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## Scope and Content

The purpose of this document is to describe the interactions of DSOs and Aggregators with the Flexibility Clearing House (FLECH) from the perspective of an actual implementation. Communication between the three parties is based on a central message broker service.

To shed light on the messages needed and the information they should contain, a timeline is presented that reflects a typical scenario of the FLECH. The purpose of this timeline is to highlight all different stages of the FLECH from opening a capacity market until actually activating some reservations.

Based on this temporal model of the communication, a message passing schema is presented. In this schema all messages between a DSO, potentially interested Aggregators, and the FLECH are mentioned explicitly. Furthermore the notation reveals what objects (e.g. a market or an offer) the messages address and how many of them are sent.

Finally, security considerations are addressed and a full description of all messages and their content is given.

The scope of this document is mainly on the reservation and activation of flexible resources in the distribution grid and the verification and settlement of reserved and activated services are considered out of scope. The verification and settlement must be transparent and the algorithms used to determine the actual activation must be easy to understand and shared between all participants.

# Communication Protocol

## *The Timeline*

The whole auction process is assumed to consist of two separate phases.

In the first phase, a DSO sends a capacity request to the market asking for flexibility in some fixed reservation period. This might happen several month or even years in advance. Once aggregators have placed their offers, the DSO receives the merit order list, chooses some subset of it and sends his selection back to the FLECH. All Aggregators that got reserved are notified by the market.

The second phase starts ahead of the reservation period. It consists of several auctions, one for every activation period. Activation periods do not overlap and together they cover the whole reservation periods. The number of activation periods that a reservation period is divided into is specified in the DSO's capacity market.

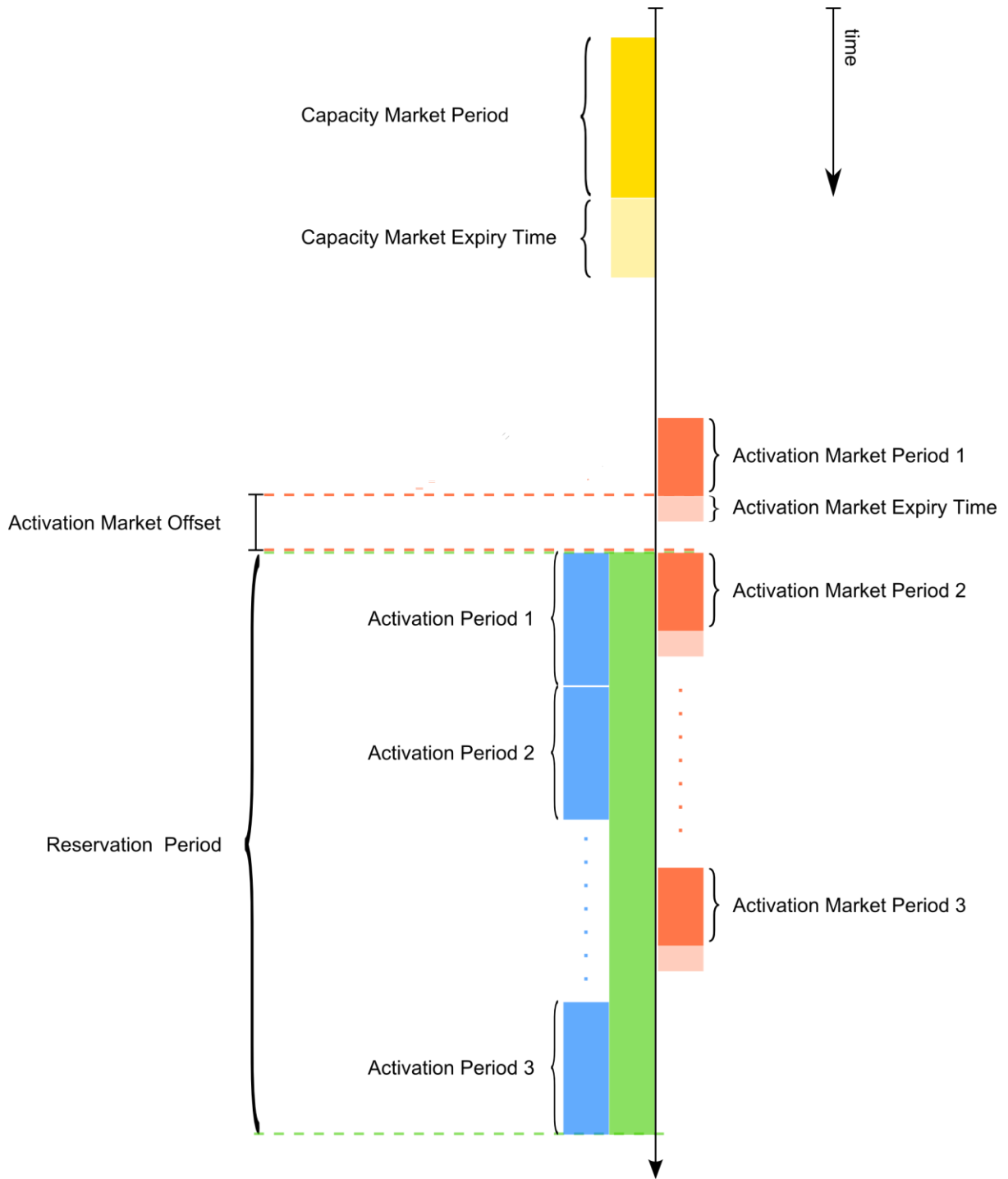
Whenever a DSO is actually interested in an activation that falls into an upcoming activation period, he explicitly asks the FLECH to open the corresponding activation market. The market then immediately notifies all Aggregators that got reserved in the first place as well as Aggregators that did not get reserved but could potentially deliver flexibility.

Similar to the capacity auction, the Aggregators' activation offers are collected, sent to the DSO, and a subset of them is accepted and returned to the FLECH. These Aggregators are requested to activate by the market.

To have a unified selection process once a market has closed both, the DSO specifies an expiry time for the capacity market and the activation markets. Once a market has closed, the DSO has to select offers within this time window. Otherwise FLECH considers the selection phase to have expired and informs all aggregators that placed offers that none of them were selected by the DSO.

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

- The open capacity market initiated by a DSO asking Aggregators to place their offers for a fixed reservation period in the (potentially far) future.
- The first activation market period asking aggregators to place offers for an activation period in the near future. Naturally, this period happens ahead of the reservation period. This might even be the case for the second market period.
- The first activation period that indicates the beginning of the reservation period.
- A sequence of activation market periods and corresponding activation periods until the reservation period has ended.



**Figure 1: Timeline of the Communication**

## ***The Message Passing Schema***

The purpose of the message passing schema is to give a more detailed view on the lifecycle of a market in the FLECH. It is supposed to include all objects involved in the timeline mentioned in the section above.

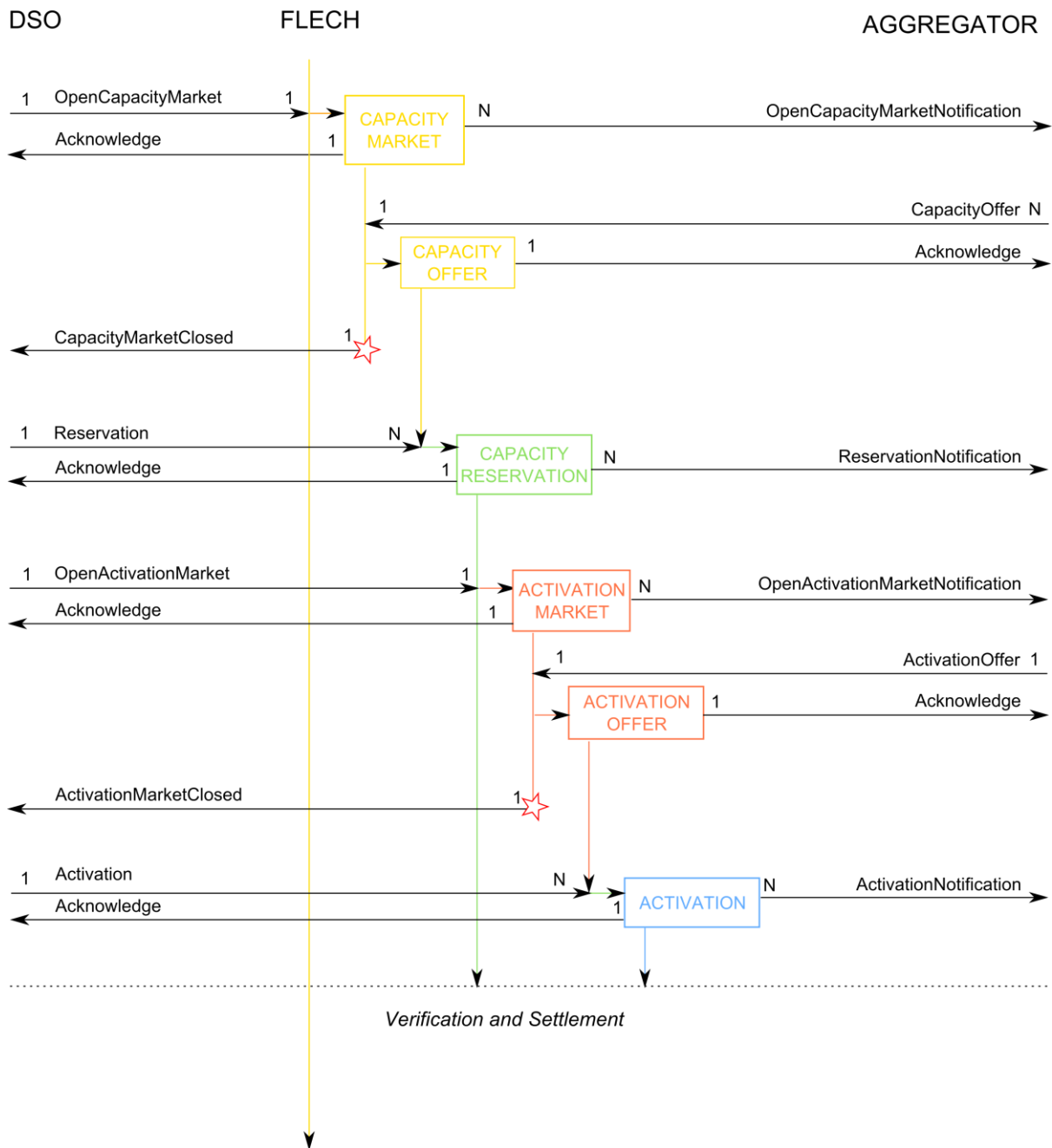
Objects at the FLECH are augmented with a vertical arrow indicating their lifetime in the communication process.

The notation of the messages uses directed edges to reveal what object a message refers to e.g. an offer relates to exactly one market. The cardinalities are borrowed from ER-diagrams with a slightly different interpretation. Depending on the sender, they have the following interpretation:

<b>Message Direction</b>	<b>Outgoing Cardinality</b>	<b>Ingoing Cardinality</b>
Participant -> FLECH	Number of messages sent.	Number of objects that the message addresses.
FLECH -> Participant	Number of participants the message is sent to.	n.a.

Messages from the FLECH to a participant don't need an outgoing cardinality – they always address only one particular participant.

Finally, time-triggered events (e.g. by some time period ending) at the FLECH are indicated by a little star.



**Figure 2: Message Passing Schema of the Communication**

Note, that due to the expiry time of capacity and activation markets FLECH might send `ReservationNotification` and `ActivationNotification` messages without receiving a `Reservation` or `Activation` message from the DSO before. This is considered to be a subset of the usual message flow and is not reflected explicitly in the figure above.



## Message Types

From the above message diagram it becomes clear, that there are three different types of messages. Messages of the same type vary only in name and information content but not in their behavior with respect to other dependent messages or events. The three types are:

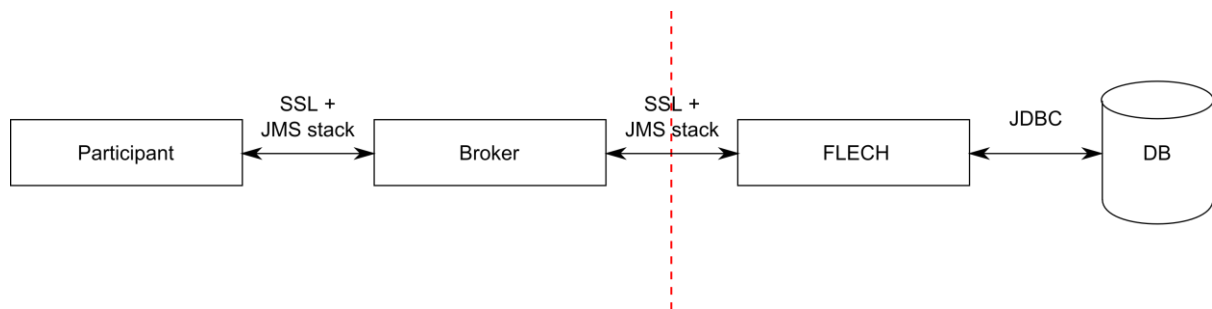
1. Time triggered messages from the FLECH to exactly one participant.
2. Messages from a participant to the FLECH triggering no follow-up messages.
3. Messages from a participant to the FLECH triggering the market to send notifications to one or multiple other participants.

## Security Considerations

Secure communication is crucial for the security of the whole system. Currently four different entities communicating are involved:

1. The message Broker
2. The FLECH
3. Participants being either DSOs or Aggregators
4. The database backend

The communication schema can be sketched as follows:



**Figure 3: Communication Infrastructure**

SSL secures the JMS communication from the participants and the FLECH to the broker. While the broker has to be available from the internet, the FLECH server and the database can operate from a subnet that is not accessible directly from the net.

## Use Cases

This section lists use-cases that describe the communication process depicted in figure 2 between DSOs, aggregators and the clearing house (FLECH) in more detail. Whenever the actor field of a use-case lists 'participant', it refers to either a DSO or an aggregator.

### *Participant Authentication*

<b>Name</b>	Use-Case Participant Authentication
<b>Description</b>	Authenticates a participant at the FLECH. The participant's credentials are verified against the information stored at the FLECH's user database. Furthermore, the destination the participant is sending from is checked against the list of valid destinations for that participant. Finally, FLECH checks whether the participant is allowed to send a message of this type depending on his role (DSO or aggregator).
<b>Actors</b>	FLECH, Participant
<b>Pre-Condition</b>	
<b>Post-Condition</b>	<ul style="list-style-type: none"> <li>If the authentication succeeds, the message is approved to be processed by the FLECH.</li> </ul>
<b>Trigger</b>	A new message is being processed at the FLECH
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>A participant sends a message together with his credentials.</li> <li>In case of a failed authentication, the reply sent by FLECH informs the participant about the failure.</li> </ol>
<b>Alternate Flow</b>	
<b>Comments</b>	This process is invoked whenever a new message arrives at the FLECH and the information necessary for authentication is part of every message.

### *Reserving Capacity*

<b>Name</b>	Use-Case Reserving capacity
<b>Description</b>	To reserve capacity in the future, a DSO opens a new capacity market at FLECH. All aggregators that could potentially deliver are informed by FLECH and send their offers. Once the market closes, the DSO receives a list of offers and reserves some of them. Finally, all aggregators are informed about the outcome of the auction.
<b>Actors</b>	DSO, FLECH, Aggregators

<b>Pre-Condition</b>	<ul style="list-style-type: none"> <li>• Successful Participant Authentication<sup>1</sup></li> </ul>
<b>Post-Condition</b>	<ul style="list-style-type: none"> <li>• The FLECH has recorded all offers placed at the capacity market and keeps track of the offers that got reserved.</li> <li>• DSO and aggregators are informed about the outcome of the auction.</li> </ul>
<b>Trigger</b>	DSO demand
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The DSO sends an OpenCapacityMarket Message to FLECH specifying the new market.</li> <li>2. The DSO receives an OpenCapacityMarketAck Message with the market ID of his new market. All aggregators receive an OpenCapacityMarketNotification Message with all information necessary to place offers.</li> <li>3. Aggregators place offers (see <b>Use-Case Placing a Capacity Offer</b>).</li> <li>4. Once the market closes, the DSO receives a CapacityMarketClose Message containing all offers placed.</li> <li>5. The DSO sends a Reservation Message with the list of offers that he wants to reserve. FLECH then sends a ReservationNotification Message to all aggregators that submitted offers to inform whether they got selected or not. Furthermore, FLECH acknowledges the reservation to the DSO by sending a ReservationAck Message.</li> </ol>
<b>Alternate Flow</b>	<ul style="list-style-type: none"> <li>• If opening the capacity market is not possible, the DSO receives a negative acknowledgement and no aggregators are notified.</li> <li>• If an aggregator sends his offer too late, FLECH rejects his message with a negative acknowledgement.</li> <li>• If the DSO does not send a Reservation Message before the capacity market expires, FLECH automatically sends a ReservationNotification with no offers selected to all aggregators involved.</li> </ul>
<b>Comments</b>	Note, that the capacity market has two attributes, maximum activation price and maximum reservation price, to limit the DSO's expenses.

### ***Placing a Capacity Offer***

<b>Name</b>	Use-Case Placing a Capacity Offer
<b>Description</b>	An aggregator places an offer on a Capacity Market to deliver service in the future.
<b>Actors</b>	Aggregator, FLECH
<b>Pre-Condition</b>	<ul style="list-style-type: none"> <li>• Successful Participant Authentication</li> <li>• The Capacity Market the aggregator is referring to exists and is open.</li> </ul>
<b>Post-Condition</b>	<ul style="list-style-type: none"> <li>• FLECH recorded the offer.</li> <li>• The aggregator received an acknowledgement of his offer.</li> </ul>

<sup>1</sup> This is not a necessary condition for the use-case itself but rather for a successful flow

<b>Trigger</b>	Available flexibility of an aggregator after an OpenCapacityMarketNotification has arrived.
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The aggregator sends a CapacityOffer Message to FLECH.</li> <li>2. FLECH acknowledges the offer with a CapacityOfferAck Message.</li> </ol>
<b>Alternate Flow</b>	
<b>Comments</b>	

## *Activation*

<b>Name</b>	Use-Case Activation
<b>Description</b>	During a reservation period the DSO actually wants the aggregators to activate during a certain upcoming Activation Period (See Figure 1). To achieve this at the lowest possible price, an Activation Market is opened ahead of the Activation Period.
<b>Actors</b>	DSO, FLECH, Aggregators
<b>Pre-Condition</b>	<ul style="list-style-type: none"> <li>• Successful Participant Authentication</li> <li>• The DSO has opened a Capacity Market in the past and the request happens during an Activation Time Period of that market (See Figure 1).</li> </ul>
<b>Post-Condition</b>	<ul style="list-style-type: none"> <li>• FLECH has recorded all offers placed on the Activation Market and keeps track of the offers that got selected.</li> <li>• DSO and aggregators are informed about the outcome of the auction. Aggregators that got selected have to activate during the Activation Period.</li> </ul>
<b>Trigger</b>	DSO demand
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The DSO sends an OpenActivationMarket Message to indicate that he is interested in an activation during the upcoming Activation Period.</li> <li>2. The DSO receives an OpenActivationMarketAck Message with the market ID of his new market. All aggregators that could potentially deliver receive an OpenActivationMarketNotification Message with all information necessary to place offers.</li> <li>3. Aggregators place offers (see <b>Use-Case Placing an Activation Offer</b>).</li> <li>4. Once the market closes, the DSO receives an ActivationMarketClosed Message containing the merit order list of all offers.</li> <li>5. The DSO sends an Activation Message with either the list of offers that he wants to activate or the total volume he wants to activate. In this case FLECH selects according to the merit order list. FLECH then sends an ActivationNotification Message to all aggregators that submitted offers to inform whether they got selected or not. Furthermore, FLECH acknowledges the activation to the DSO by sending an ActivationAck Message.</li> </ol>
<b>Alternate Flow</b>	<ul style="list-style-type: none"> <li>• If opening the activation market is not possible, the DSO receives a negative acknowledgement and no aggregators are notified.</li> </ul>

	<ul style="list-style-type: none"> <li>• If an aggregator sends his offer too late, FLECH rejects his message with a negative acknowledgement.</li> <li>• If the DSO does not send an Activation Message before the activation market expires, FLECH automatically sends an ActivationNotification with no offers selected to all aggregators involved.</li> </ul>
<b>Comments</b>	

### ***Placing an Activation Offer***

<b>Name</b>	Use-Case Placing an Activation Offer
<b>Description</b>	An aggregator places an offer at an Activation Market to activate during an upcoming Activation Period.
<b>Actors</b>	Aggregator, FLECH
<b>Pre-Condition</b>	<ul style="list-style-type: none"> <li>• Successful Participant Authentication</li> <li>• The Activation Market the aggregator is referring to exists and is open.</li> </ul>
<b>Post-Condition</b>	<ul style="list-style-type: none"> <li>• FLECH recorded the offer.</li> <li>• The aggregator received an acknowledgement of his offer.</li> </ul>
<b>Trigger</b>	Available flexibility of an aggregator after an OpenActivationMarketNotification has arrived.
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The aggregator sends an ActivationOffer Message to FLECH.</li> <li>2. FLECH acknowledges the offer with an ActivationOfferAck Message.</li> </ol>
<b>Alternate Flow</b>	
<b>Comments</b>	Note, that an aggregator who got reserved by the DSO in the Capacity Market, has to place offers with an activation price equal to or below the activation price that he promised in his CapacityOffer message.

## Message Specification

This section concludes the documentation by listing all messages appearing in the scenario of Figure 2 together with their key attributes.

To highlight the key concepts of the communication protocol only, acknowledge and notification messages are just mentioned implicitly. Whenever a message triggers the FLECH to send subsequent messages, the addressees are listed under 'Notifications'.

### OpenCapacityMarket Message

Key Properties	Capacity Market Period, Capacity Market Expiry Time,  Activation Market Offset, Duration of Activation Market Periods, Activation Market Expiry Time,  Reservation Period, Duration of the Activation Periods,  Volume, Area, Max Activation Price, Max Reservation Price
Sender/Receiver	DSO → FLECH
Acknowledged	Yes
Notifications	To all aggregators having some installations in the requested area.
Short Summary	Opens a capacity market and informs all relevant aggregators.

### CapacityOffer Message

Key Properties	Volume, Area, Activation Price, Reservation Price
Sender/Receiver	Aggregator → FLECH
Acknowledged	Yes
Notifications	None
Short Summary	Places an offer for one particular currently open Capacity Market.

### CapacityMarketClosed Message

Key Properties	List of Capacity Offers
Sender/Receiver	FLECH → DSO
Acknowledged	No
Notifications	None
Short Summary	Notifies the DSO that the market has closed and reports all received offers.

### Reservation Message

Key Properties	List of Capacity Offers
Sender/Receiver	DSO → FLECH
Acknowledged	Yes
Notifications	To all aggregators that have placed an offer in this capacity market.
Short Summary	Allows the DSO to select a set of Capacity Offers he is interested in and informs aggregators about the outcome of the auction.

### OpenActivationMarket Message

Key Properties	Reference to a Capacity Reservation and an Activation Period including all necessary information to place offers
Sender/Receiver	DSO → FLECH
Acknowledged	Yes
Notifications	To all aggregators that got reserved plus all remaining aggregators in the relevant area that could potentially offer flexibility.
Short Summary	Informs about an upcoming Activation Period and asks all participants to send their Activation Offers.

### ActivationOffer Message

Key Properties	Volume, Area, Activation Price
Sender/Receiver	Aggregator → FLECH
Acknowledged	Yes
Notifications	none
Short Summary	Places an offer for one particular currently open Activation Market.

### ActivationMarketClosed Message

Key Properties	Merit order List of Activation Offers
Sender/Receiver	FLECH → DSO
Acknowledged	No
Notifications	none
Short Summary	Notifies the DSO that the market has closed and reports all received Activation Offers.

### Activate Message

Key Properties	<b>Either:</b> List of Activation Offers to be activated <b>Or:</b> Total volume to be activated
Sender/Receiver	DSO → FLECH
Acknowledged	Yes
Notifications	To all aggregators that placed an offer in this activation market.
Short Summary	Either asks aggregators directly to activate their Activation Offers or delegates this to the market that selects them based on the specified volume and merit order.



## Change log

The message specification in the last section summarized the results of the past discussions. To keep track of changes made during the specification process of the FLECH prototype, all important decisions are collected in the following list.

### *1. Considerations made from version 1.0 to version 1.1*

- a. **Activation time window:** The possibility to specify a set of activation periods with varying duration that potentially does not cover the whole reservation period is considered to be too complex for the prototype. Instead, we suggest letting the DSO specify the duration of an activation period. Based on this, the reservation period is then divided into a sequence of activation periods of the same duration. It is then up to the DSO to actually initiate markets for the activation periods depending on the current demand.
- b. **Acknowledge capacity close message:** Only communication to FLECH is acknowledged. The knowledge that the list of offers has been delivered to the DSO is not important to FLECH. The DSO will always be able to retrieve the list of offers as a separate request to FLECH. Such startup/initialization functionality is not part of this document at the moment; the focus is on the operational aspects of FLECH.
- c. **Notifying new aggregators of market properties:** The open activation market message does contain a reference to the capacity market which has all the information. It is still open if the aggregators have to retrieve the properties themselves or if they are included in the open activation market notification. Note that the contents of the messages are easy to change.
- d. **Knowing the endpoints that an aggregator is controlling:** The question is if all aggregators get all information. At some point it becomes obvious that some aggregators do not need to get notifications from some markets. For example, a small aggregator on Bornholm does not need to get information on open markets on Jylland. We have prepared for this, and it can be implemented with different levels of granularity.
- e. **Feedback to aggregators:** Whenever a market has been closed and the DSO selects the offers, FLECH will notify all aggregators about the success of their offers. This holds for both offers that got selected and those that did not, in every capacity as well as in every activation market.
- f. **Automatic selection of activation offers:** We will offer the possibility for the DSO to only send the activated amount so that FLECH selects the offers based on merit order. However, we will keep the existing message containing the list of offers so that DSOs can also select offers individually. Thereby, the DSO will be able to know how much activation will cost before sending the activation message.

## ***2. Changes made from version 1.1 to version 1.2***

- a. **Use-Cases:** The document now contains a separate section listing use-cases for DSOs and aggregators that reflect the message passing schema presented in Figure 2.
- b. **Specification details of the markets:** Added Activation Market Period, Capacity Market Expiry Time and Activation Market Expiry Time to open capacity market message.