DigIPlat

Deliverable Task 4.1 + 4.2
Implementation of Demonstrator

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Glossary

BCM	Bid Congestion Management - the software system which shows possible integration of market platforms on balancing energy markets and DSO networks and assets. It is managing the communication, data distribution, data translation, processes and different IT technologies and protocols.
Demonstrator	The Software system which demonstrates the BCM functionality using a user interface.
PTDF	Power Transmission Distribution Factor
VTDF	Voltage Transmission Distribution Factor

1 Introduction

1.1 Initial Situation

In the course of the energy transition and the increasing integration of renewable energies, the flexible use of generation and consumption is becoming increasingly important. The provision of **balancing energy (BE)** in particular represents a key challenge, as the electricity grid must be kept stable in real time. However, the activation of balancing energy can change the grid load and thus lead to overloads in certain grid areas.

At present, **balancing energy calls and congestion management (CM) measures** are largely carried out separately, which means that potential synergies remain unused. Particularly at distribution grid level, the activation of balancing energy can lead to unforeseen load flows that exacerbate existing grid congestion or create new ones. This problem is exacerbated by the increasing number of decentralized generators and flexibility providers whose feed-in is not always coordinated with the grid capacities.

Use Case 1 addresses this problem by taking the available grid capacities into account when allocating balancing energy. The aim is to enable an **optimized selection of balancing energy bids** that is both **cost-efficient and useful to the grid**. To this end, a three-stage optimization approach is being pursued in which balancing energy bids broken down into technical units, compared with the current grid restrictions and then fed back into an optimized overall offer. This is intended to avoid grid bottlenecks in advance and ensure more efficient use of the available flexibility resources.

This challenge requires not only **technical adjustments** in market and grid control, but also stronger **interoperative networking** between transmission system operators (TSOs), distribution system operators (DSOs) and flexibility providers. By implementing Use Case 1, an important step can be taken towards a **holistic view of grid and market mechanisms**, which **improves both the security of supply and the economic efficiency of the energy system**.

As part of the **DigIPlat** research project, the technical basis for the specification and implementation of a demonstrator for **interoperability in the energy market** was developed and documented in **Work Package 3 (WP 3).** Based on this preliminary work, **Task 4.1** was commissioned with the detailed **specification** and **Task 4.2** with the **practical implementation** of the demonstrator. The **standardized framework** defined in **WP 3** and the **Use Case 1** described there serve as the central guidelines for both work packages.

Various players in the energy market in **Germany and Austria** are involved in the research project in different **market roles** and take on specific tasks for the implementation of **Use Case 1** according to their function.

The research partners provide existing **platforms and standards.** Functions, data and systems that are **not yet available** for the implementation of the use case are either **developed** as part of the project or **replaced** by suitable solutions.

1.2 Task definition

The mission of Task 4.1 is to create a specification for a demonstrator based on the use case 1 defined in WP 3. The demonstrator should represent a software-based solution that fulfils the requirements of this use case.

Task 4.2 is responsible for the practical implementation of the demonstrator. Based on the market platform for balancing energy selected in the research project and the standardized framework conditions defined in WP 3, Use Case 1 is to be implemented using existing platforms, market participants and databases. These will be provided by the participating research partners and coordinated with Fichtner IT Consulting.

The technical demonstrator is to be developed as a functional data and process integration, whereby the implementation is to be carried out as realistically as possible using existing platforms, markets and data. The aim is to analyse the functional and technical requirements of the platforms, identify divergences between the systems and market partners to be connected and determine the necessary enhancements that are required to successfully implement the use case.

2 Requirements

2.1 Functional requirements

2.1.1 Integration network model of the example region

For Use Case 1, a distribution grid from Task 4.3 is provided, which is to be used, displayed and passed on to the optimization function within the demonstrator. The grid model contains the geographical location of the lines, house connections and transformer stations.

2.1.2 Integration of network models into the demonstrator

The application must be able to manage different distribution grids, receive them via their interfaces and assign them to the associated systems of the individual distribution grids for the allocation of market bids. The available distribution grids should be offered to the user of the demonstrator (e.g. DSO employee) for selection.

2.1.3 Market-based selection of flexibility offers

The demonstrator should allow the selection of the day/date of the delivery period under consideration and the notified day type, which can typically be used in the balancing power market, for specified market and grid situations.

2.1.4 Choice of different market situations

The demonstrator should be able to provide different combinations of bids from the balancing energy market for the purpose of presenting different situations and also make these bids available for selection in the user interface. The quantity of bids provided by market platforms is summarized under one designation. The aim of the various predefined bid combinations is to analyse grid behaviour with regard to possible bottlenecks by displaying the optimization results.

2.1.5 Reading and providing market bids from flexibility platform Crowd Balancing Platform

The demonstrator should provide interfaces that can receive the quantity of bids from the market platform at any time. The bids from the market platforms should be sent in a standardized format. The standardized format, which is necessary to map Use Case 1, is to be developed and implemented in the demonstrator.

2.1.6 Visualization of the read bids and included attachments

Within a user interface, the bids provided by the market platforms within a given grid area should be displayed in tabular form with their relevant data. The installations in the distribution grid on which these bids are based should also be displayed in tabular form after selecting a bid. The systems should also be visualized in a map at their connection point in the distribution grid.

2.1.7 Activation of the optimizer for the most favourable bid combination

The demonstrator should be able to send the quantity of bids provided to it for an available distribution grid together with the type of day and the quantity of energy requested by the market to an optimizer in order to determine the most favourable bid combination.

2.1.8 Presentation of the optimization results

An interface must be provided for receiving the optimization results, which receives the result data after the optimization has been completed. The optimization results must be saved and displayed to the user in tabular form. The display is again shown as a list of bids, with the optimization results included.

2.1.9 Visualization of the results

The demonstrator should provide the user with a map representation (geography) of the selected distribution grid. This contains the topography in the form of a base map, the low-voltage infrastructure in the form of transformer stations, supply lines and grid connection points, as well as the calculated loads on the infrastructure for the lines and the connection points as representatives of the systems.

2.2 Non-functional requirements

2.2.1 Availability for all project partners

The demonstrator is to be set up in such a way that all project partners and all systems involved can be connected and accessed as easily as possible and with minimal set-up effort. The demonstrator should be designed for 24/7 continuous operation. In the first phase, however, it only needs to be available Monday to Friday during working hours.

2.2.2 Performance of the surface

The interface set up for demonstration purposes should implement the user's inputs as quickly as possible and signal waiting times to the user by means of appropriate waiting symbols and/or texts. It must be possible to operate the interface smoothly so that the user's workflow is not disrupted. Processing without an external system connection should lead to a visible reaction in less than 1 second and be completed in 5 seconds at the latest.

2.2.3 Processing performance

The demonstrator processes the data sent to it for the described Use Case 1. All processing should start immediately after user interaction or interface call and must not take longer than 10 seconds for the expected data volumes in one processing step.

The overall processing of a run includes the time of the start of the optimization, the optimization itself, the feedback of the optimization results and the processing / forwarding of the same to the market platforms or as a display to the user of the demonstrator. The aim of this overall processing is a throughput time within 2 minutes.

2.3 System environment

2.3.1 Runtime environment

In the context of the task, an environment should be provided that is technically capable of connecting the platforms mentioned. In addition, the selected platform should generally be able to meet standard market requirements in terms of data security, operational security, scalability and runtime.

Access to the demonstrator should be direct and easy for the research project and those involved.

2.3.2 Interfaces and peripheral systems

The demonstrator should consider the possibilities of the interaction of existing platforms in the context of Use Case 1 and, as far as the existing systems to be considered allow, also realize a prototypical implementation with a direct system connection.

The systems to be connected were identified as part of Use Case 1 (TransnetBW's DA/RE and Equigy's Crowd Balancing Platform). Other functional components, systems and stakeholders to be connected were also identified from Use Case 1. The systems to be considered for the demonstrator are therefore

- **Crowd Balancing Platform** (CBP) as a data broker for energy markets with flexibility bids and for system information

- **DA/RE** as a provisioning platform for network and system data in regional areas.
- **Distribution system operator** (DSO) for the provision of pre-calculated network topologies

In order to be able to implement the task of Use Case 1, functional components were also identified that are not available in the existing platforms under consideration:

- **Energy grid calculation**

  Based on topological models of a distribution grid area, the grid behaviour under different load situations is calculated. Within the research project, this functional part is implemented and provided by the Karlsruhe Institute of Technology.

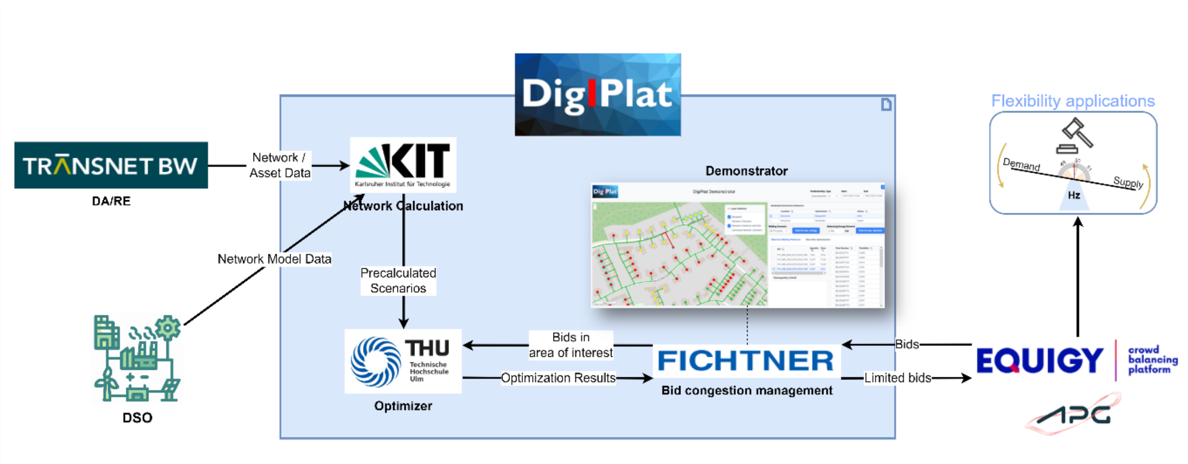
- **Bid optimizer**

  A module provided by the Ulm University of Applied Sciences with an optimization function that determines an optimized combination of bids under the conditions of the research project, taking into account the pre-calculated grid behaviour and the planned or submitted (flexibility) bids.

- **Bid congestion management**

  The "Congestion Limiter" is implemented by this module as a demonstrator to bring together all systems via interfaces and to consider the systems actually required for the systems described. All interfaces are executed here, and the use case is coordinated in its sequence.

The platforms to be integrated into the demonstrator and the systems/partners involved are shown in the following overview diagram.



3 Implementation and application design

3.1 Process description

3.1.1 Overall process of the use case

Together with the research partners, a coordinated process flow was developed for the use case, which takes into account the technical requirements and the availability of information and systems.

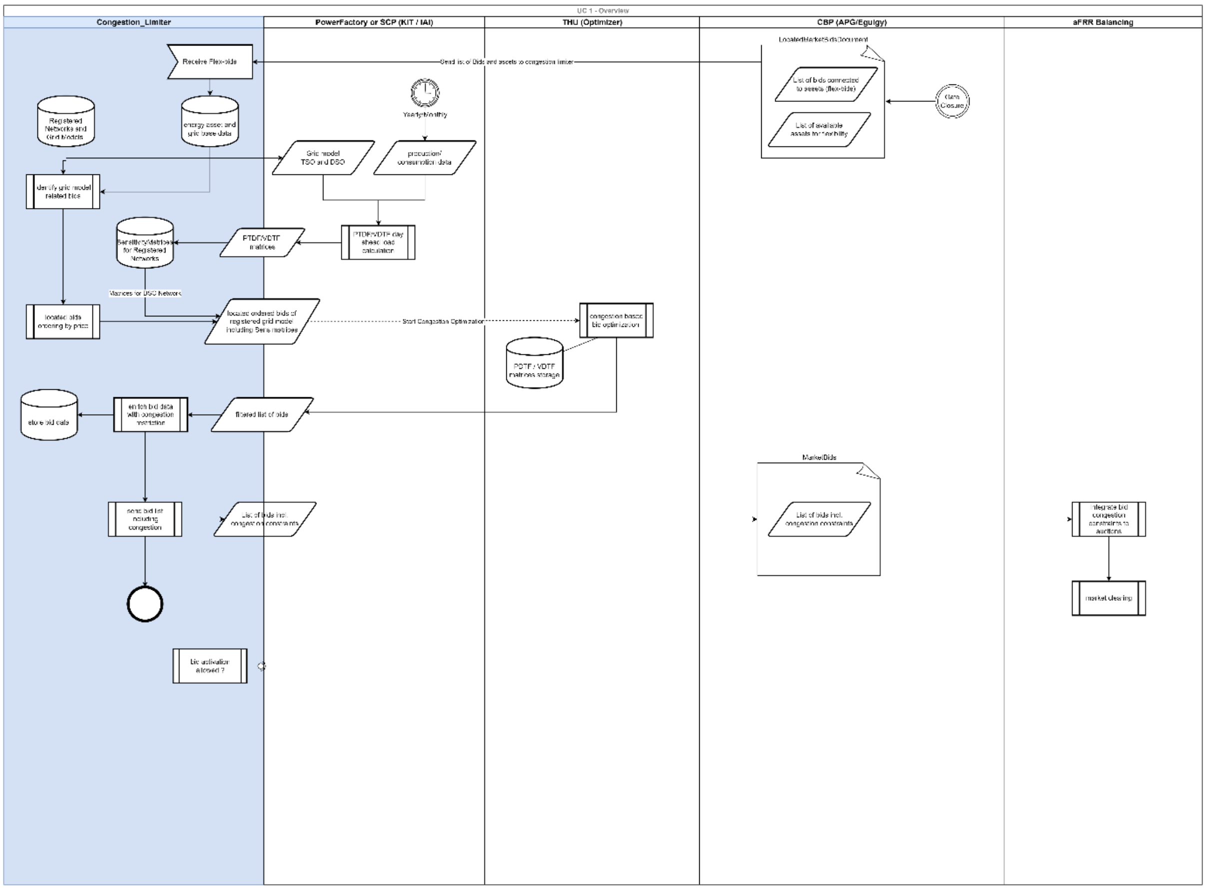


Figure 1: Overview of the flow chart of the use case under consideration

The vertical swim lanes in the flow chart show the platforms and systems involved. From left to right, these are "bid congestion management" as implementation of the demonstrator, the role of the distribution system operator (DSO) as supplier of the grid models, optimizer as external system for market bid optimization in the distribution grid, CBP (Crowd Balancing Platform) as market/integration platform for flexibility bids, aFRR Balancing as market platform for the balancing energy markets.

There are 2 sub-processes within the process flow:

I. Cyclical provision of static data and network models for the infrastructure and systems

II. Market-driven inquiry for the feasibility of the bids selected in the balancing energy market

Procedure for I:

1. Monthly or annual update of master data for the distribution grid under consideration by the distribution grid operator.
2. The distribution grid operator provides its distribution grid in the form of a geographical and node/edge structure to the BCM via an interface. The systems are represented as connection points with a unique identifier (market location) in the data provided.

3. The distribution system operator creates a calculable grid model in the form of PTDF and VTDF matrices from the grid data with the help of load data and/or forecasts (for details, see subsection 4.3).
4. These models are transferred via the interfaces to the BCM, which stores these sensitivity matrices with the associated distribution grid in an internal database.

Procedure for II:

1. A running auction for the balancing energy market reaches the time of gate closure (Start process).
2. The market platform sends the bids from the completed auction, including the system information stored on the market platform, to the BCM.
3. The BCM checks the list of bids received and assigns the bids to the registered distribution grids provided by distribution system operators.
4. BCM sends a request to the Optimizer for each distribution grid to optimize the bid quantity based on the best price while avoiding grid congestion. BCM also sends the sensitivity matrices to be used for the optimization.
5. The Optimizer returns an optimal solution to the BCM
6. The BCM supplements the market bids with information on technical feasibility within the distribution grid based on system level and cumulated at bid level.
7. The expanded bid list is returned to the crowd balancing platform.
8. The optimization result is further processed by the platform for the balancing energy auction.

3.1.2 Subprocesses I - Basics

The basis of the integration for Use Case 1 is the distribution grid model and the sensitivity matrices for the grid calculation. In the process diagram, these are the preparatory steps that originate from the distribution system operator or on behalf of the distribution system operator. According to the diagram (reference figure), this data is calculated and/or provided monthly/annually or on demand.

The BCM receives this data separately for each distribution grid and stores it internally in a database. This information from the distribution grid is used within the BCM for the following sub-steps:

- Calculation of the grid status regarding bottlenecks,
- Preparation of market bids for technical bids
- Passing on technical bids to the optimizer

In the following illustration, the process steps described here are highlighted in yellow.

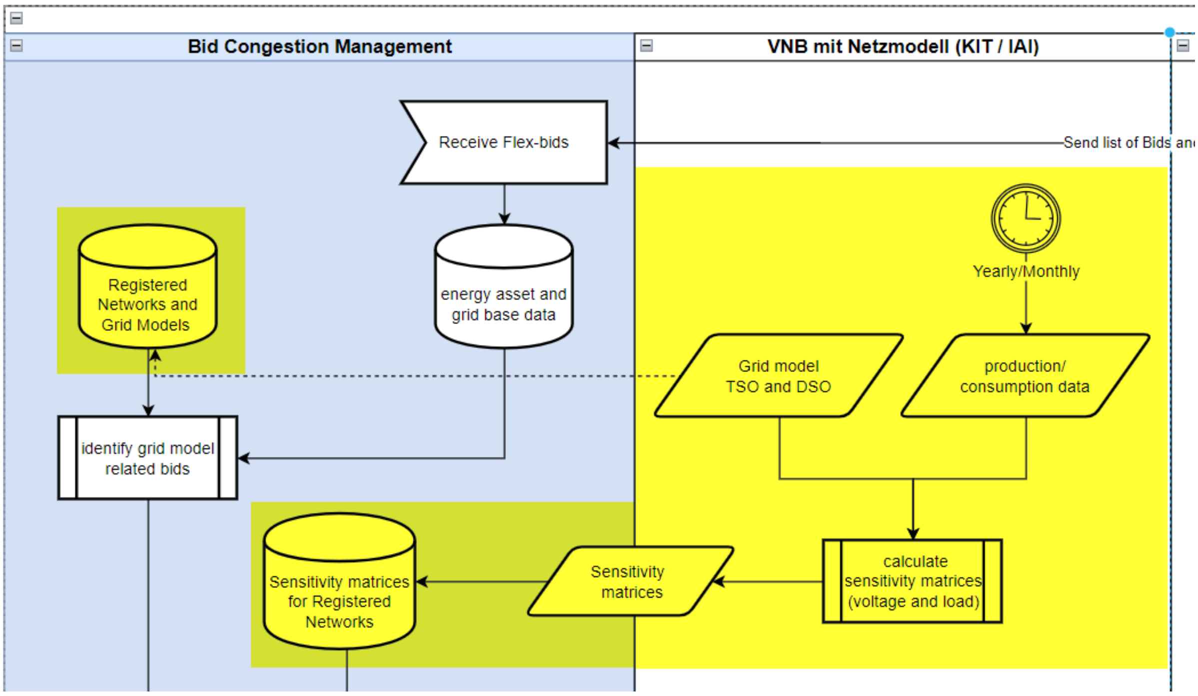
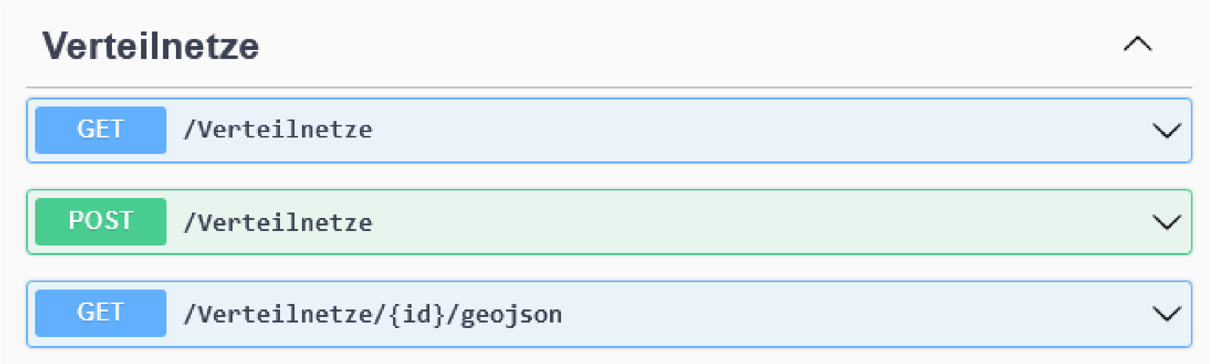


Figure 2: master data process flow

3.1.2.1 Distribution Network

The demonstrator provides the network model as a geographical representation in an interface. For this representation, the network model must be transferred to the demonstrator in a step upstream of Use Case 1. This is done by the distribution system operator as soon as the network infrastructure changes significantly. The implementation for this does not have to meet the runtime requirements of Use Case 1, as it runs outside the process flow of Use Case 1. This means that the distribution grid model can be received and integrated conventionally via file exchange and import as well as via modern interfaces.

As a modern interface, the demonstrator offers corresponding interfaces for the registration of distribution networks and their elements in the standardized GeoJSON format.



3.1.2.2 *Calculation model distribution grid*

The distribution grid calculation model forms the basis for calculating the grid utilization, which must be provided at least simultaneously with the grid model. The calculation model consists of sensitivity matrices that map the behaviour of the grid elements in the event of changes in loads (energy generation, energy consumption). In accordance with the work from Task 4.3, there are separate calculation models for different base loads of a distribution grid. Typically, these are assigned as day types to individual times of day/weekdays and months. In accordance with Task 4.3, a calculation model consists of several sensitivity matrices that map the situation of a day type depending on the grid utilization by consumers and producers between the minimum expected and the maximum technically possible situation. For Use Case 1, three different sensitivity matrices were provided for each day type in Task 4.3.

The calculation model is provided to the demonstrator via the same interfaces as the distribution grid.

3.1.3 Sub-processes II - Real-time integration

Use Case 1 is ultimately implemented in the demonstrator by the "Bid Congestion Management" module, which considers the integration of platforms, grid models and flexibility providers as described in the chapter "Interfaces and peripheral systems" under real conditions of existing solutions.

3.1.3.1 *Bid reception from market platform*

A registered market platform uses the SSM01 - CheckBids interface to signal a request to check the bids entered on the platform for technical feasibility within the distribution grids available in the BCM. The interface can be called at any time with the existing bids on the market platform. Ideally after gate closure, when all bids have been finally submitted. The sections of the overall process for this are shown in the following diagram.

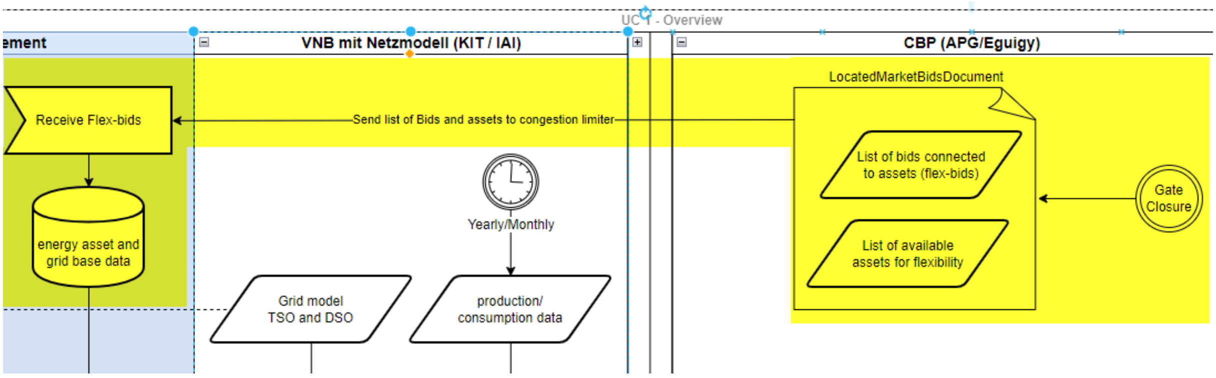


Figure 3: process flow CheckBids

The BCM stores the bids within its own database in accordance with the extended data model (see static description) and acknowledges receipt to the calling market platform.

The next process steps are then carried out in BCM demonstration mode.

3.1.3.2 Disaggregation to technical bids

After receiving the bid list and thus the request from the market platform to check the technical feasibility, the BCM first generates the so-called technical bids. Technical bids are necessary in order to be able to assign the flexibilities offered on the distribution grid to grid points where these flexibilities affect the grid. A distinction can be made between the following cases:

a. A flexibility requirement affects various grid connection points in the distribution grid
b. A flexibility requirement affects exactly one grid connection point in the distribution grid
c. A flexibility requirement does not affect any grid connection point in the distribution grid

Case a and case b are used for optimization. Case c does not require its own optimization by the BCM, as it does not have any information about the distribution grids of the flexibility bid in case c.

As defined in the static description, the existing standardized data model for bids on the balancing energy market must be extended for Use Case 1 so that the provider transmits the grid connection points and the flexibility planned at these grid connection points in addition to the bid. The transmission must contain a unique identifier for the grid connection point. In the use case, the market location identification was considered sufficient. The market location is assigned to a physical point (e.g. connection to address) by the grid model. For this purpose, the distribution grid model carries the market location information.

If only a mapping of the metering locations is possible in the distribution grid model, the BCM must be provided with an allocation table between market locations and metering locations.

The BCM uses this information to check which bids market locations have in the registered distribution grids and converts these into technical bids using the flexibilities per market location (schedule document).

Technical bids must be introduced in order to determine the point within a grid at which the offered power is effective precisely enough for a valid grid calculation to be carried out in the first place. Any connection point within the distribution grid under consideration is sufficient for this allocation. In the market, the market location IDs can be used here.

CASE STUDY A

As it is not possible to determine directly from a market bid of the balancing energy market, which is made up of different plants within a control area, which parts of the electricity grid are affected by the offered capacity / flexibility, it is necessary to request the schedule document described in SSM01 from the provider via the flexibility platforms. As this document shows the intended maximum output for each system, it is easy to break down the technical bids. The sum of the capacities of the technical bids is not necessarily the total amount of flexibility offered. This can occur if the BCM does not know all the distribution grids of the flexibility market per control area or if the grid model does not have all the market location IDs. In both cases, market locations transmitted in this way from the schedule document cannot be taken into account in the optimization and it is assumed that the flexibility of the plants can be used in the bids without grid restrictions.

If several distribution grids are registered and installations in different distribution grids are listed in the bids, this results in new quantities of technical bids corresponding to the different distribution grids, which must be submitted for optimization per distribution grid. This is shown as an example in the following figure.

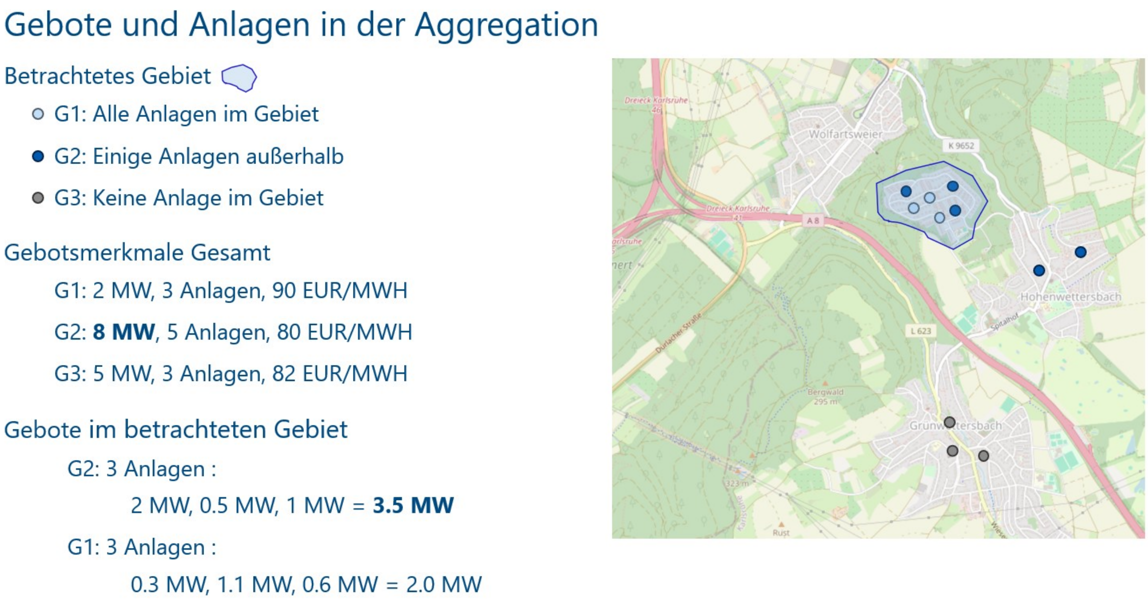


Figure 4: Illustration of bid distribution on the distribution grid

CASE STUDY B

This case can be regarded as a special case of case a, in which only one metering location is transmitted. In this case, the bid size of the flexibility in the schedule document must match or not fall below this. In this case, the technical bid is identical to the market bid and is passed on as a single technical bid with the price and capacity of the market bid.

Special case "Multiple flexibility bids at one metering location"

This case is irrelevant for the consideration and approximation of the effects of Use Case 1 on the flexibility bid and the BE market, as the flexibilities acting at a metering location always occur in aggregated / mutually balanced form on the distribution grid. The summed / balanced value can also be seen here as representative of a number of stored bids.

The findings from this assumption are discussed again in chapter 4.2 .

3.1.3.3 Load calculation distribution grid

The BCM itself does not require load calculations on the distribution grid for integration. However, a representation of this situation is implemented for the demonstrator to illustrate and estimate the grid load situation. For this representation, the demonstrator must display the information provided by the network infrastructure and the sensitivity matrices for node voltages and line loads under the selected initial situation.

The data required for this is provided to the demonstrator by the DSO (in the research project by the KIT) in the form of tables:

- Networkvoltages
  - All active network elements (nodes) of a registered distribution network
  - with standardized voltage loads based on the nominal voltage of the network element
  - Nodes can be network connection points or network connection points.
- NetworkLoads
  - All network elements (lines) of a registered distribution network

   - with load values standardized to the designed maximum load of the network element. Value range between 0 (no load) and 100 (maximum load).
- Sensitivity matrices for voltages
   - The voltage dependencies of power changes to other node elements are provided for all nodes.
- Sensitivity matrices for loads
   - The load dependencies of load changes of the grid connection point nodes are provided for all edges / lines.

Each grid load situation is based on an assumption about the maximum flexibility acting on the grid in the form of consumers and/or feeders. Only the total load acting on the network of the systems downstream of a grid connection point is considered. This assumption is evaluated as a 100% situation at a specific point in the day.

In addition to this 100% assumption, sensitivity matrices for 50% and 0% are also provided by KIT. For more details, see deliverable for Task 4.3 [5].

The demonstrator selects the values provided in the 100% assumption to display the grid load situation at the selected time of day. The colouring is based on the following limit values:

- Loads L:
   - 0 <= L <= 80: green
   - 80 < L <= 100: yellow
   - L > 100: red
- Tensions V:
   - 0.97 <= V < =1.03: green
   - 0.95 <= V < 0.97 or 1.05 <= V < 1.03: yellow
   - V < 0.95 or V > 1.05: red

3.1.3.4 Handover to optimization and optimization results

After disaggregation into technical bids, the BCM calls up bid optimization via the SSO1 interface.

For this purpose, the BCM must determine the distribution grids on which the technical bids have an effect, as well as the optimizers registered for the distribution grids.

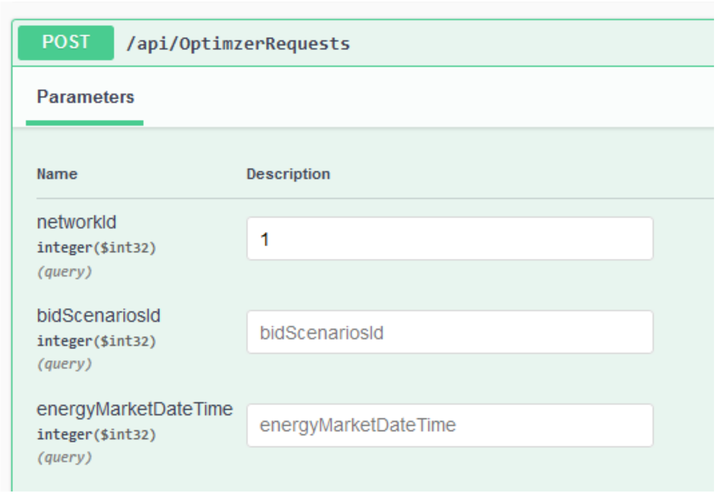
For this purpose, a so-called "logic app" is called within the integration platform, which represents a self-contained function module. This module handles communication with the end point of the optimizer within the system environment of the THU, transfers the technical bids to be optimized, collects the results of the optimization process and transfers these in turn to the BCM as a return value. From the BCM's point of view, this logic app executes the optimization function in a synchronized manner. This means that the function execution of the BCM waits for the optimization result before continuing with its own execution.

For the implementation of the demonstrator, an interface for this call was introduced in BCM for better illustration. With this interface, optimization can be carried out again at any time even without transferring the market bids via SSM1 - CheckBids.

The interface can be accessed via the path "/api/OptimzerRequests" as a POST request. The optimization for the specified distribution network is carried out by calling this interface.

The parameters of the interface are:

- networkId: Identified distribution grid (in the demonstrator, it is assumed that the optimizer already knows the distribution grids based on its own identification).
- bidScenariosId: Selected bid scenario (selected in the demonstrator, identifies the market bids available in the BCM for disaggregation)
- energyMarketDateTime: Delivery period for the bids



Return structures and values from the optimization:

After a successful run, the optimizer returns the optimization results in the form of a nested JSON structure. The return structure is described in chapter 3.3.5. The returns are illustrated again in the example shown.

```
{
    "FlexQuantityOptimal": [{
            "MarketlocationId": "BB_102540560",
            "FlexQuantityOptimal": 0.0321626199656899 2,
            "AssetId": "102540560"
        },
    ....
        ],
    "CostOptimal": 19517.93683024928,
    "UsedReferencePoint": "0.5"
}
```

Figure5 : Example of an optimization result

The BCM saves the optimization results and thus concludes the optimization run. It also signals to the demonstrator that the results are available and can be displayed in the demonstrator interface.

Before the results are returned to the market platforms, the next step of aggregation and allocation to the platform's market bids must be carried out.

3.1.3.5 Aggregation to marketable bids

After successful execution of the optimization, the BCM receives the results as described at 3.3.5.

As the technical results are only returned at technical bid level and are therefore to be seen at grid connection level from the grid's perspective, the BCM must perform an aggregation on the bids supplied by the market platforms.

In the use case, it can be assumed that no duplicates occur at the grid connection level within a market tender. This means that a connection point around a network may only be used once as a location across all offers within a market tender.

Based on this premise, the BCM assigns the results of the Optimizer to the market bids using the location information. The BCM evaluates the Optimizer result according to the individual values per location known from the market. This evaluation for constraints is made as follows:

- If the optimized performance is identical to the offer value, this is left unchanged
- If the optimized output is less than the bid value, the bid for this system is marked as "restricted".
- If the optimized power = 0, the bid for this system is marked as "forbidden".

The maximum output of a market bid permitted by the optimizer is then calculated by adding the optimized output of the individual systems. This value can be lower than the capacity offered in the market bid.

3.1.3.6 Return to market platform

The interface for returning the grid-optimized bids was specified in the demonstrator (see section 3.3.3), but not implemented in the field test in consultation with the project partners, as this requires an addition to the crowd-balancing platform (selected market platform), for which no sub-project or research assignment was formulated in the research project.

3.2 System architecture

The core of the system is a modern multi-layer architecture based on individual service components. The chosen architecture makes it easy to replace individual components as long as the described interfaces between the components are implemented and available. Extensions are also possible at any time by integrating additional services or applications via the interface architecture.

This architecture guarantees a secure system environment and data storage with maximum flexibility and fundamental independence of the individual components.

The fully integrated Fichtner BGI Framework, which provides a corresponding map interface and middleware components, is provided as a module for the front end for the visualization of geographic data. In order to keep dependencies on other components to a minimum, the **GeoServer** (http://geoserver.org/) normally used for geodata is not used in this architecture. The geodata content for the demonstrator is delivered directly in the demonstrator's programming in standardized GeoJSON format. PostgreSQL with the PostGIS add-on is used as the database system. This combination has long been established for the storage of geodata and is used in many web GIS solutions.

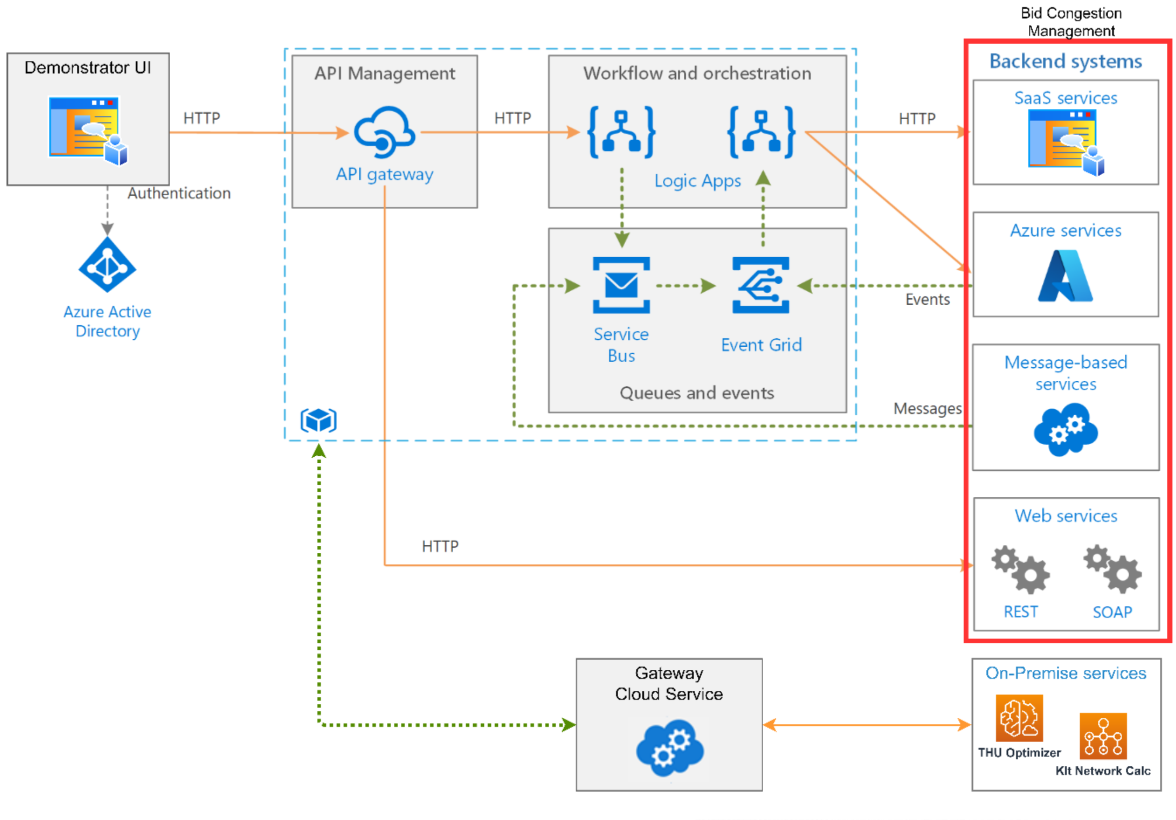


Figure 6 Solution architecture for the demonstrator

3.2.1 Implementation

The architecture is implemented via Microsoft's Azure cloud infrastructure. The resources required for the use case are provided within a resource group:

- App Service Plan (scalability)
- App Service (hosting for the demo application)
- Azure database - PostgreSQL

- Logic App - Execution of integration logic
- On-premises data gateway - access to local applications (not cloud)
- Api Management - Provision of external interfaces
- Virtual internal network for internal communication and for external web addresses

Where necessary, resources are reserved for 2 stages: Development and Demonstrator.

The implementation of the demonstrator follows this overview:

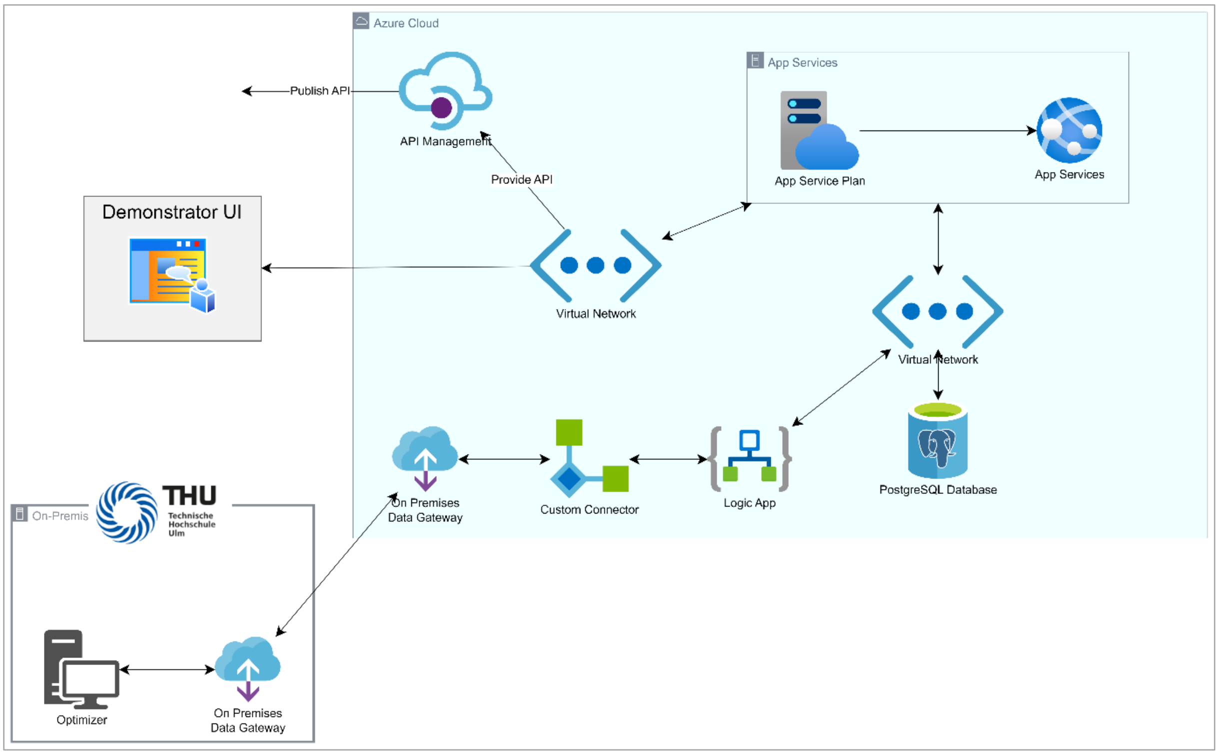


Figure 7: Technical implementation demonstrator

3.3 Interfaces

The demonstrator is provided as a "Bid Congestion Management" (BCM) module in the form of a service-oriented web API. This backend implementation provides interfaces for the relevant partners and coordinates communication for the use case mentioned.

The interfaces are implemented via current technologies as REST endpoints with JSON exchange format. The endpoints are secured with authentication and authorization in accordance with data transmission security requirements.

In the demonstrator, a web interface allows the user to control the operation of the BCM with the data received via the interfaces. The BCM module implements the aforementioned requirements of Use Case 1 and the associated web interface with map display is provided.

3.3.1 Overview of the interfaces

The interfaces required for the implementation of Use Case 1 were identified and defined for the respective platforms to be connected.

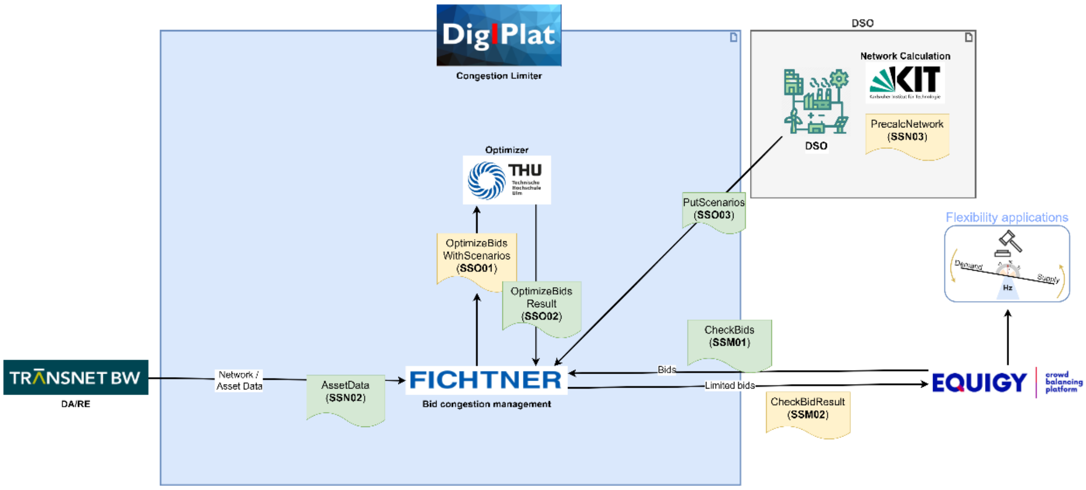


Figure 8: Overview of the BCM interfaces

Designation	Brief description
SSM01 - CheckBids	The BCM provides a suitable interface that allows the market platforms to provide the bids placed after gate closure with the information on the assets within the bids In the demonstrator, the flexibility platforms are represented by the Crowd Balancing Platform (CBP).
SSM02 - CheckBidsResult	The BCM sends the filtered / restricted bids back to the associated flexibility platform (CBP in the demonstrator). The flexibility platform provides a suitable interface for receiving the bids.
SSO01 - OptimizeBidWithScenarios	Transfer of bid information including system identifiers/system information of a defined distribution grid to the optimization function.
SSO02 - OptimizeBidsResult	Transfer of the optimization results in the form of permissible or non-permissible variants or schedules of the given bids of a distribution grid.
SSO03 - PutScenarios	Receipt of various precalculated load situations on the grid load model of a distribution grid in the form of PTDF and VTDF matrices as well as the reference data for the observation period.
SSN01 - PutNetworkModel	Receiving a network model in the form of a node/edge model with electrotechnical properties

	of the nodes/edges as a basis for modelling the network behaviour.
SSN02 - AssetData	Receipt of system data for defined distribution grids with identifiers (Ids) and technical properties. Generally provided by the distribution grid operator or its systems. For optimization within a distribution grid, information is required on which real systems can be used for a bid and which properties these systems have. If the properties of the systems of a bid are already known (e.g. through the computable grid model), this interface can be dispensed with.
SSN03 - PrecalcNetwork	Outgoing interface to precalculate a grid load model based on the infrastructure data of the grid model and the expected generation and consumption situation (day type).

In coordination with the research partners, the demonstrator implements the following interfaces:

- SSM01 - CheckBids
- SSO01 - OptimizeBidsWithScenarios
- SSO02 - OptimizeBidsResult
- SSO03 - PutScenarios
- SSN01 - PutNetworkModel
- SSN02 - AssetData

3.3.2 SSM01 - CheckBids

This interface is operated by the flexibility platforms, which can transfer the complete list of bids received to the demonstrator after gate closure in accordance with Use Case 1.

The aim of the interface is to receive the bids from the flexibility platform with the simultaneous task of checking the transmitted bid list for technical feasibility in the distribution grid and finding a more economically favourable solution with simultaneous technical feasibility.

In order to define the requirements for the structures, formats and content of the bid list, we consider the selected integration platform CBP (Crowd Balancing Platform) of APG/Equigy in Use Case 1. This Austrian platform serves as an integration system between any flexibility providers and any balancing energy markets. It is primarily used on the Austrian market.

CBP defines the document structures "ReserveBidDocument" (ENTSO-E:[2]) for the exchange of bids in accordance with the European standard (ENTSO-E:[1]). The formats used in the CBP are implemented in JSON (JavaScript Object Notation) syntax - in extension of the ENTSO-E specifications. The platform's interface endpoints follow the RESTful (Representational State Transfer [3]) architecture standard.

The use case sets out a number of requirements for the list of bids. These are

- Network location of the installation of the bid in the form of a unique identifier.

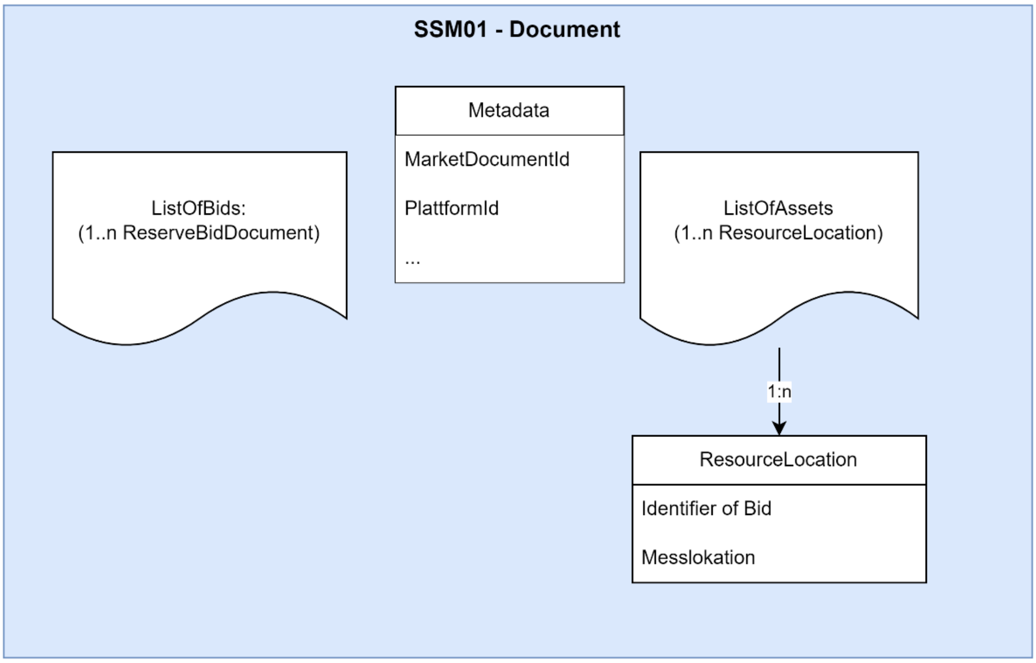
- Output (MW)
- Price (€/MWh)
- Associated balancing group area or/and distribution grid

Document description for the interface

Bids from the Flex platform CBP are received as a list of extended bid structures of the ReserveBidDocument type (for a description, see APG-CBP_ImplementationGuide_v1.3, section 5.3.2). For the implementation of Use Case 1 in DigIPlat, it is necessary to extend these bids to such an extent that at least the information required for Use Case 1 is available. The bid documents to be transmitted are supplemented by the location information of the installation/installations of a bid. The location information represents the grid connection point. The metering location at the grid connection point is used as a unique identifier for the implementation.

The balancing group area is passed on via the information in the "ReserveBidDocument" document. The distribution grid is determined by BCM from the metering locations of the installations.

Document elements



Description SSM01 Document:

Element	Description	O/M	
ListOfBids		M	
Array [ReserveBidDocument]	All bids that remain after Gate Closure. Each Bid includes all bidTimeSeries entries of the bids		
ListOfAssets [ResourceLocation]	Separated list of all assets from all bids.	M	
BidId [ID of bid references]	Identifier for a single bid from one entry in bidTimeSeries (from		

	ReserveBidDocument) for each ReserveBidDocument		
AssetIdentifier [meteringPointId]	Unique Identifier of the asset within the market used within the bid.		
Metadata			
MarketDocumentId	Identifier of flexibility platform for this document		
PlatformId	Identifier of sending platform given from Congestion Limiter upon platform registration process		

The metering point number and bid number are contained in the list of assets (ListOfAssets). The list is part of every bid.

Within the ReserveBidDocument, the time slice is defined for each defined bidTimeSeries in the "seriesPeriod" structure and the bid information is defined in "bidPoint". Data points relevant for Use Case 1 within the BCM and their units are included:

- quantityMeasurementUnit: MW
- currencyUnitName: EUR
- priceMeasureUnit: MWH
- energyPriceMeasureUnit: MWH
- flowDirection: UP (delivery) / DOWN
- seriesPeriod.timeInterval: TimeWithTimeZone
- seriesPeriod.resolution: Duration (PT4H / PT15M)
- bidPoint.quantity: Capacity without sign
- bidPoint.priceAmount: (Optional) Capacity Price, max 2 decimal places
- bidPoint.energyPriceAmount Energy Price, max 2 decimal places

Return:

Element	Description	O/M	
		M	

The standard ENTSO-E "AcknowledgementDocument" is used for the return.

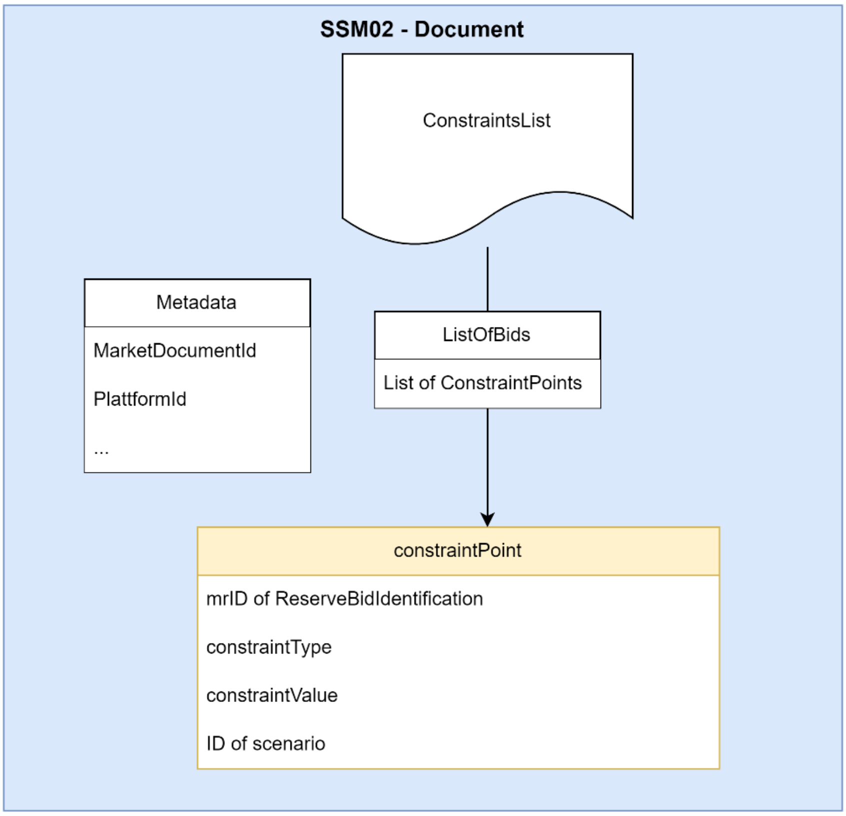
3.3.3 SSM02 - CheckBidsResult

This interface must be provided by the flexibility platform so that the results of the request made with CheckBids can be returned to the platform. This interface sends back the bid restrictions determined for the bids submitted via SSM01. The returned information is formed from the optimization process for the load distribution of the distribution grid. A new merit order list is not specified directly. However, the associated constraints represent secondary conditions for the formation of a new merit order list, which can be taken into account in the auction under consideration in terms of grid and cost optimization

The possible restrictions of the bids are defined as constraintTypes:

- PowerLimit
    - Value of the maximum flexibility output that is possible in the distribution grid without grid restrictions. ConstraintValue is then the maximum possible output. The unit is MW.
- DSOFeasability
    - Information on whether the bid power is possible at the selected time in a grid-compatible manner. True/False field. If not feasible due to network restrictions, this restriction is set to the constraintValue value "True".

Document description for the interface



Description SSM02 Document

Element	Description	O/M
ConstraintsList		
ListOfBids: Array [ReserveBidDocument	All bids that remain after Gate Closure. Each Bid includes all bitTimeSeries entries of the bids	M
ListofConstraintPoints Array [ConstraintPoint]	List of ContraintPoints for each single Bid submitted.	
ConstraintPoint	Defining specific constraint types for the market bids extracted from the optimization and in case	

	where multiple assets are used inside a single bid, aggregation of results might be needed.	
Metadata		
MarketDocumentId	Identifier of flexibility platform for this document	
PlatformId	Identifier of sending platform given from Congestion Limiter upon platform registration process	

3.3.4 SSO01 - OptimizeBidWithScenarios

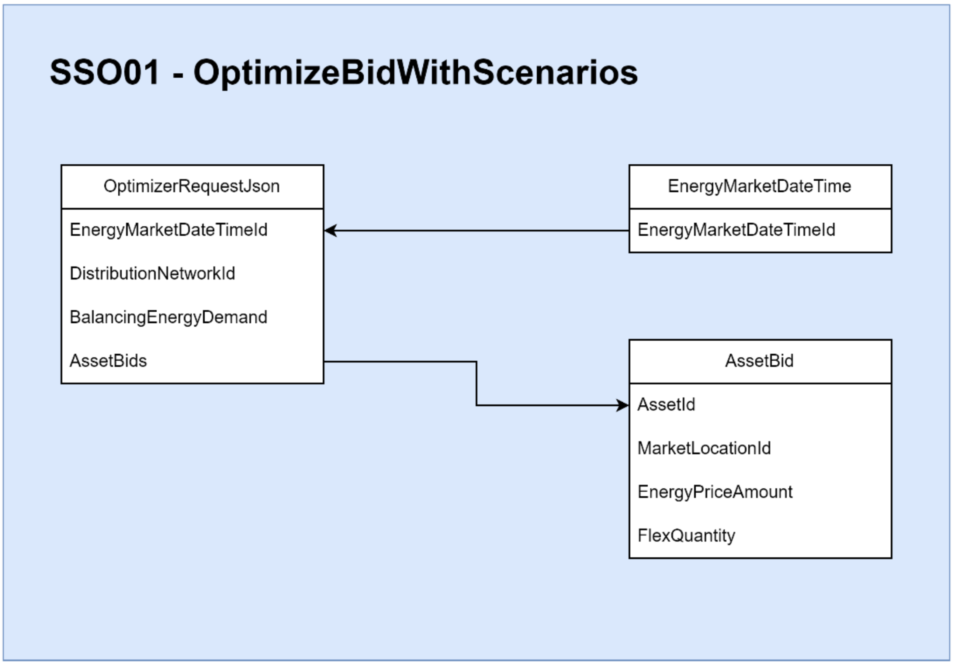
The bid data provided for the optimizer must relate precisely to a system in the distribution grid. The demonstrator examines the effects that the aggregation of bids has on the process. For the implementation of the demonstrator, it is sufficient to assume that a "bid" that is examined within Use Case 1 originates from exactly one installation. A proposal for the decomposition of aggregated bids is set out in the "Data and formats" section.

There are 2 types of optimization available in the Optimizer for transferring the bids to be optimized.

- Optimization 1: The first optimizes the output of the individual bids in order to achieve maximum total output at the lowest price from the distribution grid to be optimized without causing grid congestion.

- Optimization 2: The second optimizes the quantity of bids made available in such a way that a specified call-off capacity is achieved at the lowest price without causing grid congestion.

Document description for the interface



As can be seen from Table n, the two different optimization algorithms are distinguished by the fact that the "BalancingEnergyDemand" field is either included or omitted.

Description SSO01 Document:

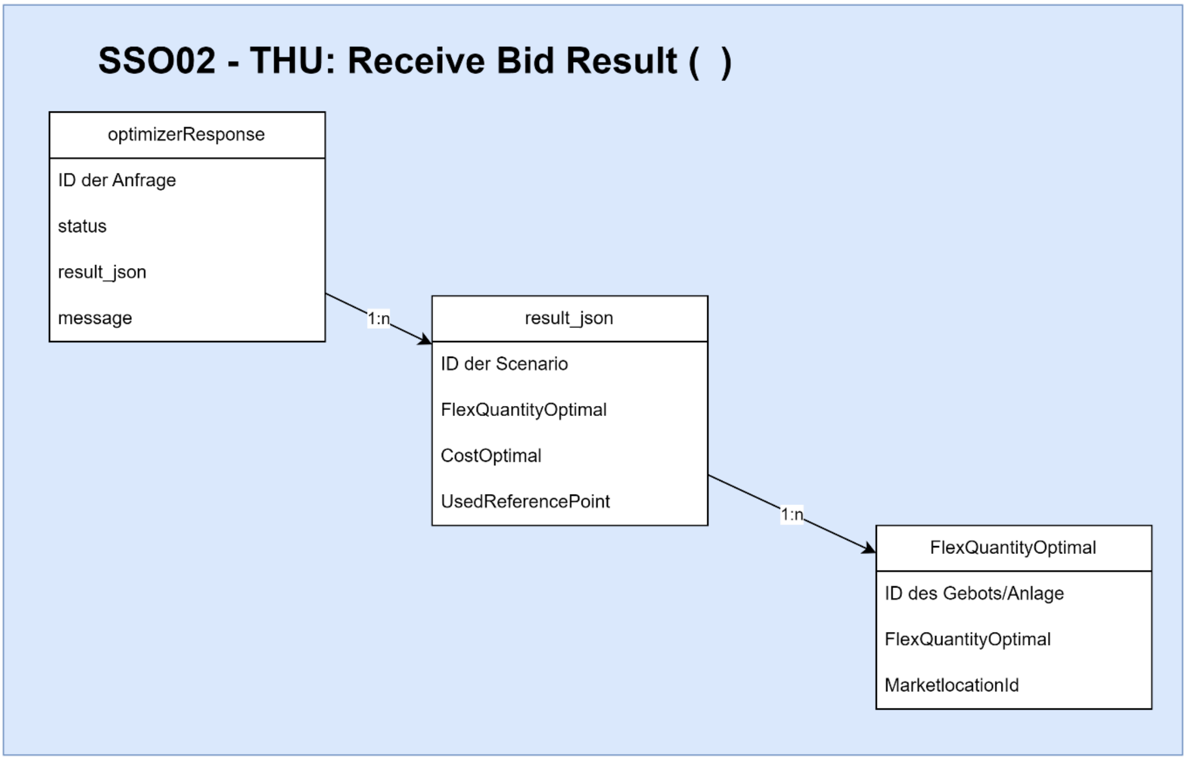
Element	Description	O/M
EnergyMarketDateTimeId	Identifier for the available EnergyMarketDateTimes for the DistributionNetwork.	M
DistributionNetworkId:	Identifier for the Distribution Network to do the optimization on.	M
BalancingEnergyDemand	Optional Parameter for indicating the mode of optimization. If given, then optimizer will try to match the given demand with the cheapest feasible solution. Unit is kW (kilowatts).	O
AssetBids Array of AssetBid Objects	List of Bids with single asset. (One asset per "Bid")	M
AssetBid		
MarketLocationId	Unique identifier of asset of the bid. This should match the identifier of the network coupling points on the network model.	M
EnergyPriceAmount	The energy price in ct/kW	M
FlexQuantity	The bidded flexibility quantity to optimize for. Unit is kW.	M

As it is assumed that the optimization process is an asynchronous process, the optimizer returns a status message directly after successfully receiving the SSO01 request with an identification of the recorded optimization job. The response consists of:

- Field "id_": Identification of the optimization job
- Status" field: if successfully added, the value "queued", which confirms that the optimization job has been added to the queue.

3.3.5 SSO02 - OptimizeBidsResult

Once the optimization process has been successfully started and completed (see dynamic description), the optimization results are sent back in the form of the following structure:



Description SSO2 document.

Element	Description	O/M
OptimizerResponse		
status	Results status of optimizing process. possible return values are: o "uninitialized" o "queued" o "running" o "failed_infeasible_or_unbound" o "failed_pre_solve_checks" o "error" o "success"	**M**
message	Text message to the return status.	**M**
result_json	Datastructure in JSON notation for the results of the optimizer run.	**M**
Result_json		
OptimizerRequestId	Identification of the Optimizer Request sent from BCM to optimizer.	M

	Optimized total costs of the requested and optimized bid combination.	M
UsedReferencePoint	Sensitivity matrix used by the optimizer as an approximation point for the load situation in the distribution grid.	O
FlexQuantityOptimals Array of FlexQuantityOptimals	List of calculated optimal flexibility for technical bids.	M
FlexQuantityOptimal	Flexibility with which the optimum is achieved without grid congestions.	
MarketLocationId	Unique identifier of asset of the bid. This should match the identifier of the network coupling points on the network model.	M
FlexQuantityOptimal	The bidded flexibility quantity to optimize for. Unit is kW.	M

3.3.6 SSO03 - PutScenarios

Transfer/provision of various pre-calculated load situations on the grid model of a distribution grid in the form of PTDF and VTDF matrices for the period under consideration. The interface goes in the direction of the optimizer and can be based on standard formats for grid calculation software (Powerfactory, Panda Power, ...) or define generic table structures.

This interface is not implemented in the demonstrator. The optimizer has been provided with the network models used in the demonstrator once and has integrated them statically. The network model to be used is identified via the unique identifier from the demonstrator.

3.3.7 SSN01 - PutNetworkModel

This interface is used cyclically within the process as required to store the calculation models for the load calculations for certain day types in the system.

This includes the sensitivity matrices, information on the loads and voltages of the network elements and meta-information on the day type and load points (see deliverable for Task 4.3).

The interface was defined in the BCM system, but not implemented as an interface. The NetworkModel data was imported directly into the BCM system database (see chapter 3.4.1 for a description of the data structures).

3.3.8 SSN02 - AssetData

Reading system data for a defined distribution grid. The system data must be assignable to the systems of the bids via identifiable properties (IDs).

Infrastructure data is typically provided by the DSO or the flexibility provider directly via a flexibility platform such as CBP.

Infrastructure data of the installations for use case 1 can be provided by the Da/Re platform. The infrastructure information is available in the form of XML documents of the BDEW master data messages in version 1.1 (see[4]).

The grid load models already take into account the loads or feed-ins at the connection points in summary form at the connection point. Details at system level are provided in this interface.

3.3.9 SSN03 - PrecalcNetwork

This interface can be used to initiate the pre-calculation of a grid model by the DSO if required internally. The DSO has data sovereignty over the infrastructure of the distribution grid and therefore also the technical basis for the grid model calculation. The DSO is responsible for the characteristics and usage cycles of these pre-calculations.

The evaluation of possible interfaces has shown that it is not feasible to pass on the detailed data of a distribution grid to third parties such as the BCM due to data sovereignty and the sensitivity of this data. For this reason, BCM has not implemented a separate interface for this purpose

If the DSO has carried out a preliminary calculation of its grid models, it can transmit these to the BCM as described in the section 3.3.7.

3.4 Data provisioning

3.4.1 Data model

For the field test of Use Case 1, various data from the systems to be integrated must be merged and processed together. As can be seen from the interfaces already described, these are as follows:

- Distribution grid model
- Calculation models distribution grid
- Bids from the flexibility platforms

The network model is transferred once to the internal data model in the demonstrator and stored as a combination of distribution network (DistributionNetwork: name and geographical location) and network elements (NetworkElement: lines and nodes).

The calculation model is transferred to the internal data model in the demonstrator via an interface or once and is available as a table group of the sensitivity matrices with the load situation used for the matrices. The tables used contain the following information:

- BaseScenario: Meta information on the model
    - Day type: typified load situation on a specific day and time
    - Load point: Percentage value (0 ... 100) of the load situation of the day type for which the sensitivity matrices were precalculated (see results from Task 4.3).
- NetworkModel: Sensitivity matrices between nodes/nodes and nodes/edges
- Loads & voltages: assumed basic values of the loads and voltages for the load point of the sensitivity matrices

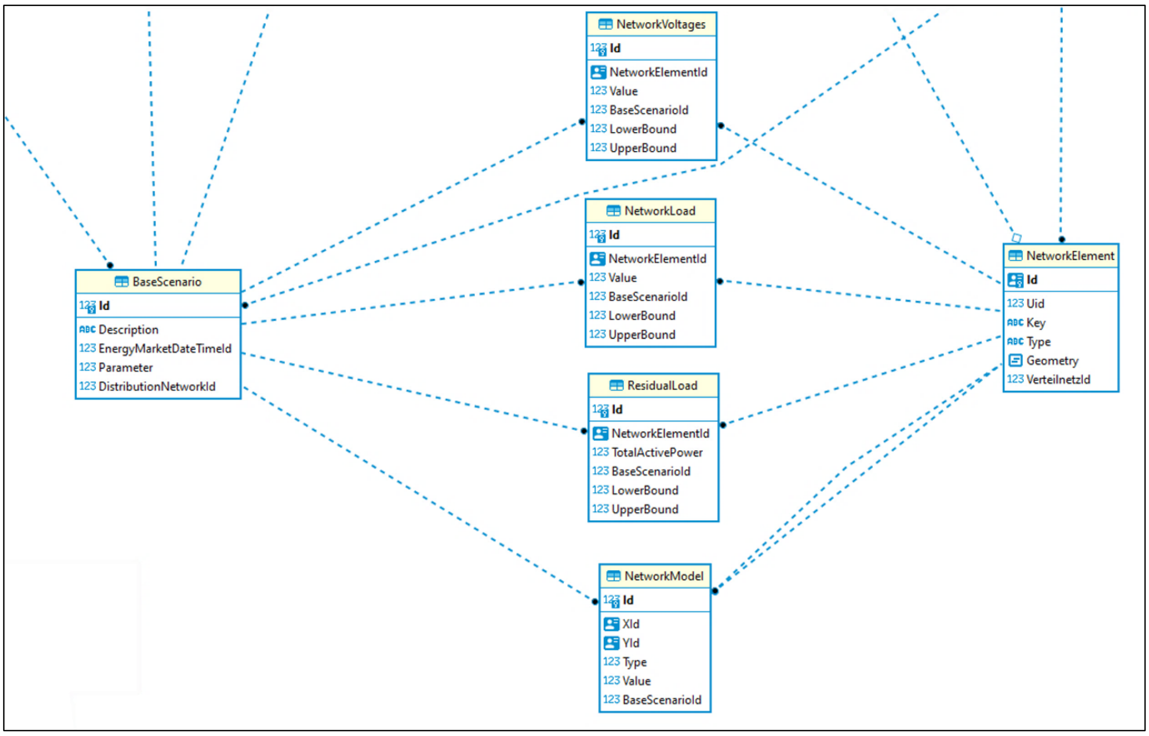


Figure 9: BCM tables for network model

The bids for the demonstrator / BCM are stored in a further group of tables, which corresponds to the standardized bid format of the flexibility platform with the specified extension to include the performance data of the systems in the bid. The following information is stored here:

- Bid document of the flexibility platform
    - The ENTSO-E "ReserveBidDocument" format
    - Assigned to a time (BidTimeSeries, TimeInterval: correlation to day type), bid quantity and bid price (BidPoint)
    - Further information about the offer
- List of assets (BidAssets)
    - List of the systems planned in this bid and your planned capacity offered.

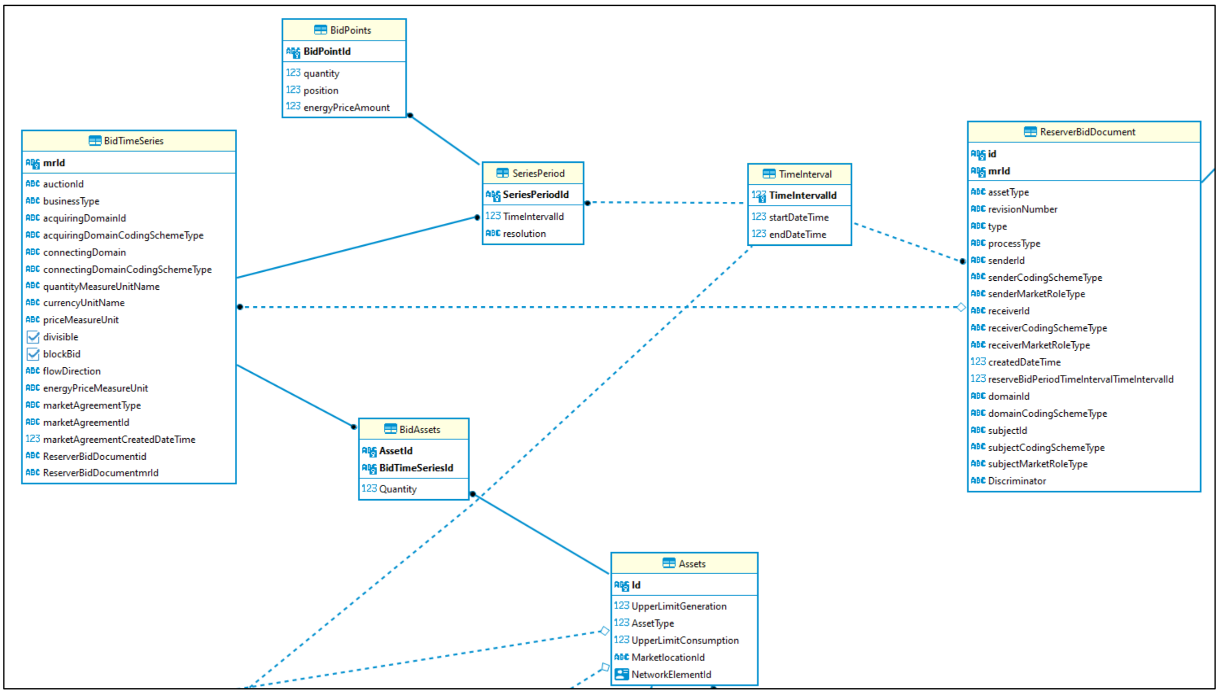


Figure 10: data model for flexibility bids

3.4.2 Processing of bids

In order for the effects of Use Case 1 to be presented in the field test by the demonstrator, simulated bidding constellations had to be set up for the defined day types and the distribution grid and made available in the demonstrator.

The approach is based on allowing bid packages of different sizes to have an effect on the distribution grid in order to be able to assess the effects of bid optimization on flexibility bids and on market activity that is beneficial to the distribution grid.

For the bid synthesis, it is assumed that all households and grid connection points have exemplary feed-in systems (e.g. photovoltaics or storage) and, based on this, flexibility for feed-in on demand. Overall, the following bidding scenarios were created:

- Medium Level Bids
    - Average utilization due to feed-in flexibilities that only overload the network on critical day types.
    - Selection of individual feed points.
    - approx. 0.61 MW total output

- Critical Level Bids
    - Critical utilization that overloads the network even on less critical day types.
    - Selection of almost all feed-in points.
    - approx. 2.32 MW total output
- All PV bidded
    - Maximum possible flexible feed-in quantity that is also offered on the market.
    - Selection of all possible feed-in points.
    - approx. 2.34 MW total output

For the selection of the individual feed-in points, nodes were determined that are located on the critical paths of the network in order to provoke an overload situation in the distribution grid even with fewer bids.

Aggregated market bids were then compiled from the individual flexibilities at the feed-in points/nodes, which were fed into the system via the SSM01 interface.

The individual market bids were then summarized in bid scenarios. These scenarios therefore represent different bid variants on the markets.

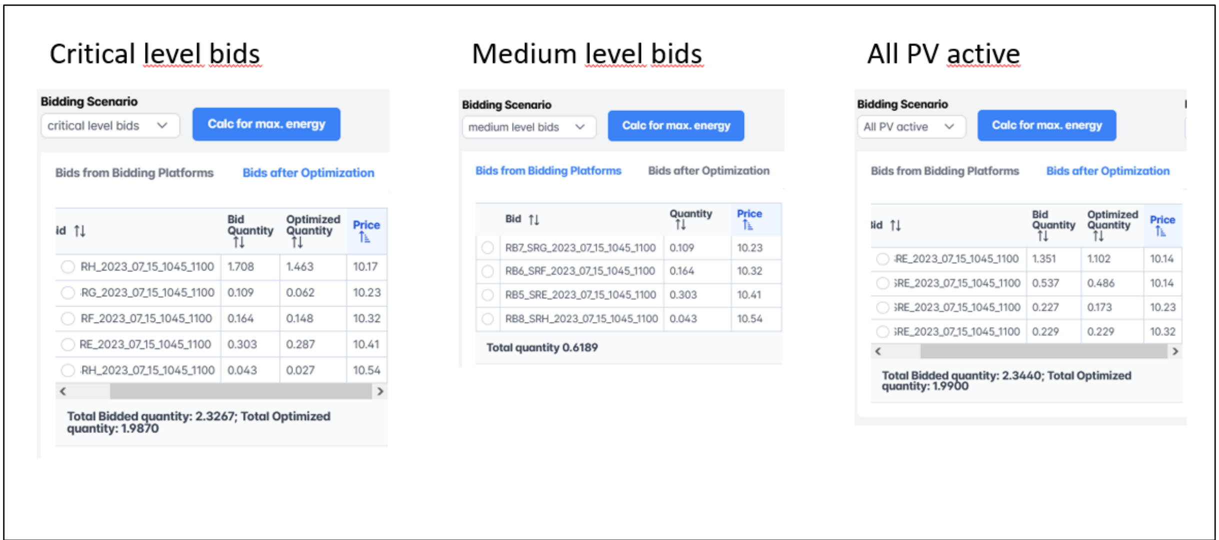


Figure11 : Overview of the synthesized bidding scenarios

3.5 User interface

In order to create the possibility of playing through various scenarios using the demonstrator, a configurable interface was also created in the research project and made available to the research partners (https://angularincloud.azurewebsites.net).

The aim of the interface is to provide a clear presentation of the effects of use case 1 in various predefined scenarios. For this purpose, the data structures presented in chapter 3.3 were set up in a relational database and made available to the user as a website via the demonstrator backend application.

The structure of the surface is divided into:

- Selection options for different day types
- Selection option for distribution grid
- Selection option for various bid constellations as a simulation of bid requests from flexibility platforms (bid scenarios)
- Presentation of the bids of the selected bidding scenario
- Map display of the lines and grid connection points of the selected distribution grid
- Level switching of the map for the use case steps under consideration:
    - Forecasted load situation of the selected day type (forecast)
    - Forecast including the flexibilities of the selected bidding scenarios
    - Forecast including grid and price-optimized use of flexibility

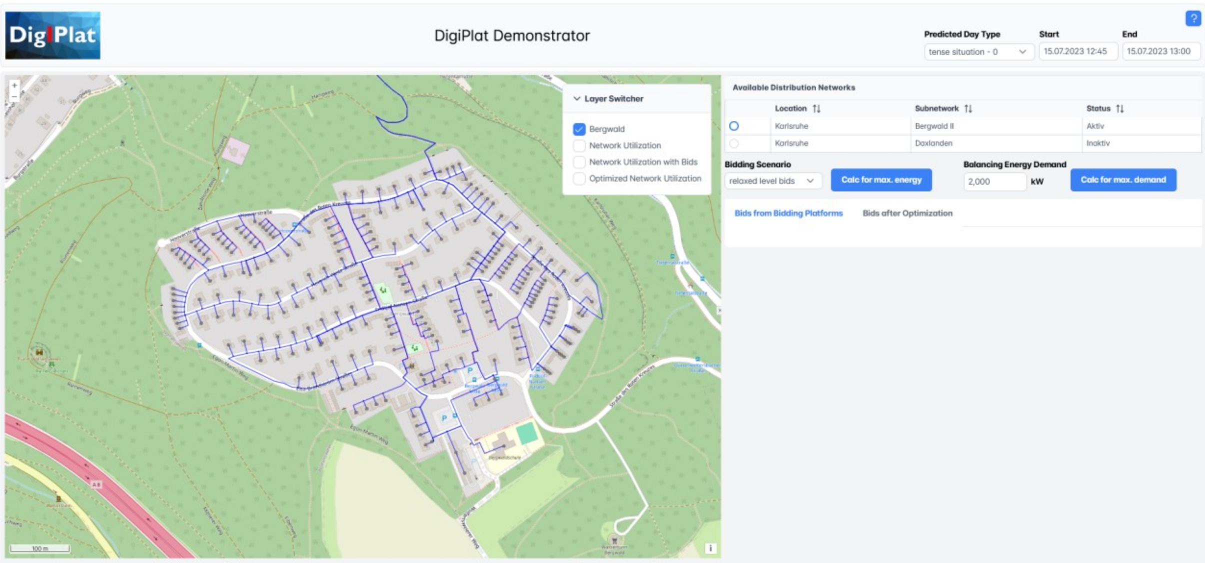


Figure12 : Surface of the demonstrator

4 Results and findings

4.1 System and stakeholders

In this chapter, we look at the results and insights gained from the integration of the connected systems, their data and interfaces.

4.1.1 Crowd Balancing Platform (Equigy)

Scope of integration

As a representative of a platform that can record flexibility bids and provide markets, the aim was to integrate both the standardized bidding model of this platform and the data and interface concept. The interface and data structures were modelled in collaboration with the project partners, but the developer (Equigy) was unable to connect a test system to the real system as part of the research project.

Data structures

The data structures for bids operated by the platform are derived from the ENTSO-E reference model in version 5. The reference model is in constant development, so we must assume that an implementation of an integration system such as the demonstrator must be able to work with the different versions of the reference model for different flexibility platforms in the future.

Technical connection

Interface calls between the flexibility platform and the demonstrator can always be synchronous (waiting for processing) or asynchronous. An asynchronous call structure was selected for the use case. This increases the complexity of the interface and the management of the corresponding interface calls on both sides. IT solutions for these requirements exist in established standards and still need to be included in these if the demonstrator is continued.

4.1.2 Distribution system operator (KIT)

Scope of integration

As no distribution system operator took part in the research project, an alternative for the integration to a DSO was required. This was provided by the KIT. In this role, KIT prepared and provided the electricity distribution grid of the selected example area "Bergwald" near Karlsruhe.

The network model was provided in the geographic standard GeoJSON and could be integrated very well into the database and the data model of the demonstrator.

A standardized procedure for the sensitivity matrices was used to provide the calculation model (see deliverable from Task 4.3), which were also simply incorporated into the demonstrator.

4.1.3 Da/Re (TransnetBW)

Scope of integration

The Da/Re platform was selected to provide flexibility as well as system data from distribution grids and transmission grids

Findings

The analysis of the platform's data structures has shown that basic integration into the demonstrator is possible and what other system data can be provided. The evaluation of this additional system data has shown that it is not necessary to access this data within Use Case 1. Therefore, there was no compelling need for a connection in the research project and this was not realized

4.1.4 Optimizer (THU)

Scope of the integration

In order to connect the optimizer to the demonstrator / BCM, the interface SSO01 - OptimizeBidsWithScenarios (see chapter 3.3.4) was fully implemented in the field test and integrated into the demonstrator interface

The interface was implemented as an asynchronous interface with a pull principle in anticipation of the previously unknown computing time for the optimization run. Sequence of the interface: After calling SSO01, the optimizer supplies an identifier with which the demonstrator / BCM queries the status every 5 seconds and reads out the results when the optimization has been completed successfully.

Findings

The provision of an interface within the Optimizer was quick and easy to accomplish. The corresponding connection to the cloud infrastructure of the demonstrator / BCM system required a local installation of a connection component (on-premise data gateway) and registration in the Microsoft cloud environment. Communication was then handled completely securely via the infrastructure provided. The security in the form of authentication and further encryption on the part of the optimizer through the technology used (Python) was tested and is basically possible in accordance with the requirements for secure operation. Implementation in work package TP 4.2 was dispensed with.

4.2 Findings from network calculation

When integrating Use Case 1 into the demonstrator / BCM, the load calculation had to be calculated with the full load (100% of the bid loads) to represent the grid load situation assuming that all bids in the distribution grid under consideration are activated. The demonstrator performs this calculation internally and is based on the specified sensitivity matrices from Task 4.3. The matrix multiplications used for this do not represent a relevant hurdle for the calculation in the optimizer and are performed in the demonstrator in real time on the distribution grid under consideration. For larger grids or for runtime optimization, a one-off pre-calculation can also take place in future, as the load situation no longer changes after receipt of the market bids (therefore also after gate closure of the bidding process).

The integration of the THU optimizer (see section 4.3 for how it works) was tested with regard to runtime. The final version of the optimizer is able to complete the optimization of the distribution grid under consideration in less than one second. Due to the selected asynchronous technology of the call with cyclic pull procedure for the results, an optimization process is completed after 10-12 seconds in the demonstrator/BCM. Without changing the procedure, this time can be reduced to < 5 seconds by setting the pull query to a cycle of 1 second, for example.

The selected calculation method for the load situations cannot do without a forecast model for a day type. This represents the typical expected load situation at the time of service delivery to which a bidding procedure refers. Typically, different times of day, weekdays / weekends. Seasons/seasonal characteristics and special events (Christmas/New Year etc.) are the parameters that determine different forecasts for a particular grid. In addition to the sensitivity matrices, this forecast model must therefore also be known in order to be able to make an associated load statement on the grid with the deviations arising from the flexibilities offered. The demonstrator uses this information for visualization, the optimizer for calculating the load status and optimizing for price and avoiding grid congestion.

The accuracy of the approximate calculation of the grid load situations with sensitivity matrices was carried out in the demonstrator and, according to our findings, was within the expected tolerance range compared to an iterative load flow calculation. Detailed results can be found in Task 4.3.

Excursus: Different bids at a grid connection point

To approximate the consideration of the effects of market bids on distribution grids, it was considered sufficient for Use Case 1 that the load acting on the grid as a "visible load" is sufficient for grid calculation and optimization.

If different system types (e.g. photovoltaic, heat pump, storage, ...) are offered in flexibilities, the chosen approach of a "visible load" does not prevent a representation and differentiation in the interface, should different system types occur behind a grid connection point in different bids.

However, this approach prevents different offers from different operators/aggregators behind a grid connection point from being optimized for price, as different prices behind a grid connection point are not mapped. A possible solution for this would be to expand the sensitivity matrices to include the plants/units behind a grid connection point and to assign the grid connection points/measuring location to plant-specific market locations. These market locations are then themselves part of the offers as before. This approach can be examined for practicability in a further research project.

4.3 Findings from visualizations

Map display

The visualization was supported in the demonstrator with the help of the well-known "OpenLayers" framework. This allows the modular compilation of map content to be displayed and can be used very flexibly. OpenLayers is a quasi-standard for the integration of map content on user web clients.

For the visualization of the load situations of the lines, it has been shown that load-dependent colouring clearly indicates the load on lines and nodes.

However, there is a limitation if the routes of different pipelines are set exactly identically geographically. These then lie directly on top of each other on the map and run identically. In this case, the representation of one line overlaps the underlying representation of another line. There is therefore a risk that the visual information of the underlying line is lost in the visualization. A solution for this was not implemented in the demonstrator. Approaches could be that the display sequence draws the critical elements in the display sequence "on top", a transparency is used, or that lines lying on top of each other are shifted slightly parallel to each other geographically (practicable, as the geographically correct position is not relevant for the use case).

The grid connection points are visualized at specific points and interact with the bidding systems on the interface by means of marker colours when a system is selected from a bid. There is no differentiation by system type in the selected approach of the demonstrator interface. This could help to improve the representation in the demonstrator and the understanding of the use case.

Factual data presentation

The approach of standardized values (1.00 +/- 5%; 0 ... 100%) for voltages and loads chosen for the grid calculation is not intuitively understandable for an end user display. It would be conceivable to display the deviation of the voltage setpoint from 240V either as a percentage (+/- 5% of the setpoint) or directly in the determined voltage in volts. However, the calculation model does not provide any absolute voltage values, as these are not necessary for the load calculation. The corresponding data would have to be supplied and integrated in the data and display model by the distribution grid operator.

No further factual data on the grid elements is required for the use case. However, additional grid information in the view can be helpful for the assessment from the perspective of a distribution grid operator. By using standardized formats and the modular concept of the demonstrator, additional levels and factual data can be easily integrated.

5 Conclusion

As part of the DigIPlat research project, work packages Task 4.1 and Task 4.2 comprehensively analysed and implemented the basic principles and requirements for the specification and practical implementation of a demonstrator for interoperability in the energy market. The demonstrator developed is based on a modern, service-oriented multi-layer architecture that enables the flexible and expandable integration of various service components. By implementing it on the Microsoft Azure cloud infrastructure, a scalable and secure platform was created.

A key result of the study is the successful integration of existing platforms and standards as well as the development of new modules and interfaces. However, technical and organizational challenges were also identified that made it difficult to connect certain platforms directly.

The implementation of the demonstrator, in particular the **Bid Congestion Management (BCM) module**, illustrates how flexibility bids in the energy market can be efficiently processed and optimized in order to avoid grid congestion. The developed interfaces, data models and the integration of sensitivity matrices show the technical feasibility and efficiency of these approaches.

The relevant interfaces and data structures were successfully merged and tested in the field test. The results confirm that the demonstrator enables reliable testing and optimization of flexibility bids while taking grid load into account. In addition, these findings were clearly presented in a user-friendly interface that visualizes various scenarios and their effects on the grid.

In summary, the **DigIPlat project** has **provided key insights into the integration and optimization of decentralized energy markets**. The concepts developed and the demonstrator form a solid basis for future applications and extensions in the area of market platform integration and grid optimization. It is recommended that the knowledge gained be further developed and used as a basis for future research and practical applications in the energy industry.

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