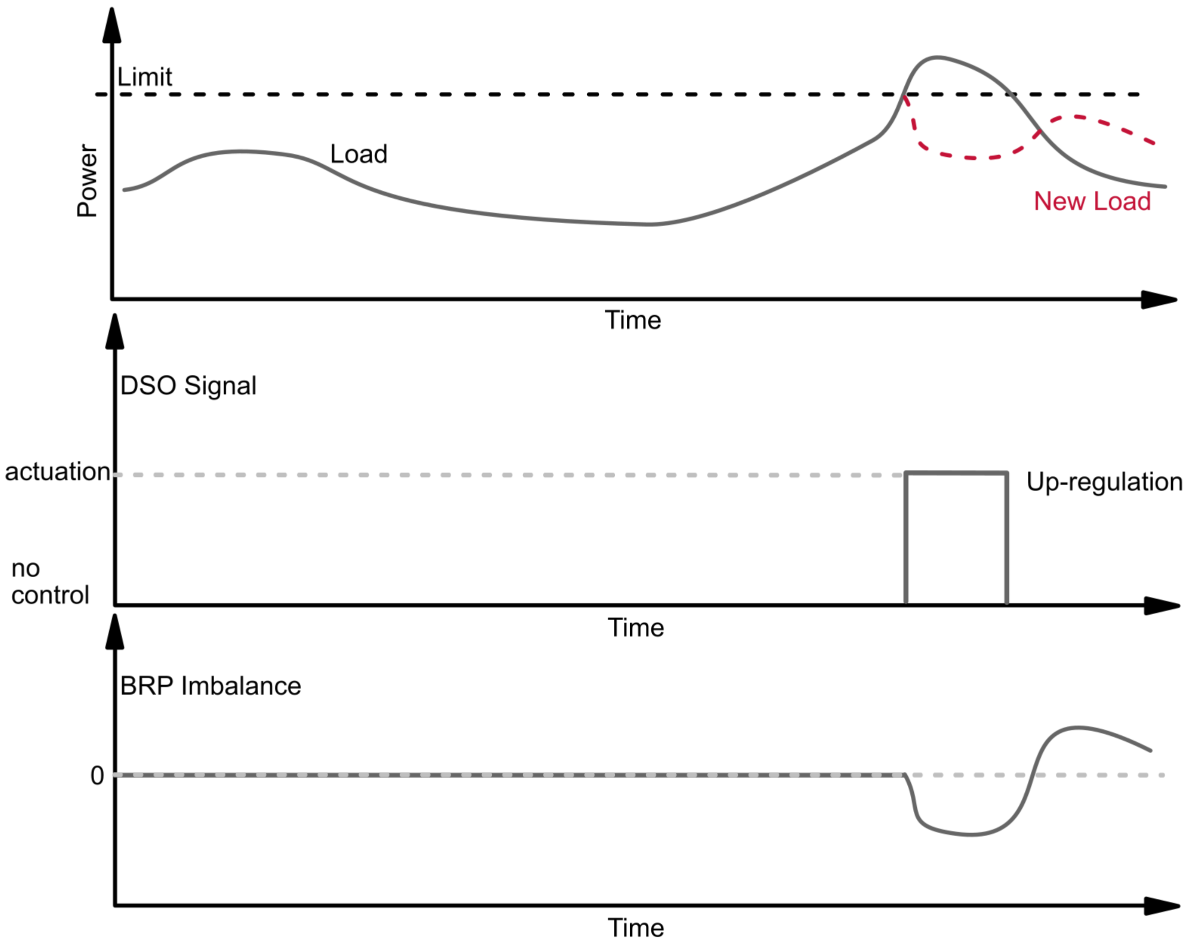
	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope
5.1 Main case	DSO counteracting TSO activation	DSO is unaware of activation of several, larger flexibility assets and counter-activate another flexibility asset on the same feeder.	X			X	X	
5.2	DSO counteracting TSO activation in A/E grid operation	One single, larger flexibility asset activated at the wrong time during Alert or Emergency grid operation		X		X		X

4.8 Conflict case 6: Dynamic Growth in Consumption

The DSO may engage in a long-term contract with a flexibility asset on a specific feeder where the general load increase over time has exceeded the cable capacity in peak hours. The flexibility assets could be activated on daily basis during the peak load time in which case the energy consumption pattern would be predicable for the BRP and is not likely to represent any conflict.

But in case the DSO only activate the flexibility assets occasionally (due to Alert/Emergency grid operation or other reasons for reduced grid capacity) the relevant BRP becomes imbalanced.

A graphical representation of the case is shown below.



Long-term contracts with selected flexibility assets could also be instrumental for the DSO to mitigate the impact of implicit demand response (conflict case 1).

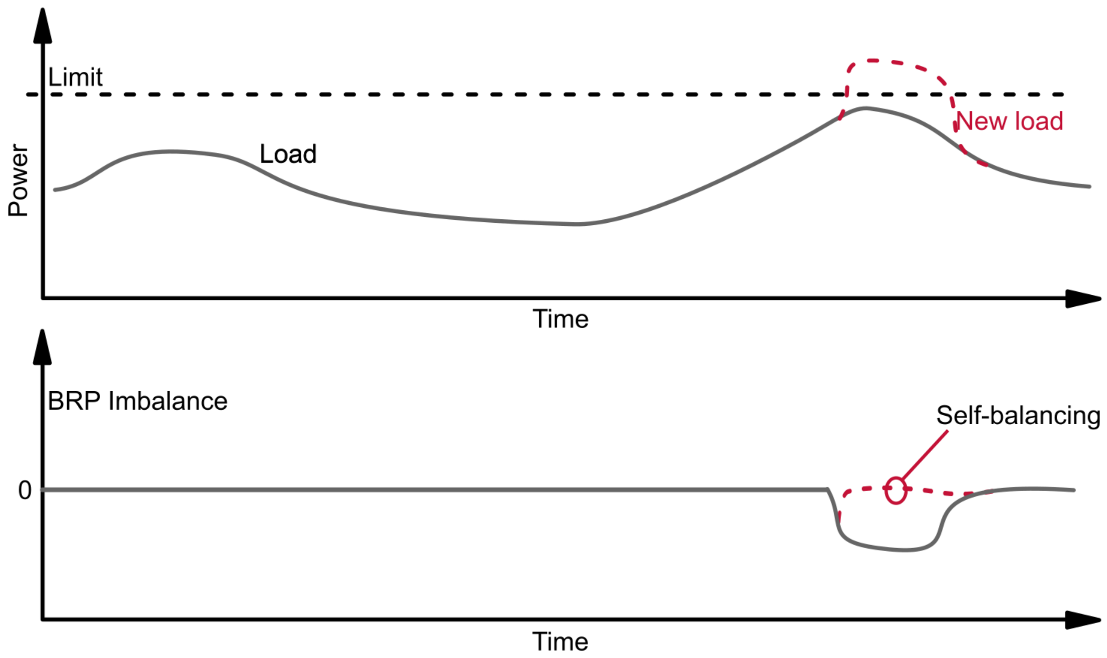
	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope
6.1 Main case	DSO activated flexibility asset occasionally	The sourcing of energy is unpredictable for the BRP		X		X	X	X

4.9 Conflict case 7: BRP Self-balancing

This situation is very similar to conflict case 4 (TSO-DSO Conflict); however, here the problem is caused by self-balancing of a BRP.

The BRP needs to contact an AGR for activation of flexibility assets. The problem occurs when several flexibility assets are activated (downward regulating) at the same time, resulting in a high concurrency factor.

A graphical representation of the case is shown below.



The conflict is not relevant day-ahead as the need for self-balancing occurs momentarily for the BRP.

If the AGR is an independent entity that have sold the balancing service to the BRP, the BRP may be unaware of where the flexibility asset is located and what problems it may cause. Still the solution may have to be found with the AGR.

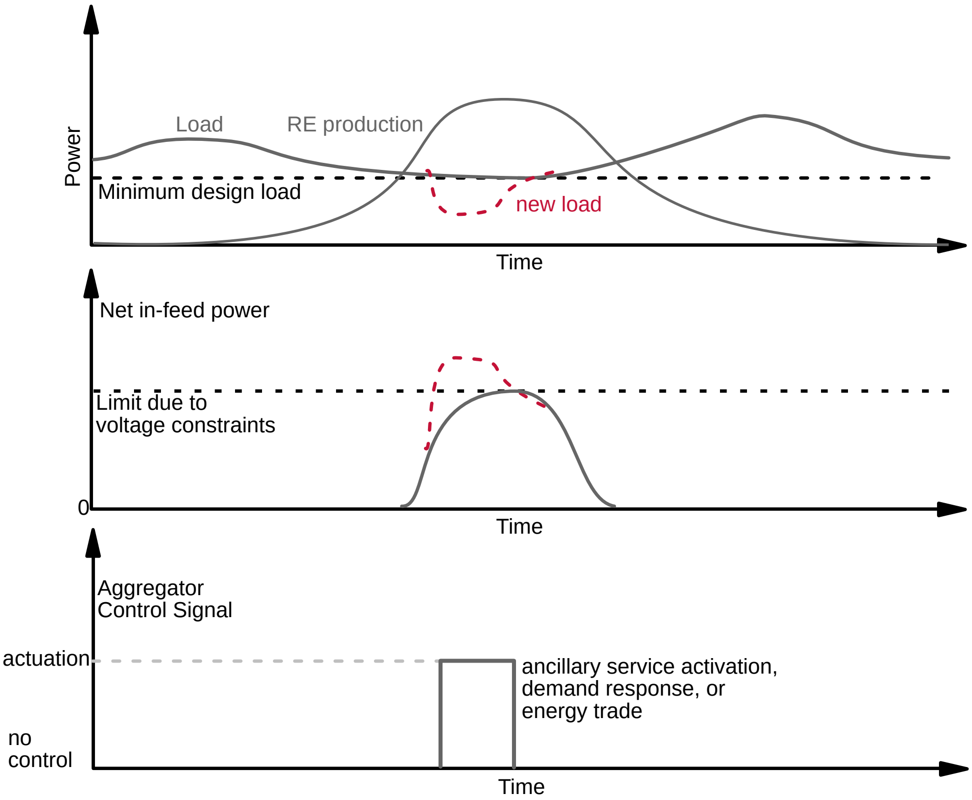
	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope
7.1 Main case	BRP self-balancing cause over-load. Several flexibility assets	BRP is activating several flexibility assets through an AGR causing concurrency factor to raise to 1	X			X	X	X
7.2	BRP self-balancing cause over-load. Single flexibility assets	BRP is activating a single flexibility asset but at a time inconvenient for the DSO.		X		X		X

4.10 Conflict case 8: In-feed Overload

In case of a mixed load and in-feed from renewable energy plants, the maximum load on the transformer and cables is calculated as the maximum in-feed power subtracted with the minimum load. This mean that the transformer capacity may be less than the full in-feed power alone.

In case that the load is traded on system markets or subject to energy management service the difference between in-feed power and load may exceed the transformer or cable capacity. Quite a number of cases could cause the reduced load and it could happen momentary or on day-ahead planning basis.

A graphical representation of the case is shown below.


Power
Load
RE production
Minimum design load
new load
Time
Net in-feed power
Limit due to
voltage constraints
0
Time
Aggregator
Control Signal
actuation
ancillary service activation,
demand response, or
energy trade
no
control
Time

	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope
8.1 Main case	TSO upward regulation of several flexibility assets	Case (4)	X			X	X	X
8.2	BRP upward regulation for self-balancing service	Case (7)	X			X	X	X
8.3	Opposite of (2) in Explicit Demand Response	AGR offer energy management to several customers for reducing load in spot price peak. Only day-ahead situation	X		X		X	X
8.4	Unexpected renewable in-feed power	Load flow exceed prediction. Only momentary.				X	X	X

4.11 Inter-relations between Use Cases

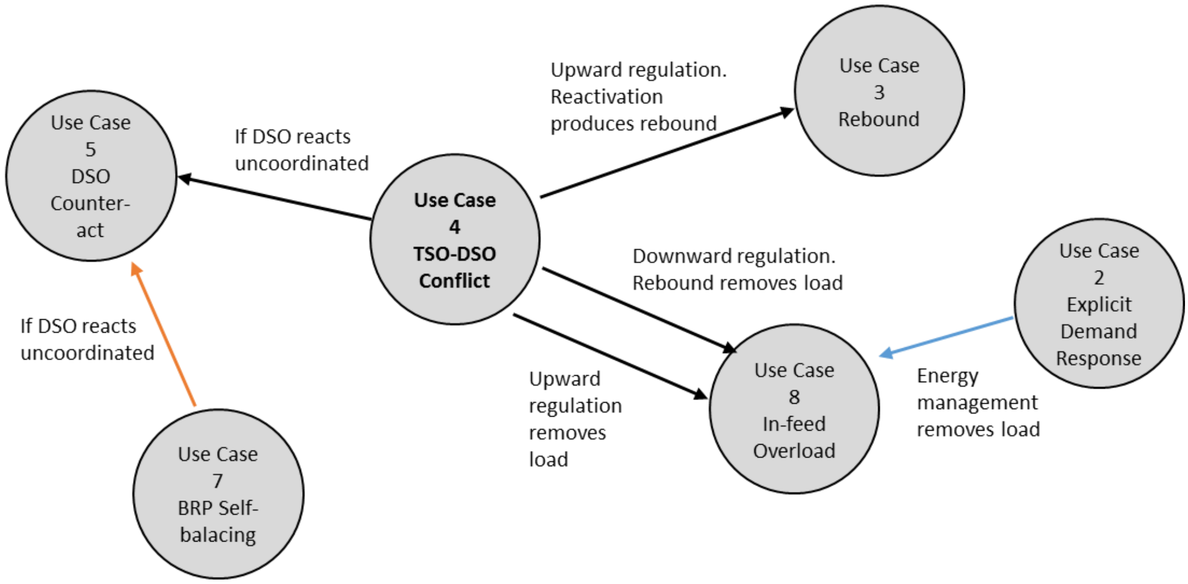
Some use cases can lead to other use cases depending on the reaction from the DSO and under certain circumstances.

The most simple and common use case 4 (TSO-DSO conflict), where the TSO activates a number of flexible assets simultaneously at the time of the load peak, could lead to use case 3 (Rebound) in case of upward regulation and if all flexibility assets attempt to regain the lost energy after the activation period. This could also lead to use case 8 (In-feed overload) if the simultaneous activation lowers the load on the feeder below the expected minimum at a time with maximum renewable energy infeed.

Use case 4 (TSO-DSO conflict) could also lead to use case 8 (In-feed overload) in case of downward regulation if a negative rebound lowers the load on a feeder with high renewable in-feed.

Use case 4 (TSO-DSO conflict) could also lead to use case 5 (DSO counteracts flex activation) if the activation of flexibility assets is uncoordinated due to the lack of communication between parties. Likewise use case 7 (BRP self-balancing – DSO) could leat to use case 5 if the DSO reacts without coordinating with the other parties.

Use case 2 (Explicit demand response) could lead to use case 8 (In-feed overload) if an AGR's simultaneous control of a fleet of flexibility assets lowers the load at a specific feeder below the expected minimum level.


Use Case
5
DSO
Counter-
act
If DSO reacts
uncoordinated
Use Case
4
TSO-DSO
Conflict
Upward regulation.
Reactivation
produces rebound
Use Case
3
Rebound
Downward regulation.
Rebound removes load
Use Case
2
Explicit
Demand
Response
If DSO reacts
uncoordinated
Upward
regulation
removes
load
Use Case
8
In-feed
Overload
Energy
management
removes load
Use Case
7
BRP Self-
balacing

5. Traffic Light Solution Concept

Across Europe, traffic light models have been used to illustrate various solutions regimes with regard to congestion management in the distribution grid. USEF[7] has recently worked on compiling a number of experiments and pilot projects in Europe which can all be adopted to the traffic light concept. All of these concepts differ from each other; therefore, no general guideline has emerged regarding the handling of congestion problems by the DSO.

The traffic light model was already proposed in a paper in 2015[8] as a model for discussion with respect to how participants and network operators could interact in the future. In the USEF paper mentioned above, a number of traffic light models are represented, corresponding to the array of experiments carried out in Europe. All of these models are different and mirror the specific problems each experiment intended to solve, as well as the context of the national regulation it was executed in.

We have identified the following solution regimes which primarily derive from the workgroup discussion of relevant solutions regimes in a Danish context and which we believe offer the most complete picture. The colours chosen here do not directly map to those in the USEF document, but the overall framework is the same.

Red	Interruption of customers without notice in order to mitigate a critical (e.g. force majeure) situation in the grid. Could be commanded by the TSO. No agreement with customers concerning interruption.
Orange	Long term contract with specific customers who own a flexibility asset. The contract may be concluded on the basis of a direct bilateral negotiation or based on tendering if more flexibility assets exist on the same feeder.
Yellow	The DSO issues a tender for immediate downward or upward regulation of load on a specific feeder. This will happen on relatively short notice (day ahead at most) facilitated by a fast track system.
Green	DSO congestion avoidance mechanisms directly based on grid codes or other regulatory tools, which enable the DSO to prevent congestion.
Grey	Technical solutions implemented by the DSO which do not involve customers or other agents; e.g. energy storage facilities, re-configuration of the grid, and OLTCs.

The grey solution regime is always a possibility where the DSO has such technology installed. This work focuses on market solutions and therefore the grey regime will not be discussed further.

Likewise, the red solution regime is always a possibility and serves as the last line of defence for the DSO. When everything else fails and a situation becomes critical, the DSO has the possibility to

[7] Universal Smart Energy Framework. www.usef.eu. For traffic light models see other models used in Europe in USEF Workstream. An Introduction to EU Market-based Congestion Management Models.

[8] Bdew. German Association of Energy and Water Industries. 2015. Smart Grid Traffic Light Concept.

disconnect one or more customers to protect the grid or to prevent a blackout for a larger number of customers. Therefore, the red solution will not be considered further.

With respect to the network design process, the n-1 criterion[9] prescribes a load maximum for each cable corresponding to 70% of its rated load. A temporary overload relative to the 70% level (n-1) may not cause problems unless the grid switches to Alert/Emergency operation and the full capacity is no longer available. Flexibility contracts may not be allowed to be executed under such circumstances if they would worsen the situation.

The DSO is obliged to deliver a certain capacity to customers which is agreed upon during connection to the grid. In reality, the DSO relies on a concurrency factor, i.e. not all customers require full capacity at the same time. The concurrency factor is usually approximately 0.4. Deploying the green solution regime consequently requires further development of the current grid code if the reason for grid congestion is the simultaneous downward regulation of multiple flexibility assets at the same feeder.

A closer economic analysis is required to determine what is most beneficial for society as a response to the increasing concurrency between individual loads: reinforcement of the grid to create additional capacity, resulting in a very low utilization of grid assets during regular operation, or the introduction of a mechanism to limit the participation of flexibility assets in ancillary services markets under certain circumstances.

[9] N-1 refers to the ability of the grid to withstand a failure of any single asset without a resulting brownout or blackout. In the context of distribution grids, this is implemented by limiting the design load of each cable to 70% of its rated load such that two neighbouring cables each can pick up half of the defective cable's load.

5.1 Proposals for Solution Regimes

After the first set of workshops identified and defined the conflict cases, thus agreeing on what potential market conflicts may arise in the future, the workshop participants were tasked with identifying possible solutions that enable the DSO to perform congestion management. In this way, the participants reduced the potential bias towards certain solutions that may have been beneficial to only some of the market players.

The workshop participants were introduced to the traffic light concept presented in the previous chapter, and thereafter split up into three different teams. These teams were tasked with mapping green, yellow, and orange solutions for a set of conflict cases and their sub-cases. All conflict cases were covered by at least one team. The red and grey solutions were ignored, since they represent current solutions which the DSO already utilizes today.

The proposed solutions are summarized in the following tables, which build on the previous tables (presented in Chapter 4) by adding three columns for green, yellow, and orange solutions. It was not in all sub-cases where solutions were found for each colour and the corresponding space has been left empty. Note that in most cases, a solution of one colour precludes any other solution, however, there are some cases where solutions of different colours complement each other, e.g. a green solution if no other solution is possible. During the workshops, the participants also hinted at which solutions they found most beneficial.

The filled tables were analysed by the project members, evaluating each possible solution, in order to synthesise as few as possible framework solutions that would cover all cases. The final part of this section presents some general conclusions with respect to the analysis, before presenting the synthesised solutions in Chapter 6.

Explicit Demand Response	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Operation	Green	Yellow	Orange
2.1 Main case	AGR control of several customers	Customers are controlled simultaneously by AGR on basis of a long-term contract regarding energy management. Simultaneous factor could raise significantly when re-engaging flexibility assets.	X		X		X	X	If no options, the DSO should be entitled to limit the AGR's control schedule	This is trade on wholesale market and DSO could counteract the negative effect with other flexibility asset. Require a liquid market for tendering.	This is trade on wholesale market and DSO could counteract the negative effect with other flexibility asset. Contract with an asset is already in place (long-term contract).
2.2	AGR offer demand response to system markets	AGR operate on behalf of the TSO or BRP. Technological limitations in private households' energy equipment and energy use may render this case unrealistic	X			X	X	X	The DSO should be entitled to limit the AGR's control schedule		

Rebound Effect	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Ope	Green	Yellow	Orange
3.1 Main case	AGR offer energy management for customers	Even though the AGR portfolio is registered with the DSO, the Rebound Effect may occur without the DSO knowledge as the AGR control scheme is unknown	X		X		X	X	If no options the DSO should be entitled to limit the AGR's control schedule	This is trade on wholesale market and DSO could counteract the negative effect with other flexibility asset. Require a liquid market for tendering.	This is trade on wholesale market and DSO could counteract the negative effect with other flexibility asset. Contract with an asset is already in place.
3.2	TSO activated customers	The fled of flexibility assets could be traded on system markets in which case the flexibility asset is known to the DSO and relative easier to find solutions for (this is use case 4)	X			X	X	X	The DSO should be entitled to limit the AGR's control schedule		
3.3	BRP Self balancing through AGR	Unless the AGR portfolio is registered with the DSO, the Rebound Effect may occur without the DSO knowledge	X			X	X	X	The DSO should be entitled to limit the AGR's control schedule		

TSO-DSO Conflict	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid	Alert/Emergency Operation	Green	Yellow	Orange
4.1 Main case	TSO activated; several flexibility assets.	The flexibility assets are traded on system markets but the flexibility asset is known to the DSO, through the flexibility assets prequalification for market trading.	X			X	X	X	The DSO should be entitled to limit the AGR's control schedule		
4.2	TSO activated; one single flexibility asset but Alert/Emergency Grid Operation	The flexibility assets are traded on system markets but the flexibility asset is known to the DSO, through the flexibility assets prequalification for market trading.		X		X		X	The DSO should be entitled to limit the AGR's control schedule		

DSO Counteracts Flexibility Activation	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Operation	Green	Yellow	Orange
5.1 Main case	DSO counteracting TSO activation	DSO is unaware of activation of several, larger flexibility assets and counter-activate another flexibility asset on the same feeder.	X			X	X				
5.2	DSO counteracting TSO activation in A/E grid operation	One single, larger flexibility asset activated at the wrong time during Alert or Emergency grid operation		X		X		X			DSO could counteract the negative effect with other flexibility asset in an emergency situation.

This scenario is not a market conflict for the DSO to solve but rather a market conflict produced by the DSO. The solution should be found by enhanced communication between parties. Scenario 5.1 is in particular not an acceptable situation. Scenario 5.2 could in the extreme case occur but is more likely to be seen as scenario 4.2. Counteracting with another flexibility asset on the same feeder will not negatively affect the BRP's self-balancing (unless it is the same BRP).

Dynamic Growth in Consumption	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Operation	Green	Yellow	Orange
6.1 Main case	DSO activates flexibility asset occasionally	The sourcing of energy is unpredictable for the BRP		X		X	X	X			

This scenario is not a market conflict for the DSO to solve but rather a market conflict produced by the DSO. The BRP should be informed about the activation of a flexibility assets (by an AGR) due to a DSO's request.

A derivative to this case can occur when the DSO directly activates flexibility from large units (without an AGR nor agreement with a BRP). In this case, the activated unit must settle any imbalance with its associated BRP.

BRP Self-balancing - DSO	**Sub-cases**	**Description**	**Multiple customers**	**Single customer**	**Day ahead**	**Momentarily**	**Normal Grid Operation**	**Alert/Emergency Operation**	**Green**	**Yellow**	**Orange**
7.1 Main case	BRP self-balancing cause over-load. Several flexibility assets	BRP is activating several flexibility assets through a AGR	X			X	X	X	The DSO should be entitled to limit the AGR's control schedule		DSO could counteract the negative effect with other flexibility asset in an emergency situation.
7.2	BRP self-balancing cause over-load. Single flexibility asset.	BRP is activating a single flexibility assets but a time inconvenient for the DSO.		X		X		X	The DSO should be entitled to limit the AGR's control schedule		DSO could counteract the negative effect with other flexibility asset in an emergency situation.

In-feed Overload	Sub-cases	Description	Multiple customers	Single customer	Day ahead	Momentarily	Normal Grid Operation	Alert/Emergency Operation	Green	Yellow	Orange
8.1 Main case	TSO upward regulation of several flexibility asset	Case (4) Lack of load cause the in-feed to exceed the capacity	X			X	X	X	The DSO should be entitled to limit the AGR's control schedule		
8.2	BRP upward regulation for self-balancing service	Case (7) Lack of load cause the in-feed to exceed the capacity	X			X	X	X	The DSO should be entitled to limit the AGR's control schedule		DSO could counteract the negative effect with other flexibility asset
8.3	Opposite of Scenario 2; Explicit Demand Response	AGR offer energy management to several customers for reducing load in spot price peak. Only day-ahead situation	X		X		X	X	If no options, the DSO should be entitled to limit the AGR's control schedule	This is trade on wholesale market and DSO could counteract the negative effect with other flexibility asset. Require a liquid market for tendering.	This is trade on wholesale market and DSO could counteract the negative effect with other flexibility asset. Contract with an asset could already be in place.

Scenarios 8.1-3 are similar to already analysed situations. The difference is that it is the reduction of the concurrency factor which causes the problem, and not the increase of the factor.

In conclusion of the study of scenarios, general trends are recommended:

1. When the scenario concerns the wholesale market and should be predicable at least one day ahead (but maybe more), the solution should be market based. Whether the Yellow or Orange solution regime is viable depend on the situation. The Yellow solution regime require a liquid market narrowed to the relevant feeder to be relevant for a DSO. It will still take some time for sufficient amount of flexibility assets to emerge for such liquid market and in the near future the Orange solution regime may be the most relevant.
2. When the scenario concerns the system markets only a narrow window is open to act for the DSO. The conflict is assumed to occur almost momentarily. However, the DSO are not necessarily required to act instantly. For instance, PEX cables can manage 117% overload in up to 50 hours, but some switching gear may only manage overload in less than one hour. The choice of solution regime depends however, not only on the time for managing a market solution, but also the fact that market solution by nature includes activation of a counteractive flexibility asset, which in the case of trading on system markets only create a new conflict. The Green solution regime is therefore the preferred approach that allow the DSO simply to interrupt an ongoing trade. Scenario 5.2 is a special case, which is at least theoretical possible but maybe never would be preferred by the DSO.
3. When the scenario concerns BRP self-balancing, the Orange solution regime would still be eligible even though the situation occurs momentarily, as counteracting the activated flexibility asset of the BRP will not neutralize the objective of the BRP (unless it is the same BRP for the DSO activated flexibility asset).

The general scheme looks like below.

Day ahead	Wholesale market	(Green)	Yellow	Orange
Momentary	Self-balancing	Green		Orange
Momentary	Balancing market	Green		(Orange)

Scenario 6.1 represents a special (but probably quite normal) situation in the near future and requires coordination between the AGR and the BRP associated to the flexibility assets.

5.2 Scenario 9

The scenarios presented in the table above all take departure in conflicts created by trade on system or wholesale markets. Planned maintenance or extension of the grid may result in reduced grid capacity, which cause the DSO to limit trade. We assume that momentary faults in the grid cause Alert/Emergency grid operation status and this situation is covered by the scenarios already described.

Reduced grid capacity due to planned maintenance could in theory be compensated for by activation of flexibility assets (in a market setting) but the DSO may prefer the safer solution of just preventing potential downward regulating flexibility to be traded of fleet energy management control that could lead to rebound effect etc.

We call this scenario 9 (DSO Planned Maintenance). The scenario is a DSO produced conflict (of interest when assuming that another party wants to use a flexibility asset on the feeder in question) that is not fitting to the terminology of solution regimes.

6. Solution Design

The above-mentioned proposals for solution regimes were discussed in one of the final workshops, agreeing on certain requirements (such as anonymity between DSO and AGR). In this section, we propose a set of solutions to address the conflict cases considering the requirements and the general trends shown at the end of Section 5.1.

The focus on the design of the solutions has been to make framework solutions, such that the solutions are of a general nature and not kludges that may eventually complicate the operation of the system in the future. In the following subsections we define the framework solutions. Each of these solutions have been indexed by an acronym, e.g. R-1 for the first regulatory proposal, yet we stress that the following proposals have to be seen as one global solution that will address all conflicts listed in the previous chapters. Table 1 gives an overview of these solutions.

Table 1: Summary of the framework solutions proposed by the DREM project

Solution acronym	Solution name
R-1	**Registration of flexibility units on the DataHub**
R-2	**Redefining the DSOs installed capacity obligation**
R-3	**Aggregators must be attached to a BRP**
R-4	**DSOs are not required to reimburse for trade interruptions**
R-5	**DSOs are not responsible for redispatch impact**
M-1	**Use of flexibility markets for DSO services**
M-2	**Redefinition of services to include rebound**
C-1	**Establishing a dynamic information broker for allowing the DSO to communicate limits to BRP/AGR**
C-2	**AGR/BRPs submit operational schedules**

We have divided the solutions into those necessary for a base solution, and those that could be optional. Specifically, the registration of flexibility units in a common database (R-1) is necessary for the DSO being able to estimate how much flexibility exists in its system. This allows for:

- the DSO to know how much capacity it must make available (R-2),
- how much flexibility it can buy as a service (M-1),
- and allow the DSO to send relevant limitations on the DSO installation numbers through the dynamic information broker (C-1).

Furthermore, the establishing of a dynamic information broker (C-1) partially depends on the existence of a DSO service market (M-1). In order to avoid market gaming, the DSOs must be held free from responsibility for trade interruptions (R-4) and redispatch impact (R-5).

Furthermore, the correct functioning of a DSO service market (M-1) depends partially on the AGR being associated with a BRP (R-3), such that the DSO does not cause imbalances in the system by activating flexibility. At the same time, the inclusion of the rebound as part of the service definition (R-3) depends partially on the existence of DSO service market (M-1, for the definition of DSO flexibility services with rebound) but should also be applied to the definition of ancillary services (the

TSO service market). Finally, the optional communication of operation schedules by the BRP/AGR to the DSO (C-2) depends on there being an actual system to communicate these schedules (C-1). These necessary and partial dependencies are shown graphically in Figure 2.

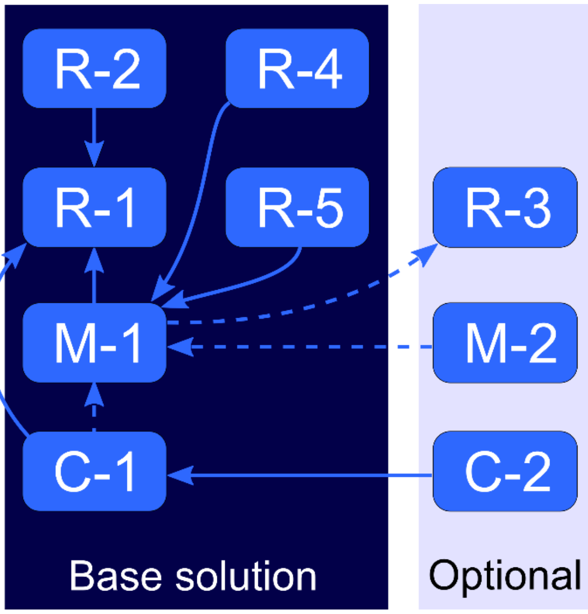


Figure 2: Graphical representation of the base solution and optional solutions. The solid arrows represent necessary dependencies and the dashed arrows represent partial dependencies.

An explicit requirement that was discussed during the workshops was the need for anonymizing the interactions between the DSO and AGR/BRPs, since it could potentially cause competition issues between AGR on the same DSO network, amongst other problems. This requirement flavours the solutions presented below.

6.1 Regulatory framework

R-1 Registration of flexibility units on the DataHub

As elaborated above, an increased degree of coordination between the different actors is required in order to enable a DSO to anticipate problems caused by flexibility assets, and in order to identify which flexibility assets could be contracted as part of a solution to a network problem. As the analysis showed, congestion problems occur primarily when the concurrency factor raises to 1 (or becomes considerable higher than assumed during grid planning) or when the full grid capacity is not available due to maintenance, reconfiguration of the grid due to faults etc.

Figure 3 shows the schematic configuration of a typical distribution grid. Congestion could affect one or multiple low voltage transformers. It is important to impose limitations on the smallest possible yet sufficient set of customers. While the DSO knows the grid connection point of an asset, it has no information about which aggregator may be controlling the asset at a given time, if at all.

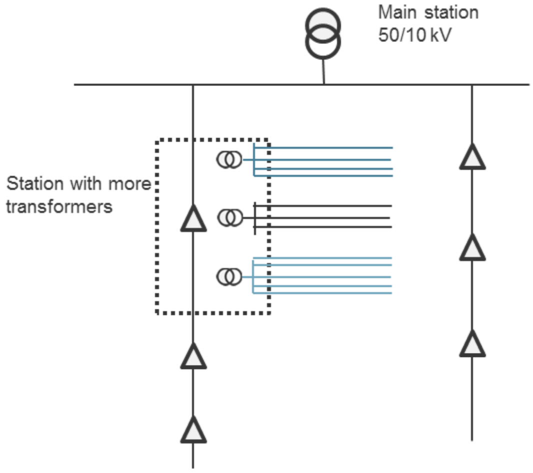


Figure 3: Typical distribution grid configuration

Aggregators on the other hand do not have any knowledge about the real-time load state and/or topology of all points of the electrical grid at which their assets are connected. In the example feeder in Figure 4, congestion could be caused due to simultaneous activation of flexibility assets, but not all flexibility assets of each aggregator need to be deactivated in order to solve the problem. It is necessary for a DSO to be able to issue limitations to flexibility assets in specific network locations.

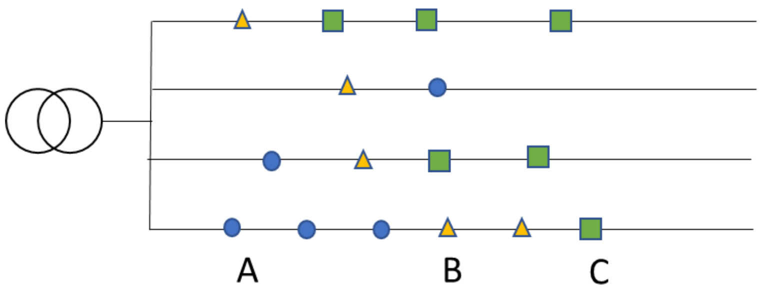


Figure 4: Schematic drawing of assets from three aggregators A, B and C distributed between multiple feeders

The direct exchange of information between the two parties is not likely to be a viable solution to the above problem: Both the real-time composition of an aggregator's portfolio as well as real-time DSO network operation data are considered sensitive business data. Consequently, an independent data exchange platform is needed as an intermediary, in order to provide the DSO with an opportunity to communicate with the controlling entity (aggregator) of a particular flexibility asset while anonymizing the identity of the controlling entity, thus preventing the disclosure of sensitive portfolio information.

Rather than creating new infrastructure, the reuse or extension of existing systems would be desirable. The authors propose an extension of the DataHub[10] metering database operated by Energinet. The current DataHub contains a record for each energy meter in Denmark located at the

[10] More information on the DataHub can be found on https://energinet.dk/El/DataHub#Dokumenter

point of common coupling. Each meter is identified by a metering point identifier (aftagernummer) and is cross-referenced with customer information and metering timeseries (see figure 5).

Figure 5: Data organisation in DataHub (conceptual)

The proposed extension adds two additional fields/columns to the database record: Flexible capacity and operator reference (see figure 6).

Flexible capacity refers to the largest possible grid impact from the flexibility asset, expressed as the highest expected power ratings for upward (+) and downward (-) flexibility, respectively. As an example, if a load rated at 500kW has been contracted by an aggregator such that the aggregator can request up to 100kW of load reduction but no load increase, the upward flexibility would be zero while the downward flexibility would be 100kW. It would be the aggregator's responsibiltiy to report a flexible capacity of +0/-100 and to update this rating whenever the contract conditions change.

The operator reference is an anonymized identifier (e.g. a hash code) allowing the DSO to issue flexibility constraints for individual resources to their respective aggregrators, without being able to reconstruct the aggregators' portfolio information. For units which are not under control of an aggregator, both fields would be empty. It would be the responsibility of an aggregator to update the information on DataHub whenever a unit enters or leaves the aggregator's portfolio.

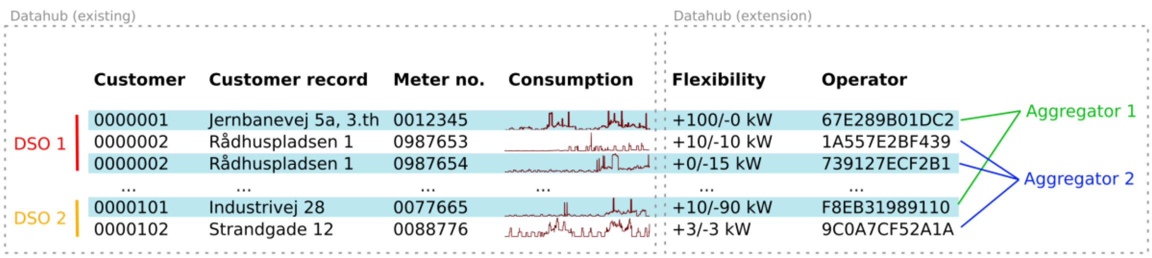


Figure 6: Proposed DataHub extension (conceptual)

It should be noted that the above capacity rating does not change regardless of how much of this capacity is used at any given point in time - i.e. the capacity rating is not real-time information but represents the worst case from the DSOs point of view. This is a necessary compromise given the much higher effort required for, and the many data security and privacy issues connected to, a system where the actual use of flexible resources would be reported in real-time. It is also in line with the design capability of the DataHub which was not conceived as a real-time database.

R-2 Redefining the DSOs installed capacity obligation

When being connected to the distribution grid, each customer procures a specific amount of connection capacity at the point of common coupling. However, this capacity is assigned under the assumption that the full capacity of all customers is not utilized at the same time. In residential sections of the grid, grid capacity determination will typically take the following form:

$$Cap_{min} = \alpha \cdot 11kW \cdot n$$

Here, the minimum power distribution capacity which the DSO must make available in a given section of the grid depends on the total number of households *n* multiplied by the maximum load of each household (typically 16A * 230V on three phases or approximately 11 kW) and multiplied by the concurrency factor α (typically about 0.4).

The choice of these design rules is entirely in the DSO's discretion. However, the DSO is regulated by the regulatory framework of SAIDI/SAIFI[11] which penalizes the DSO financially in case of power failures. The DSO therefore performs a risk-benefit analysis as part of the grid investment planning, weighing the risk of bad investment due to overallocation of capacity against the risk of customer dissatisfaction and regulatory punishment.

It must be noted that this requirement is different from the DSO's internal grid planning process which motivates the decisions on where the grid needs to be extended or reinforced. The latter is usually more complex and based on detailed load predictions. The former represents a capacity promise to the end consumers, which the grid planning process aims to fulfil in the most resource efficient way.

In a scenario where a significant part of the installed load becomes flexible, the above approach will show a number of shortcomings. Firstly, flexible units which are part of an aggregator's portfolio will not necessarily exhibit the same coincidence factor as uncontrollable load. If for example an entire portfolio of electric vehicles is contracted by an aggregator to provide regulating power to the TSO, the coincidence factor could reach very high values close to 1 at times of high regulating power demand.
Secondly, flexible units in the DSOs network could be contracted by a DSO (through an aggregator) in order to alleviate capacity problems, e.g. as part of a congestion management service or a voltage control service. This would potentially provide another degree of freedom to the DSO in choosing the best means to follow the regulatory capacity obligation - but only if the capacity formula recognized DSO flexibility services as an alternative to grid reinforcement.

For these reasons, it will be beneficial to separate the capacity obligations for flexible loads from those for non-flexible loads, taking into account (a) that flexible loads, if operated under an aggregator, may exhibit a significantly higher concurrency factor than non-flexible loads, and that (b) flexible loads may be contracted as a service to mitigate problems in the grid, including those related to increased concurrency at certain times.

There are many ways in which such a differentiated capacity obligation could be defined. Developing an exact definition falls outside the scope of the DREM project and would be a task for a regulatory body; however, the general concept is proposed as follows:

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[11] SAIDI: System Average Interruption Duration Index
SAIFI: System Average Interruption Frequency Index

$$Cap_{min} = \alpha \cdot 11kW \cdot n + \beta \sum P_{flex,installed} - \sum P_{flex,services}$$

Here, the minimum capacity that the DSO must make available depends on three elements:

1. The installed non-flexible load from the households, i.e. the total number of households *n* multiplied by the maximum load of each household (11 kW, the maximum load of an average Danish household) and multiplied by the coincidence factor α (traditionally 0.4)
2. The potential load from the installed flexibility and a given concurrency factor β (to be defined by the regulatory agency).
3. The total contracted flexibility used for services, e.g. in order to avoid grid reinforcement

In such a setting, it would be the DSO's obligation to ensure that activations of flexible units within the capacity limit can be realized under normal operating conditions. If an aggregator contracts and activates flexible units beyond the capacity limit, the DSO would not need to guarantee that the flexibility can be activated.

In an operational setting, practical values for the "flexibility coincidence" β would have to be determined and refined over time, and may have to be continuously adapted as flexible units and flexibility services proliferate. It does not appear useful to operate with a single value for β covering all of Denmark, or even entire supply areas.

R-3 Aggregators must be attached to a BRP

In the Clean Energy Package by the European Commission, it is stated that any AGR must be associated to a BRP, such that the flexibility trade cannot create system imbalances. This is adopted as a solution since it neatly solves conflict case 6. Provisions for submetering are required accordingly.

Scenario 6.1, which regards a rather general case of dynamic growth in consumption, is addressed through R-3. The DSO may activate flexibility from an aggregator, leading to imbalances to the associated BRP, but it is the responsibility of the aggregator and BRP to resolve these problems between themselves.

R-4 DSOs are not required to reimburse for trade limitations

It has been agreed during the workshops that the DSO should in general not reimburse agents for limitations of trade as this creates opportunities for gaming the system. Without this rule, there would be an incentive for aggregators to deliberately control their portfolio in such a way that a problem in the DSO’s grid is created. The DSO would then subsequently have to pay the aggregator to solve this problem. This constitutes a non-constructive market principle which has no value for society.

R-5 DSOs are not responsible for redispatch impact

Likewise, it was agreed that the DSO should not be responsible for any re-dispatch obligations arising due to flexibility limitations. Re-dispatch occurs when a flexibility asset is activated and (in principle) produces unexpected imbalance to a third party (another BRP). The re-dispatch obligation should be embedded in the flexibility offer provided by the aggregator in question.

6.2 Market framework

M-1 Use of flexibility markets for DSO services

It is desirable for the DSO to acquire reserves such that they can postpone or substitute grid reinforcement investments (see R-2). Thus, the acquisition of flexibility services is expected to be a reserve which the DSO can activate when needed (or schedule in advance). This topic has been addressed in the iPower and EcoGrid 2.0 projects, where a Flexibility Clearing House (FLECH) is used to match DSO needs in a given area. This work assumes such a market exists and adds that such a market must anonymize the aggregator towards the DSO as well as define the services with respect to an area only identified by a list of installation numbers.

Regulatory issues have to be considered. There are several possible models for the regulation of the remunerated utilization of flexibility assets, and the financial consequences have to be closely analysed in order not to create negative incentives for the DSO.

M-2 Redefinition of services to include rebound

Ancillary services should be redefined so they include the rebound of a response. Furthermore, the rebound is also subject to respecting the capacity limit imposed by the DSO. This concept has already been proposed in literature, see the work by O'Connel et al [1]. In this work demand response services are composed of an activation part and rebound part, with magnitude and duration for both parts. In order to verify services delivered by an AGR, it is important that the verification is done on basis of the metering/measurements of the AGR's portfolio, and not upon measurements done at substation level. This avoids the AGR being blamed for a rebound/peak not associated to its own portfolio control. This solution addresses directly conflict case 3.

6.3 Communication/operational framework

C-1 Establishing a dynamic information broker for allowing the DSO to communicate limits to BRP/AGR

One of the conclusions from the workshops was that the DSOs were not interested in interfering or validating market transactions between AGR/BRPs and the wholesale market (as it is done in the USEF setup). Thus, a solution was formulated where the DSO could communicate relevant grid constraints to the AGR controlling flexibility units under a given metering point. This should ideally occur before market closure, such that the AGR can submit its regular bids while taking into consideration the constraints relevant to parts of their portfolio. This can be done as part of the daily operation of the DSO networks. Since the limitations are pushed out to the AGR, the same system can be used for communicating sudden limitations due to general alert situations, as well as communicating start, stop, or hold signals to the units in case of DSO-alert or emergency situations.

This communication is envisioned to occur through a trade permission system (TPS), which contains two new elements: a dynamic information broker and static information regarding the available flexibility units. R-1 proposes that the static information should be kept in Energinet's DataHub, and the dynamic information broker could either be a module running on a FLECH-like flexibility market. It is important to note that if the relation between AGR and DSO are to be anonymous, a system such as the suggested communication broker is necessary.

Finally, when the DSO communicates a limitation for assets connected to specific metering points, it must choose whether the limitation is based upon the power rating of the unit, on a load forecast, or similar provisions of a limitation/curtailment baseline. This introduces a question of fairness: If more than one AGR operates on a network with problems, which units are to be curtailed the most? The biggest in terms of units? The biggest in term of absolute load? We therefore define that a "fairness filter" must exist in the TPS such that limitations are fair. This fairness filter must be part of the dynamic information broker, since one of the constraints of the design is anonymity between DSO and aggregators. This software program is depicted in Chapter 7, yet the design of the filter itself is an open research question that lies outside the scope of the DREM project.

This solution (in conjunction with R-1, R-2, M-1, and C-2) addresses conflict cases 2, 4, 5, 7, and 8, in that it avoids a conflict as long as the AGR/BRP respects the imposed limitation of the DSO when bidding into other markets.

Figure 7 shows an overview of how the Trade Permission System would fit into the proposed setup. The sequence of events for this solution are further explained in Chapter 7.

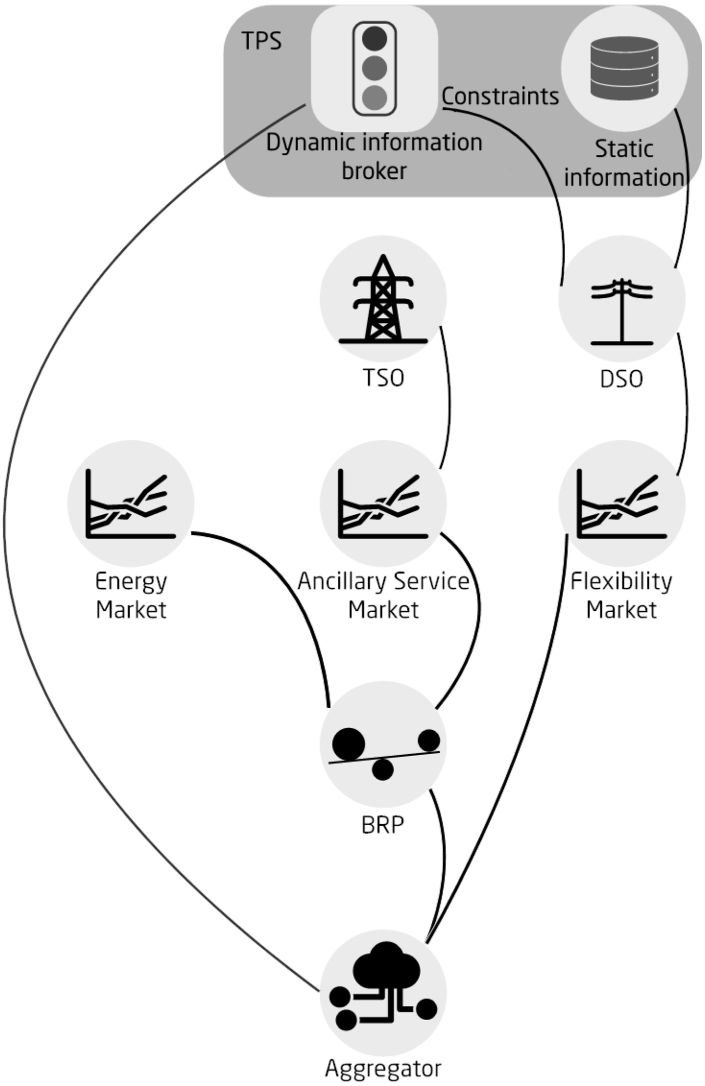

Figure 7 Architectural overview of the Trade Permission System with respect to the market setup.

C-2 AGR/BRPs submit operational schedules

As an option for AGR and BRPs, they can submit their daily operational schedules through the dynamic information module, such that the DSO can better identify potential issues and make more accurate limitations.

7. Communication Sequences

1.1 Market trade sequence

The Yellow and the Orange solution regimes are considered as market solutions. At present, where very few flexibility assets are represented at each feeder that is available for the DSO, an activation contract may be established on basis of bilateral negotiation. Still, prices are formed on basis of the interests under free market conditions. But as the market liquidity increases, it will make sense to make use of the mechanisms such as the Flexibility Clearing House (FLECH).

In Figure 8, a message sequence diagram shows how the DSO may acquire services (either Yellow or Orange regime) through the FLECH.

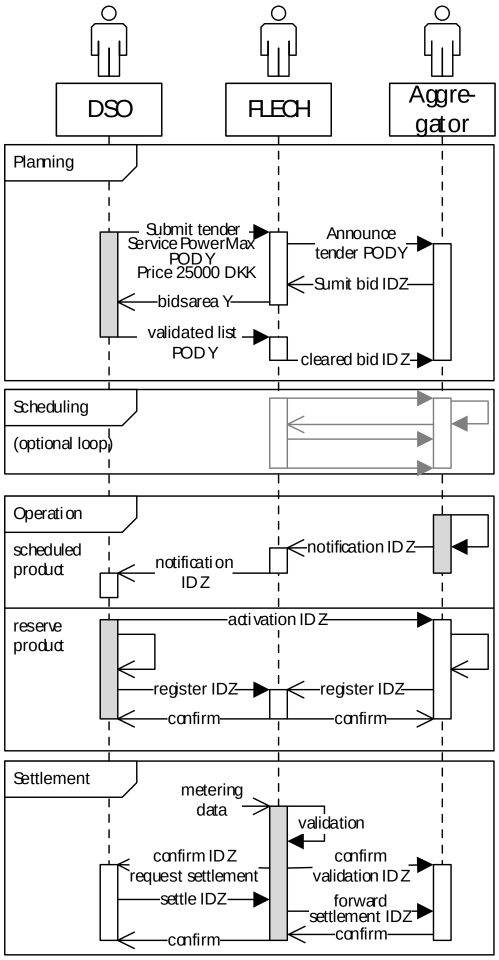

Figure 8 Message sequence diagram for flexibility trading on a market basis, originally developed under the iPower project, for more details see [2].

The specifics of how this market works are outside the scope of DREM, but readers can see [1] for further details.

7.1 DSO limitation sequence

Whenever situations arise where the DSO needs to communicate limitations in its grid, the capacity limitations are sent out through the dynamic information broker. Figure 9 shows how these limitations can be estimated and pushed out to the appropriate AGR. First, the AGR registers its units at the static part of the DataHub (as explained in R-1). The DSO uses this information to identify potential network issues. The DSO can check the dynamic information broker to see if any relevant metering point (flexibility unit) has an associated schedule. These schedules can be used to further refine the load forecast and identify potential issues. If the DSO finds that the load may exceed what he is obliged to provide as capacity, he can apply capacity limitations to the relevant metering points. These limitations are pushed out to the relevant AGR through the dynamic information broker, which must have a table associating metering points to their corresponding AGR. Thus, the DSO does not know which AGR controls the flexibility unit it limits. As described previously, the limitations may be sent through a fairness filter in order to ensure that the limitations are fair to all AGR.

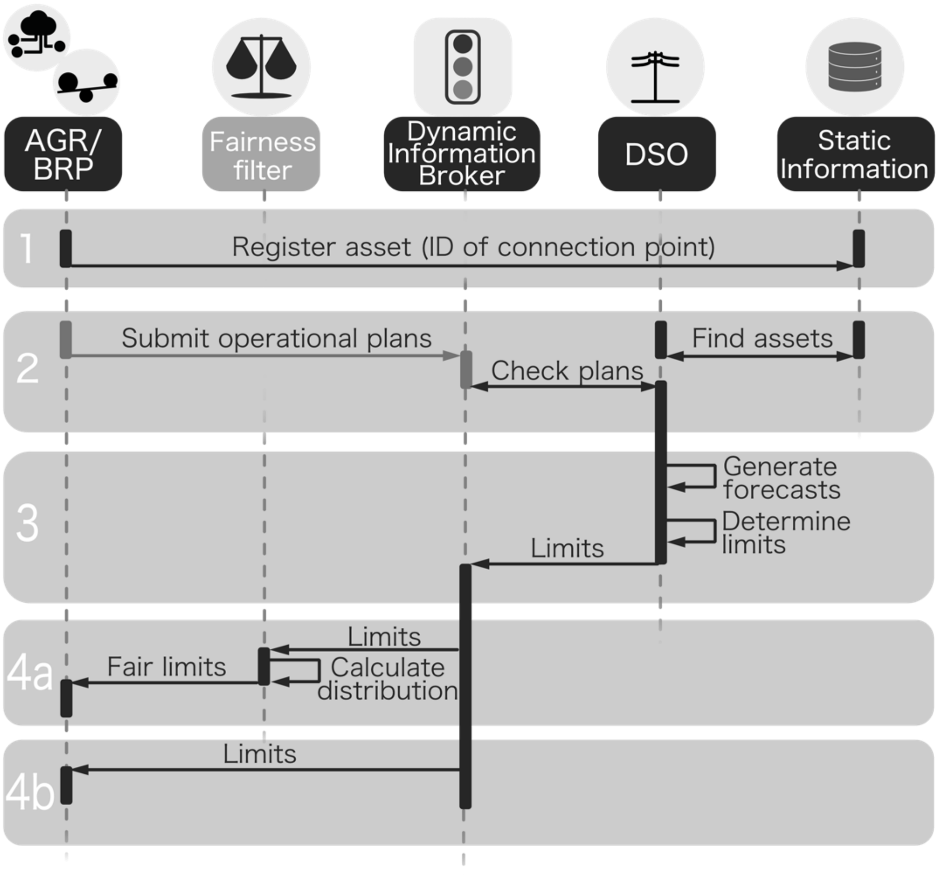

Figure 9 Message Sequence Diagram depicting the order of signals and messages to be exchanged in order to communicate the DSO limitations or orders.

The same system can be used in cases where the limitations occur due to sudden faults. These sudden limitations are pushed through the same system. Thus, the information broker can also be used for unforeseen capacity issues due to faults in the system (see Figure 10). In such a case, the information model and the DSO actions are different, since the emergency signal would either be a "stop all flexible units", "start all flexible units", or "maintain current load as it is". These signals are sent in order to avoid brownouts.

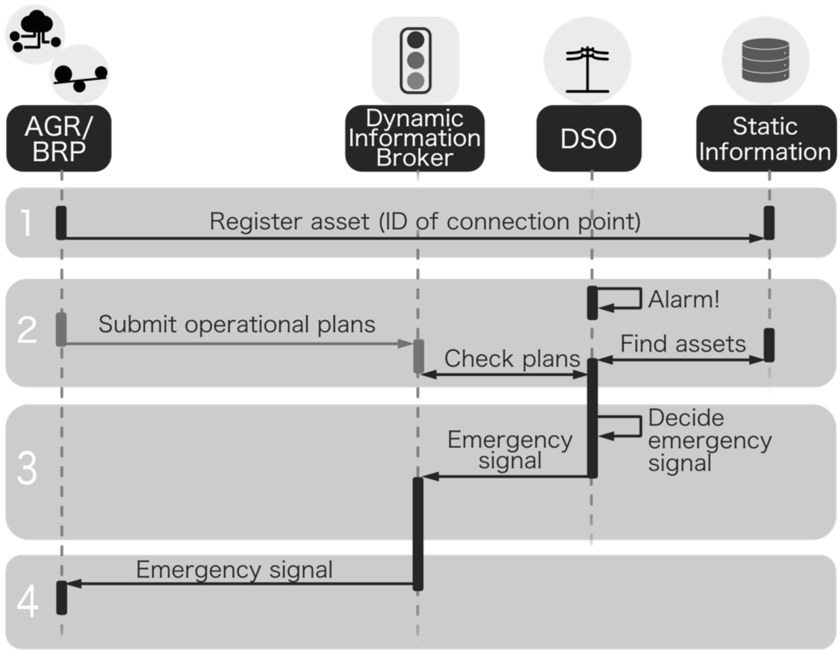

Figure 10 Message sequence diagram in case of unforeseen events

8. References

[1] O'Connell, N., Pinson, P., Madsen, H., & O'Malley, M. (2015). Economic Dispatch of Demand Response Balancing through Asymmetric Block Offers. *IEEE Transactions on Power Systems*, *31*(4), 2999-3007. DOI: 10.1109/TPWRS.2015.2475175

[2] Heussen, K., Bondy, D. E. M., Hu, J., Gehrke, O., & Hansen, L. H. (2013). A Clearinghouse Concept for Distribution-Level Flexibility Services. In *Proceedings of IEEE Innovative Grid Technologies Europe 2013* IEEE. DOI: 10.1109/ISGTEurope.2013.6695483