Active Distribution Grid Management – a decentralized approach for the management of flexibility options

Michael Merz, PONTON, 20.05.2020

Abstract

Facing the energy transition, decentralized renewable sources of energy as well as decentralized consumers can lead to congestion situations both horizontally at the transmission grid level and vertically within the areas of distribution grids.

Grid-supportive flexibility is a solution to mitigate such congestions. In order to roll-out a standardized process for congestion management, Austrian DSOs (distribution system operators) conducted the project Active Distribution Grid Management (ADGM) in early 2020 in order to test if the existing data communication infrastructure can be re-used to offer and activate flexibility, to simulate typical congestion scenarios, and finally to visualize the impact on involved asset managers and grid operators.

This paper presents the ADGM project results and how it is applied to a distribution grid congestion scenario. It specifically shows how a distributed flexibility management process is implemented.

1 Introduction

Facing the energy transition, decentralized renewable sources of energy as well as decentralized consumers will lead to congestion situations both horizontally at the transmission grid level and vertically within distribution grids.

Grid-supportive flexibility is a solution to mitigate such congestions. In order to roll-out a standardized process for congestion management, Austrian DSOs (distribution system operators) conducted the project Active Distribution Grid Management (ADGM) in early 2020 in order to test if the existing data communication infrastructure can be re-used to offer and activate flexibility, to simulate typical congestion scenarios, and finally to visualize the impact on involved asset managers and grid operators.

There are various ways to organize the allocation of flexibility – many are market-based such as Enera [1], GOPACS [2] or NEW 4.0 [3], using a central or decentral platform to match orders between producers and consumers of flexibility. Others are based on bilaterally offering flexibility to the local DSO as being currently implemented in Germany, following the Redispatch 2.0 model, which is, in turn, based on the NABEG legislation [4] (Grid Expansion Acceleration Act, German: Netzausbaubeschleunigungsgesetz).

From an Austrian perspective, it is important to address the requirement for a market-driven allocation of flexibility as 100% of the energy production will be renewable by the year 2030, at least balance-wise (this is the target of the Austrian “Mission 2030”). The Austrian way, as it is foreseeable today, follows first a decentralized approach, similarly to Redispatch 2.0, but allows, secondly, also the trading of flexibility on a market platform.

The rationale for the ADGM project is to explore the process, data formats, data exchange protocols, and scenarios for the interaction between asset operators (also called FSP – Flexibility Service Providers), DSOs and the TSO.

This paper reports on the results of the project and is organized as follows: In section 1, the ADGM process is described. Section 2 focuses on the technical set-up for the project itself plus the existing EDA data communication infrastructure [5], which is re-used by ADGM. Section 3 introduces a simplified grid modelling language while Section 4 finally presents a simulation scenario together with the visualization of the data exchange and activation of flexibility.

2 Flexibility Offering and Activation Process

The offering and activation of flexibility is performed in the following way: On the day prior to delivery (D-1) FSPs from the production and consumption side submit their asset production schedules to their respective DSO. At the same time, the simulation sets the demand for flexibility for both DSOs and TSO, expressed by a demand schedule. This is created on D-1 as well for each grid operator.

For the processing of the offered flexibility, a cycle may be defined for data processing, e.g., 2 or 4 hours. On the delivery day, this cycle is used to process submitted data in order to calculate the activation for the ahead period. As an example, using a 2-hour cycle, the target period 14:00 – 16:00 is calculated at 12:00h. Flexibility that is offered intraday prior to this cut-off time can still be used for the target period.

Whenever a DSO calculates the target period, the own flexibility demand, grid restrictions and available flexibility from FSPs is used to determine the volume required per 15 minute period within the grid area of the DSO. Any further volume that is not required by a DSO is forwarded to the next-higher grid operator as an anonymized merit order list (MOL).

The TSO, as the operator of the highest level in the grid hierarchy, calculates the own demand for flexibility, also based on the own grid restrictions, and maps it against the MOLs received from underlying DSOs. As a result, the TSO sends an activation message back to each DSO from which flexibility is requested. The latter aggregate demand for flexibility of the TSO and of their own and finally send an activation message to the selected FSP.

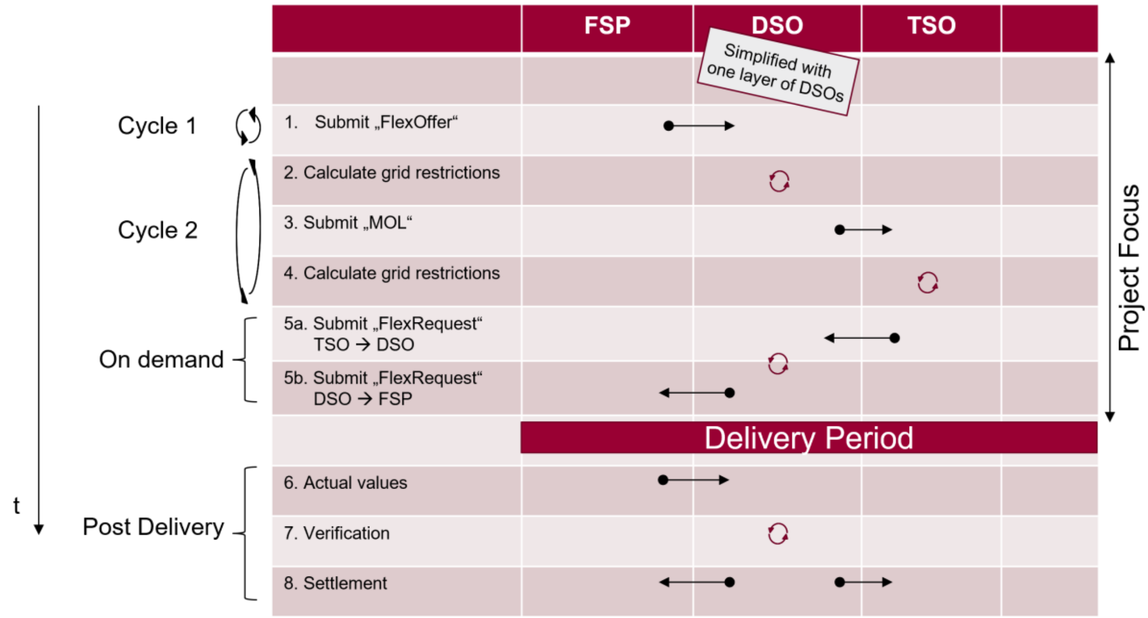

Figure 1: Process Model

3 Technical Foundation

The ADGM project builds upon the existing EDA infrastructure. EDA stands for "Energy Data exchange in Austria" which represents the general interoperability layer for a range of Austrian market processes. Originally, EDA was established in the year 2012 to provide a unified, standardized, and decentralized data communication infrastructure for the supplier switching process. As the regulator demanded, a switching process had to be accomplished within 12 business days, while the individual message transfer between process participants had to be accomplished within 5 seconds. So a reliable data communication service was introduced that allows for interoperability between a large number of participants and processes.

In turn, this required a standardized end-to-end communication with full digitalization and process automation. EDA has addressed this by using exactly the same communication endpoints for all participants in the entire energy sector, including TSO, DSOs, suppliers, customers, and many other market roles. Thanks to the high level of standardization, EDA allows for over 99 percent of the switching processes to be accomplished within seconds.

In case of EDA, there is no tight link between a given functional process layer (such as "supplier switching") and the communication layer. I.e., the EDA communication infrastructure can be re-used for any other business process. This helps minimizing the implementation cost for new processes such as, e.g., the management of flexibility.

For this reason, EDA could easily be utilized for any data exchanged in the ADGM process model described above: Each simulated player uses an EDA communication endpoint as illustrated in Figure 2. As part of the ADGM project, only the role-specific, functional logic of the FSP, DSO and TSO needed to be implemented. In addition to interacting through the EDA infrastructure, all participants reported monitoring data to a further participant, the Visualization Server. This is used to collect, synchronize, and illustrate input data from all process participants.

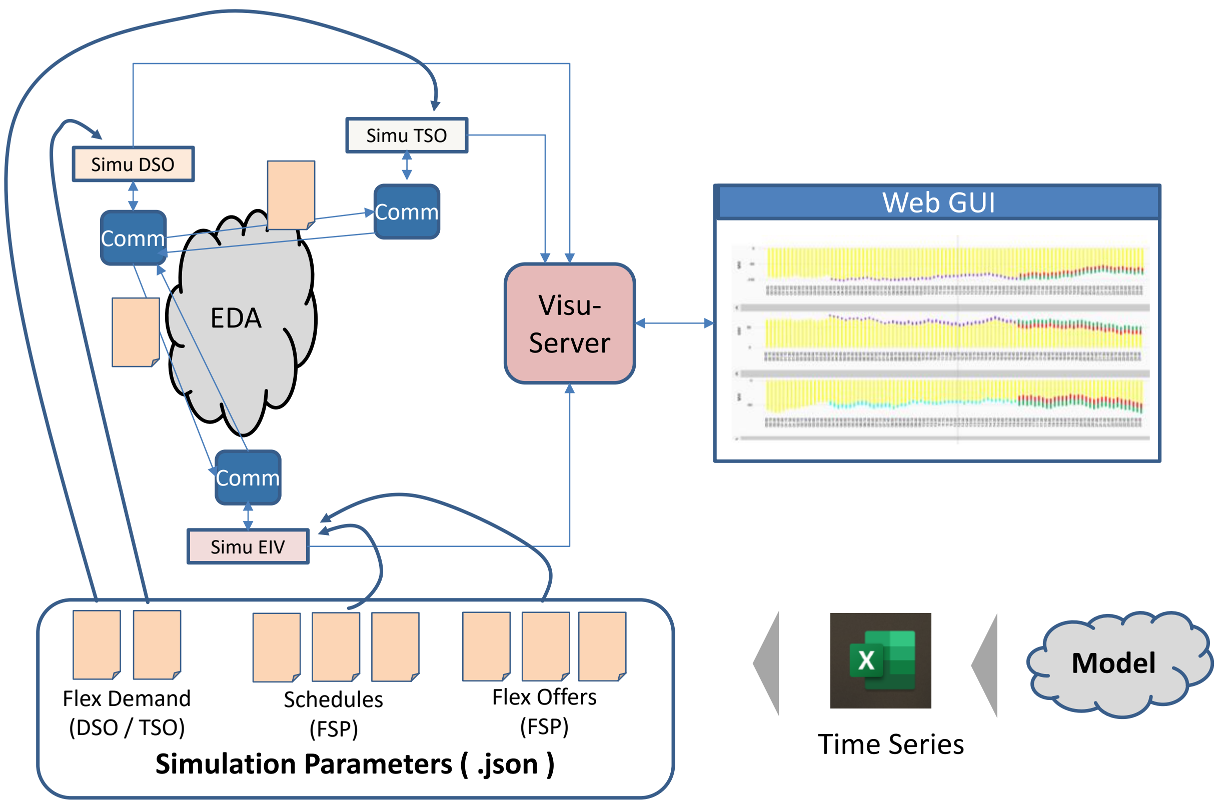

Figure 2: Technical Setup

Whenever a message is exchanged between process participants, it is also copied to the visualization server, leading to an update of the status display for available and demanded flexibility for the given time interval.

The simulation project allows to set parameters for all types of time series involved: Production schedules, flexibility demand and supply curves. With these parameters, any congestion situation can be defined at any location in the simulated grid. Time series are defined using an Excel sheet that is transformed into schedules represented in the JSON format.

4 Simplified Grid Modelling Language

The interconnection of participants is described using a simplified grid modelling language. This language has been developed to model

- the grid hierarchy of the TSO and DOSs with its basic resources,
- the connection of production and consumption assets within the grid topology, and
- the sensitivity of assets. Production / consumption may have a different impact on grids as distribution grids and assets at the 110 kV layer may be connected through redundant lines to the transmission grid – this is called sensitivity.

Usually, a grid modelling language such as GGM (Common Grid Model) and its exchange format CGM-ES (CGM Exchange Standard) [6] could be used for the ADGM project. However, as the runtime was only four months, we preferred to develop an own, simplified language with still provides enough expressive power so that the modelled grid and its participants could be sufficiently described.

This simplified grid modelling language is used to define the following building blocks:

- “Lines”, representing lines at the different grid layers.

- “CPs”, representing vertical or horizontal connection points that form a grid hierarchy out of individual lines. In order to model congestion flows, the TSO grid is separated into horizontal lines which are also connected through a connection point. Alternatively, a connection point links a lower grid element to a higher one.
- “Assets” (producers and consumers) are linked to a line in the grid hierarchy.
- Should a distribution grid be connected to more than one TSO line, the sensitivity needs to be defined as well per connection point. As can be seen from Figure 3, the impact of the left 110 kV grid towards the left UHVG line is 30% and towards the right is 70%.
- TSO / DSOs. The operator of a grid is attached to a Line element. Naturally, it is the TSO attached to the two UHVG lines, while DSOs are attached to distribution grid lines. If a high-level DSO is attached to a 110 kV line without any further DSOs being attached to subordinated lines, then all subordinated distribution grids are controlled by this DSO. In all (more realistic) other cases, subordinated grid layers may be controlled by second- or third-level DSO. If these exist, they are just attached to the lower grid such that a hierarchy of multiple DSOs can be formed.

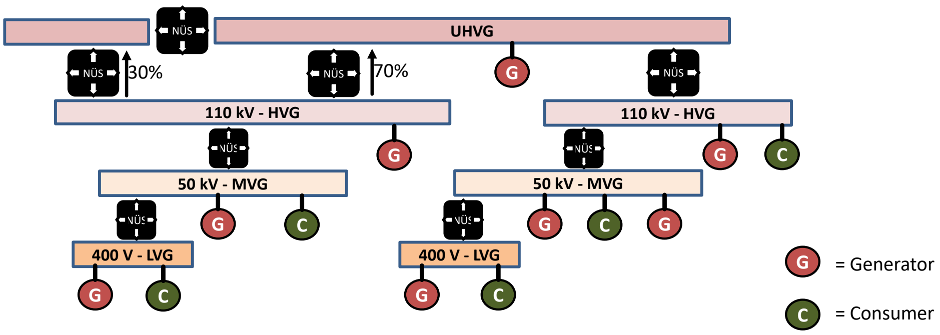

Figure 3: Simplified Grid Model

The grid layout displayed in Figure 3 is constructed from a list of definitions as the following example shows:

```
GridTopology {

Name = „UpperAustria";

Line { Name „APG-East"; Type „UHVG” }
Line { Name „APG-West"; Type „UHVG” }
Line { Name "Steyr”; Type "HVG” }
Line { Name "Gmunden”; Type "HVG”}
Line { Name "Kremsland”; Type "MVG”}
Line { Name "Donauland”; Type "MVG"}
Line { Name „Neuhofen"; Type „LVG”}
Line { Name "Hinterhofen”; Type "LVG"}


TSO {Name „APG" Line „APG-East" }
TSO {Name „APG" Line „APG-West" }
DSO {Name „Netze OÖ" Line „Steyr" }
DSO {Name „Netze OÖ" Line „Gmunden" }
DSO {Name „Netze NÖ" Line „NÖ" }
DSO {Name „Netze Steiermark" Line „Steiermark" }
DSO {Name „Netze Neuhofen" Line „Neuhofen" }


CP { Name "APG-East-APG-West”; Line "APG-West”; Line "APG-East” }
CP { Name "APG-Steyr-East”; UpperGrid "APG-East”; LowerGrid "Steyr” }
CP { Name "APG-Steyr-West”; UpperGrid "APG-West”; LowerGrid "Steyr” }
CP { Name "APG-Gmünden”; UpperGrid "APG”; LowerGrid "Gmünden” }
CP { Name "Steyr-Kremsland”; UpperGrid "Steyr”; LowerGrid "Kremsland”
       Sensitivity { APG-Steyr-West; 0,3 } Sensitivity { APG-Steyr-East; 0,7 } }
CP { Name "Gmünden-Donauland”; UpperGrid "Gmünden”; LowerGrid "Donauland” }
CP { Name "Kremsland-Neuhofen”; UpperGrid "Kremsland”; LowerGrid "Neuhofen” }
CP {Name "Donauland-Hinterhofen”; UpperGrid "Donauland”; LowerGrid "Hinterhofen”}
```

```
FlexProvider { Name = "BigCoalPlant"; Line "APG-West" Type „Producer"}
FlexProvider { Name = "Voest Alpine"; Line "APG-East" Type „Consumer"}
FlexProvider { Name = "HydroPlant1"; Line "Kremsland" Type „Producer"}
FlexProvider { Name = "HydroPlant2"; Line "Gmünden" Type „Producer"}
FlexProvider { Name = "GasPlant"; Line "Steyr" Type „Producer"
       Sensitivity {APG-Steyr-West; 0,3 } Sensitivity {APG-Steyr-Ost; 0,7 } }
FlexProvider { Name = "BiogasPlant"; Line "Donauland" Type „Producer"}
FlexProvider { Name = "Battery-1"; Line "Kremsland" Type „Prosumer"}
FlexProvider { Name = "Battery-2"; Line "Neuhofen" Type „Prosumer"}
FlexProvider { Name = "Bäcker Huber"; Line "Neuhofen" Type „Consumer"}
FlexProvider { Name = "Biogas Bauer Bunge"; Line "Hinterhofen" Type „Producer"}
FlexProvider { Name = "Elektrolyseur Erwin Egenhofer"; Line "Kremsland" Type „Consumer"}
}
```

5 Simulation Run

In the course of the ADGM project, a couple of simulations have been performed. Some of them focused on horizonal congestions at the transmission grid level and the possibilities to help mitigate them from a DSO's perspective. The simulation presented falls in the category of a vertical congestion, it is characterized by a high load from decentralized production at the lower grid layers. As means for mitigation there are various possibilities given:

- Increase local consumption close to the affect grid layers,
- Decrease production in the grid layers,
- And/or involve the TSO to support with flexibility activated at locations beyond the distribution grid.

The following Figure shows a vertical grid hierarchy with anonymized idenitifications:

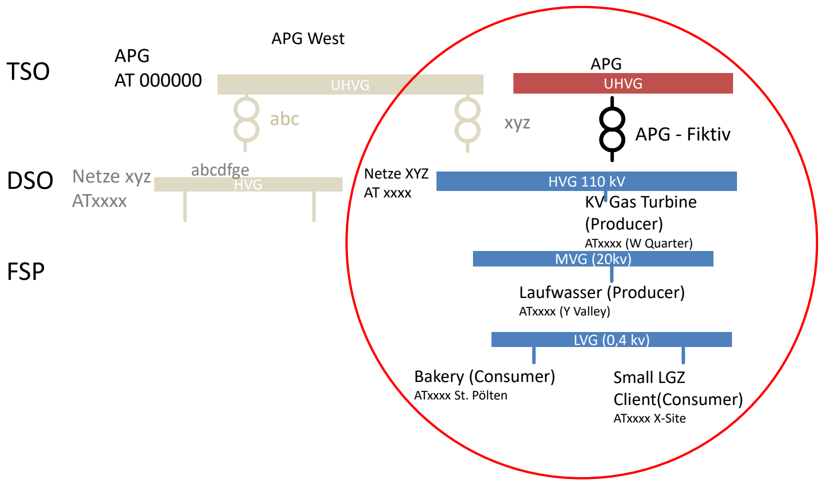

Figure 4: Simulation of a vertical Congestion

The following daily cycle visualizes the congestion situation and measures to mitigate it:

- Early in the morning, there is demand for redispatch to increase production (green DSO curve between 10:00 and 12:00). This leads to the activation of positive flexibility (displayed in violet color), offered by the two FSPs AT002001 and AT002002. The offered flexibility has been requested by the DSO at 08:00 in the morning.
- Around noon, there is demand on the TSO side to reduce production. Different offers from FSPs are available as they have been sent from the DSOs to the TSO as a MOL.

Consequently, the TSO requests its demand of 1 MW for four 15 minutes intervals from the DSO, which, in turn, activates FSP AT002001 (displayed as reduced production in light blue color).

- For the afternoon, positive flexibility is requested again by the DSO and activated at both FSPs (violet bars).
- The time interval after 18:00 is not yet covered by the process as this is still more than one cycle ahead of the simulated time. Flexibility offers are still available here (green for positive and red for negative flexibility).

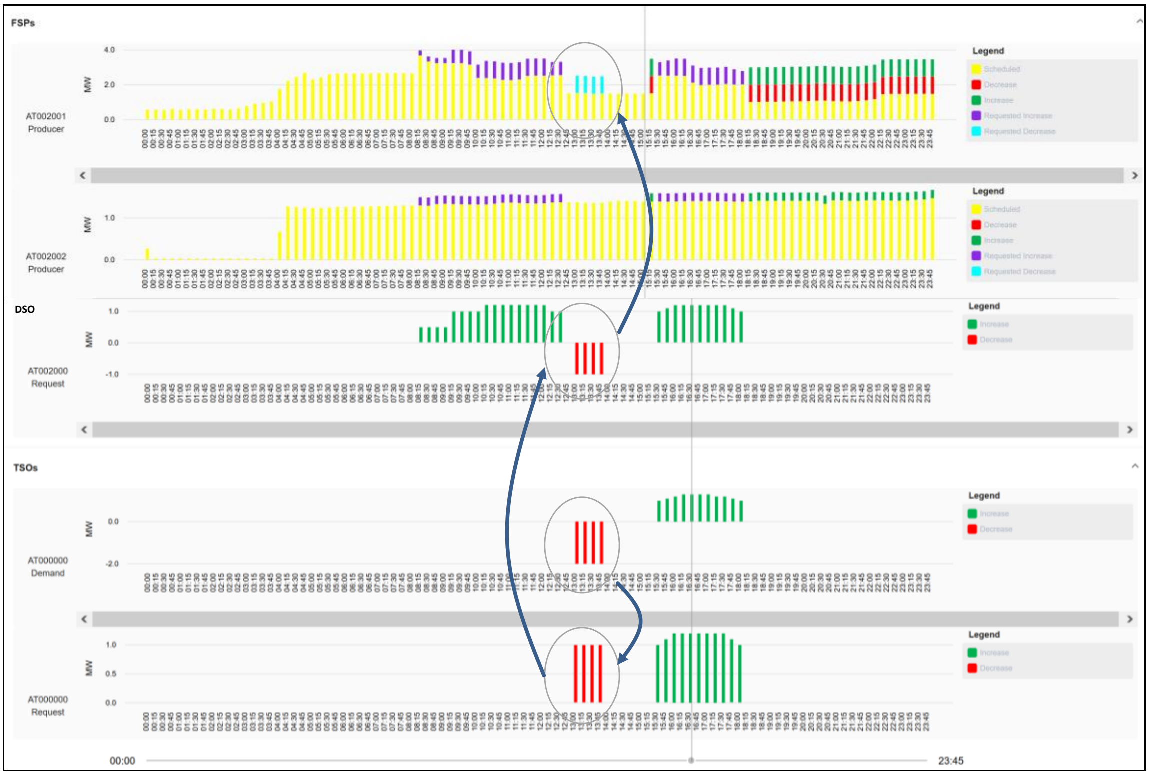

Figure 5: Simulation output

6 Conclusions

The main gain in knowledge of the ADGM project lies for the involved grid operators in the following points:

1. The existing EDA infrastructure can be re-used for the process of flexibility management in a decentralised manner without any severe adaptation effort.
2. The chosen process is capable to let FSPs offer their flexibility for day-ahead or intraday time intervals and to let grid operators decide on the selection and usage of flexibility based on the location, volume and price of the given offers. The cycle interval can be flexibly adjusted.

For PONTON, the project delivered valuable insights in how flexibility offers and activations can be efficiently and securely exchanged between market participants and grid operators. It was also insightful to simulate the activation of flexibility based on a grid model which has a drastically reduced complexity compared with CGMES, but which is sufficiently flexible to model various congestion situations.

As a next step, Austrian grid operators may apply the gained knowledge to advance a common standard process for flexibility management across all grid layers and possibly also with partnering EU member states.

An interesting extension would also be to intensify a market-based redispatch mechanism which applies within the given cycles of two or four hours: As soon as the allocation for a cycle is finalized, market participants may continue to offer and activate the trading of flexibility in a way that is known from the spot market, i.e., on a quarter-hourly basis.

References

[1] ENERA project website: https://projekt-enera.de

[2] GOPACS project website: https://gopacs.eu

[3] NEW 4.0 project website: https://www.new4-0.de

[4] NABEG (Netzausbaubeschleunigungsgesetz): https://www.netzausbau.de/EN/home/en.html

[5] EDA project website:
https://www.ebutilities.at/energiewirtschaftlicher-datenaustausch.html

[6] CGMES – Common Grid Model Exchange Standard

https://www.entsoe.eu/digital/cim/cim-for-grid-models-exchange