

Technical University of Denmark



## FLECH – Technical requirement specification

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*Publication date:*  
2013

*Document Version*  
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*  
Hansen, L. H., Sundström, O., Harbo, S., & Villefrance, R. (2013). FLECH – Technical requirement specification. iPower Consortium.

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STRATEGIC PLATFORM FOR INNOVATION AND  
RESEARCH IN INTELLIGENT POWER [IPOWER]

# FLECH – TECHNICAL REQUIREMENT SPECIFICATION

<i>Category</i>	<b>Deliverable</b>
<i>Identifier (task etc)</i>	<b>WP4.8</b>
<i>Status</i>	<b>Released for External Use</b>
<i>Version</i>	<b>Version 1</b>
<i>Access</i>	<b>Consortium Partners</b>
<i>Editors (name and affiliation)</i>	<b>Lars Henrik Hansen, DONG Energy Olle Sundström, IBM Silas Harbo, Dansk Energi Rasmus Villefrance, DTU Elektro</b>
<i>Date</i>	<b>09-12-2013</b>

**Funding:** Joint by partners and Danish Government (iPower platform has been granted support from SPIR – Strategic Platform for Innovation and Research).

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## 1 GENERAL NOTES

### 1.1 GENERAL NOTES

This document is based on two main sources:

- The work reported by iPower WP3.8 on development of a DSO-market on flexibility services (Nordentoft, et al., 2013). A condensed version can be found in (Zhang, et al., 2013). An analysis of selected services has been presented in (Heussen, Hu, Bondy, Gehrke, & Hansen, 2013).
- The work of a task force, who participated in the preparation of the FLECH demonstration event at Energiens Topmøde (June 6th, 2013). This work has been maintained in an internal power point presentation and a corresponding report on implementation aspects (Schmidt & Sundström, 2013).

A general introduction to FLECH is presented as a power point presentation in (Hansen, 2013).

This report also serves as background for the FLECH - Market Specification Analysis of FLECH report (Harbo, Hansen, & Heussen, FLECH - Market Specification Analysis, 2013) and the FLECH - Market Regulation Specifications report (Harbo, Hansen, & Birke, FLECH - Market Regulation Specifications, 2013).

Furthermore, this report together with (Harbo, Hansen, & Heussen, FLECH - Market Specification Analysis, 2013) and (Harbo, Hansen, & Birke, FLECH - Market Regulation Specifications, 2013) serve as basis for a subsequent report on the IT Requirement Specification.

### 1.2 PURPOSE

FLECH (FLExibility ClearingHouse) is a market oriented platform developed in iPower for trading ancillary services between DSO and aggregated DERs. The purpose of this report is to establish and document the technical requirement specification for the necessary functionality concerning DSO ancillary services to be implemented in a prototype FLECH implementation.

This document is also a container for the discussion and agreements made between the partners, so it is possible later in the process to remember what decisions were made, and what the thoughts behind those decisions were.

### 1.3 SCOPE AND UTILISATION

It is important to realize that the FLECH concept as such will continue to evolve also after the finalization of this document. Thus, the scope of the document is limited to the above mentioned implementation only. The document cannot be used to determine anything about decisions and rationales which falls beyond its scope.

Since the Aggregator has the key function in aggregating DER flexibility, this report on requirement specification will assume the Aggregator as main actor concerning provision of DSO ancillary services. This assumption is not a limitation – since the Aggregator still can be associated with the market through a BRP or the Aggregator itself can obtain BRP status – it just simplifies the description.

Furthermore, due to the *Engros model* (M. N. Hansen) combined with the demand of low transaction costs and the iPower Mission (Østergaard, et al., 2012), the market solution is preferred to regulatory demands.

The technical requirements of FLECH will serve as:

- An outlined description of FLECH market dynamics concerning the first DSO service.
- As teaser for further analysis – both technical and economical.
- As a guideline for the IT platform implementation.
- As background information, when defining demonstration scenarios.

## 2 INTRODUCTION

Future utilization of the flexibility embedded in DERs for distribution systems can be through regulatory demands or a market driven approach. In this work the market driven approach is pursued.

### 2.1 MAIN STAKEHOLDERS

The main stakeholders in the Nordic electricity markets are as follows:

- **NordPool:** NordPool is the operator of the energy exchange markets Elspot (Day-ahead market) and Elbas (Intra day market). The NordPool area is divided into a number of trading zones.
- **TSO:** The TSO (Transmission System Operator) is a monopoly, who is concerned with power system balancing in a particular subset of trading zones. The TSO has no generation assets. Therefore ancillary services for balancing etc. are acquired through dedicated markets (primary reserve, secondary reserve, manual regulating reserve and manual regulating power). The TSO would appreciate more competition on the ancillary service markets.
- **BRP:** The BRP (Balance Responsible Party) is a market actor, who is either concerned with generation or consumption regarding energy deliveries in the trading zones administrated by NordPool. The BRP has a function similar to a wholesaler. Today provision of TSO ancillary services is mainly done by generation BRP's. Consumption BRP's could use e.g. flexible consumption to avoid or minimize internal imbalances (according to their energy delivery obligations) or use DER flexibility to get new business in both TSO ancillary service markets and future DSO ancillary service markets. However, the BRP typically does not possess the technical skills, it requires to aggregate DER flexibility. Under the current market regulation, only a BRP can trade on the energy markets and serve the TSO ancillary service markets.
- **Retailer:** On the consumption side yet another actor exist. It is the Retailer, who today does the contracting with the end consumers. On behalf of his customers (the end users), the Retailer orders energy from his associated BRP, which in turn buys this energy on the energy exchange market. The Retailer is not listed as a stakeholder. As in the case of the BRP, the Retailer typically does not possess the technical skills, it requires to aggregate DER flexibility. Furthermore, since many Retailers have a flat rate contractual agreement with a BRP, they have no incentive to minimize internal imbalances. On the production side, Retailer and BRP are assumed to be the same entity in this document.
- **Consumer:** The typical end customer is the Consumer. The Consumer is not flexible in consumption. He most likely has a flat rate contract with a Retailer. To him electricity is a commodity.
- **DSO:** The DSO (Distribution System Operator) is a monopoly, whose main target is highest possible supply security. The DSO fulfills this target through grid planning and grid reinforcements. As an alternative to costly grid reinforcement, the DSO could request and utilize DSO ancillary services. However, DSO ancillary services are not yet available.
- **Aggregator:** The Aggregator is a new actor or function, whose mission is to aggregate DER flexibility and provide the aggregated flexibility to the BRP. Due to the current market regulation the Aggregator is dependent on cooperation with a BRP, since only BRP's have market access. In this setup, the Aggregator fulfills an aggregation function for the BRP. Assuming the Aggregator has obtained BRP



properties, the Aggregator could provide ancillary services to both the TSO and the DSO's independently of a BRP.

- **DER owner:** A new type of end customer is the DER owner, who possesses a flexible DER. The flexible DER serves a primary process, which is most likely the main reason, why the DER owner purchased it. A consumption DER will in average be a conventional energy consumer. Due to the flexibility of the DER, the DER now also becomes a power service provider. Thus, to the degree that doesn't disturb the primary process, the DER owner would be willing to offer/sell this flexibility to an Aggregator.

Further detail on these stakeholders can be found in e.g. (Nordentoft, et al., 2013) and (Bondy, Hansen, Heussen, & Tarnowski, 2013).

The stakeholders in the current Nordic market layout and their relations are depicted in Figure 1. The consumer can pick their favorite Retailer, as supplier of electrical energy. The Retailer in turn has a cooperation with a BRP, who is acquiring the energy on the energy exchange markets of NordPool. If the BRP has any flexibility in his portfolio, this could be offered to the ancillary services markets of the TSO. Figure 1 only depicts the consumption side. An equivalent drawing for the generation side, could be made showing a BRP with bids and contract possibilities as in Figure 1. However below the BRP direct links to the production facilities is the case, since BRP and Retailer are merged into a *production BRP*.

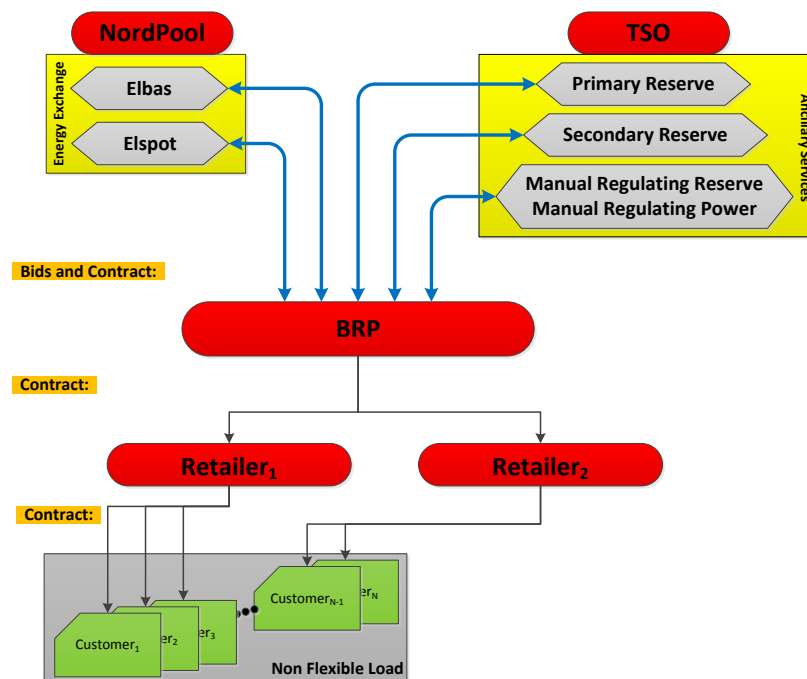


Figure 1. Stakeholders in the current Nordic market layout with focus on the consumption side.

How to incorporate the new flexible DERs into the market layout is still an open question. One possible design is shown in Figure 2. The existing layout is maintained and the new stakeholders – DSO, Aggregator and owners of flexible DERs – are integrated in a parallel structure. The DSOs can acquire services through the new trading platform – FLECH – and the Aggregator can offer his flexible portfolio to FLECH or to the BRP. As the figure implicates Aggregators can corporate in nested structures. Even though the suggested design in Figure 2 is relatively simple and intuitive, the relations between BRP and Aggregator might be complex. The Aggregator can either be:

1. An operator of the flexibility present in a BRPs or a Retailers portfolio,
2. Equivalent to a Retailer – just of flexible loads,
3. An BRP with Aggregator skills.
4. An independent stakeholder/market actor, who offers its flexible portfolio to FLECH and BRPs – or maybe in a future context also the ancillary markets.

The first three designs more or less fit within the current regulations, which state that any electrical outlet must be associated with a BRP, whereas the fourth design would require changes in the regulations. The four designs imply different business cases and it is beyond the purpose of this work to analyze and select the best design seen from a socio economic point of view. The common factor in the four designs is, that the Aggregator is the key to aggregation of the flexible DERs. Further elaboration in these issues can be found in (Bondy, Hansen, Heussen, & Tarnowski, 2013). However, in the this work, the description will be centered around the Aggregator, as this stakeholder functionality is essential in mobilizing the flexible DERs.

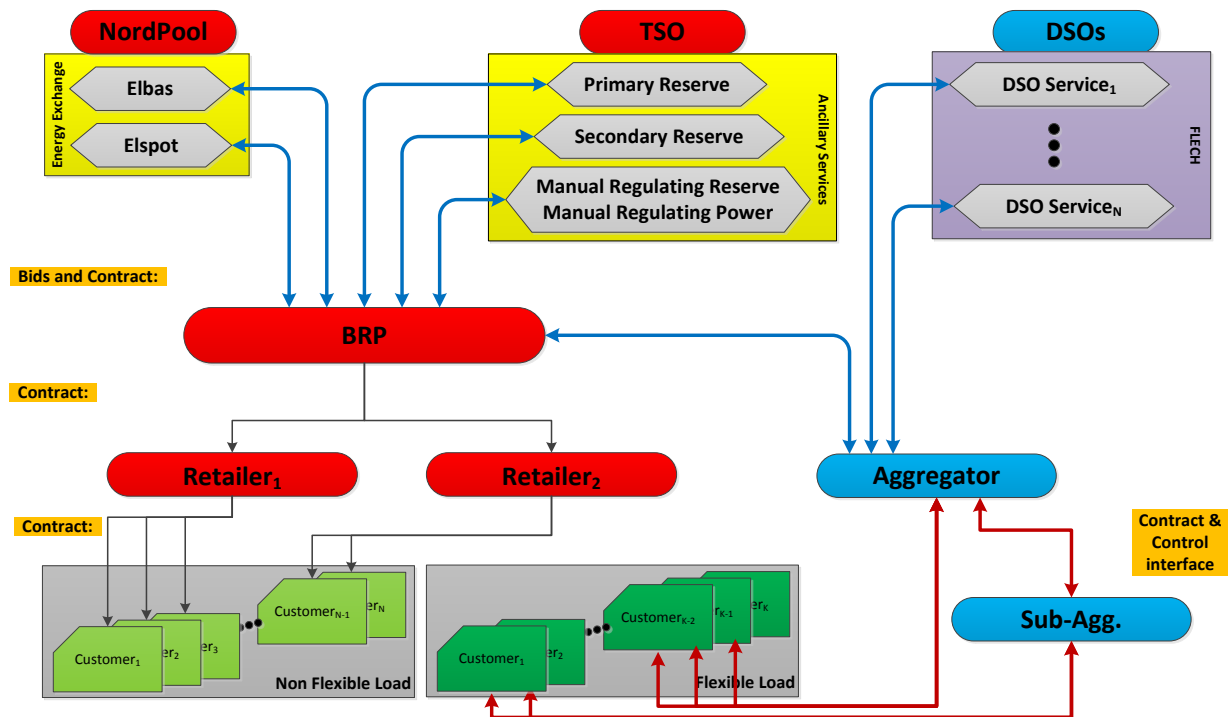


Figure 2. Suggestion on how to integrate the new stakeholders – DSO, Aggregator and owners of flexible DERs through the new FLECH market platform – in the current Nordic electricity market layout (with focus on the consumption side).

Figure 2 suggests to integrate the flexibility provided by flexible DERs through an Aggregator, who then organizes and offers the aggregated flexibility to the BRP(s) and to the DSOs through the new market platform, FLECH. With the new DSO service market, new challenges can arise. The type and implications of some of these challenges have been discussed in (Jóhannsson, et al., 2013) and (Heussen, Hu, Bondy, Gehrke, & Hansen, 2013). A conclusion of (Jóhannsson, et al., 2013) is that DSO services should have priority to the TSO services. One way to address this could be to establish some kind of coordination between FLECH, the Ancillary service markets through dedicated communication. A more simple approach is to place the gate closure of DSO services before the gate closure of TSO services and the energy exchange markets. This strategy will be pursued in this work.

## 2.2 THE MARKET DRIVEN APPROACH

As stated above, the utilization of the flexibility embedded in DERs can be through regulatory demands (grid codes) or a market driven approach. Since an approach based on regulatory demands does not guarantee an economical optimal utilization of DER flexibility, the iPower project has settled for the market driven approach as defined in the iPower Mission (Østergaard, et al., 2012). The mission of iPower is aiming to develop and utilize flexible consumption and production solutions which:

1. enable increased integration of fluctuating renewable energy sources.
2. offer new possibilities for optimal handling of distribution grids.
3. are based on market solutions ensuring an efficient energy system.
4. incorporating user behavior and enhance end-users' awareness shaping the solutions.
5. enable new business opportunities for the energy industry and commercial energy users.

The market driven approach is defined by item 3. Furthermore, as defined by item 2 the focus of the iPower project is mainly concerned with the DSO area and less concerned with TSO issues. Combining item 2 and item 3 leads to market based solutions for handling of distribution grids.

## 2.3 DSO DRIVERS

Before designing new possibilities for optimal handling of distribution grids, it is important to analyze and understand the drivers for DSO business and potential market integration. The main DSO objectives are:

- Highest possible supply security @ lowest cost.
- No gain of profit, since the DSO is a monopoly.

A high level analysis of main future DSO challenges identifies:

- Increased power consumption due to electrification.
  - Examples of new loads in the grid are: Heat pumps, EVs, battery charging stations, ...
  - The increased power consumption can lead to bottleneck scenarios as illustrated in Figure 3.
  - Due to the incorporated flexibility in e.g. heat pumps and EVs, their consumption can be influenced given the right incentives. A large volume of flexibility combined with incentives could even cause new challenges – e.g. if the majority of the flexible load is allocated in the cheapest day-ahead hour, this could cause new peak-load scenarios in the distribution grid.
- Increased share of distributed generation.
  - Examples of new sources in the grid are: PV, micro wind,  $\mu$ CHP, ...
  - Distribution grid design is traditionally based on one-directional power flow – i.e. consumption scenario with flow from the high voltage grid towards the low voltage grid. Distributed

generation will both challenge the safety design of the current distribution grid and it will influence voltage levels and power quality.

- Due to the incorporated flexibility in distributed generation units, their production capabilities (both power and reactive power) can be influenced given the right incentives.

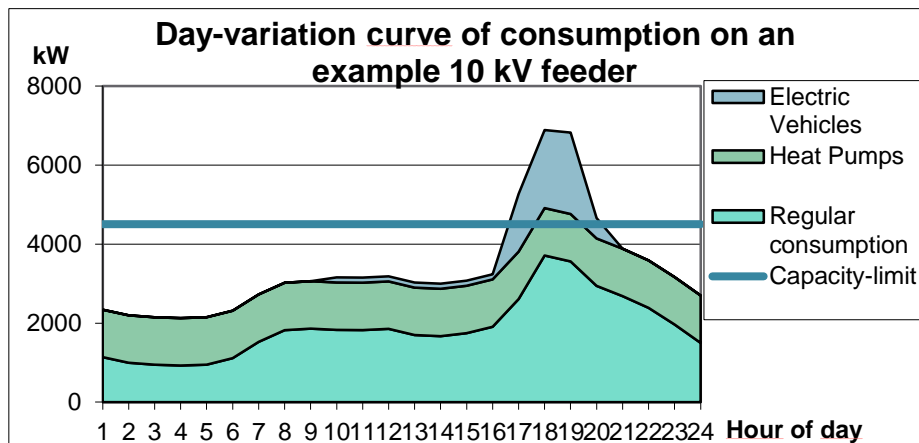


Figure 3. Example of load profiles from new consumption units resulting in bottleneck scenarios.

These challenges can be handled through a number of optional solutions:

- The conventional solution – Grid reinforcement. The DSO performs a continuous monitoring of grid load conditions versus grid capacities. If an area of the distribution grid is forecasted and identified as being insufficient, a grid reinforcement of this particularly grid area will be scheduled.
- Introduction of tariffs. A simple example of a tariff scenario is a three level daily fixed profile with the highest tariff level during the normal peak hours and lowest tariff level during normal low consumption periods. In a very inexpensive way this will motivate flexible consumption to move from the expensive tariff level to the less expensive level. Tariffs can however not remove the risk of bottlenecks. If the energy spot price happens to be low during a high tariff level, a lot of consumption would be allocated to this period even though the tariff is high. Increased power consumption due to electrification will undermine this option. Thus tariff can be regarded as a "temporary" alternative.
- The smart grid solution. This solution assumes the presence of flexible DERs. As previously discussed the flexibility of DERs can be utilized through:
  - Regulatory demands (grid codes).
  - Market driven approaches.

In any case – regulatory or market – an essential precondition for this solution is the DSO “smart grid” capabilities. The DSO must be able to monitor the state of his distribution grid on a short-term basis. This capability depends on:

- Installed type and density of measurement equipment in the distribution.
- Capabilities of the DSO grid control center.

Many DSO are running their grid planning based on yearly meter readings. This DSO category will have to invest in better capabilities, if they want to apply smart grid solutions. DONG Energy Distribution is an example of a modern DSO, who is able to monitor the load in the 10 kV grid every 10 minutes.

iPower researches the market driven approach. In (Nordentoft, et al., 2013) seven potential DSO services have been identified and described. Based on the discussion above and a DSO capability point of view, the most simple between these services should be given highest priority and the most complicated should be given lowest priority.

The most important thing to remember is the goal for the DSO:

- To secure the network without expensive grid modifications.

So why does the DSO need to build new grid? The main reason appears, when the capacity of the network is stretch beyond the limit in terms of either power flow or minimum voltage level in either normal or reserve situation.

Thus does the flexibility service need to counteract this in the most effective way? The DSO forecast their system usage based on historic data and identify their problems through this historic analyses. Therefore, an applicable flexibility service must be targeted to work with this kind of analyses.

The market solution and the flexibility services must target:

- Measurability; based on a historic baseline for a specific customer or a sum of aggregated customers, the DSO can request a reduction, which is based on the historic calculations and affect the same calculations. In this way there will be transparency in the value for the DSO.
- Documentability; it must be possible to document a service based on a common agreed calculation of a baseline. In this way, the DSO has a very clear measure whether the Aggregator has provided the service, and the Aggregator has a very clear target of what to deliver.
- Operationalibility; the services should be applicable to the DSO (and Aggregators) in a very effective way.
- Responsibility; the services must support a precise and easy way to implement responsibility delegation, where the DSO has the responsibility of the grid and the grid problems, while the Aggregators have a clear responsibility to aggregate and offer the services based on their portfolio.

## 2.4 BASELINE METHOD

The service provided to the DSO has to be quantifiable and measurable – otherwise, the Aggregator is unable to prove that a contracted service has been provided. One approach is through introduction of a baseline concept. A definition of a baseline can be expressed as:

- A baseline is the consumption (or production) trajectory a DER will exhibit, if it is left running without any external control interference.

The challenge is now, how can knowledge about the baseline be established. Two baseline methods are reported in (Harbo, Biegel, & Meibom, Contracting flexibility services, 2012). An alternative approach to the baseline methods is presented in (Biegel, Westenholz, Hansen, Stoustrup, Andersen, & Harbo, 2013). Yet

another baseline method is briefly presented in (Harbo, Hansen, & Heussen, FLECH - Market Specification Analysis, 2013). The latter is applied further on in this document, and it will hereafter be referred to as the **contractual baseline**. The basic idea is as follows:

- When FLECH clears the market, the winning Aggregators are identified.
- For each Aggregator portfolio, FLECH requests historical data from the DSO and establishes a portfolio baseline. These portfolio baselines will become a part of the contracting process with the winning Aggregators (i.e. the contractual baseline).
- The baseline can be seen as a type of forecast, which estimates the expected performance of the portfolio, when the portfolio is operating in free flow without any Aggregator interference i.e. the Aggregator is not using the portfolio for any services.
- If an Aggregator is activated, the Aggregator can establish a portfolio schedule based on the baseline less the offered volume. This is how the provision eventually will be checked and verified during settlement.

The contractual baseline is based on historical data from any given DER in a portfolio. FLECH is responsible for a robust, operational and transparent definition of the contractual baseline. Furthermore FLECH is responsible for dissemination of how to calculate the contractual baseline.

The described procedure with the contractual baseline presents a couple of the advantages:

1. The contractual baseline is put into the contract between FLECH and Aggregator. Hence the provided service can be measured and verified after the service has been provided – i.e. the Aggregator is accountable relative to the baseline.
2. The contractual baseline can be calculated up front by any Aggregator before bids are submitted. Thus the Aggregator has no reason to reject the baseline put in the contract.

### 3 FLECH MARKET PLATFORM DESIGN

This section describes the environment in which the FLECH implementation interacts. The section does not as such describe how the FLECH implementation works, but provides the reader with an overview of the surrounding environment.

#### 3.1 GENERAL OVERVIEW

The traditional decomposition of the energy control process in electrical power systems has four main tasks: planning, scheduling, operation and settlement, as depicted in Figure 4. This is a proven strategy. Therefore, it will also be used as fundamental strategy in the development of the FLECH functionality.

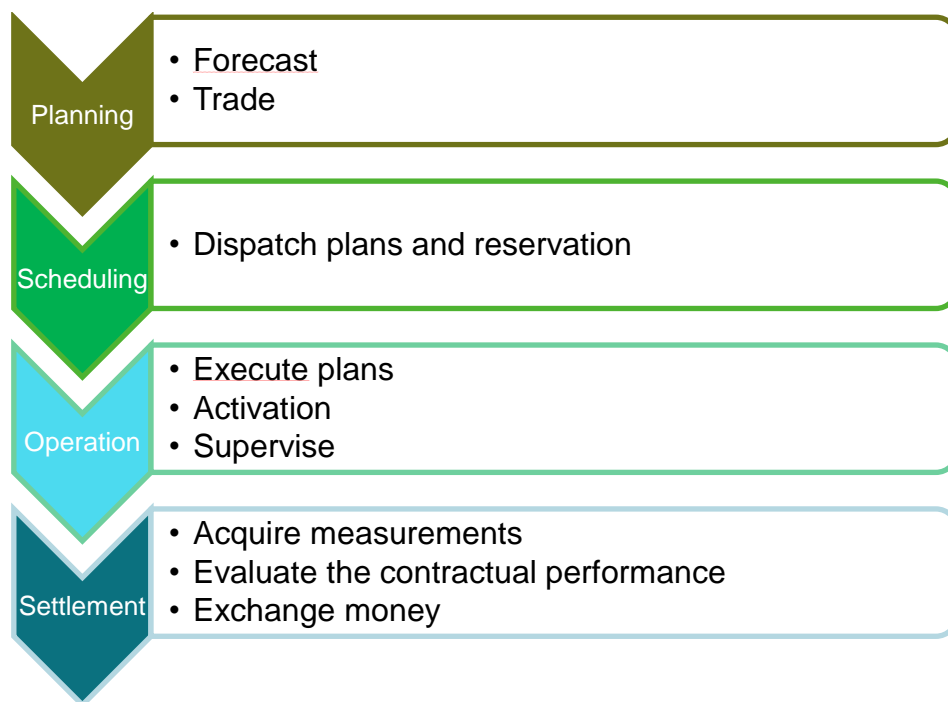


Figure 4. Traditional decomposition of the energy control process in electrical power systems.

An attempt to apply the traditional decomposition of the energy control process in a DSO context is sketched in Figure 5, where the individual tasks have been associated with both DSO functions as well as Aggregator functions. In the planning phase:

- The DSO is using all available information to derive his needs for DSO services. Based on the forecasted needs, the DSO requests services.
- Simultaneously, the Aggregator forecasts the flexibility of his portfolio combined with his contractual obligations in various markets. Surplus flexibility can be offered as DSO services.

In the scheduling phase:

- The DSO evaluates the offered flexibility, and if feasible issues contracts on this flexibility and updates his planning tools with the scheduled services.
- The Aggregator takes his winning bids and converts them into operational schedules in his planning tool.

In the operational phase:

- The DSO evaluates the needs for flexibility and activates the contracted services if deemed necessary.
- The Aggregator awaits activation from the DSO. If activation is issued, the scheduled DSO service is executed.

Finally in the settlement phase:

- The DSO evaluates grid performance based on metered data. If the performance was satisfactory, payment can be issued to the contracted Aggregators. If not, the DSO can ask the contracted Aggregators to document their DSO service provision. Performance can be analyzed and settlement can be verified and finalized based on the contractual baseline.
- The Aggregator will evaluate his DSO service provision, i.e. check whether the involved DER portfolio has performed as scheduled e.g. according or relative to a baseline. The Aggregator will do settlement with the involved DER portfolio. If requested by the DSO, the Aggregator will send documentation of DSO service provision to the DSO.

The horizontal center block in Figure 5 is showing the functions, which are carried out by FLECH. The red feedback arrows (above the DSO and below the Aggregator) indicate that the process can be conducted for several DSO service, which most likely will stretch over different time horizons.

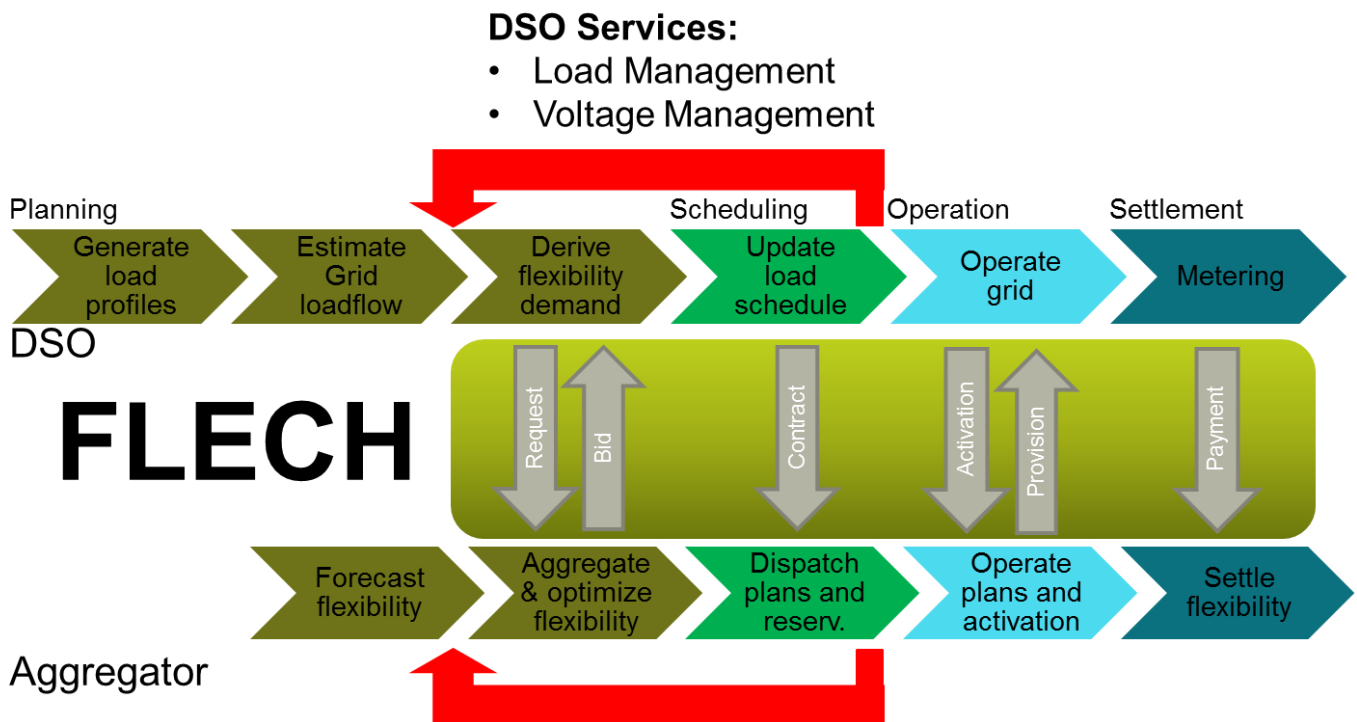


Figure 5. Overview on expected FLECH functionality demands.

### 3.2 SELECTION OF DSO SERVICE

As described above, the functionality of FLECH is to support and execute the trading process of the DSO services. Potential candidates of these services are listed in Table 1.



Table 1. Reported DSO services in (Nordentoft, et al., 2013).

Services for Load Management	Services for Voltage Management
<ul style="list-style-type: none"> <li>• PowerCut Planned</li> <li>• PowerCut Urgent</li> <li>• Power Reserve</li> <li>• PowerCap</li> <li>• PowerMax</li> </ul>	<ul style="list-style-type: none"> <li>• Voltage Support</li> <li>• VARSupport</li> </ul>

The reported DSO services in Table 1 cover quite a number of aspects, which indeed involves various skills at the DSO. Concerning these smart grid services the DSO is challenged on his:

- Measurement infrastructure (equipment, signals and sites),
- Level of grid automation, and
- DMS (Distribution Management System) capabilities (analysis, planning and operation tools).

Mapping these skills against the listed DSO services in Table 1 *PowerCut Planned* is conceived as the least demanding service. Therefore, *PowerCut Planned* is selected as the first DSO service to be targeted. For further analysis on *PowerCut Planned* refer to (Harbo, Hansen, & Heussen, FLECH - Market Specification Analysis, 2013).

An analysis and a case study of *PowerMax* is presented in (Heussen, Hu, Bondy, Gehrke, & Hansen, 2013).

### 3.3 THE FIRST DSO SERVICE – POWERCUT PLANNED

As described in (Nordentoft, et al., 2013), *PowerCut Planned* is used to handle the predictable peak loads for periodically daily capacity issues. This service does not put high demands on DSO smart grid capabilities. Whenever the DSO during the planning phase forecasts a bottleneck somewhere in the distribution grid, *PowerCut Planned* would be an interesting alternative to grid reinforcement. The trading of this service comes naturally in two steps:

1. A long-term reservation of capacity to ensure sufficient flexibility. Since this service is a direct alternative to grid reinforcement the lead time is rather long – probably between half year and up to two years
2. A short-term activation scheme. When time is close to the operational hour the DSO will know with higher certainty whether activation of the service is necessary or not. The lead-time will be from hours to day-ahead.

Due to this nature of the required service functionality, the trading process of *PowerCut Planned* is divided into:

- A Capacity Reserve market – where the DSO requested flexibility is reserved, and
- An activation reserve market – where the activation part is handled.

In principle, it is relatively easy for the DSO to prescribe/forecast the future. Therefore, the DSO can easily issue a Capacity Reserve market call of an arbitrary power size. However it should be noted, it is quite difficult for the Aggregator to commit a given power size as a DSO service. Since the DSO service is based on flexible DERs, which by nature to some degree are stochastic in performance, the Aggregator must be ready to take on some risks. The Aggregator can reduce the risk by two means:

1. Establish knowledge about the expected DER performance.
2. Increase the portfolio size (law of large numbers).

Item 1 will incorporate techniques like: baseline methods, weather forecasts, etc. The Aggregator risk will of course be reflected in both the *reservation price* and the *activation price*.

### 3.3.1 CAPACITY RESERVE MARKET

This subsection is concerned with the description of the process necessary to carry out a reservation of capacity in the case of the service *PowerCut Planned*. The description is kept in a general form, as this process could be used as process for some of the other services.

The suggestion for FLECH Capacity Reserve market in case of Service X (e.g. *PowerCut Planned*) is presented now. The forecasted DSO needs are converted to a service request, which follows the outline:

- A capacity is acquired in the FLECH Service X Reserve market.
- Gate closure has lead-time (before operation) of minimum 5-6 months (depending on the time it takes to reinforce the grid).
- DSO specifies parameters:
  - Service type: *PowerCut Planned*, ...
  - Period of Capacity Reservation: *start and duration*.
  - Expected daily Reserve Activation period: *start and duration*.
  - Volume: requested capacity.
  - Area: list of *PODs* (Point of delivery).
  - Optional parameters:
    - *Max Reservation Price*,
    - *Max Activation Price*.
    - *Expected number of activations*

The DSO has now framed the request through a set of basic parameters. This specification includes three optional parameters: Max Reservation Price, Max Activation Price and expected number of activations. The prices can be used to specify upper price limits – i.e. what will the DSO be willing to accept. If no bids comes below the upper limits, the DSO will simply grid reinforce. The expected number of activations, coming from the DSO planning procedures, is very useful to the Aggregator, when it calculates his reservation and activation prices. (Harbo, Hansen, & Heussen, FLECH - Market Specification Analysis, 2013) derives a deeper understanding of these parameters.

FLECH will broadcast the DSO request and the Aggregators will check the flexibility of their portfolio. If an Aggregator forecasts to have sufficient available flexibility – relative to the calculation of the contractual baseline defined by FLECH – he will issue a bid:

- Aggregator bids:
  - A *volume* (which can be a subset of the requested capacity).
  - List of *PODs* (which can be a subset of the requested area).
  - A *reservation price* (for the period involved)
  - An *activation price* (per kWh involved)
  - *Max. number of expected activations*.
- *After gate closure:*

- *FLECH action* :
  - FLECH performs the clearing, as *merit order (this also includes bidding of one Aggregator only)*.
  - If clearing says "go",
    - First version: FLECH requests historical data from the DSO.
    - Second version: FLECH requests historical data from the DATAHUB.
    - FLECH establishes the contractual baseline(s), which is used when FLECH closes the contract(s) with the winning Aggregator(s).
  - If "no go", FLECH clears this request.
  - FLECH sends the clearing result to the DSO.
- Finally, FLECH broadcast a service request result report.

FLECH will use merit order, when the clearing is performed. As defined in (Harbo, Hansen, & Birke, FLECH - Market Regulation Specifications, 2013) FLECH cannot edit bid volume sizes in order to make the bids meet the requested volume. However, FLECH is entitled to overrule the merit order principle in cases, were a subset of more expensive bids can fulfill the requested volume at a lower price compared to the merit order solution. Thus, as the result of a successful clearing process, FLECH will establish the merit order prices for the combined *reservation price* and *activation price* times *activation duration* times *expected number of activations*, and the winning Capacity Reserve Aggregators. The *activation price* will be used as *Max. activation price* in the Reserve Activation market.

After clearing, FLECH has been given two versions: a first version and a second version. In the beginning, FLECH will request data directly from the DSO. In a Danish context, FLECH will be able to get these data from the DataHub (alias version 2). More information on DataHub can be found at (Jacobsen, 2013).

Comments to FLECH Reserve market in case of Service X:

- Service X is to be perceived as a bottleneck service as e.g. *PowerCut Planned*.
- Service duration could be 1-2 years.
- FLECH must disseminate clear rules for calculation of the contractual baseline.
- The DSO will estimate number of activation. Combined with reservation price and activation price, the DSO can calculate the expected service cost.
- The Aggregator must bid both a reservation price and an activation price.
- FLECH will do the market clearing based on merit order.
- The DSO announces a penalty structure as a part of the call for reservation which is a permanent part of the deal.
- Parties must notify each other 6 months in advance if contract is to be terminated.

A first version of regulations for FLECH Reserve market is presented (Harbo, Hansen, & Birke, FLECH - Market Regulation Specifications, 2013).

A sequence diagram of the suggested trade process in the Capacity Reserve market is shown in Figure 6. The figure is showing the first version FLECH action, where the clearing is done by the DSO. Later, the clearing can be moved to FLECH.

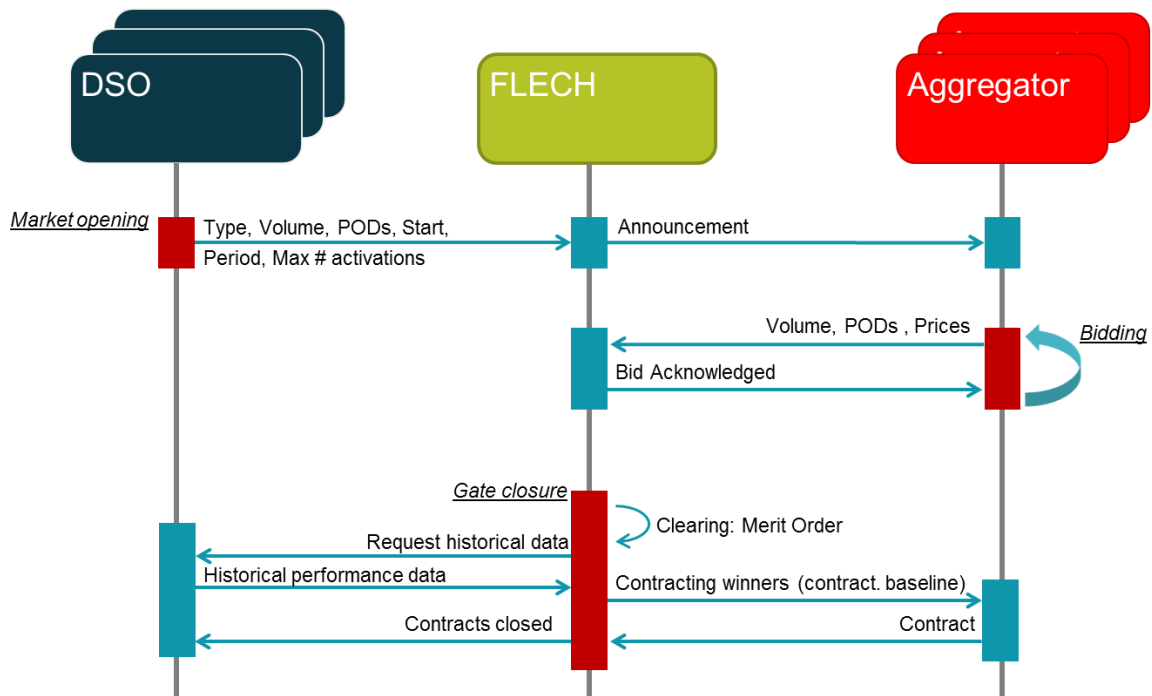


Figure 6. Overview sequence diagram of a successful clearing of the Capacity Reserve market (first version data source).

### 3.3.2 RESERVE ACTIVATION MARKET

The Capacity Reserve market takes care of contracting a reserve capacity. However, the DSO would only activate this reserve, if there is a real need. Thus, this subsection is concerned with the description of the process necessary to carry out an activation of capacity in the case of the service *PowerCut Planned*. Again, the description is kept in a general form, as this process could be used as process for some of the other services. Since it might be the case (especially due to the long lead time) that other Aggregators could have a portfolio with surplus flexibility in the requested area, the activation is shaped as a new market. In this way Aggregators get the opportunity to compete on provision of this service.

The suggestion for FLECH Reserve Activation market in case of Service X (e.g. *PowerCut Planned*) is presented now. Whenever a Reserve Activation market is issued by the DSO, this is to be seen as a potential activation request to the winning Aggregators of Capacity Reserve market service request. Thus, if no Aggregator can compete on the resulting activation price from Capacity Reserve market service request, the winning Aggregators will know they have to activate the scheduled reserve. If however, an Aggregator can provide the requested service at a lower activation price, he will win the activation and be activated for provision of the service.

The forecasted DSO needs are converted to a service activation request, which follows the outline:

- Activation of service from the Capacity Reserve market is acquired in the FLECH Service X Reserve Activation market.
- Gate closure is e.g. Day-ahead at 9am – before the day-ahead market and the TSO ancillary markets have gate closures in order to get access to highest free volume available.
- DSO specifies parameters:
  - *Service type: PowerCut Planned, ...*

- *Capacity needed (in kW)*
- *Max. activation price (per DKK/kWh)*
- *Volume: list of PODs (area).*
- *Activation period: start and duration of the coming activation.*

The DSO has now framed the activation request through a set of basic parameters. Except for the *Max. activation price* the other parameters are inherited from the original Capacity Reserve market request. The *Max. activation price* specifies the upper bid ceiling.

FLECH will broadcast the DSO activation request and the Aggregators will check the flexibility of their portfolio. If an Aggregator forecasts to have surplus flexibility – relative to the calculation of the contractual baseline defined by FLECH, which can compete with the specified *Max. activation price*, this Aggregator will issue a bid:

- **Aggregator bids:**
  - List of PODs (which can be a subset of the requested area).
  - *Volume*, (which can be a subset of the requested capacity – in kW)).
  - The *activation price* (DKK/kWh).
- **FLECH action :**
  - FLECH performs the clearing, as *merit order (this also includes bidding of one Aggregator only)*.
  - If clearing says "go",
    - First version: FLECH requests historical data from the DSO.
    - Second version: FLECH requests historical data from the DATAHUB.
    - FLECH establishes the contractual baseline(s), which is used when FLECH closes the contract(s) with the winning Aggregator(s).
  - If "no go", FLECH clears this request and the Aggregators having Capacity Reserve contract will then be notified concerning activation.
  - FLECH sends the clearing result to the DSO.
- Finally, FLECH broadcast a service request result report.

Again, FLECH will use merit order, when the clearing is performed. As defined in (Harbo, Hansen, & Birke, FLECH - Market Regulation Specifications, 2013) FLECH cannot edit bid volume sizes in order to make the bids meet the requested volume. However, FLECH is entitled to overrule the merit order principle in cases, were a subset of more expensive bids can fulfill the requested volume at a lower price compared to the merit order solution. Thus, as the result of a successful clearing process, FLECH will establish the merit order prices for: *activation price*, and the winning Reserve Activation Aggregators.

After clearing, FLECH has been given two versions: a first version and a second version. In the beginning, FLECH will request data directly from the DSO. In a Danish context, FLECH will be able to get these data from the DataHub (alias version 2). More information on DataHub can be found at (Jacobsen, 2013).

As stated in the FLECH action, if no FLECH cannot successfully clear the Reserve Activation market, the winning Aggregators from the corresponding Capacity Reserve market (the Capacity Reserve Aggregators) will be notified that they have to activate their scheduled reserve.

The timing of Reserve Activation market in relation to the other markets is essential as addressed in the comments to Figure 2 in section 2.1. To overcome the conflict identified in (Jóhannsson, et al., 2013), the gate closure of the Reserve Activation market is to place before the gate closure of the other markets – in particularly in a Danish context before the day-ahead market (Elsport) at 12:00 noon. The intraday market Elbas is a running

market with gate closure one hour before operation. Primary reserve has gate closure at 3:00 pm. Secondary reserve is a monthly market. Balance Power (Manual Reserve Capacity Reserve) has gate closure at 9:30 am. Finally, Regulating Power (Manual Regulating Power) is a running market with gate closure 45 minutes before operation. Hence, gate closure of the Reserve Activation market should be placed no later than 9:00 am.

Comments to FLECH Activation market in case of Service X:

- Service X Reserve Activation assumes prior execution of Service X Capacity Reserve.
- An Activation market is executed within the Service duration of the Service X Reserve – only if the DSO calls for it.
- An upper activation price, *Max. activation price*, is announced in order to get competition relative to the contracted Service X Capacity Reserve.
- The DSO may request a Reserve Activation volume, which is different from the volume specified in the Capacity Reserve market.
- Gate closure of the Reserve Activation market should be placed no later than 9:00 am.
- The Reserve Activation market triggers the service provision – based on start time and duration, the winning Aggregators knows when to provide the service.
- If the Reserve Activation market is not successfully cleared, the winning Aggregators of Capacity Reserve market will be notified concerning scheduled activation their DERs allocated for reserve.
- Using the Reserve Activation market as trigger, provision is only executed when needed.
- An Aggregator can fulfil the service relative to the contractual baseline commitment through any combination of his PODs specified in the contract.
- The provided service can be verified relative to the contractual baseline.
- In a future setup:
  - Activation duration could be split in blocks of e.g. hourly duration. If so, a activation market on every sub interval would have to be executed.
  - The DSO could also adapt the requested volume according to the newest estimate.
  - The DSO could adjust the requested volume (compared to reserve call)

A sequence diagram of the suggested trade process in the Reserve Activation market is shown in Figure 7.

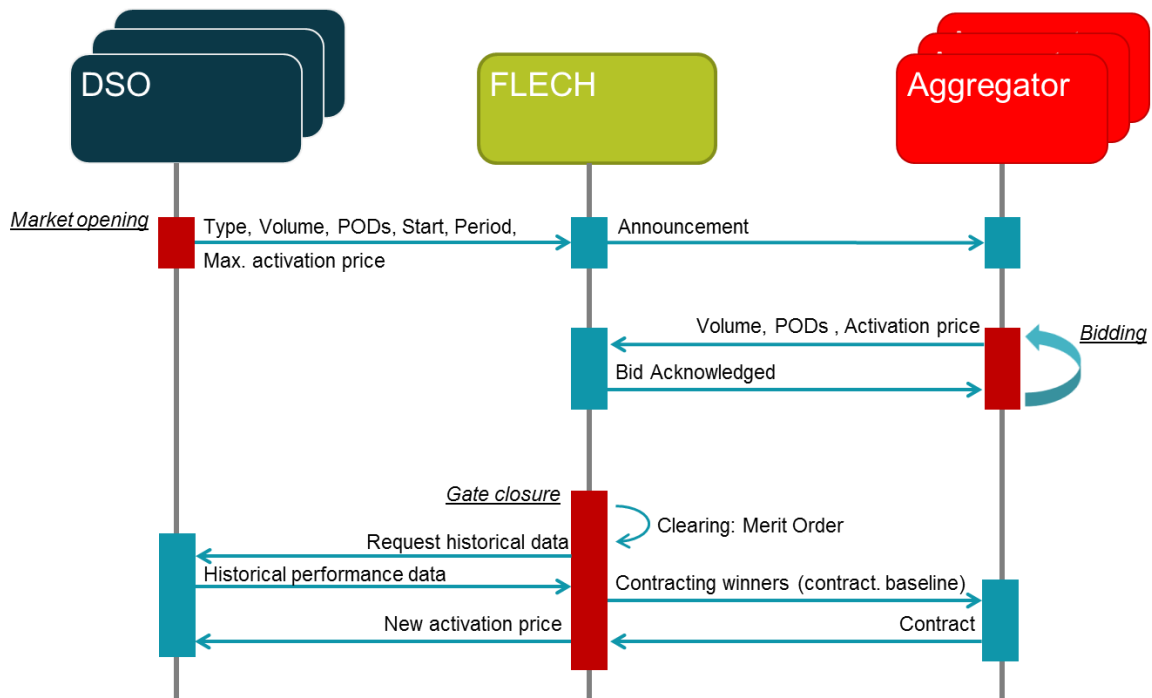


Figure 7. Overview sequence diagram of a successful clearing of the Reserve Activation market (first version data source).

### 3.3.3 SETTLEMENTS

When the DSO services have been delivered, it is time for settlement as indicated in Figure 4. Since the Reserve Activation market is sustaining the Capacity Reserve market, it is natural to first prescribe the settlement of Reserve Activation market and afterwards the Capacity Reserve market. The general settlement mechanism is: the FLECH will check the rendered service against the contractual obligation, and pay the bill. In this context the money flow will be from the DSO to FLECH, and from FLECH to the contracted Aggregators – i.e. FLECH will pay the Aggregators and invoice the DSO.

#### Reserve Activation market settlement

Based on historical grid data, FLECH will be able to evaluate whether or not the contracted Aggregators have rendered the contracted service. FLECH will simply compare metered data against the contractual baseline less the offered volume by successfully cleared by the contracted service. The verification process has one of two possible outcomes:

- Acceptable. The rendered service compared to the contractual obligation is within predefined limits. FLECH will issue payments to each Aggregator worth:

$$Payment_i = Volume_i \text{ times activation price times activation duration,}$$

where *i* refers to the contracted Aggregators and the *activation price* is the clearing result of the merit order. FLECH will then invoice the DSO:

$$Invoice_{DSO} = \text{sum of } (Payment_i) + \text{a transaction fee}$$

The *transaction fee* is a user oriented way to cover and finance the existence of FLECH. If FLECH is to be finance in another way, this will have to be negotiation between the DSOs and the operator of FLECH. The settlement process is sketched in Figure 8.

- Unacceptable. The rendered service compared to the contractual obligation is not within predefined limits. An Aggregator (or several) has failed to provide the contracted service. FLECH will document this and acknowledge the DSO. The DSO will judge whether to activate a penalty as discussed in (Harbo, Hansen, & Heussen, FLECH - Market Specification Analysis, 2013).

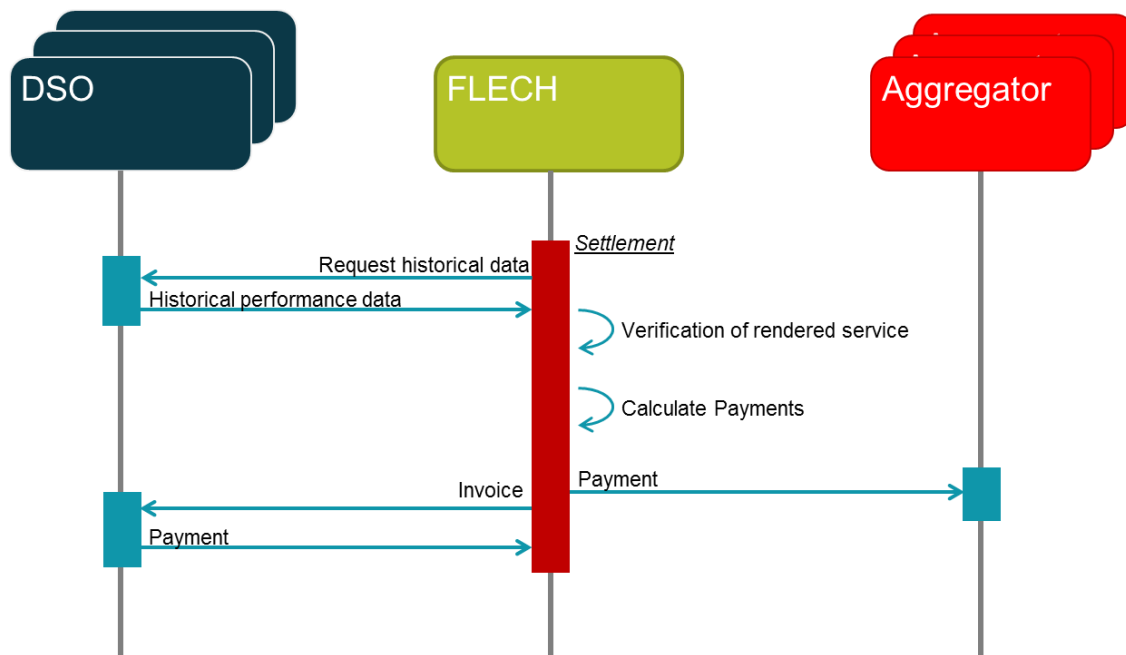


Figure 8. Successful verification of a Reserve Activation market service.

#### Capacity Reserve market settlement

Based on historical Reserve Activation market performance, FLECH will be able to evaluate whether or not the Reserve Activation market has been successfully cleared by the contracted service. FLECH could on a weekly, monthly or quarterly basis evaluate the performance. The evaluation would then be based on whether the Aggregators contracted in a Capacity Reserve market have performed correctly in the Reserve Activation market. Correct performance would then be defined as:

- The Aggregator was ready to provide service, but no Reserve Activation market was carried out in the evaluation period.
- The Aggregator did provide services, whenever activated by Reserve Activation market during the evaluated period.

Provided that these terms are fulfilled, FLECH would then issue a payment to the involved Aggregators worth:

$$Payment_i = (\text{weekly or monthly performance duration}) / (\text{reservation duration}) \text{ times reservation price}$$



where  $i$  refers to the contracted Aggregators and the *reservation price* is the clearing result of the merit order. And FLECH would invoice the DSO:

$$\text{Invoice}_{\text{DSO}} = \text{sum of } (\text{Payment}_i) + \text{a transaction fee.}$$

The *transaction fee* is motivated as described in the Reserve Activation market settlement.

If an Aggregator fails to fulfill the correct performance – i.e. provide services whenever activated by Reserve Activation market – the DSO will judge whether to activate a penalty as discussed in (Harbo, Hansen, & Heussen, FLECH - Market Specification Analysis, 2013), e.g. by not getting a Capacity Reserve market payment in the targeted period or whatever has been put in the contract.

When the DSO requested the Capacity Reserve market, the DSO also set an *Expected number of activations*, refer to Figure 6. The bids placed by the Aggregators concerning *Reservation Price* and *Activation Price* will most likely be influenced by this number. Thus in case of Aggregators having a Capacity Reserve contracts, if their *Actual number of activations* during the defined Capacity Reserve market duration turns out to be higher than the *Expected number of activations*, this could undermine the business case for which the Aggregators calculated the bid values on *reservation price* and *activation price*. The cause for this scenario is that the DSO underestimated the need for this service. Therefore, this scenario should be associated by a kind of compensation factor – or in other words a higher payment (e.g. a higher *activation price*) in order to compensate the contracted Aggregators on their extra inconvenience. How to define a fair compensation scheme is postponed as a future research topic.

The successful settlement process is sketched in Figure 9, where it is suggested that the settlement is performed on a periodical basis during the Capacity Reserve contractual time period.

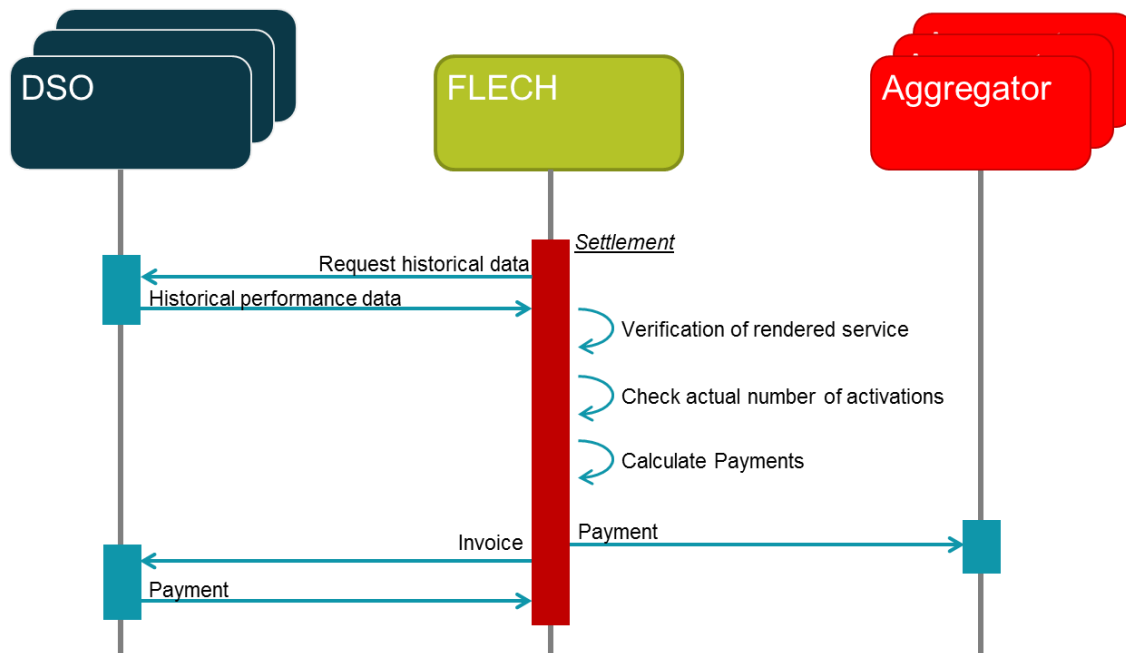


Figure 9. Successful verification of a Capacity Reserve market service on a periodical basis.

### 3.4 TIMELINE SUMMARY

As described in Section 3.3, the whole auction process of the first selected service is assumed to consist of two separate phases.

In the first phase, a DSO sends a Capacity Reserve request to FLECH asking for flexibility in some fixed reservation period. This might happen several months or even a year in advance. Once Aggregators have placed their offers, FLECH does clearing by merit order, i.e. establishes the merit order prices for: *reservation price* and *activation price*, and the winning Capacity Reserve Aggregators. All Aggregators that get reserved are notified by the market as illustrated in Figure 6.

The second phase potentially starts ahead of the Capacity Reservation period. It consists of several markets, one for every Reservation Activation period. Reservation Activation periods do not overlap and together they cover the whole Capacity Reservation periods. The number of Reservation Activation periods that a Capacity Reservation period is divided into is specified during the Capacity Reservation market.

Whenever a DSO forecasts the need for service provision that falls into an upcoming Reservation Activation period, he explicitly asks the FLECH to open the corresponding Reservation Activation market. The Reservation Activation market then immediately notifies all Aggregators that get contracted as outlined in Figure 7. If the Reservation Activation market is not successfully cleared, the Aggregators that have a corresponding Capacity Reservation contract are notified to deliver their flexibility service in the following Reservation Activation period.

To summarize the description above, the timeline presented in Figure 10 covers the following stages in chronological order:

- The open Capacity Reservation market initiated by a DSO asking Aggregators to place their offers for a fixed reservation period in the (potentially far) future.
- Duration between the Capacity Reservation market and the Capacity Reservation period might be six months or even more than a year.
- The first Reservation Activation market period asking aggregators to place offers for an Reservation Activation period in the near future. Naturally, this period happens ahead of the reservation period. This might even be the case for the second Reservation Activation period.
- The first Reservation Activation period that indicates the beginning of the Capacity Reservation period.
- A sequence of Reservation Activation markets and corresponding Reservation Activation periods until the Capacity Reservation period has ended.
- The DSO decides when to open a Reservation Activation market. Once a Reservation Activation market is opened, it is always followed by a Reservation Activation period with provision and a settlement, as indicated by the red frames in Figure 10.
- The Capacity Reservation period is always followed by a settlement. During the Capacity Reservation period a number of intermediary Capacity Reservation settlement can be performed – especially if the Capacity Reservation period is long (not illustrated in Figure 10).

Figure 10 only present the timeline of the Capacity Reservation market and Reservation Activation markets. As discussed in section 3.3.2 the gate closure of the other markets are also important. However, Figure 10 would become too complex if they were depicted as well. The important part here is that the gate closure of the Reservation Activation markets is suggested to be at 9:00 am – i.e. before the first of the competing market.

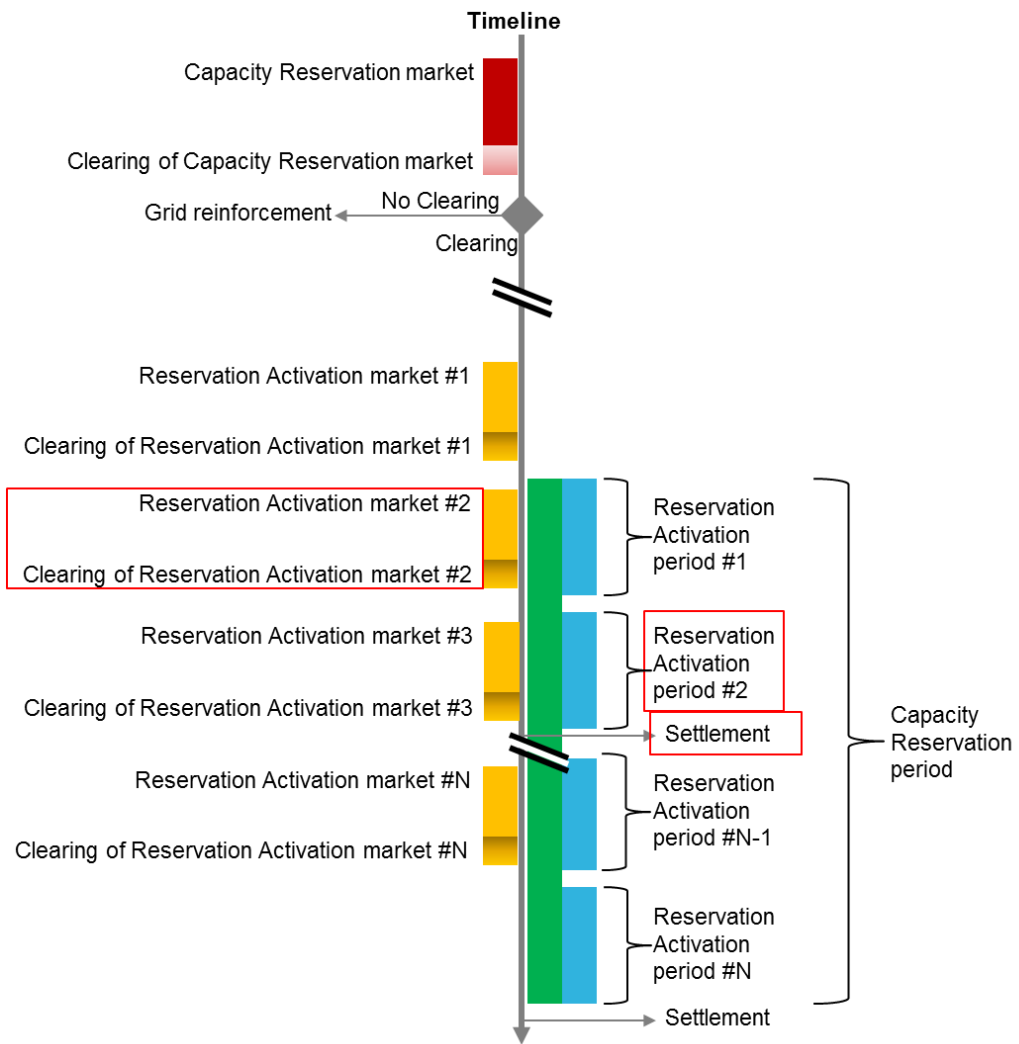


Figure 10: Timeline of the Capacity Reservation market and Reservation Activation markets. The red frames indicates an active Reservation Activation market, which is executed the following day followed by a settlement.

Non-functional issues such as e.g. what happens if an Aggregator goes bankrupt etc. has been addressed in (Harbo, Hansen, & Birke, FLECH - Market Regulation Specifications, 2013).

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