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Spatial Aggregation of Local Flexibility – Horizon2020 project experiences

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Abstract. With the growth of renewables, the increased interconnection of European grids, the development of local energy initiatives, and the specific requirements on TSO–DSO cooperation as set forth in the different Network Codes and Guidelines, TSOs and DSOs face new challenges that will require greater coordination. The aforementioned measures encourage procurement of services at both the transmission and the distribution level, recognizing that this will enable more efficient and effective network management and will increase the level of demand response and the capacity of renewable generation. Digitalization is a key driver for coordination and active system management in the electricity grid, enabling TSOs and DSOs to optimize the use of distributed resources and ensure a cost-effective and secure supply of electricity. It also empowers end-users to become active market participants, supporting self-generation and providing demand flexibility. To support the transformation, the INTERRFACE project, started in 2019, will design, develop and exploit an Interoperable pan-European Grid Services Architecture (IEGSA) to act as the interface between the power system (TSO and DSO – transmission system operator, distribution system operator) and the customers, and allow the seamless and coordinated operation of all stakeholders to use and procure common services.
This paper describes the approach of one INTERRFACE demonstration, the spatial aggregation of local flexibility and its realization that contributes providing a clear market approach to include local constraints into the already well-established and working wholesale energy market solutions.

Key words. spatial aggregation, local flexibility, mFRR, aFRR, market enablement

1. Introduction

EU's Clean Energy Package aims to incentivize the participation of the distributed energy resources in the wholesale market by changing its regulation [1]. Aggregators are the key to fully utilize this potential, but aggregation itself is hindered presently, as the current market structure cannot represent the local network constraints (thus true value of distributed resources cannot be monetized), and it neither provides incentives the participation of small units. This is the case in the Romanian market as well, where the power market has evolved throughout the last decades on the premises of aiming towards an unconstrained "copper-plate" wholesale energy trading. This resulting uniform wholesale pricing approach did not lead to the desired outcome, as the socialization of the local network constraints through system usage tariffs led to inefficient price incentives.

However, if the locational information from the distributed sources providing energy and/or new types of flexibility bids can be channelled into the market optimization algorithm, this new aspect can only provide more welfare outcome of trading platforms. This spatial dimension can be introduced into the current wholesale market design, by the extension of EUPHEMIA's PUN-like (average price based) pricing scheme – with the introduction of a special type of demand bid to be cleared based on average of multiple zonal prices [2].

Within this task, spatial dimensions will be introduced into an existing wholesale market design by a holistic mathematical formulation for optimal market outcomes and the optimal use of local flexibilities [3]. Shadow-prices to determine order clearing prices are used, as an efficient way of solving grid related constraints regarding flexibility sources on the DSO level, and to demonstrate by simulation. Effects of DSO-usage of such resources on bidding zone market outcomes were simulated, and a relevant subset of different usages were prototyped. Data used for the demonstration was provided by affected DSOs and TSOs, while the behaviour of market players is to be examined by the involvement of actual market participants of the demonstration area [4].

2. Demo progress and architecture

Demonstration realization of the previously set market design is based upon a tailored intraday market solution with both energy and capacity products and refined congestion zoning for both TSO- and DSO-level congestion. Running the market algorithm with several specific scenarios for the Romanian demonstration area has been selected, and realigned as per the somewhat restricted availability of the market-specific but business sensitive datasets [5]. Further datasets have been obtained during the demonstration runs, including full balancing market datasets. Regarding day-ahead energy markets the project aim is to eliminate generic assumptions. It has been largely eliminated using the local power exchange's data transparency publications with a fine representation of the completes supply and demand curves for each trading hour of the DAM [6].

The method to include spatial dimension and the resolution of the spatial dimension have been developed into an early and full prototype (AMPL-based) tool in Q3-Q4 2020. A multi-zonal, hierarchical approach was prototyped for the DSO usage of local flexibility, already realized in a simulation environment with dedicated capacity products for operational congestion management services. The nergy product is used for short-term congestion management, along with the general energy trading, BRP schedule adjustment purposes. Thus synergies between different use cases can enhance the liquidity of the market. Data has been gathered from partners for the initial tests in 2020 with a defined data provision process. The whole architecture was aligned with the partners [7].

The market animation algorithm has been fully finalized by the early weeks of third project year and sent into production. Focused work on the delivery of the IT solution of the standalone demonstration tool, based on the prototype, has been successfully carried out [8]. To specify the details of the demonstration, stakeholder requirements were identified in the second project year, also to set the corresponding market designs in co-operation with WP2 and WP3, describing common TSO-DSO services and generalized market framework in the INTERRFACE project [9].

The benefits of such an approach for Spatial aggregation of Local Flexibility includes distribution of costs incurring from local flexibility procurement: PUN pricing is extended to include not only energy but flexibility capacity products as well [10]. The resulting market model is tuned to incentivize local flexibility by enabling local participants to bid on a connected TSO-DSO level market. The connection of both the global-TSO and the local-DSO dimension, and the joint allocation of energy and local flexibility provides proper price incentives through coupling different slices of trading. The actual benefits are shown in the demonstration and further analyzed to provide the input of the concluding milestone and the project deliverable. Also, market description has been elaborated to facilitate the documentation of the work on the demonstration development [11].

IT platform planning has been carried out to realize IEGSA connection of the standalone demonstration. IEGSA stands for an integrated architecture for grid services. Realization of the demonstration tool also required setting up a server environment at the BME. The standalone demonstration solution, custom developed in a Python environment has been finalized. It handles bids and the order book, and also provides an interface for aggregated bids. Excel order templates are developed to facilitate individual bidders. Automated runs of auctions are developed and deployed using a cloud-based input-output feeding structure. Results are interpreted separately for settlement, publication and individual bidder (bid and bidder ID management.)

The complete solution with IEGSA has several steps in demonstration:

1) Grid prequalification: DSO specific assesses local parameters.

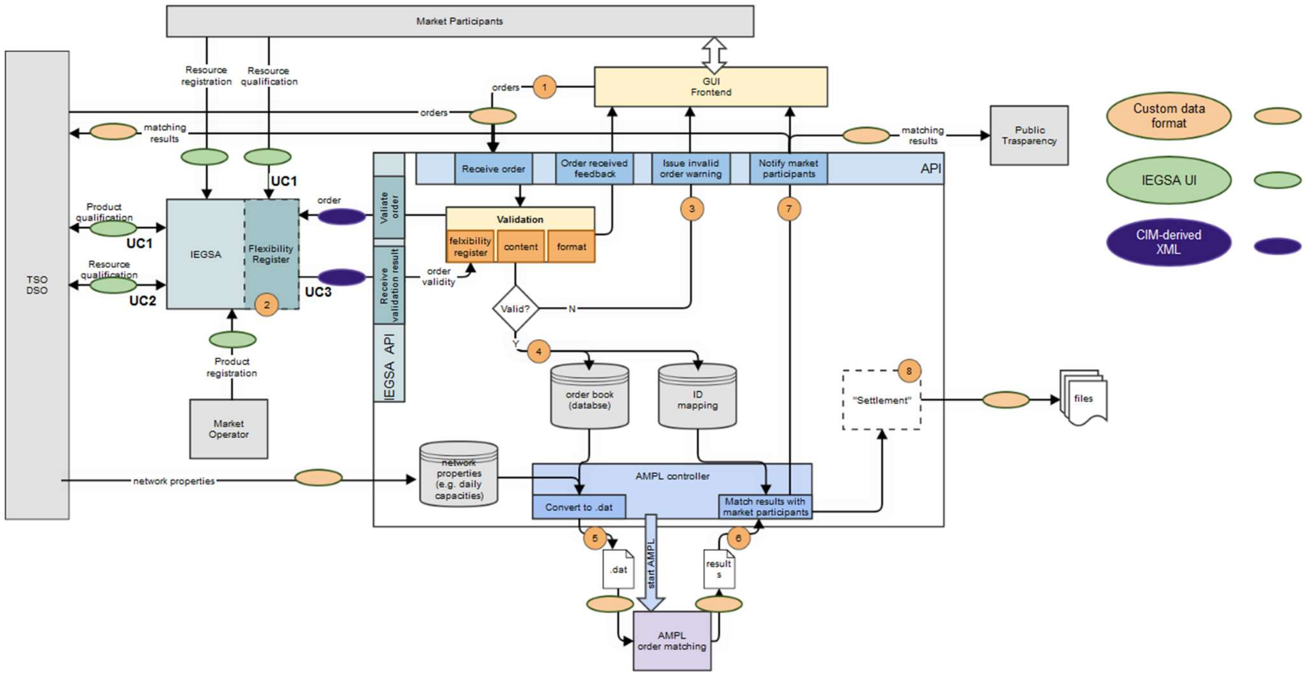
2) Product prequalification with energy and mFRR-like capacity bids.

3) Daily auction process (Local and TSO connected flexibility service provider (FSP) bidding, Bid prequalification with Flexibility Register, Compiling order book, Bid matching (auction based optimization).

4. Publishing auction results. Local implementation uses custom order book formats and standalone FSP bidding templates in Excel/.xml formats.

Data conversion tools are finalized and in productive deployment to map real-market datasets. First and second data batches are completed. Replanning of data scenarios is carried out.

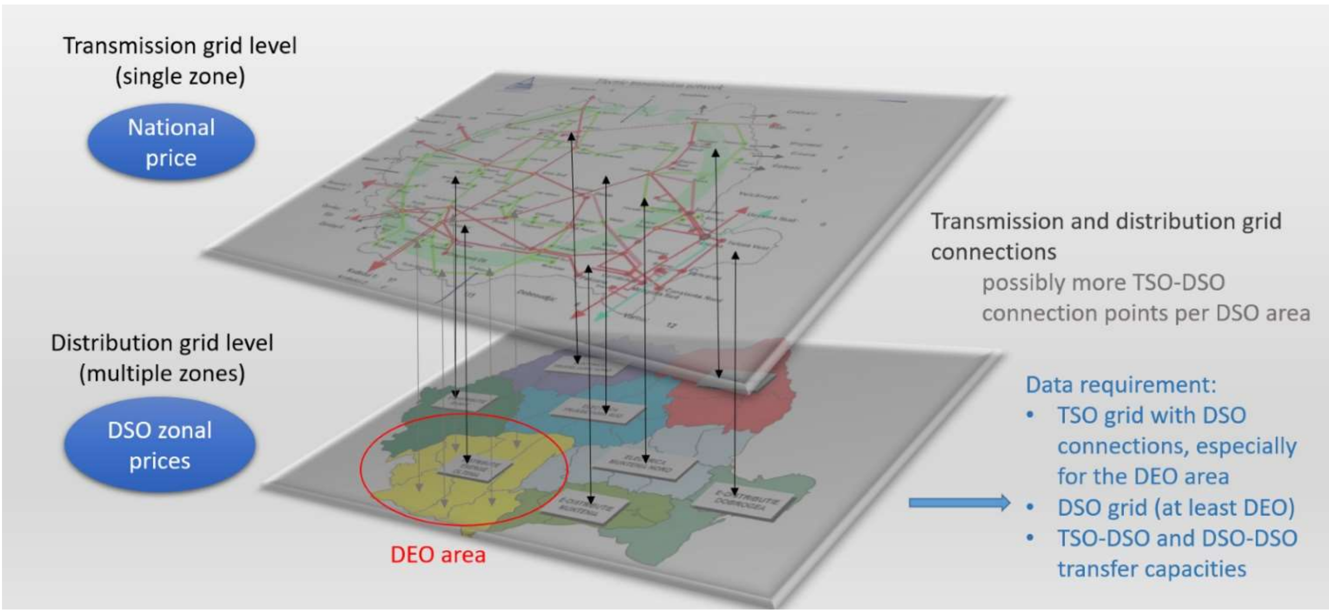
Connection with IEGSA is defined – IEGSA functionalities are fully covering the need for completing T7.2 integration. Development of .xml messaging is completed on the sending side. Update and elaboration of process descriptions is to enable final sprints of connection development, and effort has been focused on completing the interface development of custom .xml transactions.



1. Figure Demo business architecture – bid representation from Romanian DAM, IDM and BAM

3. Network constraints and auxiliary **parameters**

Illustration of considering the hierarchical grid in the market:



2. Figure: The hierarchical grid in the market

A market platform was created for DSO flexibility in an auction-based zonal pricing wholesale market [12].

If the locational information from the distributed sources providing energy and/or new types of flexibility bids can be channelled into the market optimization algorithm, this new aspect can only provide more welfare outcome of the day-ahead/intraday trading platforms. This spatial dimension can be introduced into the current wholesale market design, by the extension of a PUN-like bidding pricing scheme. PUN stands for Prezzo Unico Nazionale (National Uniform Pricing), a feature introduced in the Italian power market, which enables a special type of demand bid to be cleared, based on average of multiple zonal prices [13]. In this case, however, a hierarchical arrangement of different locations will be managed through market pricing. The PUN was applied in the Italian market to manage price differences between zones [14]. In the method, there are special set of orders, because the PUN demands bids to be cleared at an average price. In the proposed market, there are two kind of pricing schemes. The first pricing is in the case of a hierarchical TSO-DSO zone; while the second pricing, which is the pricing of flexibility need, is based on the order clearing price averaging effect [15].

PUN creates a special internal account for cross-financing – this helps create price incentives for local flexibility, as the costs of this capacity can be distributed to the highly liquid energy market [16].

PUN is an abbreviation used in the Italian day-ahead market. This price is equal to the average of the prices of geographical zones, weighted for the quantities purchased in these zones. Italy is divided into market zones geographically (North, Central-North, Central-South, South Sardinia and Sicily) [17], and the day-ahead market clearing algorithm considers the transmission capacity limits between the zones.

Accepted supply offers are evaluated at the clearing price of the zone. This price is the equilibrium price determined on hourly basis by the intersection of the demand and supply curves. Accepted demand bids, pertaining to consuming units, are evaluated at the single national price (PUN), which is the purchase price for end customers. It is computed as the average of the zonal prices weighted by zonal consumptions [18].

In the basic mathematical model of co-optimized local flexibility, wholesale energy allocation contains three variables. These are energy order, upward local flexibility order and downward local flexibility order. The purchase of the flexibility orders is for a DSO requirement. Each order has a location parameter (zone) specifying where the energy/flexibility capacity is offered to be produced/consumed. The constraints of the model are the energy and flexibility balance throughout the zones. The network constraints are hierarchy-based, using ATC between the TSO and the DSOs. In the model, the PUN pricing is for the flexibility bids.

4. Algorithm framework

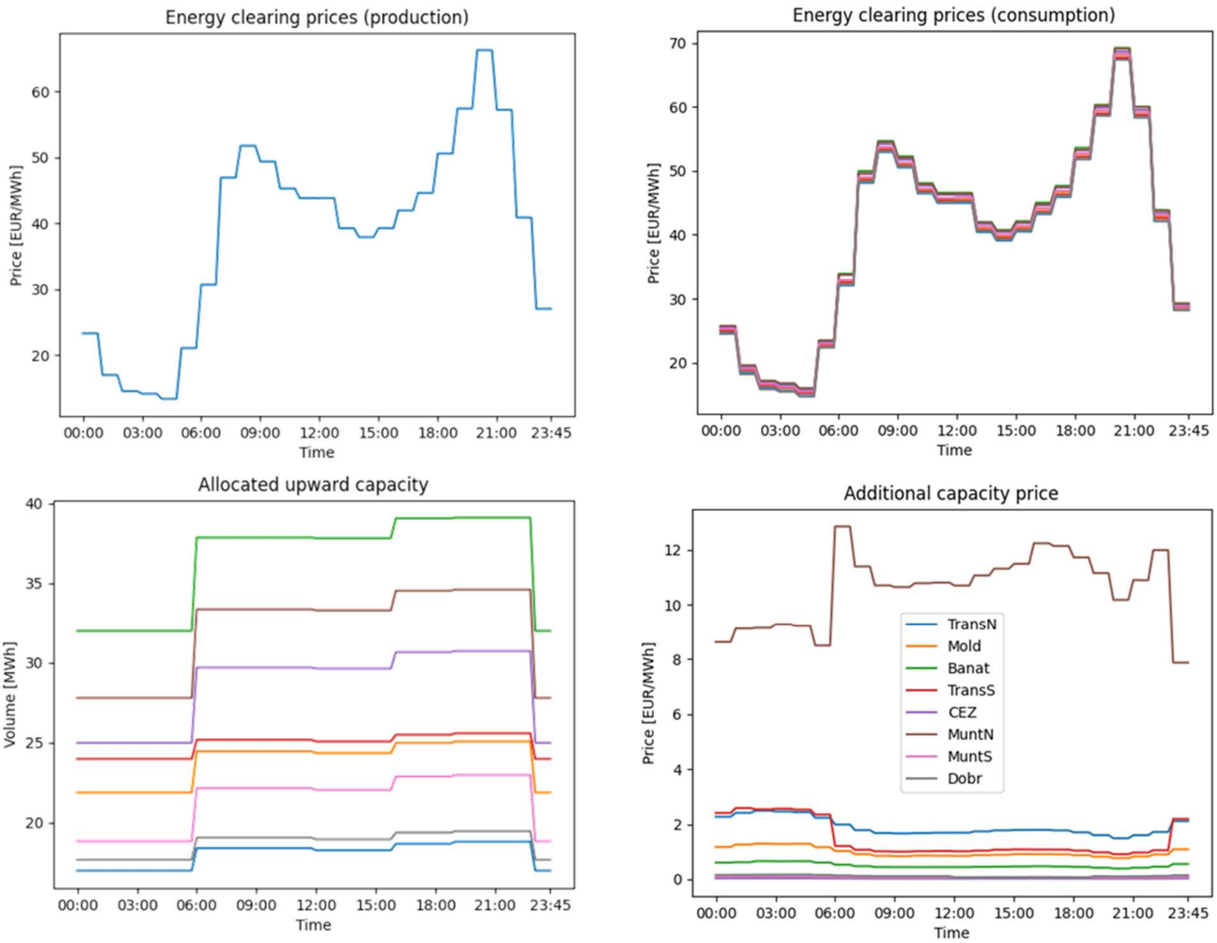
The high-level summary of the clearing process needs to take 5 steps into account.

1. Market and network data are collected for the purpose of bid matching / market clearing calculation. Several inspections and checks need to take place at this stage, such as the supervision of bid configuration in TSO and DSO bidding zones, the signs of consumer order quantities, the magnitude of reserve requirements, etc.
2. AMPL is used to create the bid matching (clearing) optimization model from the resulting data set. AMPL is a programming language and software environment that is able to formulate the clearing problem as an exact optimization model. The software applies a pre-defined mathematical model template, including optimization model constraints and the objective function.
3. The AMPL environment launches a generic solver routine (in this specific case CPLEX is used as a solver) in order to find the optimal solution for bid matching.
4. The results of Step 3 are collected and evaluated. (For the purpose of easier handling and interpretation, every market order has an identification parameter. Identifiers are therefore not used during the model formulation and solution processes.) Most importantly, it is first inspected if there is an appropriate feasible solution at all. This is necessary, because due to the complexity of the optimization, finding a first feasible solution may prove to be a computationally very intensive task. The optimization problem shall therefore be thoroughly checked against generally infeasible scenarios to have more time for a fall-back method or a pre-defined modification of the bid matching process.
5. If the evaluation finds that there is no appropriate feasible solution (either before the optimization process or by hitting the predefined time limit), a fallback algorithm might be necessary. The fallback process must have the same five steps.

The complete algorithm framework is wrapped around by a Python solution to ensure proper integration to other tools and data channels.

The results can be grouped into the following:

- Base-case energy (supply) prices follows the expectations.
- Demand prices are different in the zones due to additional capacity prices.
- Additional capacity prices are around 1-3 EUR/MWh, with 1-2 exceptions.
- Zonal characteristics are presented on the demanded volume.
- Zonal configurations and characteristics are to be further analysed.



2. Figure Base-case and only local market trading volumes

5. Conclusions

The market design and functionality have been set in collaboration with demonstration partners and analysis of the Romanian market design. The method to include spatial dimension and the resolution of the spatial dimension has been selected, zonal representation is favored to align the market algorithm to the existing EUPHEMIA-type common European Single Day Ahead Coupling Solution. The DSO usage of local flexibility will be realized in simulation. In alignment with the WP3 results, it is defined as an mFRR-like capacity product. The market provides short-term congestion management services as its primary grid service, according to the stakeholder needs. Also, this intraday auction based platform provides opportunity to trade energy in a finer, 15-min. time granularity (that allows BRPs to mitigate balancing cost), while allowing pricing of internal congestions according to corresponding Capacity Allocation and Congestion Management Network Code.

Regarding the EUPHEMIA-based market platform to include local flexibility resources tool (“Spatial Aggregation of Local Flexibility” demo), the technical description of the tool was elaborately presented, along with the list of IEGSA requirements that are covered by the demo. Moreover, the Scenario and results have been discussed and analysed.

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