MARKET-BASED FLEXIBILITY SERVICES FOR CONGESTION MANAGEMENT - A COMPREHENSIVE APPROACH USING THE EXAMPLE OF GERMAN DISTRIBUTION GRIDS

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ABSTRACT

According to the European Clean Energy Package (2019) Distribution System Operators (DSOs) shall effectively use flexibility services from local and regional assets to safely host more renewable energy sources in the electricity grid. Electricity prosumers become crucial players due to their potential to provide flexibility by adapting their production and consumption behaviour. Yet, integrating new types of assets into the distribution grid to use flexibility creates complexity and hardly predictable power flows in the distribution networks. The European H2020 demonstration project EUniversal aims to overcome the existing limitations in the use of flexibility. For that purpose, smart grid tools for grid state assessment and active system management are developed. A demonstration pilot is set up to test the flexibility value chain from congestion detection to market-based flexibility procurement via a local flexibility market. The pilot is conducted in the LV grids of the German DSO MITNETZ STROM, examining the use of flexible resources in the LV grid for congestion management. The article describes the set-up of the flexibility value chain and shows how all individual parts are integrated into the complete process.

INTRODUCTION

Need for flexibility in distribution networks

The European Union aims to create a more sustainable energy system. Therefore, system operators need to safely integrate more renewable energy sources (RES), while considering new load patterns due to higher amounts of electric vehicles, heat pumps and other small-scale assets in the low voltage (LV) distribution network. With the growth of power system generation and load intermittency, the challenge of ensuring the operational reliability of distribution networks is a complex problem to solve. Distributed flexibility and smart-grid solutions are needed to cope with the increased volatility of the grid power flows to prevent an increased number of congestions. Grid congestions in this article mean the thermal overloading of lines as well as voltage violations.

Within the European H2020 project EUniversal [1], a demonstration is set up in Germany to test a comprehensive approach to overcome limitations and challenges in the use of flexibility by DSOs. Furthermore, the demonstration examines solutions to guarantee the security of supply, while avoiding unnecessary network investments, through a combined use of principles of the German mandatory scheme Redispatch 2.0 [2] and local flexibility markets.

This article describes the set-up of the flexibility value chain in the German demonstration, explaining the different smart grid tools and the market-based flexibility procurement [3].

Demonstration site characteristics

Figure 1: Region of MITNETZ STROM

The demonstration takes place in LV Grids of the German DSO MITNETZ STROM, one of the largest regional distribution system operators in Germany. MITNETZ STROM is responsible for supplying electricity to 2.2 million electricity consumers in East Central Germany, visualized in Figure 1. The grid area covers 30,804 km² and consists of mainly rural conditions with a high share of renewables. The installed capacity of renewable energy reached more than 10 GWs for the first time in 2021. [4]

For the demonstration, a set of LV grid feeders with a relevant infeed of RES and cross-sector loads (EVs, Heat pumps, batteries) was chosen.

Connection to Redispatch 2.0

Redispatch 2.0 describes measures to reduce the active power output of power plants to protect line sections from congestion in Germany. In case of a congestion risk in a section of the grid, a redispatch of the power feed-in by the power plants near the congested area is done, to create a load flow that counteracts the congestion.

Since 2019, the Redispatch 2.0 regulation affects all generation units with an installed capacity >=100kW and their connected system operators (incl. DSOs). An optimized and iterative reporting procedure was developed for the data exchange between DSOs, TSOs and plant operators as shown in a simplified form in Figure 2. [2]

Basic features such as iterative congestion forecasting and bidirectional data exchange between the voltage levels are part of this mandatory process and are also adopted in the framework tested within the demonstration. The advantage is that the tested framework is based on proven ideas and potentially creates opportunities for expanding the Redispatch 2.0 process into lower voltage levels. Ultimately, the idea is to facilitate access to flexible resources that are not included in the Redispatch 2.0 regulation via the local flexibility market.

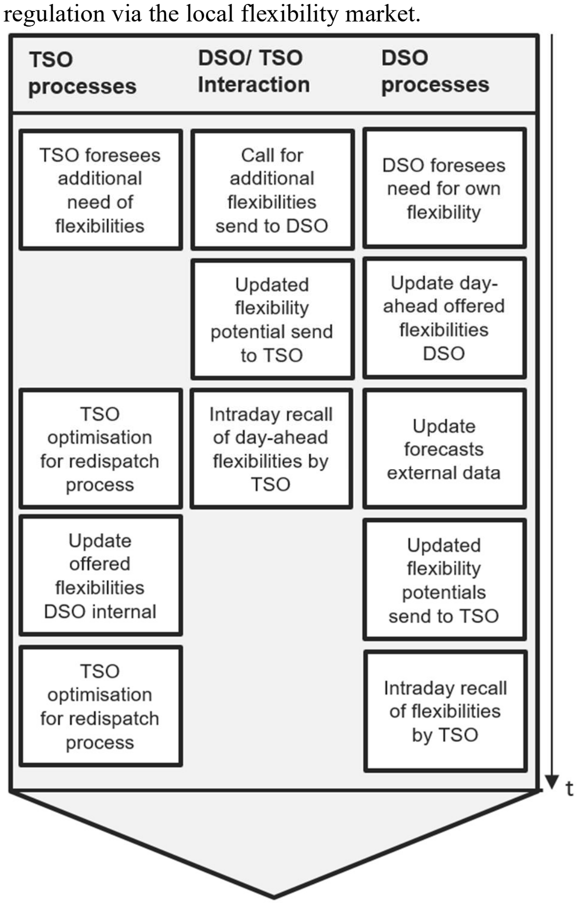

Figure 2: Redispatch 2.0 processes

DEMONSTRATION APPROACH

Within the demonstration, a set of smart grid tools is sequentially and iteratively used for precise grid state forecasting, analyses, and flexibility need assessment when congestions are identified. The DSO then connects with the flexibility market to find the most effective flexibility offers in terms of location, volume, and price from the resources registered on the market platform to relieve the forecasted congestions. Furthermore, the registered flexibility can be made available to the higher voltage levels in a cascaded process to be used for system-wide services. This architecture, as implemented for the demonstration, is shown in Figure 3, and consists of the following two steps:

I. Congestion Detection and Flexibility Need Quantification

- Flexibility resources are registered and prequalified on a flexibility market.
- A congestion forecast is performed and the headroom capacity for secure flexibility activation on the network is calculated.
- A distribution state estimation is run to allow monitoring of the real-time system state prior to activation.
- A network flexibility needs assessment is performed to determine the minimum amount of flexibility needed for ensuring network operational integrity.

II. Market-based flexibility service selection and activation

- An optimal bid recommender helps to select the most appropriate flexibility bid for the identified congestions.
- After identification of the required flexibility, the flexibility bid is submitted to the flexibility market. The FSP submits flexibility offers according to the registered local assets. Orders are cleared continuously applying Pay-as-Bid.

This operational set-up is implemented within a continuous, iteratively running framework, starting 48h-ahead, and extending to intraday, close to the delivery time when the flexibility is required. The iterations ensure higher accuracy of the calculation results due to more accurate weather forecasts while time progresses. Furthermore, they support the coordination between different system levels as corresponding assistance systems can consider the last forecast of the connected grid level without requiring a common computational model. This enables coordination across multiple voltage levels without having to disclose critical data, even in the case of several system operators. In the demonstration, the LV and MV grid levels and their respective flexibility requirements are considered.

As mentioned previously, the same procedure can potentially also be used to make the link to the German congestion management process Redispatch 2.0, now

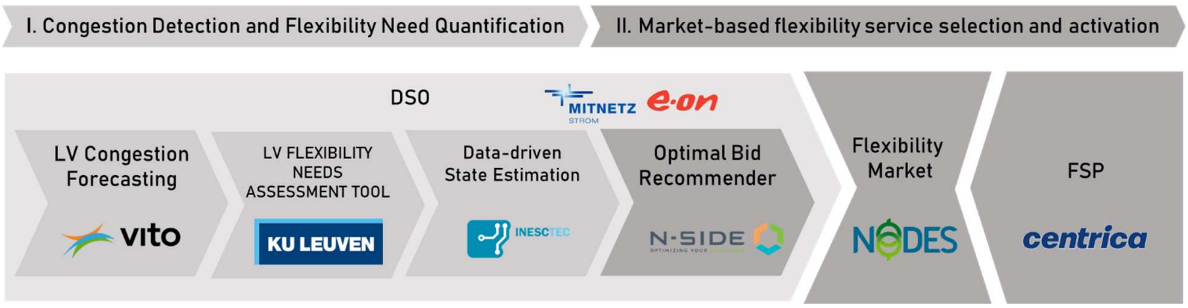

Figure 3: Process diagram showing the different smart grid tools, and the market environment set-up.

operated in High Voltage and Extra High Voltage, by adding further needs assessment and headroom calculation layers, as well as the necessary data and communication models.

In the following section, a further explanation of each smart grid tool and the market-based procurement is given.

Congestion Detection and Flexibility Need Quantification

LV congestion forecasting and headroom calculation

As a first step a congestion forecast is done 48h-ahead to detect the risk for congestions. A statistical approach ensures that the variation in offtake patterns of LV customers is considered. An example of such forecast result is illustrated in Figure 4, showing the forecasted current at one feeder head in the demonstration. The corresponding congestion probability is also shown in the same figure.

Simultaneous activation of multiple flexible resources on the LV network, e.g. to solve issues on the MV level, could cause congestions on that LV network.

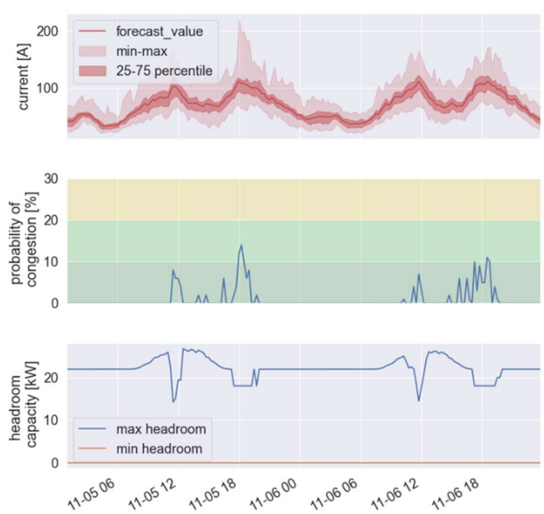

Figure 4: Congestion forecast of one feeder in the pilot. The predicted current through the main branch is shown in the top plot, the corresponding probability of congestion is shown in the middle plot, and the maximum and minimum headroom capacity is shown at the bottom.

Therefore, the available headroom capacity for a secure flexibility activation on the network is calculated. This headroom capacity indicates the maximal flexibility that can be activated by any device without creating congestions for every time step. The headroom capacity drops when congestion probability increases (Figure 4).

Flexibility Needs Assessment

Flexibility needs assessment (FNA) refers to the amount of flexibility a DSO needs to procure from the flexibility market to avoid probable congestions [5]. The congestions are captured simulating various scenarios considering different nodal load patterns and generation forecasts with their respective error range. Then, a flexibility needs assessment optimal power flow (FNA-OPF) problem is solved for each of the scenarios. Only considering the worst-case scenario for flexibility procurement would lead to substantial over-procurement. To avoid this, a risk-based index, is introduced. A higher risk index implies a higher risk for unresolved congestions. A schematic framework for the FNA is shown in Figure 5.

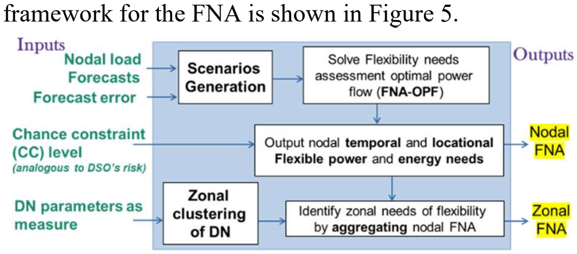

Figure 5: Flexibility needs assessment tool

Data-driven State Estimator (DdSE)

The DdSE estimates both voltages and powers based exclusively on historical information gathered by the smart grid infrastructure along with some real-time measurements and exogenous information, like weather forecasts, and calendar information (hour of the day, day of the week, etc.). This leads to the following innovations [6]:

a) Use of a very limited number of real-time metering points (assuming that smart meter measurements are sent every 24 hours or every week) (Figure 6).
b) The output takes the form of quantiles representing uncertainty in the state estimation process. This enables the creation of probabilistic alarms for voltage problems, e.g., 95% probability of overvoltage in a specific node.

c) Neither topological information, nor electrical characteristics of the grid are necessary.

This state estimator is used to keep real-time track of the actual grid state, after possible activation of flexible resources and thus serves as a supplement to the statistical forecast, for validating the results. If the flexibility activation is not sufficient, emergency measures can be taken so that secure grid operation is ensured.

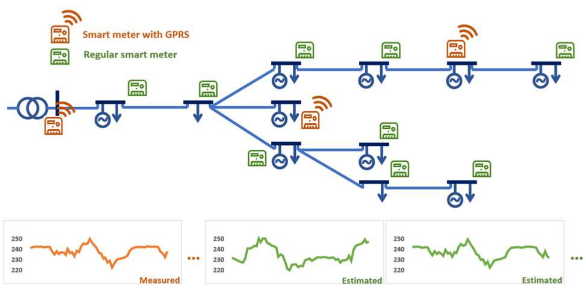

Figure 6: Voltage estimations for the meters without real-time communications.

Market-based flexibility service selection and activation

The market-based procurement process in the demonstration is set up according to the digital flexibility value chain, illustrated in Figure 7, with the DSO MITNETZ STROM as a buyer, Centrica as Flexibility Service Provider (FSP) and NODES as independent market operator. Furthermore, N-Side`s optimal bid recommender is interconnected on the buyer' side to ensure the selection of the most effective flexibility service for the specific grid problem.

Optimal bid recommender

The optimal bid recommender (OBR) is a tool to help the DSO to select a combination of flexibility bids that solves as many congestions as possible at the lowest price (Figure 8). When launched, the OBR will first gather the inputs: the grid static data that gives a view of the network topology, the grid state forecast (defined by the headroom capacity) and market-related information. Then a market-clearing engine within the OBR will determine the optimal bid selection by solving a mathematical optimization problem.

After a solution is found, it is transmitted to the DSO, which will then be able to submit 'buy' bids to match the recommended 'sell' bids.

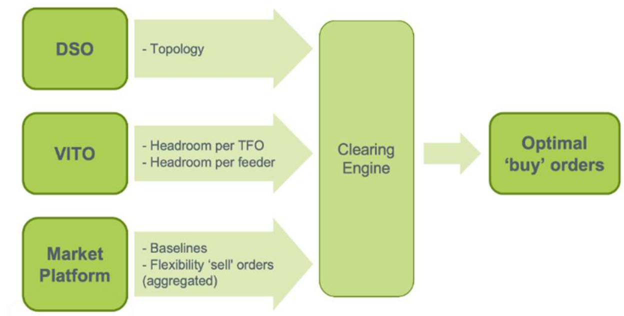

Figure 8: Inputs and outputs of the N-SIDE Optimal Bid Recommender (OBR)

Flexibility Market

NODES as independent market operator provides the central environment for market-based procurement of flexibility enabling the correct and transparent transactions between buyers and sellers. Using NODES integrated market design, shown in Figure 9, flexibility can be offered bottom-up and bought top-down allowing for an efficient use of available flexibility resources across all grid levels. To ensure the correct interactions between stakeholders and hence to overcome the operational challenges of managing numerous flexibility assets in the LV grid, NODES flexibility market covers all necessary services related to each trading phase, i.e. registration and prequalification, flexibility procurement, and validation and settlement.

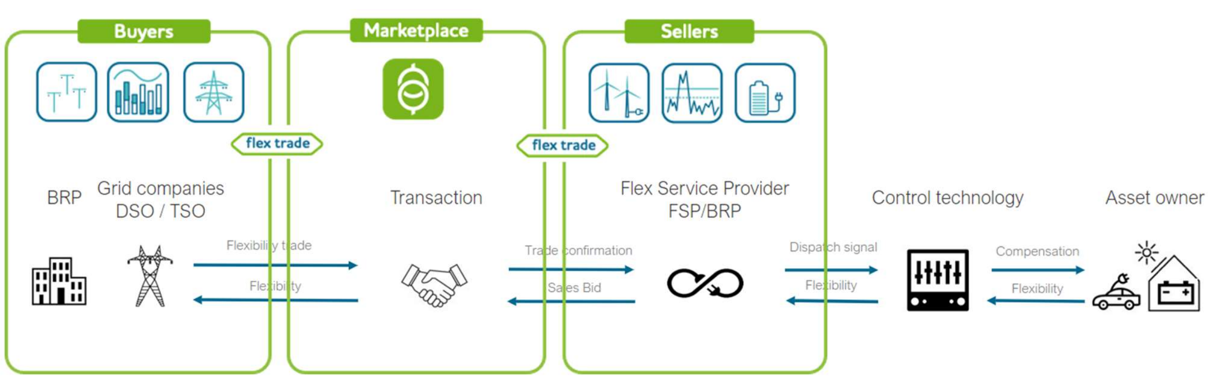

Figure 7: Digital flexibility value chain [7]

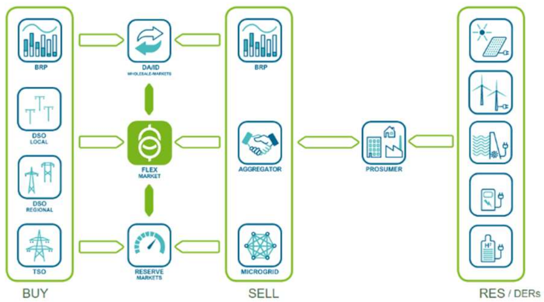

Figure 9: NODES integrated market design [7]

Flexibility Service Provider

Centrica has the role of the FSP in the demonstration and offers the flexibility services of one or multiple resource(s) through aggregation to DSO. The process starts with the registration of the flexible assets into NODES market platform, followed by the development of a physical model for each flexible asset. The FSP is also responsible for defining different portfolios (clusters of resources) and for solving an optimization problem to compute the optimal bids for each portfolio, which are then, together with the baselines, submitted to the flexibility market. After the market clearing, the FMO sends a notification to the FSP regarding the accepted bids. The FSP needs to dispatch the accepted offers via individual assets and must make sure that the service is delivered in real-time.

CONCLUSION

This article illustrates a comprehensive process to incorporate flexibility services for congestion management for the DSO.

The smart grid tools used for congestion detection and flexibility needs assessment, as well as the NODES flexibility market design are outlined. The proposed framework will assist system operators to make sensible decisions for flexibility planning and procurement while considering congestion probabilities and the cost of flexibility activation. The outlined approach shows how the different tools interact to enable a straightforward congestion management within the practical environment of German LV grids.

Final evaluations will be made after all tests have been completed, during the coming period.

Acknowledgments

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