Deliverable 3.3. Definition of multifunctional flexibility use cases

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Executive Summary

This deliverable discusses the potential efficiency gains of interoperable flexibility platforms in the context of Europe's energy transition towards carbon neutrality. While numerous flexibility platforms already exist, they are not yet interoperable, which limits the potential for flexible resources to participate in them. The DigIPlat project - in which the research for this deliverable was conducted - aims to provide measures for implementing standardized digital solutions for the interaction of transnational flexibility markets, as well as new use cases for maximizing the value of flexibility for multiple system services. This deliverable specifies three different use cases regarding the interoperable use of flexibility for balancing, congestion management, and intraday markets. Use Case 1 focuses on the use of balancing energy considering network restrictions, implementing an optimization approach that minimizes balancing energy costs considering possible grid congestion. Use Case 2 proposes procuring balancing capacity (BC) together with additional information to be applicable for RD. Use Case 3 aims to connect Balancing Energy and Continuous Intra-Day Markets. The document concludes that interoperability is essential for realizing the full potential of flexible resources in Europe's energy transition.

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List of abbreviations

aFRR	*automatic frequency restoration reserve*
ALPACA	*Allocation of Cross-zonal Capacity and Procurement of aFRR Cooperation Agreement*
AT	*Austria*
APG	*Austrian Power Grid*
BC	*balancing capacity*
BE	*balancing energy*
BEO	*balancing energy orders*
BSP	*balancing service provider*
BDEW	*Bundesverband der Energie- und Wasserwirtschaft*
CACM	*regulatory framework for capacity allocation and congestion management*
CBA	*cost benefit analysis*
CBMP	*Cross Border Marginal Price*
CHP	*combined heat and power*
CM	*congestion management*
DA	*day ahead*
DACF	*Day-Ahead Congestion Forecast*
DE	*Deutschland*
DigIPlat	*Digital Solutions for Interoperability of Flexibility Platforms*
DR	*demand response, demand response*
DSO	*distribution system operator*
EB	*GL Electricity Balancing Guideline*
EIV	*Einsatzverantwortliche*
ElWOG	*Elektrizitätswirtschafts- und -organisationsgesetz*
EnWG	*Energiewirtschaftsgesetz / German law for electricity and gas supply*
EU	*European Union*
FAT	*Full activation time*
FCR	*frequency containment reserves*
FG	*framework guideline*
FG	*DR Framework Guideline on Demand Response*
FSP	*Flexibility Service Provider*
GCT	*gate closure time*
GOT	*gate opening time*
ID	*intraday*
IDCF	*Intraday Congestion Forecast*
IDM	*intraday market*
IGCC	*International Grid Control Cooperation*
KPI	*Key Performance Indicators*
LFC	*load flow calculation*
MARI	*Manually Activated Reserves Initiative*
mFRR	*manual frequency restoration reserve*
NEMO	*Nominated Electricity Market Operator*
NRA	*national regulatory authority*
PICASSO	*Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation*
RD	*redispatch*
RES	*renewable energy sources, renewable energy sources*
SA	*schedule activation*
SDAC	*single day ahead coupling*
SGU	*Significant Grid Users*
SIDC	*Single Intraday Coupling*
SO	*system operator*
SO Gl	*System Operator Guideline*
SP	*service provider*
ToE	*table of equivalences*
TSO	*transmission system operator*

VC	*voltage control*
WAPP	*Week-Ahead Planning Processes*

Introduction

The goal of this document is to detail the outputs of the DigIplat Work Package (WP) 3.3 “Definition of multifunctional flexibility use cases”. WP 3.3 comprises the specification of high-level use cases for the framework of interoperable flexibility platforms and standardized flexibility in the D-A-CH (Germany, Austria, and Switzerland) region, in the context of Europe's energy transition towards carbon neutrality. The document also describes the specific Key Performance Indicators (KPIs) for each use case to be monitored during the project to assess the technical and economic performance of the demonstrated solution.

The energy transition aims to make Europe carbon-neutral by the middle of the century. This is accompanied not only by further expansion of renewable power generation, but also by the decentralization of energy resources and the coupling of different sectors of the energy system. This transition is encouraging transmission and distribution system operators (TSOs and DSOs) to deploy digital solutions and coordinated market processes that can provide optimal operation of the electricity system. In this context, flexibility platforms have emerged to facilitate or coordinate the trade, dispatch and/or settlement of energy or system services between TSOs/DSOs and Flexibility Service Providers (FSPs). However, standards for flexibility platforms, interoperability, and specifications of flexibility requirements have not yet been defined. These questions are addressed by the research project "Digital Solutions for Interoperability of Flexibility Platforms (DigIPlat)". The main objective of DigIPlat is to identify measures for the implementation, adaptation and knowledge transfer of standardized digital solutions for the interaction of transnational flexibility markets. In addition, it is meant to provide novel use cases for maximizing the value of flexibility for multiple system services. Currently, numerous flexibility platforms already exist (e.g., PICASSO, MARI, DA/RE) and operate at different grid levels [1][2][3]. These platforms, however, are not yet interoperable, i.e., no interface between individual platforms exists yet, thus limiting the potential of flexible resources participating in them. In addition, flexibility products are not yet fully interoperable, that is, they are subject to different technical and product requirements. The main flexibility products at the transmission level - the focus of this document – include balancing and congestion management. These are essentially carried out separately from each other. As a result of this document, new use cases have been defined to enable coordinated trading, dispatching and settlement of these services as well as their coordination with the intraday electricity market. Concisely, three use cases regarding an interoperable use of flexibility for balancing, congestion management, and intraday markets.

First, the status quo is defined. This is followed by a description of Use Case 1, which addresses fundamental challenges and potentials of flexibility platform interoperability. This use case, which is essentially based on the existing regulatory framework, will initially be prioritized in the project process and will serve as the basis for a comprehensive IT technical demonstration and a fundamental economic evaluation. In addition to Use Case 1, two further model use cases have been defined. The actual implementation of Use Case 2 and 3 would require a significant development of the current regulatory framework, therefore will be modelled to evaluate their potential for improving the efficiency of flexibility procurement.

This document will be the basis for the implementation of the framework. Details of use cases on the IT-technical demonstration are specified in WP3.4. The planning of demonstration will be done in WP4 “Implementation of standardized framework and technical testing in a field test”. The development of details for the economic evaluation is done in WP5.

1. Status Quo

1.1. Introduction and Description of Status Quo

The two main flexibility services that this chapter focuses on are balancing energy (BE) and congestion management (CM).

BE is required by the TSO to avoid imbalances in the power grid. Balancing is commonly procured in a market-based way and is organized in two steps, 1) reservation of balancing capacity and 2) procurement and activation of BE based on actual system imbalances. A further distinction is made between positive and negative BE. Positive BE implies an increase in generation or reduction in consumption if the system is short whereas negative BE implies a decrease in generation or an increase in consumption if the system is long [4]. Standard balancing products include frequency containment reserves (FCR), automatic and manual frequency restoration reserves (aFRR and mFRR). In the balancing capacity (BC) auction, the transmission system operators award all bids submitted until the tendered amount of reserve capacity is reached. The awarded BC bids must keep the offered capacity available for activation by the TSO and are commonly settled on a pay-as-bid basis. Since the entry in force of the Balancing Energy Guideline (EB GL), guiding European BE markets, the participation in a BC market for aFRR or mFRR is no longer strictly necessary for an FSP to submit their bid in the BE market. The activation of BE by the control centers of the TSO ("call-offs") is carried out in a cost-optimized manner, as the units of the lowest-priced FSPs are called off first. Pursuant to the EB GL, the activated BE bids are settled pay-as-cleared [5].

In addition to managing energy balancing, CM forms part of TSOs' responsibilities aimed at safeguarding system security. Redispatch (RD) refers to interventions in the generation output of power plants (and, in the future, adjustments of demand) to protect line sections from congestion. That is, power plants upstream of the congestion point are instructed to reduce their feed-in while power plants on the other side of the congestion point must increase their feed-in in order to ensure that the overall generation remains the same [6]. Unlike balancing, there is no common approach to RD procurement in Europe. While the Guideline of Capacity Allocation and Congestion Management (CACM) requires TSOs to procure RD in a market-based way, derogations may apply if sufficient competition cannot be secured and the potential for gaming is high [7]. For instance, the so-called RD 2.0 regime for CM is to be applied in Germany since October 2021. It allows the TSO to request generation adjustment (incl. Renewable Energy (RE) and combined heat and pump (CHP) plants), storage facilities of 100kW and above [8]. As a result of cost-based CM, plants cannot earn any additional revenue by participating in CM. Meanwhile, the German TSOs are currently developing a complementary CM regime, known as RD 3.0 combining cost-based and market-based procurement of RD [9].

1.2. Scenario Workflow

The use of BE and the implementation of CM measures are both responsibilities of TSOs but are essentially carried out separately. The timeline of gate opening and gate closing of BE as well as CM are illustrated in Figure 1. It covers bid call-offs timing of aFRR and mFRR. Balancing Service Provider (BSPs) submit energy bids for BE begin with the gate-opening day before the delivery date at 9:30am for aFRR, at 10:00am for mFRR respectively. The gate closure of the BE is 25min before the delivery period (in red arrow). Besides, CM can be taken day-ahead, intraday, in real time (in blue arrow).

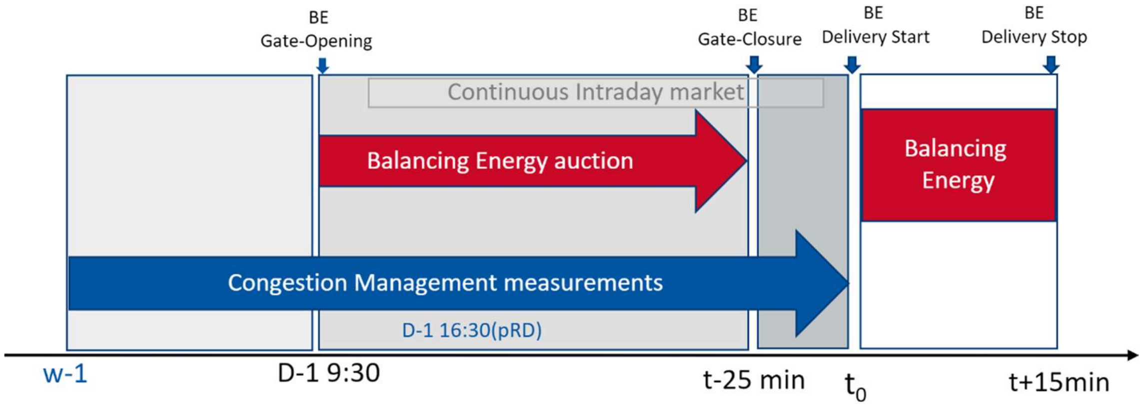

Figure 1: Timeline of procurement and activation of BE and measurements of CM

1.3. Market Design & Regulation

This section introduces current market design and regulation of Balancing Market and Congestion Management at national level namely in Austria, Germany, Switzerland as well as international/EU level.

1.3.1. Balancing Market (National level)

As mentioned in the introduction, in general there are three balancing products FCR, aFRR and mFRR which differ in their activation time and how these products provide balancing service. In addition, the specifications of the tenders and market rules differ from country to country.

FCR Market

In Germany, Austria and in Switzerland the procurement of FCR handled via a primary balancing capacity tender. Currently, FCR is tendered via FCR cooperation, an internet platform jointly operated by the TSOs responsible for the control areas. (See International Balancing Market section) [10].

aFRR Market

In Austria and Germany, aFRR with separate procurement of reserve capacity and balancing energy. The use cases will focus on Balancing Energy market:

- Balancing Energy market for aFRR
  - In Germany and in Austria market design is as below [11]:
    - Gate Opening: d-1 09:30, Gate Closing Time (GCT): T-25 min,
    - Activation time: 5 min
    - Product resolution: 15-mins, 96 gates per day
    - Minimum Maximum bid size: 1MW – 9,999MW
    - Pricing rule/remuneration: pay-as-cleared auction
    - Winner determination: Merit Order
    - Price cap: 15,000 EUR per MWh
    - unit-/portfolio-based bidding: both possible
  - In Switzerland, aFRR with procurement for only balancing energy market [12]:
    - Gate Opening: d-7, GCT: T-25 min,

- Activation time: 5 min
- Product resolution: 15-mins, 96 gates per day
- Minimum Maximum bid size: 5MW-100MW
- Pricing rule/remuneration: pay-as-bid auction
- Winner determination: Merit Order of energy price
- Price cap: 15,000 EUR per MWh
- Unit/portfolio-based bidding: portfolio

mFRR Market

Same as aFRR, mFRR with separate procurement of reserve capacity and balancing energy. The use cases will focus on Balancing Energy market:

- Balancing energy market for mFRR
- In Austria (AT), Germany (DE)[1] and Switzerland (CH) market design is as below [13], [14]:
  - Gate Opening: d-1, GCT: T-25 (AT, DE), T-15(CH)
  - Activation time: 12.5 min (AT, DE)
  - Product resolution: 15-mins, 96 gates per day
  - Minimum Maximum bid size: 1MW- 9,999MW (AT, DE), 5MW- 100 MW (CH)
  - Pricing rule/remuneration: pay-as-cleared/ cross-border marginal pricing (AT, DE), pay-as-bid (CH)
  - Winner determination: Merit Order
  - Price cap: 15,000 EUR per MWh, +/- 15,000 EUR per MWh (CH)
  - Unit-/portfolio-based bidding: both possible

Merit Order Listing (MOL) for aFRR& mFRR

In many countries in Europe, a merit order list determines who gets the acceptance of the bid. This means that bids are ranked by price in ascending order. In case of activation, bids are called until the demand has been met. This means that an expensive bid is less likely to be accepted than a cheaper one [15].

1.3.2. Redispatch (National level)

Congestion Management involves preventive measures to manage the limited transmission capacity available. To avoid congestion, TSOs have the right to take special measures. Unlike balancing, there is no common approach to RD procurement in Europe.

Austria

As of today, the RD procedure in Austria is as follows: After receiving load and generation schedules at 14:30 DA, the TSO conducts load flow calculations. If the TSO expects congestion after this process, a start-up request is sent day-ahead to the contracted plants. The usual duration of activation for redispatch ranges from 4 to 6 hours. In addition, Austria has “grid reserve” (dt.: Netzreserve) tendering, that contracted power plants are kept in standby for potential system support and receive a long-term capacity remuneration [16].

Germany

The Redispatch procedure in Germany currently is as follows: The operational planning process for congestion management starts with the Week-Ahead Planning Processes (WAPP) to decide if plants from the grid reserve (§ 13d EnWG) need to be requested. The main planning processes for redispatch measures (§ 13a EnWG) are the pRD-process which starts at 16:30 h day-ahead and the European DACF

[1] These product characteristics apply in the control areas of the German TSOs and will apply in the Austrian control area as soon as APG accedes to MARI in Q2 2023

(Day-Ahead Congestion Forecast) at 18:00 h day-ahead. Intraday measures are decided for in the IDCF (Intraday Congestion Forecast) at about 00:00 h. Since October 2021 smaller generation and storage units <10 MW and >100 kW (and potentially >30 kW) on all voltage levels and including RES, are obliged to participate in redispatch, which is commonly called Redispatch 2.0 [8] . A German study conducted by E-Bridge in collaboration with TransnetBW and TenneT, comes to the conclusion that the existing, cost-based redispatch is not future-proof if small-scale decentralized flexibilities and storage facilities are to be included into the redispatch regime. Instead, they propose a hybrid form of cost-based redispatch for conventional powerplants that are already used in RD 2.0 and a marked-based approach for all other flexibility resources. Both long-term capacity services and short-term energy bids shall be included in the RD 3.0 mechanism [9].

Cross-border redispatch between AT-DE

The Austrian regulatory authority E-Control and the Bundesnetzagentur have agreed on the introduction of a congestion management scheme for the exchange of electricity at the border between Austria and Germany as from 1 October 2018.

Switzerland

In Switzerland redispatch resources are available through the Swissgrid's (the Swiss TSO) integrated market platform for redispatch and mFRR. Swissgrid introduced their so-called Integrated Market in February 2020 with the aim of increasing the availability of redispatch. They have implemented a combined product that can be used for either national mFRR or redispatch. Furthermore, these products can be combined in a way that they can also be submitted for the MARI platform. The coupling of redispatch within the mFRR market is meant to increase the market liquidity for redispatch. If network congestion is known in advance, it is also treated by reductions in cross-border network capacity in the long term [17].

1.3.3. Balancing Market Initiatives (International/ EU level implementation projects)

FCR Cooperation

The Austrian, Belgian, Dutch, Danish, French, German, Slovenian and Swiss TSOs currently procure their FCR in a common market. The procurement and exchange of FCR is based on daily auctions carried out for the following dispatch day with six 4-h symmetric products which means that BSPs shall procure the same quantity for upward and downward FCR [9]. A common merit order list is being constructed, incorporating all the capacity orders submitted by the BSPs to the respective connecting TSO and finally forwarded by the TSOs to the common FCR platform for clearing [18].

International Grid Control Cooperation (IGCC)

IGCC is the implementation project chosen by ENTSO-E in February 2016 to become the European Platform for the imbalance netting process (IN-Platform) as defined by the guideline on electricity balancing (EB GL Art. 22). In principle, the IGCC performs imbalance netting of aFRR. More specifically, it is based on the communication of the power-frequency control of a single TSO, which enables online balancing of the different power imbalances. The aFRR demand of participating control areas is reported to the aFRR optimization system, which returns a correction signal to the secondary controllers or aFRR optimization systems of each IGCC operational member after each optimization step. In this sense, the counter-activation of aFRR balancing energy is avoided, and therefore the use of aFRR is optimized [19].

PICASSO for international coordination of aFRR and stable system operation

The Platform is the implementation project endorsed by all TSOs through the ENTSO-E Market Committee to establish the European platform for the exchange of balancing energy from frequency restoration reserves with automatic activation or aFRR-Platform [20]. The goal of this project is the creation of a common platform where all submitted BEOs (Balancing Energy Orders) will be gathered along with their respective needs, and they will be cleared through a common merit order list (Article 21 of Regulation 2017/2195/EC). Although the common merit order list is the target solution, many European TSOs apply, now, the pro-rata distribution methodology and, thus, modifications in their national mechanisms are required in order to achieve harmonization and integration of the balancing markets [21].

ALPACA "Allocation of Cross-zonal Capacity and Procurement of aFRR Cooperation Agreement"
ALPACA focuses on enhancing the ability of TSOs to balance the grid by improving access to aFRR and on reducing aFRR procurement cost by creating a common aFRR balancing capacity market. After the accessions to PICASSO have taken place, the overall goal is to further integrate the aFRR balancing markets which will lead to price convergence and to a general increase of liquidity of the TSOs' balancing capacity markets [22].

MARI (Manually Activated Reserve Initiative)
Similar to the PICASSO platform, the MARI platform will gather all submitted BEOs along with their respective needs, and it will use a common merit order list for clearing (Article 20 of Regulation 2017/2195/EC). Contrary to the aFRR activation rule, the common merit order list is already used by the majority of the European TSOs for activating mFRR [23]. However, modifications in national balancing mechanisms are still required for harmonization purposes (e.g., product characteristics).

1.4. Technical Framework

1.4.1. Prequalification conditions

The technical requirements are described in TSO framework documents and to some extent in the national network codes and relate to activation speed & duration which determines how fast and for how long a committed balancing resource shall provide a balancing service, also ramp rate which refers to the minimum power gradient or the rate at which the output or consumption of a unit or a pool can be increased or reduced until full activation [24].

1.4.2. IT-requirements

The IT requirements in Germany are written in "Minimum requirements for the reserve provider's information technology for the provision of control reserve" (status 01/03/2022) document in Regelelleistung home page as following [25]:

1. Basic requirements for aFRR, FCR as well as mFRR (A01-D08)
2. Notification obligation and Verification
3. Self-disclosure and verifications

2. Use Case 1: „Use of Balancing Energy considering network restrictions“

2.1. Introduction and Description of Use Case 1

The use of balancing energy (BE) and the implementation of redispatch measures are both responsibilities of transmission system operators but essentially carried out separately (see above). However, in principle large overlaps are conceivable considering the flexible energy systems used for both tasks, suggesting possible interactions Therefore, an integrated view of the previously separate tasks could be advantageous but requires partial interoperability of the two, previously separate, processes and the flexibility platforms used.

Considering the effects of a Balancing Energy deployment on grid congestion, problems can fundamentally arise in both distribution- and transmission grid: The use of BE changes grid load flows compared to the initial situation and can lead to congestions of individual grid elements.

Therefore, Use Case 1 considers available network capacities for BE deployment, i.e., a BE call of a certain BE bid combination only occurs if it does not lead to a congestion of a TSO or DSO network element. In case of imminent congestion, another bid combination is selected. **The use case thus focuses on preventing BE calls with critical effects on grid congestion**. Compared to the status quo, this requires BE bids to be plant-specific or at least only allows for aggregated bidding within a relevant network area. The use case is illustrated based on aFRR - in principle, the system would also be applicable for mFRR.

The use case implements an optimization approach that minimizes the balancing energy costs considering possible grid congestion. It determines the most cost-efficient combination of the respective BE bids for each 15-minute product period of BE - considering the bids received, different BE demands, and the current grid situation.

Figure 2 depicts the underlying intent of the use case. The BE merit order is composed of BE bids distributed over the respective grid area. In this example, the grid is congested at DSO level in the north of the grid area. Opposed to current practice, BE bids with negative effect on grid congestion are excluded (red) prior to the BE call of a certain amount using the optimization approach mentioned above. This results in some bids from the north not being called, despite a lower bid price. Depending on the amount of the BE call, different effects on load flows can occur. E.g., a high amount of BE bids called from the same side of the congestion can lead to stronger effects on the congestion than a small amount. On the contrary, compensation effects can occur as well in the case of simultaneous BE calls in other grid areas respectively. All these effects will be considered within the optimization. As a result, a merit order with eligible BE bid combinations will be determined, for each possible required BE amount and product period. For a practical implementation, changes in the market design would be necessary, e.g., for the PICASSO platform interacting with TSOs and DSOs [26].

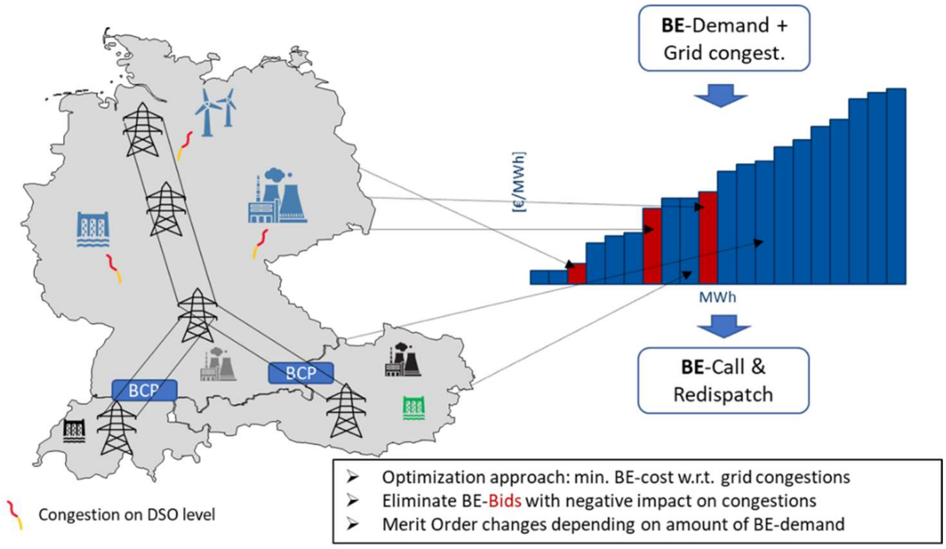

Figure 2: Use of Balancing Energy considering network capacities

In the following, the individual parts of the use case, such as process, framework conditions as well as market design and regulation, are described in detail.

2.2. Scenario Workflow

As previously stated, the core of the use case consists of optimizing the call of balancing energy, considering network congestion. The existing BE market processes, such as gate opening and closing, remain in place, but changes are made to the call-off process. With respect to the existing redispatch process, there are only indirect impacts: if necessary, the amount of redispatch can be reduced if no safety buffers in the grid have to be taken into account for BE load flows. The effects are to be quantified via network modeling.

Figure 3 shows the use case's workflow. Planning and execution of redispatch measures start unchanged one week before delivery date and continue to run in parallel to frequency securing balancing energy operations. For aFRR they start the day before delivery at 9:30 a.m. with the gate-opening of the balancing energy market. Upon BE market gate-closure at t-25min up until t-5min, the previously introduced optimization of received BE bids takes place. Principally optimization can be realized in a two-stage approach. First, each TSO creates an admissible merit order considering subordinate DSOs for each call volume and transmits it to the PICASSO platform. Then, the definition of allowable bid combinations w.r.t. the TSO network could be done by extending the platform itself, as PICASSO already offers a rudimentary approach that specifies allowable load flows between TSO areas.

The optimal result is determined as soon and close to the BE call as possible. It returns a permissible BE bid combination for the required amount of balancing energy. Upon completing the optimization, the most cost-efficient, and grid-serving BE call is made via the currently already used systems (including the PICASSO system). In certain situations, the optimal bid combination w.r.t. preventing grid congestions may lead to an insufficient available BE quantity. In that case, the optimization would select a combination with the least negative congestive effects that amounts to a sufficient BE amount. This issue is further investigated in Use Case 2.

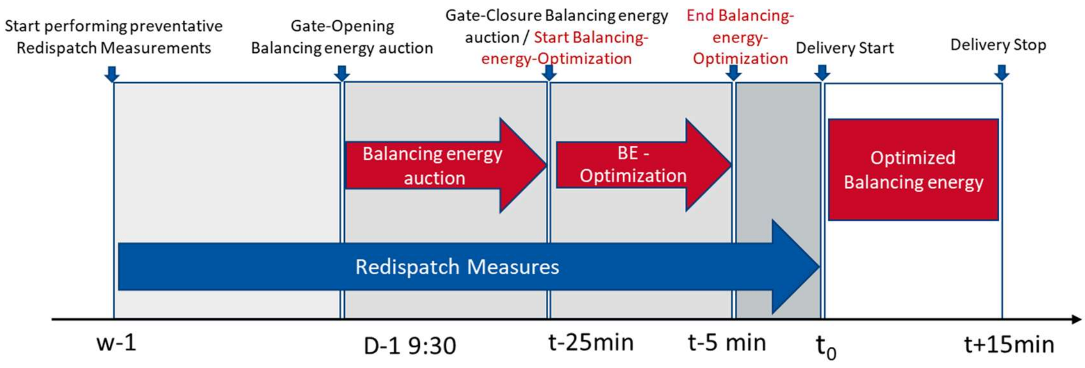

Figure 3: Workflow of Use Case 1

2.3. Modelling

The standardization and harmonization of flexibility platforms is a central goal of the project and is therefore also an important component in the implementation of the use cases. For this purpose, possibilities are being investigated to use flexibility-specific platforms for redispatch or balancing energy for the respective other flexibility as well. In concrete terms, functions such as bid submission and bid filtering are to be implemented at the TSO, DSO or platform level using components of existing platforms. Furthermore, different design options for interoperability will be investigated - How will the described functions be implemented? Combined in one module or distributed over several?

The modeling of the use case includes **the network areas Germany and Austria**. Possibilities for the integration of Switzerland are examined. The focus lies on the integration of national flexibility platforms.

The modeling includes the **transmission as well as the distribution grid level**. The consideration of flexibility platforms for the representation of the distribution grid level is to be examined. Here, **no lower capacity limit is defined** for BE providers considered, as long as their use is economically feasible. In principle, all grid levels will be considered. An approach is being developed that will make it possible to map the distribution grid in sufficient detail, while still considering the privacy of the DSOs.

The **number of plants considered** (BE and redispatch providers) is selected on a scale that allows a representative replication of the D-A(-CH) area.

The modeling includes a comparison of the results with the status quo in order to be able to classify and evaluate them.

2.4. Evaluation

For the development and evaluation of the model, at least but not exclusively, the following metrics will be considered:

- Costs for balancing power
- Costs for (curative) redispatch measures
- Called off balancing energy in MWh

- Executed (curative) redispatch measures in MWh
- Unauthorized frequency deviations in the investigated network area
- Excluded flexibility due to bid elimination in MWh

Furthermore, for the overall social assessment of the use case, the following overarching KPIs are at least, but not exclusively, taken into account:

- Welfare effects
- Distribution effects

2.5. Market Design & Regulation

Since this use case is primarily investigating the avoidance of grid-critical balancing energy calls, the existing structures of the balancing energy market and redispatch (status quo and document "DigIPlat_D3.2-Standardized Flexibility Attributes") will largely remain in place.

In order to enable the grid-serving call-off of balancing energy, **BE provider locations must be included in the BE bids**. Pooling of bids is only possible to a limited extent on a regional basis.

Bids that are inadmissible with regard to grid congestion will not be called and will not receive any compensation.

2.6. Technical Framework

Data Requirements

In the following, the data required - for the execution of the use case scenario - are listed and, if necessary, described with reference to their relevance for the modeling.

<u>Grid Capacities:</u>

Grid capacities are the maximum capacities of relevant grid elements (current limits, voltage limits, stability limits). They serve as the basis of the constraints for the optimization approach.

The first requirement to use transmission capacities efficiently is to calculate the actual available capacity. Within the framework of the network model (KIT), a capacity calculation is first performed, and the load is analyzed.

<u>Load Flows:</u>

The network load in the network area and simulation period under consideration must be taken into account. Since the inclusion of all load flows would go beyond the scope of the calculation, only load flows in relevant network sections are included by means of a suitable methodology.

The methodology to be developed considers how the load flow is distributed in the network and translates a power transaction (economic) into power flows (physical). It thus describes how a power transaction between two nodes affects all grid branches.

<u>Plant Locations:</u>

Plant location refers to the geographical location of the plants/ BE providers and their respective grid entry points. This is required for the modeling in order to evaluate the effects of BE bids on the grid capacities and to be able to map redispatch measures.

Border Coupling Points:

Border coupling points form constraints for the optimization approach in the context of cross-border network capacities. They play an important role in the interconnection of the network areas under consideration.

BE-Bids:

For the optimization of BE retrieval, plant-specific BE bids for aFRR including location information for the period under consideration are required.

BE-Demand:

The demand for aFRR for the period under consideration.

3. Use Case 2: „Coordinated Capacity Procurement“

3.1. Introduction and Description of Use Case 2

The overarching assumption of Use Case 2 is that the future goal of product standardization (as discussed in D3.2 [26]) is to identify potentials to increase the availability of flexibility products for redispatch (RD) and balancing markets. Therefore, Use Case 2 proposes procuring balancing capacity (BC) together with additional information to be applicable for RD.

An identified benefit for the TSO would be that the overall market liquidity would increase as flexibility bids could be used for more than one purpose. Additionally, this could increase the probability of a bid getting accepted. As products are available for more than one market, a broader variety of bids would increase the opportunity to select less costly bids, implying a potential reduction in overall system costs. Furthermore, through the procurement of reserve capacity, there is potential of being able to secure a fixed amount of flexibility in advance. One arising issue, of which the real magnitude and long-term effects are not known at the moment, is the additional costs for the TSO through the resulting reservation payments for RD. In general, we consider two approaches for the implementation of using BC for RD:

I. Examine the impact of integrating BC bids with additional locational information – **BC bids with locational information**
II. Create a common tool that facilitates the opportunity to re-offer unaccepted bids (or only partially accepted bids) in other (subsequent) markets – **Bid forwarding**

I. BC bids with locational information:

The idea of this approach is that balancing capacity bids with additional locational information may also be used for RD. More concretely, it could be an option to conduct the choice of balancing capacity bids considering the expected congestion and its location thus preferring the reservation of the bids in the areas of expected congestion (see Figure 4).

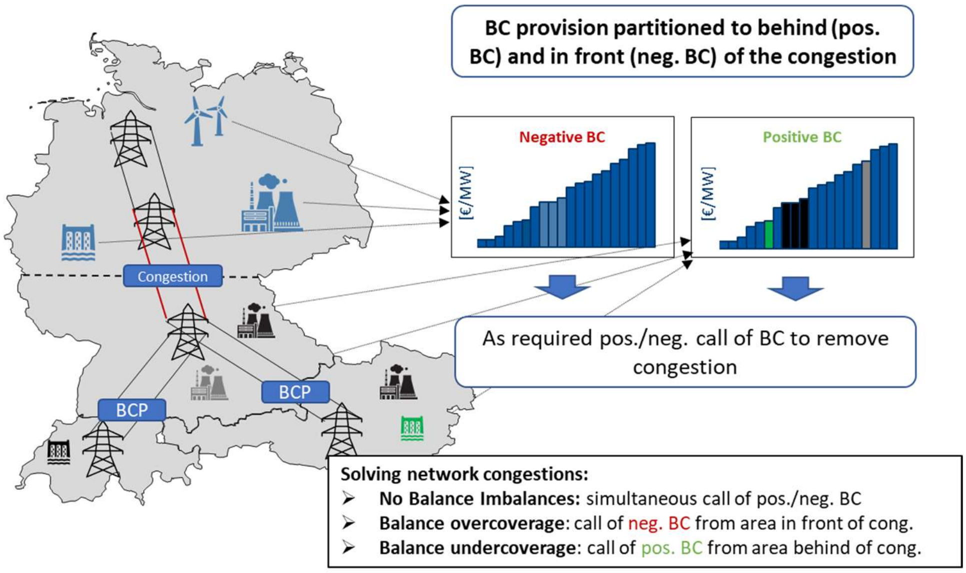

Figure 4: Schematic illustration of reservation of bids dependent on expected congestion

Generally, this approach addresses solving congestion in the following ways:

- If there is no need for balancing capacity, the reserved capacities can either be used for positive or negative redispatch to solve congestion.
- The activation of negative balancing capacity automatically reduces the need for redispatch in the congested area.
- The activation of positive balancing capacity automatically reduces the need for redispatch in the congested area.

The prerequisite is that the product in question fulfils the technical requirements of BC and RD. As the requirements for BC are for now much more restrictive than the requirements for RD, and this is not expected to change in the future, this is assumed to not pose an issue. Another crucial requirement is the additional provision of locational information for BC bids. Hence, we are considering two different scenarios regarding the availability of locational information:

A. Providing locational information is **voluntary**.
B. Providing locational information is **mandatory**.

As for now, locational information does not have to be provided for balancing products, and therefore mandatory provision would require significant interventions of the existing regulation, in the short run, Scenario A is more likely to be implemented. After a transition period, starting from an already implemented voluntary provision of locational information, Scenario B. could be the pursued goal in the long run. However, from an analytical perspective, it is still important to assess the maximum potential impact of introducing such a flexibility product.

Another important question regarding the geographical dependency of redispatch is whether an extended market-clearing approach could be beneficial. Thus, we identified two options for the clearing mechanism design:

1. Clear BC market as usual

2. Clear the BC market by favoring BC bids (with locational information) if available in areas of an expected need for RD[2].

For Option 1., the Merit Order for the BC Market contains common BC bids, as well as BC bids with additional locational information. After the clearing, only accepted bids with locational information can be used to solve congestion. Option 2. is again seen as critical insofar as such a mechanism is not implemented yet and would require a completely new type of market clearing. Furthermore, the intensively discussed issue of remuneration and relating thereto distorted incentives for FSPs arise[3]. Considering the two scenarios together with the two options leads to four different sub-cases of approach I., summarized in Figure 5.

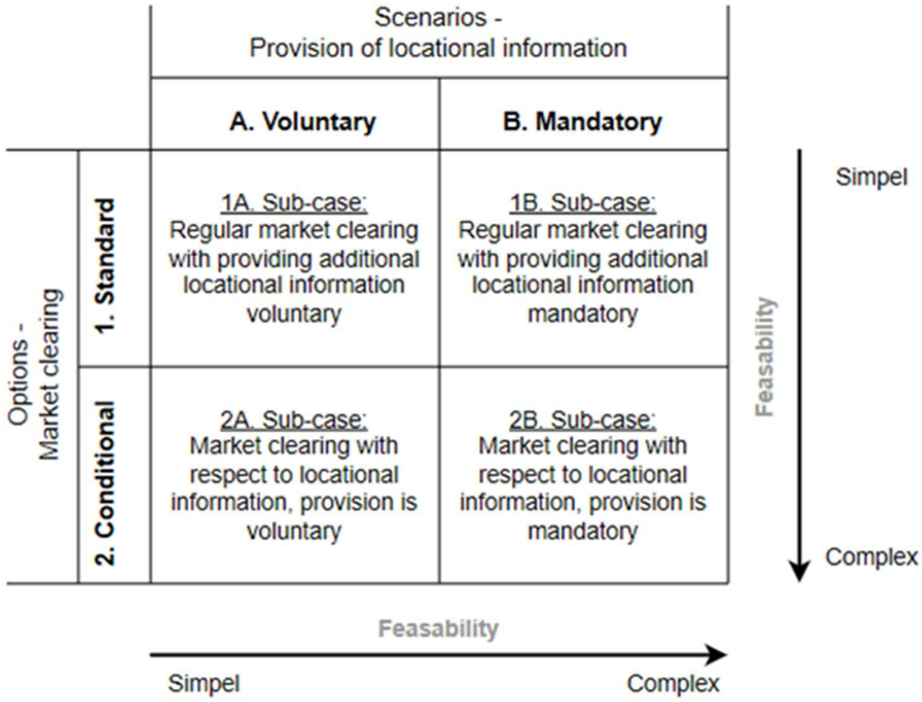

Figure 5: Overview of the defined sub-cases

In Figure 5, these four options are prioritized based on their feasibility. Since scenario B. and option 2. are relying on critical assumptions, these options are considered more complex to implement. Sub-case 1A. is accessible by just adding the locational information to existing BC products. Sub-cases 1B. and 2A. rely on revisions of either the clearing process or the general bid requirements and thus are less easy to implement. Sub-case 2B. requires the adaptation of both the clearing process and general bid requirements, and therefore is most interesting from a scientific point of view. In conclusion, it is important to mention that the focus of this use case is based on deriving theoretical insights and potential benefits of procuring BC bids with additional locational information to solve congestion.

[2] The topic of aggregation is addressed in D3.2 [26]

[3] If my bid gets remunerated less if activated for RD than for BE, I would never provide location information.

II. Bid forwarding:

Option II. refers to the bid forwarding and linking concept that has been introduced in D3.2 [26]. Again, it is required that the flexibility asset that provides a bid is prequalified for all markets the bid shall be forwarded to. In terms of the model framework, it is assumed that each FSP bids its non-awarded flexibility on each subsequent market it is prequalified for, and therefore, bid forwarding is implicitly applied.

Bid forwarding

Bid forwarding refers to a concept that would allow a market operator / TSO to forward bids that have not been awarded in one market to other markets with subsequent GCTs.

The main benefit for an FSP is the chance to participate in more than one market with the same flexible resource and therefore simplify the decision-making process on the FSP side. On the flipside, depending on the exact forwarding rules, this option might be less transparent and potentially more difficult for an FSP to plan for.

A necessary assumption for bid forwarding is that the FSP is fulfill the requirements of and prequalified for each market the bid is forwarded to or prequalification is not foreseen for a product.

3.2. Time schedule and clearing processes

As described above, this use case intends to address the reservation of balancing capacity bids, considering the expected congestion. As for now, the highest volumes of RD are procured in the D-1 timeframe, and this is expected to remain this way in the near future. It is then assumed that the current D-1 RD process remains in place. Hence, the GCTs of the existing markets stay the same only the awarding of bids is considered to be different. In the sub-cases 1A. and 1B. (see Figure 5) the BC market gets cleared regularly, additionally bids that include location information are forwarded and included for subsequent D-1 redispatch. The TSO has the opportunity to decide whether these bids are applied for redispatch or further forwarded to the balancing energy market. The redispatch market gets cleared based on optimal power flow calculations with fixed dispatches from the day-ahead market together with all bids for redispatch (i.e., including those from the BC market). Regarding sub-case 2A. and 2B. (see Figure 5) we introduce a clearing algorithm that favours bids in areas where congestion is expected by weighting them based on forecasts about the probability of occurring congestion. The whole-time schedule is illustrated in Figure 6 in chapter 3.3.

3.3. Model Framework

The aim of this use case is to assess whether the total cost of redispatch and balancing capacity can be reduced by using BC bids also for RD and with that having an impact on socio-economic costs. Thus, depending on the availability of BC bids suitable for RD, an increase in BC volumes might be necessary to still ensure sufficient availability for balancing energy. Another important issue is the role of the existing redispatch procurement methods. It is arguable, that the opportunity of prices for balancing energy has a strong influence on whether additional locational information will be provided or not. For example, when remuneration for redispatch is expected to be lower than for balancing, it is likely that no locational information will be provided. On the other hand, this combined product could increase the individual probability of being activated, which would again incentivise the decision about adding the locational information. However, this is why we are considering different remuneration methods for activated bids for redispatch, i.e., cost-based and one with market-based remuneration.

To identify the economic impact of using BC bids for RD we propose an agent-based model (ABM) approach. The model includes a balancing capacity, balancing energy, day-ahead and redispatch market. Additionally, in order to simulate the occurrence of congestion, the markets are interacting with a transmission grid model.

To assess the impact of our introduced market design on the strategies and incentives of market participants, we are using a virtual power plant (VPP) as being agents within the model. The model results of the sub-cases are compared to a baseline scenario that does not include a combined BC and RD product. The baseline scenario is based on the current market design, i.e., a separated BC market, RD remuneration (cost-based in DE and AT, market based in CH) and no flexibility platform that allows bid forwarding.

Assuming market-based redispatch remuneration within the analysis bears the risk that agents behave strategically by exploiting the opportunities between the day-ahead market and the redispatch market. A VPP is not able to adapt to such gaming behavior, thus we compare its performance with respect to generated profits to other model agents represented by a deep reinforcement learning (DRL) algorithm. Using DRL allows us to implement agents without any assumption about their bidding behavior but maximizing their own profits based on the available market and performance data. Therefore, this design ensures observing market inefficiency arising from any opportunities between those markets. Such an approach is helpful not only for comparison of the results of DRL and VPP but also for examining the impact of gaming potential in different market structures. It is assumed that both algorithms yield similar outcomes for a model with cost-based redispatch remuneration. However, when market-based redispatch is applied, it is expected that DRL would obtain higher profits than the VPP based on the opportunities for market exploitation. This supports to distingue the effects of the proposed market design adaptation from potentially new emerging issues, thus the occurrence of gaming may be avoidable by other measures but would be out of the scope of this project.

For Use Case 2 following data is used:

- PyPSA Data about transmission grid
- Historical day-ahead market data
- Historical balancing markets data
- Redispatch data is derived by calculating the power flow for the applied grid model based on the dispatch data from the day-ahead market

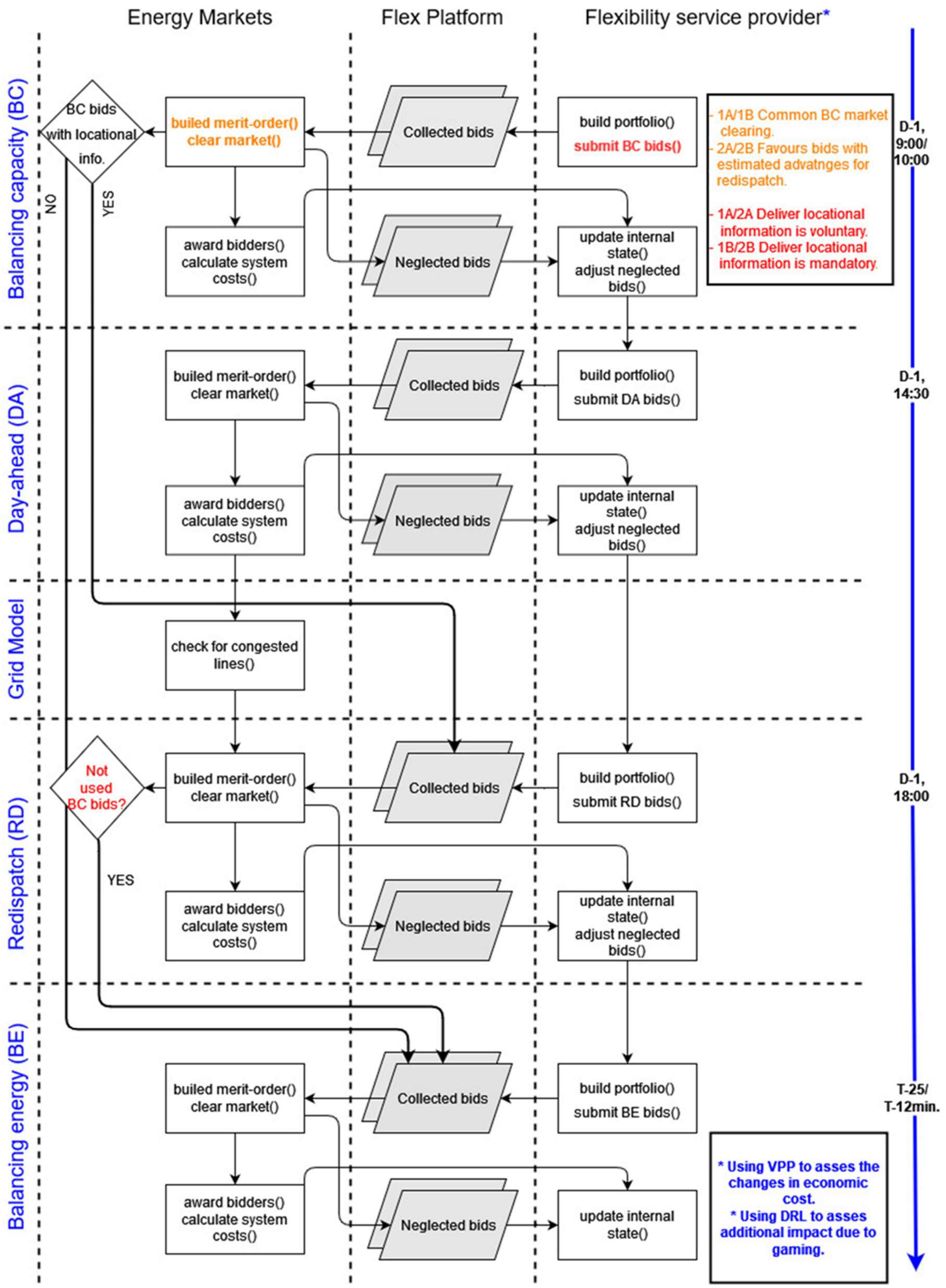

Figure 6: Use Case 2 schematic model description

3.4. Technical Framework

The feasibility of the application of Use Case 2 requires the implementation of a flexibility platform to enable the above-mentioned bid forwarding. The platform is designed to be an interface between suppliers and different electricity markets. Bids additionally contain the ID, locational information and other preferences of the supplier (e.g., if the locational information should be accessible to be available for redispatch). Further, it includes a capacity management module to filter the availability of bids for the according markets. Verification, settlement and optimization processes are still solely handled by the TSO. The process of Use Case 2 is specified in Figure 6 (i.e., Flow chart diagram).

4. Use Case 3: „Balancing Energy and Intra-Day Market“

4.1. Description of Use Case 3

Use Case 3 “Balancing Energy and Intra-Day Market” aims to connect BE and Continuous Intra-Day Markets. The goal is to enable the analysis of products and dynamics of the Intra-Day Market w.r.t. the potential of integrating them into the BE Market. This use case describes two different variants to achieving interoperability between the two markets and raises fundamental questions, aimed to be addressed in the quantitative analysis in WP 5. The optimization approach from Use Case 1 will also be applied in Use Case 3, therefore in principle, enabling involvement of all three flexibilities. Combining the Intraday with the Balancing Energy Market poses some challenges that need to be addressed.

Variant 1 considers parallel markets where the BE Market and Continuous Intraday (CI) Market both start at their usual gate opening the day before delivery. At Gate Closure (GC) of the BE Market, eligible bids are forwarded from the CI Market to the BE Market. After Market clearing, eligible bids that have been submitted via the CI Market without an award are returned to the CI Market. Bids submitted directly to the BE Market, are not returned to CI Market but forwarded to PICASSO. Currently “back-forwarding” for the BE Market to the CI Market is not performed at all. Instead, unawarded BE bids are all send to PICASSO platform for possible European BE deployment as it was expected to have positive impact on prices. However, this has not been confirmed. The effects will be analyzed as sub-scenarios within the quantitative modeling of this use case.

This approach has lower price transparency compared to Variant 2 as bids submitted directly for the BE Market are unknown to market participants. However, transparency could still be higher than in the current framework of separated markets as forwarded bids from the CI Market can be approximated via order books – depending on the type of bid compensation (see Types of BE bid compensation). The impact of this will be assessed in the analysis.

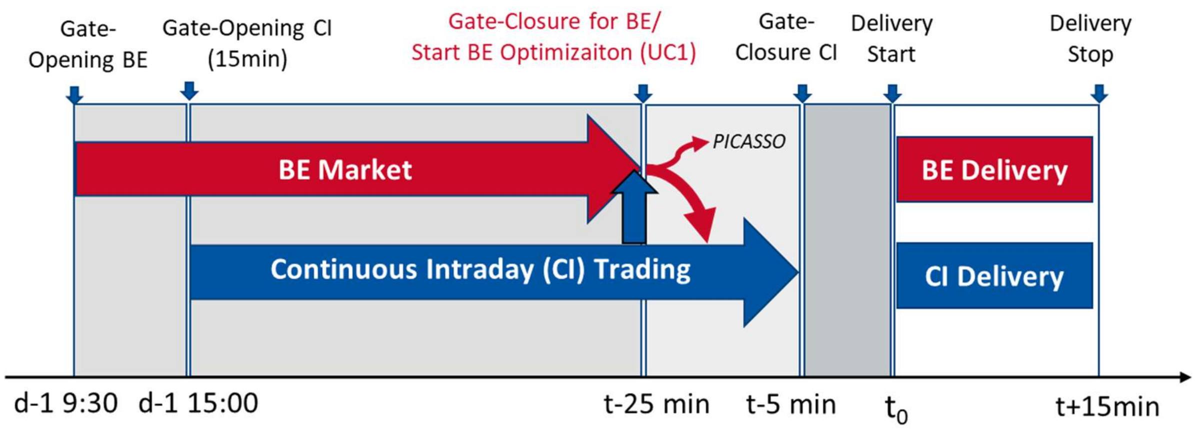

Figure 7: Use Case 3, Variant 1: Parallel Markets

Variant 2 considers market coupling via order books**, resulting in partial market fusion**, with the BE Market being integrated into the CI Market as an additional segment. This variant does in principle **not allow exclusive BE bids**. The CI Market starts as usual the day before delivery, while the segment for BE only starts 60 minutes before delivery with XBID Gate Closure of the CI Market, i.e., there is no stand-alone BE Market anymore. The start order book of the BE Segment is the order book with open positions from the CI Market at XBID Gate Closure. This variant considers three types of different bids.

1. **Exclusive ID Bids**: not eligible for BE
2. **Bids submitted to CI Market, eligible for BE**. These will be considered for BE if available at BE Market Gate-closure. The bids are also available at CI Market during the whole time of the BE Market Segment. If they are not awarded after BE GC, they will still be available for ID until ID GC t-5.
3. **Bids automatically forwarded from the Balancing Control** market as part of the awarded Balancing Control Bids. These bids will be exclusively used for BE and forwarded to PICASSO after GC if not awarded. The initial BE price specified in the BC Auction can be changed at any time after BC market clearing up until GC of the BE Segment.

At BE Gate Closure t-25min, all currently available BE eligible bids will be considered for BE market clearing and will be unavailable for CI until clearing is done. Bids without an award are returned to the CI Market after this. Depending on the type of bid compensation (see Types of BE bid compensation) a possible issue with this approach could be very high price transparency, as CI Market order books are visible, allowing BE Market clearing price approximations.

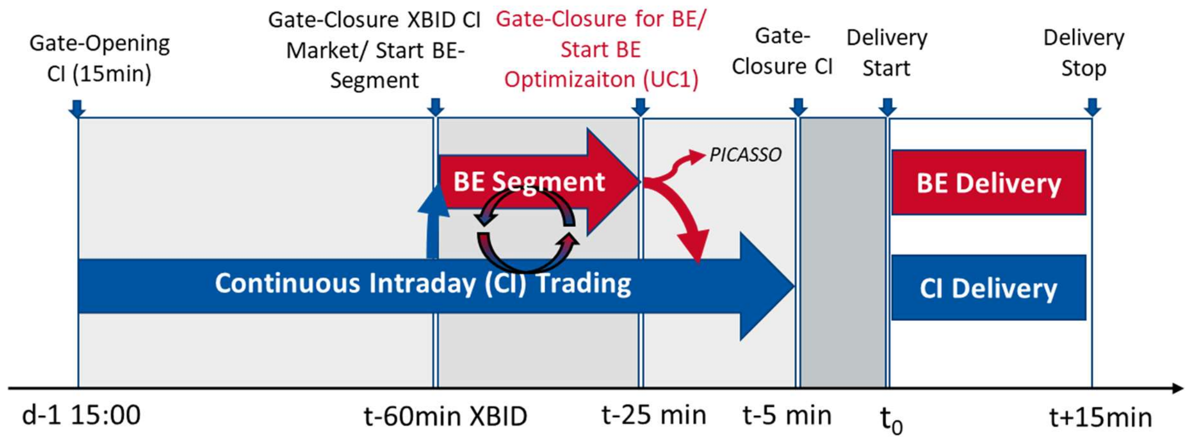

Figure 8: Use Case 3, Variant 2: Market Coupling via orderbooks

WP 5 will analyze the impact on prices and market liquidity for returning bids to the CI Market or forwarding them to PICASSO after the BE Market GC .

Usecase 3 requires an adaptation of the CI Trading bid structure. A simple approach would be to require the fulfillment of balancing energy requirements for the submission of intra-day bids. However, since not all providers in the intra-day market can meet these requirements, this would lead to a de facto exclusion of market participants and thus of important liquidity. For this reason, Use Case 3 provides for bid categorization. Suppliers must specify whether the respective offer is suitable for BE. If so, information regarding BE provider locations must be provided as stated in Use Case 1. This information will be considered to ensure optimized BE retrieval as described in Use Case 1.

Usecase 3 will consider **two different types of clearing intervals for BE**. The first is the currently used one i.e., GC to t-10min. The second one will be closer to GC as soon as the UC 1 optimization approach rejects bids. This aims to inspect potentials for markets and traders if they know the status of their BE bid earlier.

Types of BE bid compensation

Intraday calls are fixed for the whole 15-minute product interval, while Balancing Energy (BE) calls can be shorter or multiple separate calls within the 15-minute product interval can occur. This raises the question of how BE calls using intraday market bids can be compensated accordingly. Therefore, Use Case 3 investigates different types of compensation for eligible CI market bids that are activated for BE, for example:

1. **No additional compensation**. Only using current pay-as-cleared remuneration. An eligible bid that is used for BE will be awarded with the marginal price.
2. **Two prices.** A bid eligible for BE can be submitted with a price for either product, i.e., one price for BE and one for CI. Depending on where the bid is matched/awarded the corresponding price is used. This would allow also to decrease price transparency e.g., by making only the CI price visible to market participants.
3. **Premium**. If an eligible bid is awarded via the BE Segment, the bid will receive an additional premium depending on the duration it was called for BE. This aims to compensate for the above-mentioned possible difference in product intervals.

Like Use Case 2, this use case follows a long-term time horizon, with more possible and needed market flexibility due to a high share of renewable power generation in the future. By merging the markets of intra-day trading and reserve markets, comprehensive adjustments to the market design as well as to the regulatory regime are necessary.

The focus of Use Case 3 will be less on the IT-technical demonstration, but rather on an evaluation of the economic potential of market integration.

5. Conclusion

In summary, the energy transition in Europe requires the introduction of digital solutions and coordinated market processes that enable optimal operation of the power system. Flexibility platforms are emerging to facilitate trading, dispatching and settlement of energy and system services between TSOs/DSOs and FSPs. However, existing platforms are not yet interoperable, which limits the potential of flexible resources participating in them. The DigIPlat project aims to identify measures for the implementation, adaptation and knowledge transfer of standardized digital solutions for the interaction of transnational flexibility markets. By defining three use cases for the interoperable use of flexibility for balancing services, congestion management, and intraday markets, the project offers new opportunities for maximizing the value of flexibility for multiple system services. Implementing these use cases would require extensive regulatory development, but the potential efficiencies make them worth exploring. Ultimately, interoperability of flexibility platforms is key to unlocking the full potential of flexible resources and achieving the goal of carbon neutrality.

This document describes three different use cases for the interoperable use of flexibility for balancing, congestion management and intraday markets.

Use Case 1 focuses on the optimization of balancing energy deployment while considering grid congestion. The goal is to minimize balancing energy costs by selecting the most cost-efficient combination of BE bids for each 15-minute product period. The use case highlights the need for interoperability between transmission system operators (TSOs) and distribution system operators (DSOs) and suggests plant-specific or aggregated bidding within relevant network areas to prevent critical grid congestion effects.

Use Case 2 focuses on increasing the availability of flexibility products for redispatch and balancing markets by procuring balancing capacity (BC) together with additional information. The use case aims to improve market liquidity, increase bid acceptance probability, and potentially reduce overall system costs.

Use Case 3 focuses on connecting the BE market and the Continuous Intra-Day (CI) market. It presents two variants for market integration. Variant 1 involves parallel markets, where eligible bids are forwarded between the CI market and the BE market at specific gate closure points. Variant 2 proposes market coupling via order books, merging the BE market into the CI market as an additional segment. The use case explores bid categorization, different types of clearing intervals for BE, and various types of compensation for eligible CI market bids used for BE.

These use cases aim to enhance market liquidity, increase price efficiency, and optimize the utilization of flexibility resources in the context of evolving energy systems. They each require different levels of adaptations to market designs, regulatory frameworks, and IT systems.

Overall, the document concludes that interoperability is crucial for realizing full potential of flexible resources and achieving efficient operation of the electricity system. By implementing standardized digital solutions, defining use cases, and adapting market designs and regulatory frameworks, the DigIPlat project aims to contribute to Europe's energy transition and the ultimate goal of carbon neutrality.

In order to gain a deeper understanding of the defined use cases, it is necessary to conduct thorough investigations, both methodologically and technically, depending on the specific use case. These investigations will allow for a comprehensive evaluation of the proposed solutions, including an analysis of their advantages and weaknesses. Based on these evaluations, informed recommendations for further action can be formulated. By delving into the unique characteristics and requirements of each use case, valuable insights can be obtained to facilitate effective decision-making and successful implementation.

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