D3.2.2 – Design of local flexibility markets for congestion management

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Executive summary

In this deliverable, we propose a new market design for local flexibility markets dealing with congestion management at an electrical regional scale.

Following the recommendations coming from previous deliverables, we have designed local markets connected with the European intraday market and inspired by other existing pilots such as GOPACS.

The proposed local market uses local bids dedicated to the European intraday market in order to meet specific bids submitted by System Operators called *swap bids*.

Swap bids form an original type of bids submitted by the system operator to express a need to swap power injection or consumption from a zone to another. It is used by the system operator to relieve a congestion or to manage other technical issues, such as limiting power losses.

We also propose another original type of bids called loop block orders (or loop bids) to be submitted by flexibility providers who want to benefit from their capacity to swap injection or consumption from a time-step to another.

Kurzfassung

In diesem Deliverable schlagen wir ein neues Marktdesign für lokale Flexibilitätsmärkte vor, das sich mit dem Engpassmanagement auf regionaler elektrischer Ebene befasst. Den Empfehlungen früherer Ergebnisse folgend, haben wir lokale Märkte entworfen, die mit dem europäischen Intraday-Markt verbunden und von anderen bestehenden Pilotprojekten wie GOPACS inspiriert wurden.

Der vorgeschlagene lokale Markt verwendet lokale Gebote, die für den europäischen Intraday-Markt bestimmt sind, um spezifische Gebote von Systembetreibern zu erfüllen, die als Swap-Gebote bezeichnet werden. Tauschgebote bilden eine ursprüngliche Art von Geboten, die vom Netzbetreiber abgegeben werden, um die Notwendigkeit zum Ausdruck zu bringen, die Leistungseinspeisung oder den Leistungsverbrauch von einer Zone in eine andere zu tauschen. Es wird vom Netzbetreiber verwendet, um einen Engpass zu entlasten oder andere technische Probleme zu bewältigen, wie zum Beispiel die Begrenzung von Leistungsverlusten.

Wir schlagen auch eine andere ursprüngliche Art von Geboten vor, die als Loop-Block-Orders (oder Loop-Gebote) bezeichnet werden, die von Flexibilitätsanbietern eingereicht werden, die von ihrer Fähigkeit profitieren möchten, Einspeisung oder Verbrauch von einem Zeitschritt auf einen anderen zu tauschen.

Résumé à l’intention des décideurs

Dans ce livrable, nous proposons une nouvelle conception de marché pour des marchés locaux de flexibilités destinés à la gestion des congestions à une échelle régionale du point de vue du système électrique.

Suivant les recommandations des précédents livrables, nous avons conçu des marchés locaux connectés au marché européen infra-journalier et inspirés par d’autres pilotes existant comme GOPACS.

Les marchés locaux proposés utilisent les offres locales dédiées au marché infra-journalier européen et les utilisent pour répondre aux ordres émis, appelés *swap bid,* par les gestionnaires de réseaux.

Les *swap bids* constituent un nouveau type de demandes soumises par le gestionnaire de réseau pour exprimer le besoin d’un échange de la puissance injectée ou consommée d’une zone à une autre. Elles peuvent être utilisées par le gestionnaire de réseau pour résoudre une congestion ou pour gérer d’autres problèmes réseau, comme la limitation des pertes en puissance.

Nous proposons aussi une autre catégorie originale d’offres appelées ordres blocs *loop* ou offres *loop* pour être soumises par les fournisseurs de flexibilité qui cherchent à bénéficier de leur capacité à pouvoir échanger leur injection ou consommation d’un pas de temps à un autre.

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1 Introduction

The design for local flexibility markets proposed in this document is based on the integration of new local markets within the existing European intraday market.

This choice is motivated by the fact that congestion management should be done at a local scale close to real time. Moreover, it is expected that congestions on sub-transmission networks will occur because of fast and unpredictable variations on power injection due to high renewable penetration or new electrical usages.

Figure 1 shows how proposed local flexibility markets are integrated with other markets in regards to time horizons.

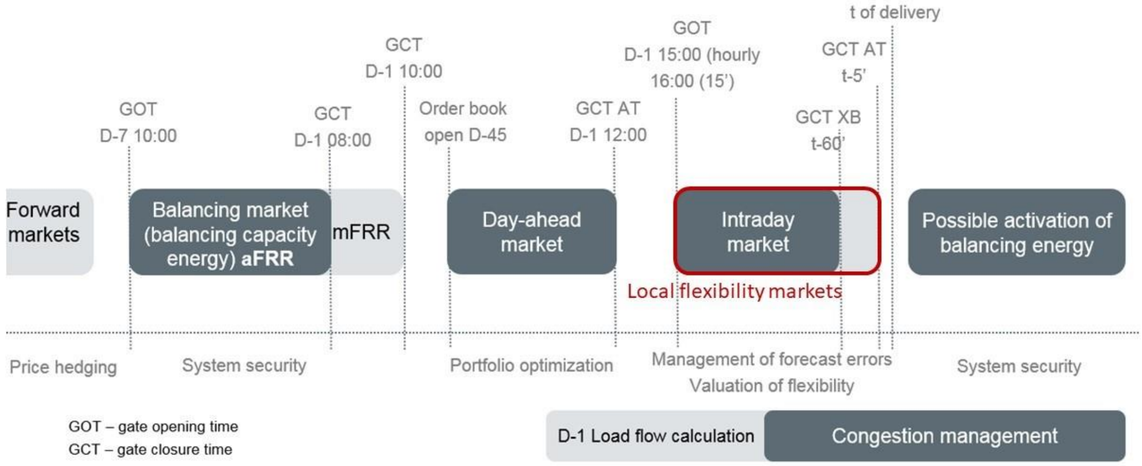

Figure 1: Integration of local flexibility market in the time horizons of electricity markets (example of Austria).

We propose that the local market occurs at a regional electrical scale, meaning on the sub-transmission network (with voltage levels between 40 and 110kV).

A single local market is wholly within a single bidding zone, and the sub-transmission network of a bidding zone could be divided into several local markets. All the local markets are connected to the European intraday market.

The sub-transmission network of a local market should be divided into several "zones" by the system operator of this network.

2 Lessons from previous deliverables

In this part we look at the lessons taken from previous deliverables, especially deliverables 3.1.1, 3.2.1 and 3.3.1, to build the proposed local market design. First part looks at the scale of the area where a local market is applied to solve congestions. The second part recalls some existing pilots, especially GOPACS. The third part gives the main points that the proposed market design needs to check.

2.1 On local market scale

The REgions project analyses regional aspects of ancillary services and corresponding markets. For this purpose, a definition of a region from an electrical point of view is provided in deliverable D3.1.1. The REgions project defines its terminology (sub-regional, regional and inter-regional) based on the voltage level rather than on geographical or administrative boundaries. Electrical regions are defined as areas powered by the same extra-high voltage to high voltage transformer (EHV/HV) (see Figure 2).

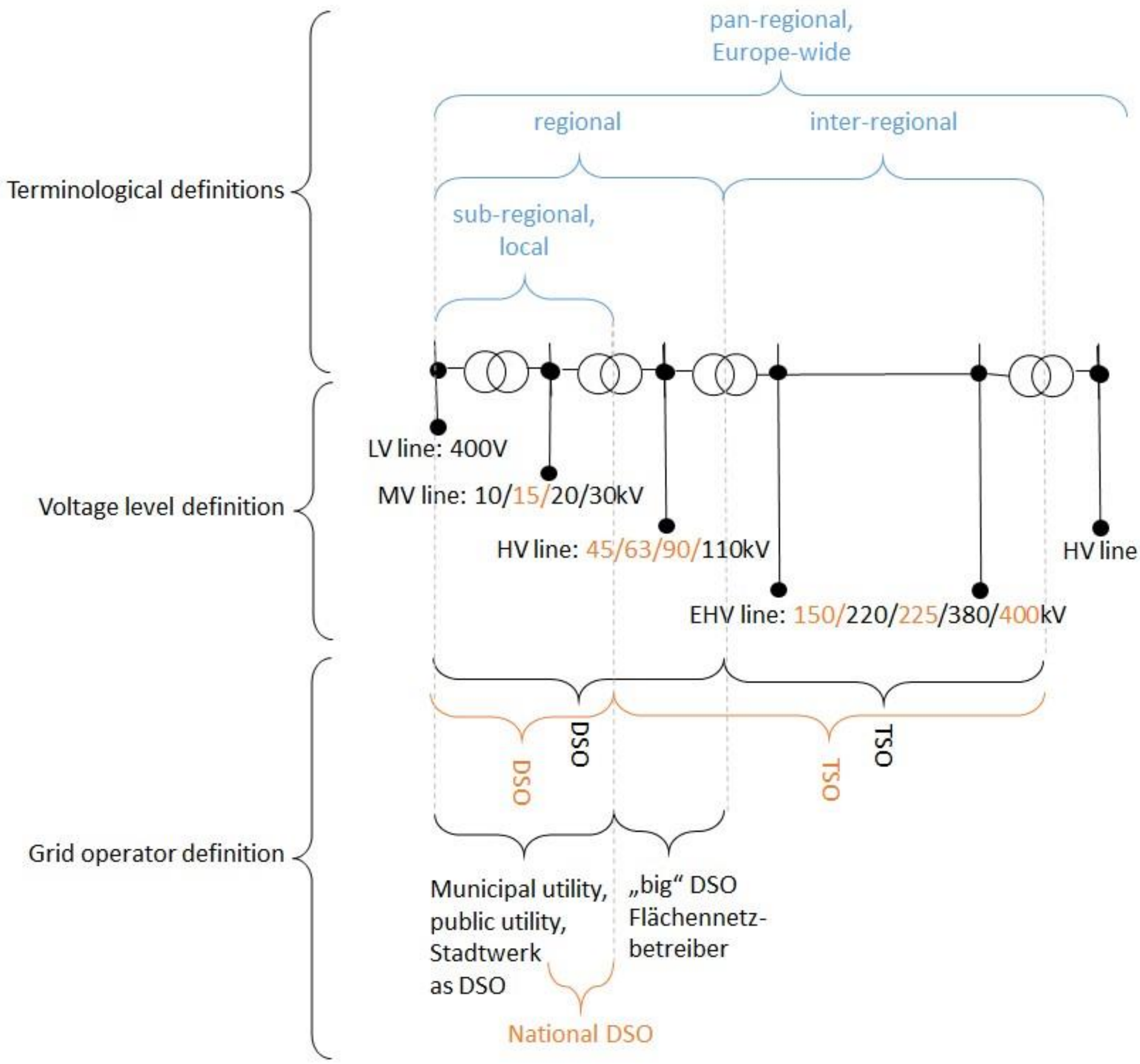

Figure 2 : Definition of REgions terminology (Blue), voltage levels and grid operators in Germany (Black) and France (Orange). Source: Fraunhofer IEE, Hespul.

Based on the above considerations, ancillary services and markets can be classified according to the following table.

Table 1 : Regional classification of ancillary services analyzed in REgions (FR – France, DE – Germany, AT-Austria)

Regionality	**Beneficiary**	**Ancillary service**
Sub-regional / local	DSO (voltage level up to 40kV)	N/A (no use case on this level in REgions)
Regional	TSO (FR) /DSO (DE, AT) (voltage level 40 to 110kV)	Congestion management (FR)
		Voltage control (FR)
		(Constrained) balancing reserve (FR/DE)
Inter-regional	TSO	Congestion management (DE)
		(Constrained) balancing reserve (DE/FR)
Pan-regional / Europe-wide	TSO	Balancing reserve (AT)

This shows that local flexibility markets dealing with internal congestion management should be designed at a regional scale.

2.2 Overview of existing pilots

The deliverable 3.2.1 details several existing pilots of market-based solutions to deal with congestion issues at a regional scale. Following table gives a summary of the studied pilots.

Table 2: Main features of some regional markets

Existing or R&D market	Service provided	Link with other existing markets	Specific features (*gate opening and closure time, minimum duration and volume of offers etc.*)	Compensation mechanism
ENKO North German Flex Market	congestion management	Day-Ahead	Day-Ahead: Opening: 12 AM Closure: 2.30 PM	Pay-as-bid
NODES	congestion management	Bids no used for congestion management are proposed to connected markets (balancing and intraday)	Aggregation of flexibility providers within a "grid location"	Pay-as-bid Dispatch and availability payment
GOPACS	congestion management	Bids proposed for the IDM can be used to relieve congestion	Need to compensate increase or decrease of production in the congestion area by an opposite offer outside the congestion area	Pay the spread between both orders
Enera	congestion management	Intra-Day market (EPEX) Bids proposed for IDM and for redispatch Platform that prevents bids to be used on both markets	Standardized prequalification procedure (especially dedicated to wind turbines)	Pay-as-bid Dispatch payment
Power Potential	congestion management and Voltage support	Balancing "mechanism": redispatch integrated in this mechanism	Sensitivity value for voltage support Proposed availability Comparison of the prices of bids with counterfactual costs	Reactive power: Availability payment Active power: utilization payment

Our proposed market design is inspired by GOPACS. Figure 3 introduces the market design of the GOPACS platform.

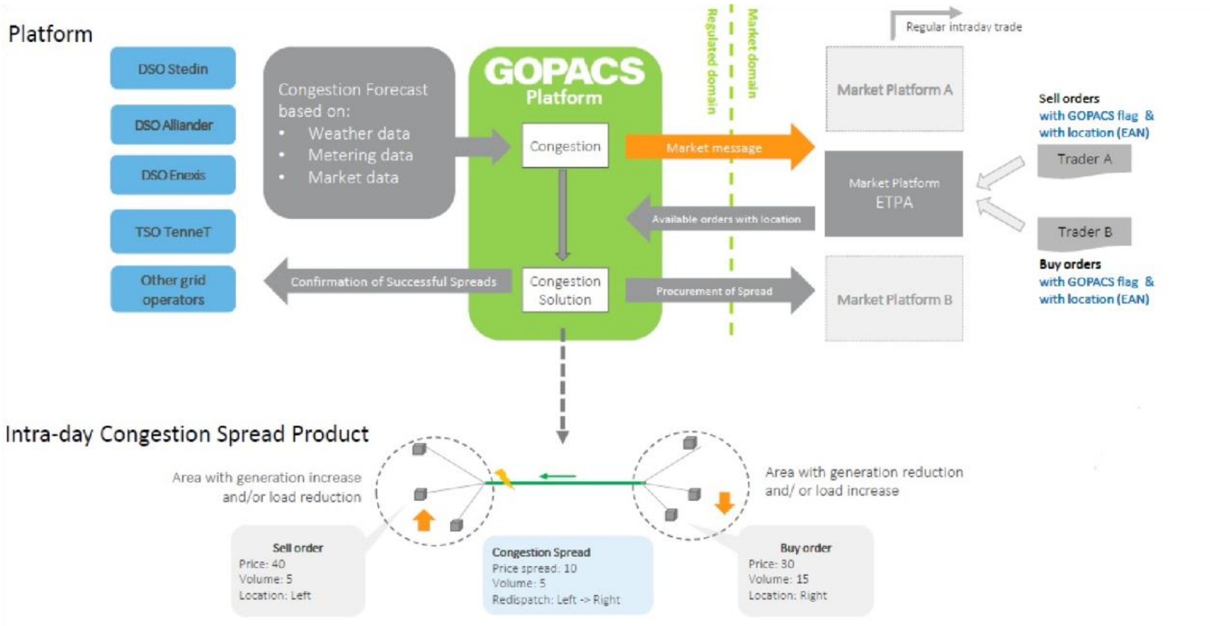

Figure 3 : GOPACS market design

Our proposed market design takes some ideas from the GOPACS market design:

- Divide the local area in zones where system operators can express a need for increasing or decreasing injection,
- Connect to intraday markets and use intraday bids.

The main difference with our proposed market design is that in GOPACS, flexibility providers bids are sent directly to intraday markets. The local market is connected to the intraday, and try to find bids to deal with congestions. On the contrary, in our design, flexibility providers bids are sent first to the local market and then to the European intraday market. It allows our market to introduce new types of bids, not existing on the European intraday market, to give more options to both system operators and flexibility providers to solve local congestions before sending residual intraday bids to the European markets.

2.3 Expected structure of the local market

Conclusions of the deliverable 3.2.1 on the state of the art on local flexibility markets, enlighten that a specific market for regional flexibility products face a major issue of gaming since only a few actors would be likely to participate, and may face a lack of liquidity.

Thus, it suggests that a local market dealing with congestion management should be connected with other existing European market such as day-ahead, intraday or balancing markets.

Deliverable 3.2.1 also looked at existing European markets to see what could be the best one to connect with:

- Connection between congestion management and balancing market is the option chosen by the French TSO, RTE, today. This possibility could become more complicated in the near future with new regulation from the Clean Energy Package. Indeed, the regulation does not allow to use redispatch offer to set the price of balancing energy market. Balancing bids could still be used for internal congestion if they are removed from the balancing merit order. Nevertheless, bids for redispatch purpose requires locational information that are not mandatory to provide on balancing platforms.

- Connection between redispatch and day-ahead or intraday market would have the advantage to beneficiate from higher liquidities. Nevertheless, because of both their actual and future level of participation in the production, variable renewable energy sources (RES) should participate in such markets. Forecast errors are then one of the biggest issues to be tackled for their participation. In Day-Ahead, market closure seems to be too early regarding forecast considerations. On the contrary, in intraday markets participants can still bid one hour before real time (or even less) thus enabling RES producers to provide better forecast for the bids they propose on the market. Thus, intraday markets seem a reasonable option for designing market coupling with redispatch.

Based on the overview of the regulatory rules and on the analysis of market interaction, several recommendations for the design of (inter-)regional markets are provided in deliverable D.3.3.1:

As it was also shown in the deliverable D.3.2.1 of the project, the most profitable approach to manage internal congestion is a market-based solution establishing a link with the short-term electricity markets, either day-ahead or intraday. The benefits of such approach are twofold:

1- On the system side, it can help network operators to keep redispatch costs in check, if, for example, redispatch activation is remunerated with the day-ahead price or the intraday bid-ask spread.
2- In particular linking the redispatch market with the intraday markets could help RES to offer redispatch based on their improved generation forecasts and ensure a reliable service delivery of short-term flexibility.

It was further concluded (paragraph 3.3 of the 3.3.1 deliverable) that redispatch and balancing in a combined market is not optimal as it is the most challenging to implement in all project countries (although it already exists in France). Secondly, it will reduce the allocative efficiency of the two markets in the future, as balancing energy will be selected close to real time since this will dramatically limit the pool of available providers of redispatch.

The creation of a new marketplace for redispatch adds yet another level of complexity to the decisionmaking of market participants. This needs to be considered in the market design to properly align the timeframes and requirements of different markets and avoid conflicts or distorted incentives.

3 Local market design

In this section, the market design is clarified, with its structure, and its logics. It details the scale of each local market, how it is connected with existing intraday market, and how the clearing process should work.

3.1 Structure of a local market

The local market design proposed in this document is defined at a regional scale and is connected to the European intraday market.

These choices are motivated by the fact that congestion management should be done at a local scale close to real time, as it was taught by previous deliverables.

We propose that the local market occurs at a regional electrical scale, that is on a sub-transmission network (with voltage levels between 40 and 110kV).

A single local market is wholly within a single bidding zone, and the sub-transmission network of a bidding zone could be divided into several local markets. All the local markets are integrated to the European intraday market.

The sub-transmission network of a local market should be divided into several "zones" by the system operator of this network.

Figure 4 shows how local markets are integrated into bidding zones and into the European intraday market.

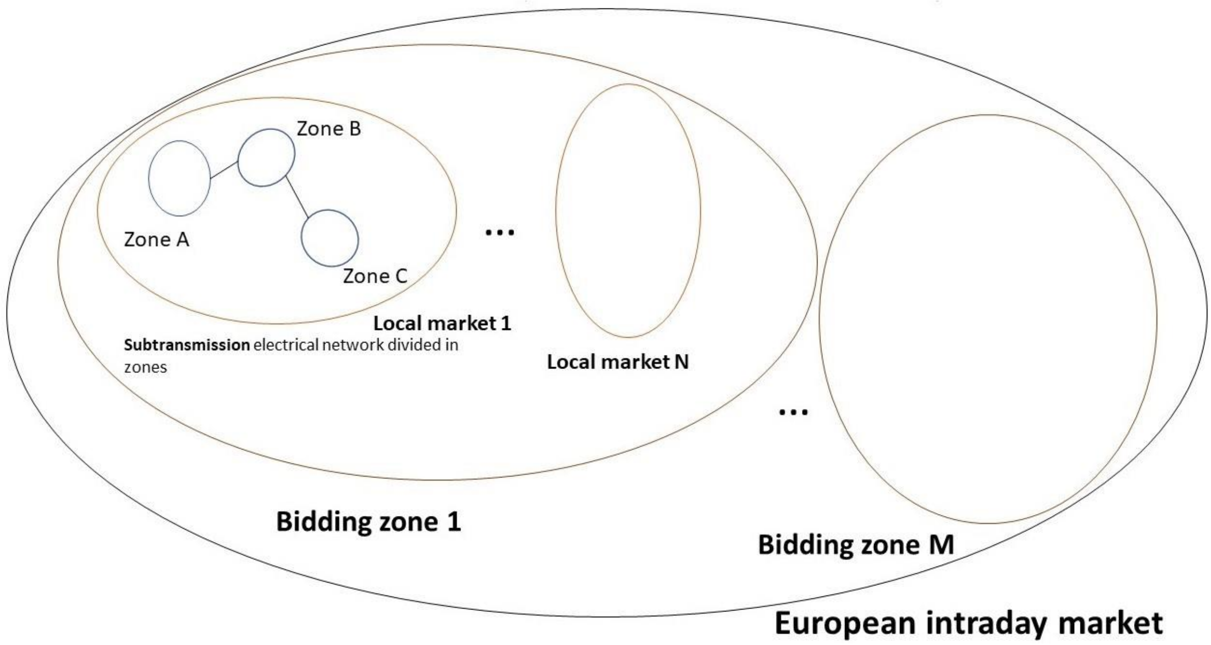

Figure 4: Schematic view of the integration of local markets into European ID

3.2 Local matching principles

The local market purpose is to solve congestion issues forecasted by the system operator. To do this, the local market gathers all bids issued by local flexibility providers to the European intraday market. The local market also receives special and original bids issued by the system operator called "swap bids". Those bids allow the system operator to express the need of an injection swapping between two zones within the local market.

Then, the local market matches swap bids and classic intraday bids issued locally. Remaining intraday bids are sent to the European intraday market. The local market can also match swap bids with local bids previously sent to the European intraday market that are not matched yet.

After the swap has been matched, the new levels of injection in the network should not cause congestions any more.

Swap bids are issued by the system operator of the sub-transmission network covered by the local market. They are composed of:

- One or more time-steps,
- A zone « up »,
- A zone « down »,
- A volume (MW) to swap,
- A spread price limit (per MWh).

The swap bid is matched with an upward bid localized in zone "up" and with a downward bid localized in zone "down". Both bids have the same volume which is the volume to swap, and the price difference (up minus down) is under the spread price limit. The spread price represents the maximum price the SO is willing to pay to match one MWh of its swap bid. This feature is largely inspired by GOPACS platform, and can be found in the RTE adjustment mechanism too. The main difference in our market design is that the SO is a market player as balance service providers are. SO provides swap bids and the market matches them with local regular ID bids. For the "mécanisme d'ajustement", the market role is played by RTE, which selects bids in a non-fully transparent way (for the purpose of congestion management).

Due to its local aspect, the local flexibility market is easier to manage than the whole European intraday market, for example it is intended to treat a largely lower number of bids. Thus, it is easier to add new type of bids to this market than in the European Intraday market. We propose below a new type of bids called "loop blocks" to allow local flexibility providers to swap their injection from a time step to another. It is designed for actors that are able to change the time of their production/consumption such as electric vehicle parc that need charge their batteries during the night without a particular timing.

To resume, here are the key characteristics of our local market design:

- Applied on a **sub-transmission** network (voltages between 40-110kV),
- Local markets gather the **bids issued locally** for the European **intraday** market,
- New types of bids can be added to the local markets to be matched with « swap bids » such as **loop blocks**
- Local markets gather special and new «**swap bids**» issued by the **system operator** for network services (avoid/solve congestions),
- Local markets **match swap bids with regular local ID bids**,
- Local markets send remaining regular bids to the European ID,
- The overall process is **upstream of the ID**, since unselected bids are transferred to ID market afterward.

Figure 5 shows the workflow of the proposed local market design.

Figure 5: Market design workflow

3.3 Example: Increase of wind production

Here we present a concrete case of congestions solved by the proposed local market design. The congestion is anticipated 2 hours before real time.

Situation:

- European intraday market anticipated price: 40€/MWh,

- Rise of the wind power production (due to an unexpected rise of the wind strength).

The following events occur in this order:

1- Wind power owners make upward bids at 35€/MWh (below the anticipated European intraday market price),

2- There is no swap bids on the local market, all bids are directly transferred to the European ID,

3- All bids are accepted because they are under the « intraday price »,

4- After an update of the power injection plan, a congestion is forecasted by the system operator between two zones (see Figure 6) within the local market, and 2 hours before real time,

5- The SO submit a swap bid at a spread price limit of 30€/MWh to the local market (equivalent to a downward need in A linked to an upward need in B with a price difference of 30€/MWh),

6- A downward bid in A and an upward bid in B are matched with the swap bid (see Figure 6).

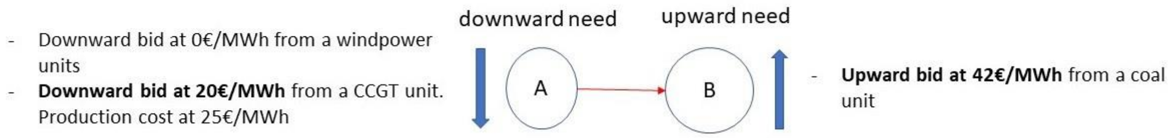

Figure 6: Congestion between two zones A and B and local bids on the local market

Results: Downward bid at 20€/MWh and Upward bid at 42€/MWh are matched with the swap bid.

The CCGT unit pays 20€/MWh to the coal unit. The 22€/MWh remaining are payed by the SO. The wind power producer is able to maximize its output.

3.4 Example: temporal swapping

Temporal swapping consists in using an original type of bids called a **loop block** to answer a swap bid issued by the SO. It combines **three bids**: two classic intraday bids and a loop block to be matched with the swap bid.

The example below shows how it works:

1- A congestion is forecasted by the system operator between two zones (see Figure 7) within the local market for 2-3AM:, the SO needs to decrease power in B and increase it in A,

2- The system operator submits a swap bid at a spread price limit of 15€/MWh to the local market,

3- There is a downward bid available in B, so the SO takes it. But there are no "classic" upward bid in A: only a loop block with an increase of power at 2-3 AM and a decrease of power at 8-9 AM. Since the loop block comes with a decrease of power at 8-9 AM, there is a need to activate an upward bid to maintain the balancing also at this timestep. Here the upward bid in C between 8 and 9 AM is taken. The downward bid in B, the loop block in A and the upward bid in C are matched with the swap bid from the SO.

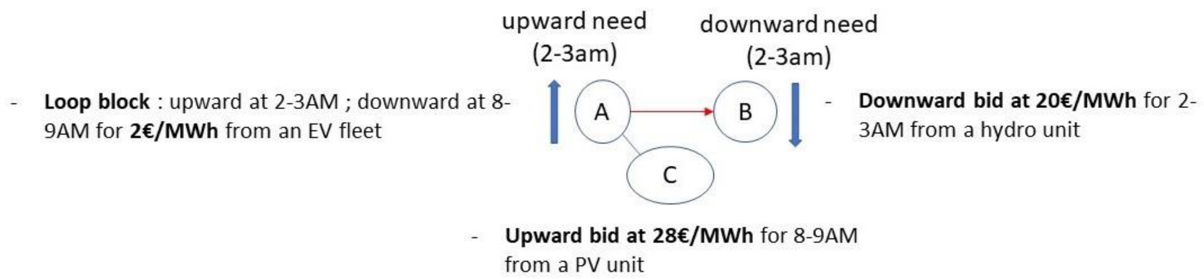

Figure 7: Congestion between two zones A and B and local bids on the local market

To resume, the SO pays 10€/MWh divided in: 2€/MWh for the EV fleet and 8€/MWh to the PV unit. The hydro unit pays the 20€/MWh to the PV unit.

4 Simulations

4.1 Overview of the planned simulations

In the scope of the tasks 4.7 and 4.8 the local market will be simulated in a software developed for the needs of REgions. This web-based software is designed to represent short term simulations for energy actors with their interactions with energy markets. In the context of REgions project, it will be able to represent market participants and networks on a dedicated map, with their data and constraints. The needed algorithms will be integrated to its simulation workflow. The software will also represent KPI and indicators based on the results simulations.

In order to simulate the local market, it is foreseen to model one specific local market in details with a representation of the regional network on the local market scale with all local actors (producers, flexibility providers, etc.), with their operational data and constraints. The European markets (Day ahead and Intraday) will be also represented in order to simulate the interaction between the local market and these European markets.

The local market algorithm will be designed in order to match all local orders for maximizing the local social welfare. It will be able to consider all orders (intraday orders, swap and loop bids). The market algorithm will find the optimal matching between all local offers available.

Once all elements are in place, the software will be able to run simulations of the local market dynamic:

1. Participation and results of the day ahead market
2. Intraday and local market participation
    a. Based on updated information (mainly data from forecast simulations), actors update their expected production and their bidding strategy
    b. SO submit new swap bids based on their network simulation, which will be simulation thanks to congestion forecast
3. Intraday and local market algorithm
    a. Either offers are cleared on the local market
    b. Or they are transferred to the intraday market

One simulation should be on one intraday session scale, i.e. 33 hours. The steps 2 and 3 are iterative, and will be repeated several times in one simulation. After the simulation, KPI will be generated in order to analyze results with indicators such as:

- The cleared volume on the local market
- The volume of swap bids cleared. For what cost for the SO

With these simulations, the market design will be analyzed in term of performances; the costs and benefits of such market design could be measured, and may be compared to existing mechanisms.

4.2 Proposed market algorithm

An algorithm is designed in order to match all the bids on the local market. In the following section we proposed a market algorithm that should be developed in the task 4.7.1. It represents our current view of the algorithm, but can evolve during implementation.

4.2.1 Main Features

The main objective of the algorithm is to maximizes the social welfare, with an advantage to the matching of the swap bids. It is not defined as a classical market clearing algorithm since no market clearing price can be defined. It is designed to be more aligned with intraday market principles.

The list of the main features of the algorithm are:

- Maximization of the welfare resulting from bid matches, with a bonus to the matching of swap bids compared to other bids. This is done also to encourage our model to accept swap bid matches with an additional welfare of 0.
- Ensuring that no inconsistent bids can be matched, meaning that a particular match always create positive welfare.
- Several constraints are added to model the fact that a same bid cannot be exchanged more than its volume.

4.2.2 Optimization model

Below we provide a first formulation of the local market algorithm.

Data:

- Set I of swap bids submitted by the SO. For each bid $i \in I$, c_i is its limit spread price, and V_i is its volume.
- Set J of downward bids submitted by flexibility providers. For each bid $j \in J$, c_j is its price, and V_j is its volume.
- Set K of upward bids submitted by flexibility providers. For each bid $k \in K$, c_k is its price, and V_k is its volume.
- Set L of loop bids submitted by flexibility providers. For each bid $l \in L$, c_l is its price, and V_l is its volume.
- Matrices $B_i, \forall i \in I$, indexed by elements of J and K and composed of 0 or 1 entries. Entries at 1 represent couples of bids (j, k) that are compatible with swap bid i. That is:
    - They must share the same time-step,
    - The zone of the downward bid must be the zone where the swap bid expresses a downward need,
    - The zone of the upward bid must be the zone where the swap bid expresses an upward need,
    - $c_k - c_j \leq c_i$.
- Matrices $S_i, \forall i \in I$, indexed by three elements: one from J, one from K and last one from L, and composed of 0 or 1 entries. Entries at 1 represent trio of bids (j, k, l) that are compatible with swap bid i. That is:
    - The upward part of the loop bid must share the same time step and a different zone with the downward bid.
    - The downward part of the loop bid must share the same time step and a different zone with the upward bid.
    - Either the upward part of the loop bid and the downward bid or the downward part of the loop bid and the upward bid must share the time-step than the swap bid and correspond with the downward and upward needs express by the swap bid at this time-step.
    - $c_k - c_j + c_l \leq c_i$.

- Matrices T_3, $\forall l \in L$, indexed by two elements: one from J and one from K, and composed of 0 or 1 entries. Entries at 1 represent couple of bids (j, k) that are compatible with loop bid l. That is:
    - The upward part of the loop bid must share the same time step with the downward bid.
    - The downward part of the loop bid must share the same time step with the upward bid. ○ $c_/ + c_3 \leq c_+$.
- Value b which represents a small bonus to incite the model to match swap bids.

Variables:

- For each element $(j, k) \in B_\%$, $V_\%{}^@{}_{,+,/}$. It is the volume selected from bids j and k to be matched with swap bid i,
- For each element $(j, k, l) \in S_\%$, $V_\%{}^A{}_{,+,/,3}$. It is the volume selected from bids j, k and l to be matched with swap bid i.
- For each element $(j, k) \in T_3$, $V_+{}^B{}_{,/,3}$. It is the volume selected from bids j, k and l to be matched with swap bid i.

Optimization problem:

$$\text{Max} \quad \text{F}_{\%\in J} \; \text{F}_{(+,/)\in @_I} \; V_{\%@,+,/} \text{G} c_+ - c_/ + c_\% + b \text{H} + \text{F}_{(+,/,3)\in A_I} V_{\%A,+,/,3} \text{G} c_+ - c_/ - c_3 + c_\% + b\text{H} + \text{F}_{3\in L} \; \text{F}_{(+,/)\in B_K} V_{+B,/,3} \text{G} c_+ - c_/ - c_3 \text{H}$$

$$s.t. \quad \text{F}_{(+,/)\in @_I} V_{\%@,+,/} + \text{F}_{(+,/,3)\in A_I} V_{\%A,+,/,3} \leq V(', \quad \forall i \in I$$

$$\text{F}_{\%\in J} \; \text{F}_{(+,/)\in @_I} V_{\%@,+,/} + \text{F}_{(+,/,3)\in A_I} V_{\%A,+,/,3} + \text{F}_{3\in L} \; \text{F}_{(+,/)\in B_K} V_{+B,/,3} \leq V(_{,}, \quad \forall j \in J$$

$$\text{F}_{\%\in J} \; \text{F}_{(+,/)\in @_I} V_{\%@,+,/} + \text{F}_{(+,/,3)\in A_I} V_{\%A,+,/,3} + \text{F}_{3\in L} \; \text{F}_{(+,/)\in B_K} V_{+B,/,3} \leq 0V0/0, \quad \forall k \in K$$

$$\text{F}_{\%\in J} \; \text{F}_{(+,/,3)\in A_I} V_{\%A,+,/,3} + \text{F}_{(+,/)\in B_K} V_{+B,/,3} \leq V(3, \quad \forall l \in L$$

The parameter b represents the extra bonus (in €/MWh) in order the encourage swap bid matches.

5 Conclusion

Following the conclusions of previous deliverables, we propose a local flexibility market design for congestion management at an electric regional scale. Those markets are connected and interact with the European intraday market.

Such markets collect locally issued bids for the European intraday market, and use them to meet local needs of power swapping, issued by the local system operators. Local markets clear local intraday bids with swap bids, solving system operator issues, such as forecasted congestions. Remaining local bids are transferred to the European intraday. Thanks to the relative moderate size of local flexibility markets, we propose to also add to them new types of local bids to be matched with the swap bids issued by the system operator, giving them more tools to manage congestions. An example is given with the loop bids which are designed to take benefit from time flexible production and consumption devices, such as electrical vehicle.

We also propose to simulate in details such a market to evaluate its ability and performance to solve local congestion issues. We finally give the current local market algorithm design, that will be implemented in the 4.7.1 task.