aFRR pilot end report

Management summary

To maintain the real-time power balance of the electricity grid in the Netherlands, TenneT contracts and activates (amongst others) regulating power, also called *automatic Frequency Restoration Reserve* (aFRR). This flexible power product is offered to TenneT by market parties which are called *Balancing Service Providers* (BSPs). Historically aFRR is mainly provided by traditional large scale production plants. In line with the energy transition it is expected that in the future less of those large scale power plants will be available and so less aFRR will be offered to TenneT for balancing purposes.

To prepare for such times and to enhance the level playing field, TenneT aims to make the aFRR market more easily accessible for BSPs that aggregate smaller scale assets, renewable generation and/or demand response to provide flexibility. With this project TenneT investigated and reduced unnecessary barriers for decentral assets and/or renewable energy sources to deliver aFRR to TenneT. The goals of the project were:

1. Assess the technical feasibility of aFRR delivery with new flexibility sources
2. Implement new data communication options between the BSP and TenneT
3. Open the aFRR market for the independent aggregator BSP
4. Identify other hurdles for aFRR delivery with new flexibility sources.

Seven pilot partners were chosen by TenneT after a selection procedure to participate in the aFRR pilot. The seven pilot partners were allowed to operate in the regular aFRR market without the prequalification status and therefore could experience the possibilities and hurdles of delivering aFRR with new flexibility sources. Pilot partners offered voluntary energy bids for aFRR that were added to the regular merit order list of aFRR. To evaluate the adequacy of aFRR delivery, the current monitoring processes were executed and new methods were developed and evaluated. The findings of this monitoring have been shared and discussed with the pilot partners to further evaluate and improve the current processes and methodologies, as well as to give feedback to the pilot partners on their aFRR delivery. Finally an audit was carried out by an independent party to verify the delivery of aFRR. The technologies used for aFRR delivery were: wind turbines, batteries, solar park, CHP's, heat pumps and electric vehicles.

TenneT concludes with this pilot that aggregation, renewables and demand response are technically perfectly able to deliver aFRR and that the aFRR market is opened for the independent aggregator BSP. TenneT implemented the necessary alternative options for a (real-time) data connection with TenneT through a private mobile network and the Crowd Balancing Platform (Equigy). The aFRR energy bid data model is slightly changed to facilitate single bids including multiple BRPs. Furthermore, a new process is implemented for imbalance adjustment and settlement, where TenneT receives the activated energy of individual assets that are activated.

TenneT perceives this as a big step forward towards unlocking flexibility.

Inhoud

1. Project goal

1.1 aFRR

To maintain the real-time power balance of the electricity grid in the Netherlands, TenneT contracts and activates (amongst others) regulating power, also called *automatic Frequency Restoration Reserve* (aFRR). This flexible power product is offered to TenneT by market parties which are called *Balancing Service Providers* (BSPs). Before a party may deliver flexibility services such as aFRR to TenneT it has to be certified as BSP by successfully performing the prequalification process.[1]

To ensure that sufficient balancing capacity is available at all times, TenneT is legally obliged to procure a certain minimum amount of *Frequency Restoration Reserve* (FRR).[2] This is based on deterministic, stochastic and probabilistic analysis and consists of aFRR and *manual Frequency Restoration Reserve direct activated* (mFRRda). In the past years the procured volume of aFRR was in the range of 300 and 350 MW[3]. The exact volumes to be procured in the future cannot be predicted. However, it is certain that aFRR will remain necessary for balancing purposes, especially since the electricity system with increasing renewables and demand response, is expected to become more volatile and more difficult to predict.

1.2 Project goal

Historically aFRR is mainly provided by traditional large scale production plants. In line with the energy transition it is expected that in the future less of those large scale power plants will be available and so less aFRR will be offered to TenneT for balancing purposes.

To prepare for such times and to enhance the level playing field, TenneT aims to make the aFRR market more easily accessible for BSPs that aggregate smaller scale assets, renewable generation and/or demand response to provide flexibility. Hence, as a follow-up project of the FCR pilot (that ended March 2018) the **aFRR pilot** was initiated.

The goals of the project are described in more detail below:

1. Assess the technical feasibility of aFRR delivery with new flexibility sources
2. Implement new data communication options between the BSP and TenneT
3. Open the aFRR market for the independent aggregator BSP
4. Identify other hurdles for aFRR delivery with new flexibility sources.

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[1] See https://www.tennet.eu/electricity-market/ancillary-services/general-documents/ for the documents *"Prequalification process for FCR, aFRR, mFRRsa, mFRRda and Reserve Power Other Purposes"* and *"Application form prequalification process"*.
[2] See *COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation*, Article 157.
[3] See https://www.tennet.eu/nl/elektriciteitsmarkt/ondersteunende-diensten/

1.2.1 Assess technical feasibility of aFRR delivery with new flexibility sources

Within the pilot TenneT was especially interested in aFRR delivery with:

- Demand response
- Renewables, mainly solar parks and windfarms
- Aggregation of small assets

Investigating the technical feasibility of aFRR delivery touched several aspects, such as technical connections to assets, activation response, aggregation- measurement- and baseline complexities etc. By gaining experience on this together with the pilot partners, TenneT could determine if these new flexibility sources are able to deliver aFRR and how the product specifications brought unnecessary barriers.

Besides this TenneT also wanted to learn from the pilot partners how to monitor aFRR delivery well and which data is required for effective monitoring (considering privacy regulation and processing of data). Special attention went to monitoring of measurement data from aggregators and "baselining" for renewables.

1.2.2 Data communication between TenneT – BSP

For aFRR activation the BSP needs a real-time connection to the control centre of TenneT. The only option for this was a leased line connection to TenneT's data centre. This is a costly option that negatively influences the BSP business case significantly. So one of the goals of the project was to design and implement a new, less costly but still reliable and secure, data communication option for the aFRR data exchange.

1.2.3 Open the aFRR market for the independent aggregator BSP

Upfront the changes necessary to facilitate the independent aggregator BSP were identified

1. Creating the possibility for aFRR bids provided by assets (also smaller than 1MW) and covered by multiple BRPs
2. Implementation of an imbalance adjustment process for the independent BSP
3. Implementation of the settlement process for independent BSPs.
4. The information exchange to the BRP

For this TenneT implemented a framework based on the mFRRda for aggregator implementation, to harmonize the products as much as possible.

1.2.4 Hurdles in aFRR delivery with new flexibility sources

TenneT wanted to learn from pilot partners in close collaboration with them on all aspects from contracting, bidding strategies to activation, complexity of activation, settlement with the aim of identifying any hurdles in aFRR delivery.
Some specific research subjects of the pilot partners were:

- Building experience with aFRR delivering with non-conventional power assets
- Explore the delivery of aFRR with an EV fleet
- Building experience with blockchain technology

2. Pilot methodology

2.1 Preceding work

The aFRR-pilot builds upon experience that was obtained in preceding work from the FCR pilot[4] and the first phase of the aFRR blockchain pilot with Vandebron[5]. The goal of the FCR pilot was to investigate the barriers of FCR delivery with renewables and decentral assets. After the successful execution it was decided to investigate also the barriers of aFRR delivery with renewables and decentral assets using the project set-up of the FCR pilot. The aFRR blockchain pilot with Vandebron gave first insights in the complications around data communication for aFRR. The aFRR pilot builds forward on these insights and the scope was expanded to the complete aFRR process.

2.2 Operation of the Pilot

The aFRR-pilot operation consists of 5 main phases (see Figure 1). The next subsections elaborate upon the tasks and objectives of each of the phases. Please note that the dates in the figure below are indicative dates and therefore not equally applicable to each of the pilot partners.

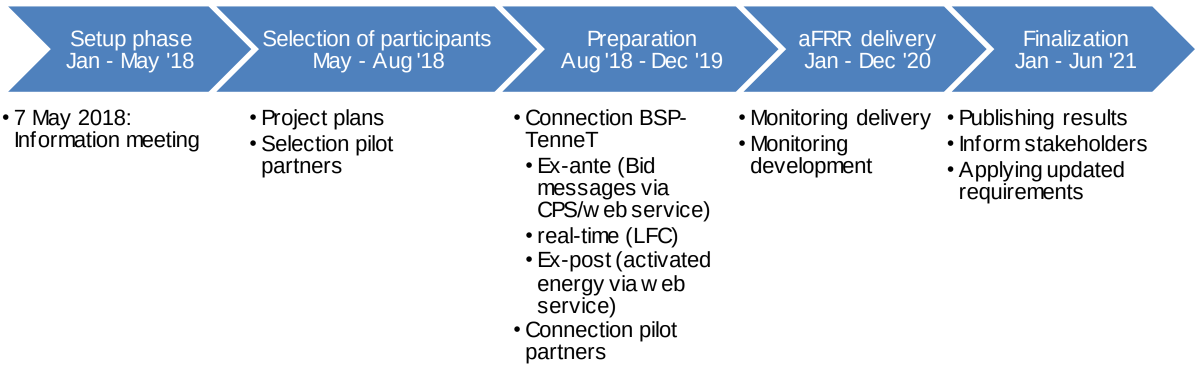

Figure 1: Phases of the aFRR pilot

2.2.1 Setup phase

In the setup phase the project objectives and project methodology were defined. A meeting took place, where interested parties were informed about the aFRR-pilot objectives and setup. Afterwards they were invited to consider their participation to the pilot, in preparation to the next phase.

2.2.2 Selection of participants

The interested parties were invited to submit a project plan to TenneT. Based on these project plans as well as meetings, seven pilot partners were selected to join the aFRR-pilot. When selecting the participants TenneT paid particular attention to ensure the widest possible range of technologies and assets, as well as different experience levels in aFRR delivery.

[4] End report of the FCR pilot: https://www.tennet.eu/fileadmin/user_upload/SO_NL/FCR_Final_report_FCR_pilot__alleen_in_Engels_.pdf

[5] https://www.tennet.eu/news/detail/tennet-unlocks-distributed-flexibility-via-blockchain/

2.2.3 Preparation

After selection of the pilot partners in the preparation phase, the initial focus was on establishing the required data communication with the pilot partners, entailing communication for placing bids, aFRR activation, monitoring purposes and regarding imbalance adjustment. Workshops have been held with the different pilot partners to tackle and discuss shared doubts and topics, in preparation for the aFRR delivery.

2.2.4 aFRR delivery

During this phase the actual delivery and verification of aFRR-delivery had the main focus. Pilot partners were, in exception with the regular market, allowed to start delivery of aFRR without prequalification status within the aFRR-pilot. Pilot partners offered voluntary energy bids for aFRR that were added to the regular merit order list of aFRR. Because of this the pilot partners operated in the regular aFRR market. To evaluate the adequacy of aFRR delivery, the current monitoring processes were executed and new methods were developed and evaluated. Part of the evaluation includes also the scope to determine which data is strictly necessary for monitoring and who should provide it. The findings of this monitoring have been shared and discussed with the pilot partners to further evaluate and improve the current processes and methodologies, as well as to give feedback to the pilot partners on their aFRR delivery. Finally an audit was carried out by an independent party to verify the delivery of aFRR.

aFRR delivery started in January 2020 with small amounts which grew to bigger amounts later. Figure 2 shows the total amount of aFRR bids send in by the pilot partners and the activation of it. Here it can be observed that from mid 2020 significantly higher bid volumes were available from aFRR pilot partners. In total more downward bid volume was sent in than upward bid volume. Only a fraction of the bid volume is activated, this is also the case for regular aFRR BSPs as we normally activate less aFRR than available.

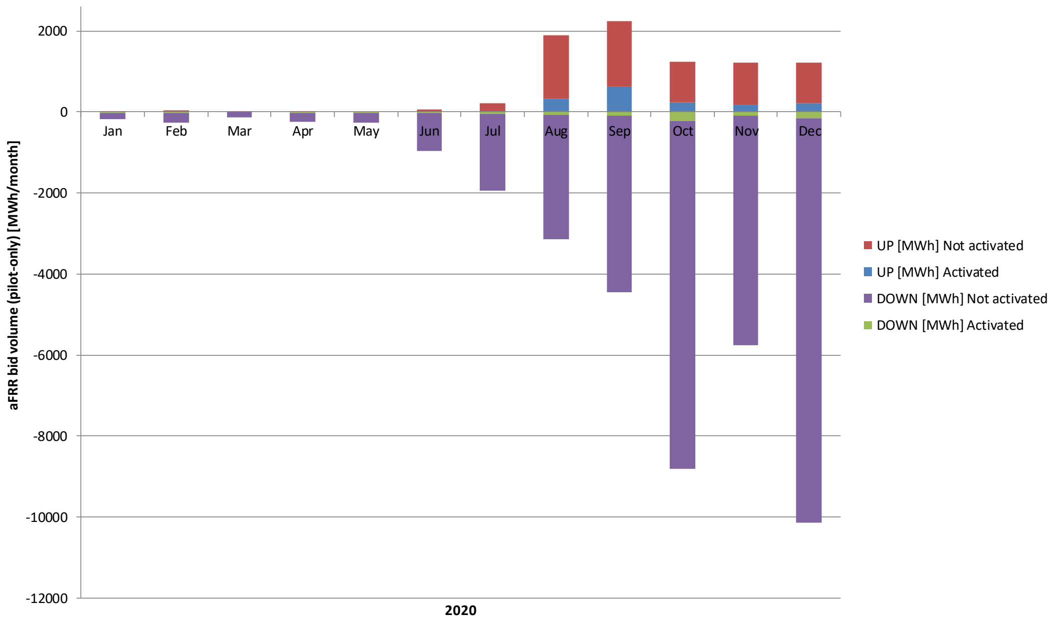

Figure 2: aFRR bid volume of the pilot partners

Figure 3 shows the total activated aFRR of the pilot partners and the regular market. During 2020 the aFRR activation of pilot partners only made up for a small fraction of the total aFRR activated volume.

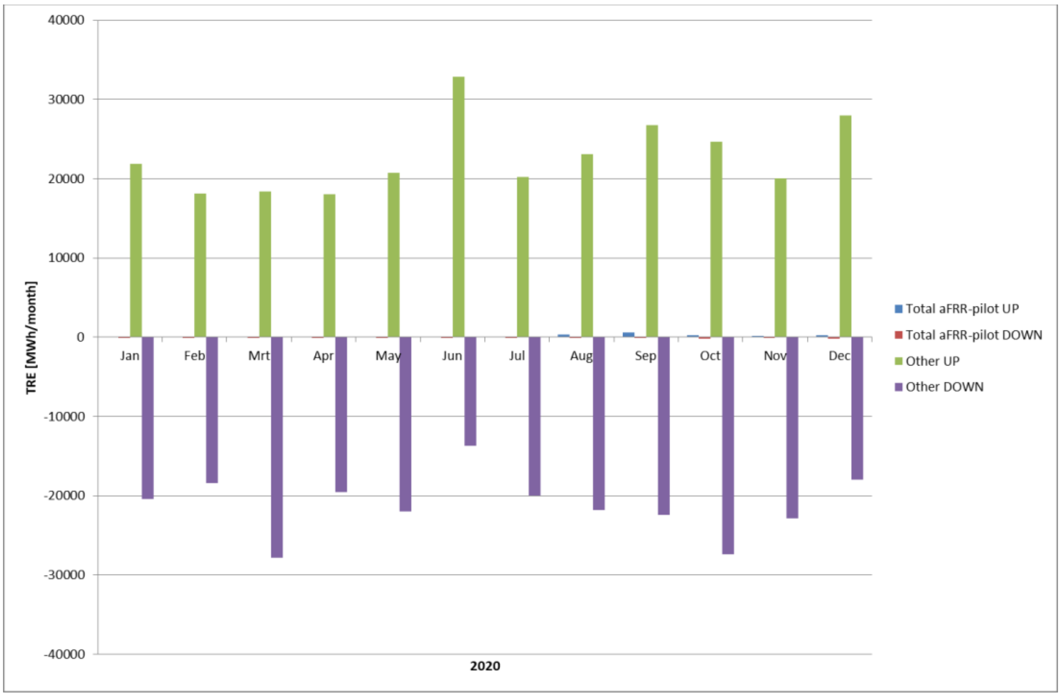

Figure 3: Activated aFRR bids of the pilot partners and regular market parties

2.2.5 Finalization

The last phase was focused on the finalization of the aFRR-pilot, publication of the pilot results, updating documentation, informing stakeholders and applying new and updated requirements.

For the purpose of disseminating the results the following deliverables were created.

- This aFRR pilot end report which describes the objective, setup, methodology and results of the aFRR pilot project.
- aFRR manual for BSPs which provides updated product specifications and further necessary information for BSPs for the delivery of aFRR.
- A report template for aFRR voluntary bids prequalification which BSPs should use for the reporting of their test results of the prequalification test for aFRR voluntary bids (will follow soon).

3. Pilot partners

TenneT collaborated with seven pilot partners during the pilot. These pilot partners are introduced hereunder.

3.1 Engie

About Engie
ENGIE group is a global reference in low-carbon energy and services. Our purpose is to act to accelerate the transition towards a carbon-neutral world, through reduced energy consumption and more environmentally-friendly solutions, reconciling economic performance with a positive impact on people and the planet. We rely on our key businesses (gas, renewable energy, services) to offer competitive solutions to our customers. With our 170.000 employees, our customers, partners and stakeholders, we are a community of Imaginative Builders, committed every day to more harmonious progress.

Pilot operation
In this pilot Engie connects the EEMS wind farm (27MW) to deliver aFRR in which the Crowd Balancing Platform facilitates the necessary data exchange by means of blockchain technology.

Learning goals
As Engie is willing to take the lead in the Energy Transition. It was clear from the beginning that this aFRR pilot from TenneT was of interest to Engie. From the start it was obvious that our primary focus should be on wind turbines, afterwards other assets should be validated for being part of the aFRR pilot.

3.2 Enova

About Enova
Enova has more than 15 years of experience in managing small power production and consumption units. Its current portfolio of some 1000 MW in production and 500 MW of consumption units comprises CHPs, assimilation lights, heatpumps, compressors, wind turbines and PV.

Pilot operation
Our focus is on supplying our customers with smart calculation models that help them in the decision-taking process for both the long term as well as the short term market for power, gas and heat. Specifically the short term markets require these processes to be fully automated for which there is an online connection with each one of the connected units.

Learning goals
In this sense aFRR is the ultimate challenge because aFRR requires extremely high speed interaction with the connected units, to keep up with the rapidly changing setpoints, sent by TenneT.
Each Enova customer uses his power production and consumption units first and foremost to meet his own

business requirements. And those are irrespective of TenneT's requirements to keep the national grid in balance. So to still be able to also track TenneT's setpoints is like shooting at a moving target and therefore much harder than the assignment of a traditional power plant.

3.3 Escozon and Energie Samen

About Escozon and Energies Samen
Escozon is an entrepreneurial cooperative that designs innovative sustainable developments to stimulate local energy markets. Energie Samen is the Dutch umbrella organization for local energy initiatives. The members of Energie Samen own and co-own many wind turbines and solar parks. Flexibility can create additional value for their assets.

Pilot operation
During the pilot aFRR will be delivered with a solar park together with a battery. The CBP will be used to send in aFRR energy bids, to receive the aFRR activation and to send in the power measurements and the reference signal.

Learning goals
Escozon and Energie Samen are very excited to participate in this aFRR pilot. This allows us to gain knowledge and experience about flexibility for the more than five hundred energy cooperatives in the Netherlands. To learn how we can use flexibility for the aFRR market, and to improve the business case of solar parks and wind farms of cooperatives.

3.4 Next Kraftwerke and Jedlix

Next Kraftwerke and Jedlix are cooperating together in the aFRR pilot.

About Next Kraftwerke
Next Kraftwerke is a company of German origin specialized in the valorization of electrical flexibility on short-term electricity markets (day-ahead, intra-day, imbalance) and reserve power markets (FCR, aFRR, mFRR). Across Europe, we valorize a portfolio of over 9000 units with a combined power of more than 8,5 GW. Next Kraftwerke Benelux was founded in 2014 and is active in the Netherlands as an aggregator of reserve power (BSP), trader, and balancing responsible party (PV-partij).

We are a leader in the digitalization of the energy market. Our Virtual Power Plant optimizes thousands of technical installations of our flexibility partners based on real-time data, short-term forecasts, market prices, and local constraints. With our technical know-how and presence in both short-term and reserve markets, we provide a one-stop-shop solution for flexibility. This is also reflected by our wide range of customers, ranging from flexible production units such as CHPs, through demand response in industry and horticulture, to smart use of energy storage. In this way, Next Kraftwerke contributes to the energy transition in the Netherlands.

About Jedlix

Jedlix develops and operates a Vehicle-to-Grid Integration platform to reduce the total cost of ownership of Electric Vehicles, optimize the use of renewable energy and facilitate their insertion into the power grid at scale. We team up with industry-leading Energy Partners, ChargePoint Operators and EV manufacturers to monetize the flexibility of the EV's charging process on energy and balancing markets. Our platform aggregates thousands of EV's and orchestrates the charging & discharging process based on each EV driver's preferences and real time data received from our partners.

Pilot operation

Next Kraftwerke and Jedlix together, are leveraging the flexibility provided by the smart charging of electric vehicles (EVs). Drivers of EVs indicate their charging preferences on the mobile app developed by Jedlix. Using fleet intelligence, the cars are then integrated into Next Kraftwerke's Virtual Power Plant (VPP) and their flexibility is bid as aFRR power to TenneT. When a large imbalance occurs in the grid and TenneT requires aFRR power, Next Kraftwerke stops or starts the charging of the EVs to counter deficits or excesses of electricity respectively.

Next Kraftwerke is taking care of the integration with TenneT's systems to offer the flexibility in Jedlix's EV-fleet as aFRR power. Next Kraftwerke places the bids, sends the necessary control signals during an activation, and takes care of the financial settlement. Gradually they add other technologies such as CHPs, flexible industrial processes, waste plants, etc. to the aFRR pool. Jedlix has leveraged the wireless connectivity of electric vehicles to influence the charging process in response to the aFRR market signals. This resulted in an automated, user-friendly and completely software-based solution that helps to restore system imbalances. Jedlix has tested and integrated this solution with several leading EV manufacturers such as Tesla, Renault and Jaguar. EVs involved in the smart charging program charge at home and have their own charging station.

Learning goals

Objective of participating in the program were among others to support balancing market access directly through the Virtual Power Plant of Next Kraftwerke, independent from the BRP/supplier and standardization in the way EVs are qualified on grid services.

3.5 Scholt Energy and Enervalis

Scholt Energy and Enervalis are cooperating together in the aFRR pilot.

About Scholt Energy

Founded in 2005 as a family business and quickly developed into an experienced energy supplier with activities in the Netherlands, Belgium, Germany and Austria. Focused on the mid- to large corporate segment, it offers its 5000 clients power and gas supply and a broad range of energy related services, such as demand response, project development solar and energy scans.

About Enervalis
Enervalis is a software provider specialized in the energy sector providing smart solutions in aggregation, optimization and monitoring. It enables and optimizes hundreds of homes and buildings, thousands of electrical vehicle charge stations, stationary batteries and other kind of assets.

Pilot operation
Scholt Energy has multiple types of assets in its flexibility portfolio, wind farm Giessenwind being one of them. Besides the participation in the aFRR pilot Scholt Energy is also active with its flexibility portfolio on the FCR, mFRR, congestion and imbalance markets. Enervalis provides the needed technology and software to communicate with TenneT on the one hand and interact physically with the asset on the other hand.

Wind farm Giessenwind is a pilot in the European DRIvE project. DRIvE ensures that initiatives can be developed to provide flexibility in the Demand Response market. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774431.

Learning goals
Scholt Energy and Enervalis are working closely together to develop and integrate wind farm Giessenwind in TenneT's CBP platform to participate on aFRR. More knowledge and experience of aFRR is gained through the pilot project. This is used to develop a new service and market ready software solution. Furthermore, the pilot helps to get insights into the aFRR specifications, market and possible revenues, as well as getting to know the CBP platform.
CEO Rob van Gennip from Scholt Energy: "Scholt Energy is contributing to the real-time balancing of the electricity system. We also want to ensure that our customers consume energy optimally, are rewarded for their use of flexibility, and at the same time contribute to the energy transition."

3.6 Sympower

About Sympower
Sympower's mission is to provide advanced flexibility software solutions that enhance the value of energy assets, shaping an intelligent and green power system. Sympower unlocks revenue streams by maximising the value of flexibility across energy markets and industries. Flexibility means adjusting power generation and consumption based on grid needs. When the grid is out of balance, Sympower temporarily adjusts the power of flexible assets through its advanced and automated demand response capabilities.

Founded in 2015, Sympower has dedicated teams based in Estonia, Finland, Israel, The Netherlands, and Sweden. With an outstanding international cross-sector knowledge and experience, Sympower can react quickly and create extra value wherever opportunities arise, actively contributing to a carbon-free future.

Pilot operation

Flexible assets can be safely and securely connected to the Sympower platform via a non-intrusive software solution. The hardware integrated into this software allows Sympower to control energy assets within mutually agreed limits and restrictions and measures the power consumption of those processes in real-time.

Sympower offers services independently from a particular energy company, enabling scaling across commercial and industrial partners, from greenhouses to supermarkets and paper factories to waste treatment facilities and opens up electricity markets to a wider range of users, contributing to a more inclusive economy.

Learning goals

Sympower is convinced that this pilot will act as a catalyst for change in the way the current aFRR system operates. More specifically, Sympower was interested by the 3 following dimensions of the pilot:

1. Moving away from hardware-oriented interfaces
2. Aggregating a pool of assets from different energy suppliers (BRPs)
3. Flexible bidding opens opportunities for a new type of distributed assets

3.7 Vandebron

About Vandebron

The mission of Vandebron is to accelerate the energy transition. Vandebron does this by providing 100% green electricity. Once all the electricity in the Netherlands is produced 100% green with for example wind turbines and solar panels, a green alternative for providing flexibility is required.

Currently, if there is more demand than supply, gas- and power plants will produce extra energy in order to balance the grid. However, Vandebron wants to provide electricity without gas- and coal power plants. Therefore another source flexibility is required. One way of providing flex is by using batteries. However, batteries are quite an expensive solution and instead of only changing the supply of electricity, it is also possible to change the demand of electricity within the households. So, Vandebron realized that electric cars are actually driving batteries, which are already bought by customers to drive in, and these driving batteries can also be used for balancing the electricity grid. The first assets which were used are Tesla's and this is now expanded with charge poles and batteries. However it is also possible to deliver flexibility with other customer owned assets, such as heat pumps and electric boilers. So, in this way it is possible to have a 100% green electricity grid whilst keeping the possibility to balance the electricity grid.

For the clients of Vandebron, the company has grown over the last years from solely an energy supplier, to a full service partner to assist individuals and businesses in the energy transition. Together with knowledge and guidance on how to reduce energy usage, Vandebron enables end consumers in an accessible way to contribute to the balance of the energy grid.

Pilot operation

Starting with the “Smart Charging” service on aFRR for Tesla vehicles from a consumer's perspective, this experience is as easy as logging into the Vandebron App, and enrolling. Following this, a number of settings can be put into place in order to guarantee the comfort of the user, having their car battery charged at the right moment while maximizing aFRR availability. Vandebron rewards the user by paying out almost all of the generated income on the aFRR market, while keeping a minimal service fee. This service has now been expanded to chargepoles, providing a similar service while not being dependant on any electric vehicle brands.

4. Data communication

Different data flows are needed with certain requirements to ensure the real-time aFRR process runs smoothly and can be trusted upon at all times. Figure 4 below depicts the required data flows for the aFRR energy bidding process with respect to bidding, activation and measurements, and settlement and imbalance adjustment. The capacity bids are not included in Figure 4 since they are not part of the aFRR Pilot scope.

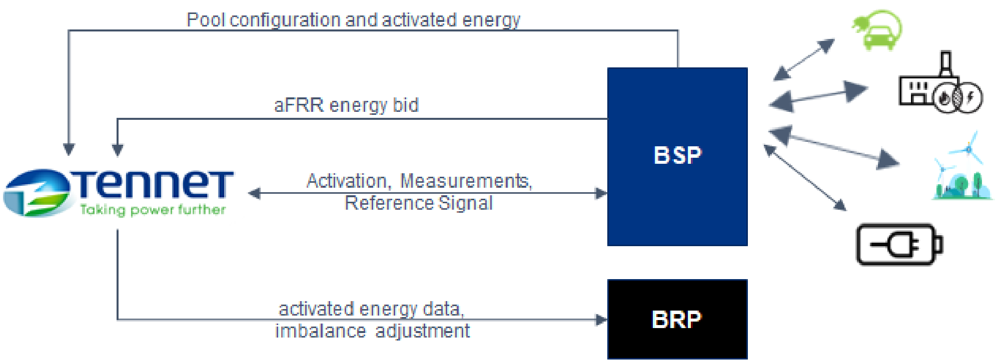

Figure 4: Functional data flows of aFRR process

The different communication technologies that were used or developed for these processes in the course of the Pilot are listed in Figure 5. The BSP can choose the data communication technology that is most suitable for their operation. Paragraph 4.1 explains the aFRR process via the Crowd Balancing Platform, while Paragraphs from 4.2 - 4.4 explain the separate steps of energy bids, activation and the imbalance adjustment and the other communication method possibility specifically for that step.

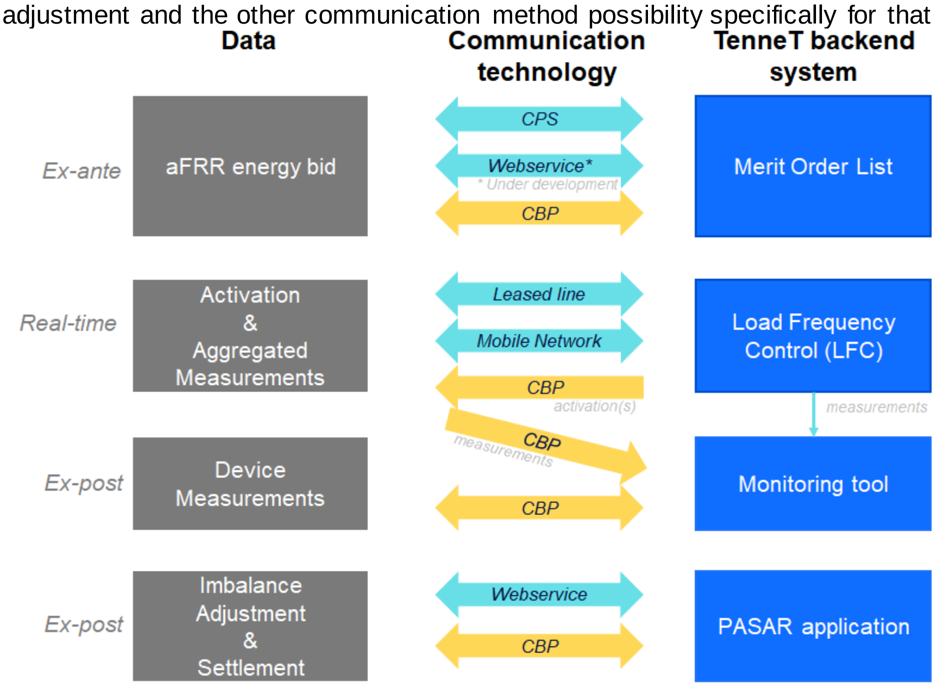

Figure 5: Overview communication technologies used for aFRR

4.1 Crowd Balancing Platform

The Crowd Balancing Platform (CBP) is developed with the goal of lowering the barriers for BSPs to enter the aFRR market. This is realised by creating one data communication method for all data streams, as can be seen in Figure 6.

The CBP is characterised by a private blockchain technology that forms the basis of the platform and ensures for a unique source of truth for all participants. Note that due to the 'private' nature of this type of blockchain technology, all participants of the network are known and trusted (which excludes time and energy consuming mining activities) furthermore, information is accessible only among parties that have access (so that commercial information is kept confidential to the parties involved).

The communication for BSPs with the CBP takes place via REST APIs. The interface between the CBP (REST API) and TenneT (all other types of formats) is designed in such a way that all data flows can be exchanged with regular TenneT backend systems.

In addition to the setpoint and aggregated measurement the pilot parties connected via the CBP were requested to exchange one additional data stream: device measurements. Since TenneT will have to deal with an increasing amount of BSPs, with an increasing amount of assets, validation of delivery is expected to become more difficult. Hence the device measurements provided via the platform were used to validate the aggregated power measurement from the BSP. Since it can concern small assets, the data resolution of the device measurement can be lower than for aggregated data.

The device measurement (power values time series with a custom granularity) are provided to TenneT once an hour, and each measurement refers to a device used in the aFRR Pool. There are currently no fixed requirements on the granularity of the device measurements, but it should be agreed upon on forehand with TenneT. These device measurements have been used during the pilot to investigate the type of data needed for effective monitoring.

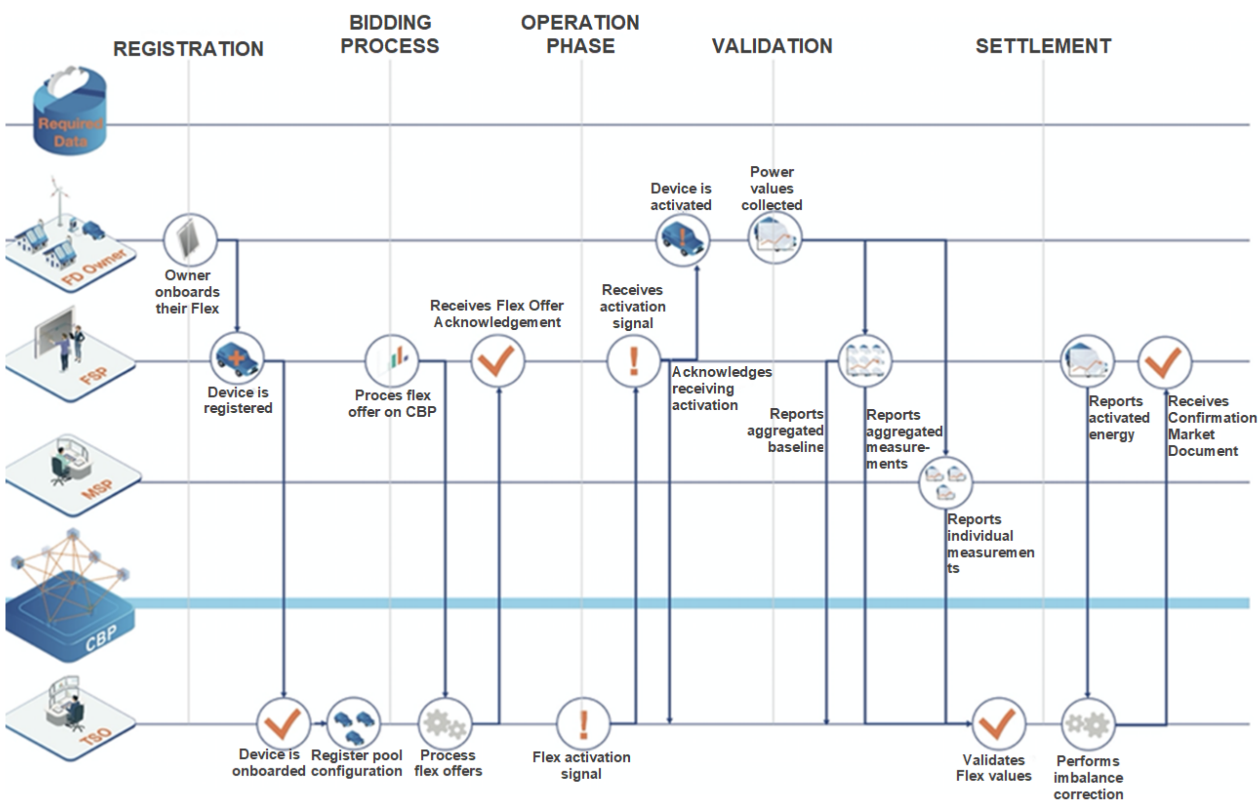

Figure 6: The process overview of delivery of aFRR via the Crowd Balancing Platform

4.2 aFRR Energy Bid

The pilot partners operated in the regular aFRR market for energy bids. To start the aFRR operational process a BSP sends an aFRR energy bid to TenneT. A bid has to be sent at least 30 minutes (two entire imbalance settlement periods, ISPs) before the start of the relevant ISP and the bid should have a minimum size of 1MW. The minimum bid size was not reduced during the pilot, since the energy bids are placed on the merit order list and compete in the regular market.

In regular operation, the aFRR bids are submitted to TenneT in EDINE format, once a connection with the Central Post System (CPS) is established. In the context of the aFRR pilot, two alternative possibilities have been explored:

- Submission of aFRR bids in XML (based on ENTSO-e format) via the TenneT webservice;
  The possibility to submit aFRR bids in XML is currently only available for pilot operations. However, it aligns with parallel developments that make sure future communication for aFRR bids is in XML as well (via the TenneT webservice).
- Submission of aFRR bids via the Crowd Balancing Platform (CBP), for those parties that are connected via the CBP;

4.3 Activation and aggregated measurement

TenneT continuously measures the imbalance of the control block of the Netherlands and activates aFRR bids on a 4-second interval. This is done by sending a delta-setpoint (power-value) to BSPs by the Load Frequency Control (LFC). These delta-setpoints are integer values and are sent when the requested volume changes with respect to the current requested volume.[6]

In return, TenneT receives the real-time aggregated power measurement and aggregated reference signal (baseline), on a 4-second interval basis, to be able to verify that the BSP delivered aFRR according to the product specifications.

In the following paragraphs the different methods on delivery of the activation and aggregated measurement are described.

4.3.1 Leased lines

The activation and (aggregated) measurement data is exchanged in real-time, and it is important that this data flow is reliable and secure at all times. A proper way to do ensure this is by communication via leased lines with a IEC 60870-5-101 or IEC 60870-5-104 protocol for security reasons. Leased lines are directly connected to TenneT data centre via leased lines.

But in case of BSPs steering small scale decentralized assets in the distribution grid, can be rather expensive and time consuming to physically connect to the TenneT datacentre. Therefore it is seen as a barrier for new BSPs.

Considering the above, an alternative solution for real-time data exchange was found to be necessary to reduce the barriers of the aFRR market. Stability and reliability of any solution are key. Two alternatives were drafted, set-up and used during the pilot project: a Private Mobile Network and the CBP. Both options are explained in the following paragraphs.

4.3.2 Private Mobile Network (M2M)

The private mobile network is rolled out because of the need of a direct approved low-cost real-time data-exchange with a 4 seconds interval. With the private mobile network no physical line between the BSP and TenneT is needed, which reduces the costs and installation time significantly. The used communication protocol (IEC 60870-5-104 protocol) is similar to the communication protocol that is also used for leased lines, this is chosen for time and security reasons.

For this solution, the BSP has to install a Remote Terminal Unit (RTU) with the IEC 60870-5-104 protocol, compliancy tested according to TenneT Protocol Implementation document, in their own environment. The BSP receives a router from TenneT that communicates with TenneT's private mobile network which brings a reliable, secure and less costly connection with TenneT.

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[6] For detailed specifications please read the *aFRR manual for BSPs* on https://www.tennet.eu/electricity-market/ancillary-services/afrr-documents/.

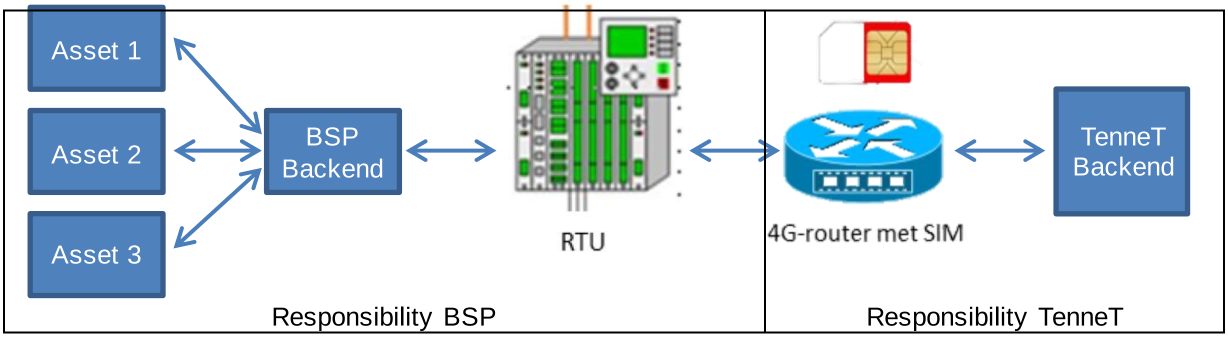

Figure 7: Overview private mobile network

The requirements for the BSPs are:

- to use an RTU which is conformance tested according to the TenneT standards;
- to place the router in The Netherlands because of redundancy for network providers and potential maintenance;
- to ensure a good connection with the router.

4.4 Ex-post data for settlement and imbalance adjustment

The aFRR activation has to be adjusted on the portfolio of the involved BRPs to ensure that it does not impact the BRP's imbalance position. Formerly common BSPs are also the BRP of the activated asset. Therefore the BRP is assigned in the bid message and the imbalance adjustment is done on the BRP specified in the bid message. But when an BSP aggregator delivers aFRR, the activated assets can be at allocation points of different BRPs. The BSP aggregator does not know on forehand which assets he will activate to deliver the requested aFRR activation. Indicating the BRP information in the bid message can therefore not be used for the imbalance adjustment of an aggregator activation.

To solve this issue, the application PASAR is built during the pilot. PASAR implements imbalance adjustment for aFRR with the same framework as done for mFRRda (by the application called IRIS). The BSP has to send two messages: a pool configuration message and an activated energy message. The pool configuration message contains all the allocation points of the BSPs portfolio and the BRPs responsible for the allocation points. Additionally, when a BSP is activated he sends an activated energy message at the end of the day, indicating the activated energy by the BSP at every allocation point on a 5 minutes interval.

The main difference between the mFRRda implementation and the aFRR implementation is that the activated energy message of mFRRda is sent at the moment of activation, while the activated energy of aFRR is send once a day. This choice (in agreement with the BRPs) is made because the activation of aFRR is a more continuous process. The requested amount of aFRR can change every 4 seconds, sending the activated energy directly after each delta-setpoint change could lead to an unnecessary overload of data.

This data stream is serviced via the CBP and via the TenneT webservice. Starting from the 1st of October 2020, the connection to PASAR is requested as part of the IT-connections to be set-up during the prequalification process of new BSPs, with the aim to have the same process for all BSPs.

5. Monitoring

5.1 Reference signals

For monitoring of balancing services a difference in power output needs to be observed. To be able to verify the delivery of aFRR, the deviation from the foreseen power output by the actual power output is monitored. In order to do so TenneT uses a reference signal provided by the BSP on portfolio level, that represents what the power output of the pool would be without aFRR activation. For avoidance of manipulation of the reference signal, the signal needs to be sent 1 minute ahead of time. Otherwise the requested power (deviation) could be exactly reflected in the reference signal at moment of notice, thus making it impossible to determine the exact delivery.

However, for some types of technologies setting up a reference signal in this manner is rather challenging. For instance the power output of renewable assets (such as wind farms or EVs) is less predictable than for conventional units (such as coal- or gas-fired power plants). In the pilot, reference signal for different types of assets were evaluated to address how monitoring of the delivery with different types of pools can be ensured.

5.1.1 Wind

The challenge for the reference signal with wind is that the power output of wind is not sufficiently predictable on a 4-seconds basis with a one-minute horizon. This is due to the variety of wind speed and direction. Furthermore, wind gusts or drops are foreseen on larger scale but not on each wind farm or individual wind turbines. As found out during the project, the real-time power output of wind seems to the best prediction of the wind production in the near future (1 minute ahead). However, during aFRR activation the real-time power output cannot be used as a reference signal (which is by definition the estimation of what the pool would do without aFRR activation). To comply with the requirement on the reference signal to be calculated independently from the presence of an activation from TenneT, other signals were evaluated such as usage of the measured wind speed instead of the actual power output of the wind turbine (which would include the aFRR activation). In the context of this evaluation, it has been concluded that the accuracy of such a signal increases if it is sent in real time. More generically, TenneT has concluded to allow the possibility for BSPs to propose to use a reference signal without lead-time (instead of one minute) if this leads to a more accurate reference signal and in case of problems regarding the realisation of the 1 minute lead-time reference signal. The proposal will be evaluated by TenneT on a case-by-case basis during the prequalification process. The 1 minute lead time reference signal will still remain the preferred method for the reference signal, but reasons for proposing a reference signal without a lead time may be, for example, that the variability of the power is such that a reference signal with a lead time of one minute is insufficiently.
The quality of the reference signal can be evaluated by comparing the reference signal outside of an activation and the aggregated power of the aFRR pool, for this reason the baseline should be calculated in the same way during and outside an activation.

5.1.2 EVs

The challenge for the baseline of electric vehicles (EVs) is represented by the dependency of the assets availability on human behaviour. When a certain EV plugs into or unplugs from the grid it is therefore available or unavailable. This relatively unpredictable behaviour of the car owner should be taken into account and the baseline should be adjusted accordingly. If this unpredictability aspect is taken into account and mitigation measures are used when an EV plugs into or unplugs from the grid, the reference signal for EVs can result in an accurate estimation of the behaviour of the whole pool. An example of this is to have sufficient power and capacity available as back-up/replacement when EVs become unavailable for aFRR. From the experience of the Pilot, we concluded that when the above is taken into account by the BSPs, it is possible to construct an accurate reference signal for EVs.

5.1.3 CHPs

Within the aFRR-pilot, it has been seen that CHPs can ramp within the required time and also the baseline can be constructed properly. However, depending on the CHP, it seems not feasible to construct an appropriate baseline during start up. The reason for this is that the starting time is not exactly predictable nor always the same and can vary between 2 and 10 minutes. Because of this, aFRR can be delivered best when the CHPs run stable and a baseline can be constructed in an adequate manner. Aggregating the baseline of many individual CHPs is suitable and practical possible, but, as also for other type of assets, a proper data communication with the asset should be in place.

5.1.4 BSP portfolio

The portfolio of BSPs normally consists of multiple assets and/or types of assets. As described in the previous paragraphs, the determination of the reference signal of different types, wind, solar, EVs and CHPs is challenging in itself. To have an appropriate baseline signal for a portfolio of the named types it can be as easy as just adding up the individual reference signal, however in practice this may also be non-trivial due to, for example, interaction between technical installations or the improved predictability when looking at the aggregated pool of assets.
In case of a mixed portfolio of predictable and unpredictable assets, the reference signal without lead-time can only be requested for that part of the aFRR portfolio that is deemed unpredictable. For the remainder of the aFRR portfolio, the preferred method (expected power exchange one minute later of the aFRR portfolio) applies. In this case, this may entail that the BSP should provide multiple reference signals to TenneT. These reference signals will be combined on TenneT side to perform the monitoring of the aFRR delivery at portfolio level.

5.2 Aggregation of measurements

During the aFRR-pilot TenneT has concluded that it may be challenging for a BSP to have all measurements from individual technical installations on a time resolution equal to the time resolution requested for the aggregate signals.

For that purpose, during the aFRR pilot, interpolation or extrapolation of device measurements was allowed for aFRR-pilot partners in order to construct the necessary data points for the aggregated signal with 4 second resolution.

The suggested method to be used is 'zero-order hold'

The most easy and transparent way to extrapolate device measurements, is keeping them constant until another value is measured. This is also known as the zero-order hold method. Practically this means that for each (connected) technical installation in the pool the *latest available* device measurement is included to build the aggregate measurement value.

BSPs are also free to develop other suitable methods for the aggregation of measurement.

During the Prequalification Process TenneT examines and approves the aggregated measurements.

TenneT has decided to continue to allow the extrapolation of device measurements after the aFRR-pilot. During the PQ process TenneT will verify whether the (implemented method to construct the) aggregated measurements is acceptable.

5.3 Updating monitoring process

TenneT monitors the delivery of aFRR. To enhance and facilitate this process TenneT also focussed on updating the monitoring processes during this pilot. As such the aim was to verify aFRR delivery faster and more comprehensively, not only for the BSPs participating in the aFRR-pilot but eventually for all BSPs. One of the main updates on the monitoring process following the pilot is the possibility for a BSP to propose utilisation of a zero-minute lead time reference signal, as described in section 5.1.1. This was implemented to make proper monitoring of portfolios with unpredictable nature possible.

Furthermore, the enhancement of the monitoring processes at TenneT side had the objective to further automate both the verification of the following of the activation pattern regarding power, as well as the comparison of requested energy versus actually delivered energy per imbalance settlement period (ISP). This facilitates the detection of both inadequate and insufficient delivery. The steps done to automate the monitoring were:

1. automated monitoring per BSP,
2. automated monitoring of all BSPs per day
3. automated monitoring of all BSPs for a month and evaluating their performance

One of the main challenges faced in automated monitoring for BSPs is the difference in response times of different technology in their portfolios. In addition the quality of BSP communicated signal to TenneT will play a vital role in BSP performance evaluation hence it will be an incentive for the BSP to improve their communicated signal.

6. Privacy agreement

By aggregating a large amount of assets for flex delivery, the size (capacity) of the individual assets could decrease. Even until the level that they include household customers, such as electric vehicles or home batteries. From the moment household customers are involved, TenneT and the BSP are obliged to set up a contract that preserves agreements regarding GDPR regulation, to ensure the privacy of the asset owners.

Since customer assets could be involved for all BSPs and all products in the future, a general template for a Privacy Agreement was set up that can service all those cases. The "Agreement *for the processing of personal data between TenneT and BSP"* template can be found via tennet.eu.

The main body of the document describes general requirements/agreements that are derived from the GDPR. In the separate appendixes, three topics are described in more detail that are related to a process or technology specific implementation of ancillary services:

- Appendix I Prequalification process;
- Appendix II Imbalance adjustments;
- Appendix III Crowd Balancing Platform.

Depending on the product and type of technology used, the agreement can be easily composed from the template.

7. Independent BSP

An independent BSP is a BSP which is operating without having any task as BRP. Historically, BSPs are also the BRP of the connection(s) that they steer. To open the balancing markets for more flexibility providers, European regulation prescribed that TenneT has to implement a BSP role for parties that deliver balancing services without being the same entity as the BRP(s).

7.1 Settlement and imbalance adjustment

As explained in chapter 4.4 a new framework for settlement and imbalance adjustment is set up to facilitate independent BSPs, but also regular market parties. Traditionally TenneT settles and corrects the complete aFRR activation. When the BSP and the BRP are one company the risk of imbalance in case of non- or underdelivery, is sufficient incentive to deliver aFRR (in case of energy bids). This logic does not apply in case of an independent BSP, since that party isn't incentivised by the risk of imbalance cost in case of underdelivery. Next to that the BSP can have a portfolio with assets that are part of different BRP portfolios. Hence, an alternative method for settlement and imbalance adjustment was set up:

- Settlement is based on the activated energy of the assets by the BSP, capped by the requested volume resulting from TenneT's setpoint(s); as TenneT will not remunerate more than the requested volume
- Imbalance adjustment is determined by allocating the activated energy of the assets of the BSP to the relevant BRPs[7].

The setpoint sent from TenneT to the BSPs should be the same as the aggregated setpoints sent from the BSPs to the assets. But in practice there can be differences[8]. There can be under- or overdelivery by the BSP.

Underdelivery

In case of underdelivery the BSP is remunerated based on the setpoint that the BSP sends to the asset (activated energy), although traditionally the BSP was remunerated based on the setpoint from TenneT to the BSP, which is higher in case of underdelivery.

Example:

- *TenneT sends a setpoint of 4 MW to the BSP during a complete ISP (requested energy is 1 MWh);*
- *BSP sends a setpoint of 2 MW to asset A (delivering 0,5 MWh) and 1 MW to asset B (delivering 0,25 MWh);*
- *The activated energy of the BSP is then 0,75 MWh.*

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[7] Because the activated energy (setpoints from BSP to assets) is transparent for the BRP through PASAR, the BRP can settle non-delivery with the BSP (via the asset, depending on the agreements between the BRP, BSP and asset).

[8] TenneT monitors the delivery of the BSP based on the setpoint sent from TenneT to the BSPs, and verifies this with the activated energy message of the BSP. Underdelivery by a BSP could result in a financial or non-financial penalty.

	Traditional method Settlement based on TenneT setpoint (requested energy)	***New method*** Settlement based on TenneT setpoint (requested energy) and BSP setpoint (activated energy)
Settled energy with BSP	1 MWh	0,75 MWh
Imbalance adjustment BRP	1 MWh	0,75 MWh
BRP imbalance because of aFRR activation	-0,25 MWh	-

With the traditional method the BSP would be remunerated for 1 MWh, and the BRP mentioned in the bid message would receive an imbalance adjustment of 1 MWh, resulting in an imbalance of 0,25 MWh as only 0,75 MWh was activated. In case where the BSP is the same as the BRP, this gives the right incentives. When the imbalance price is different than the balancing energy price (this occurs in system state 2)[9], there is a financial risk for the market party in case he underdelivers (the imbalance price paid as BRP for the imbalance of 0,25 MWh is higher than the balancing energy price received as BSP for the 'extra' 0,25 MWh that he did not deliver).

Independent BSPs do not have this incentive. Therefore the BSP is only remunerated for 0,75 MWh in the new method. Since this is the amount that he actually activated. This is a transparent way of settling with the BSP and the imbalance adjustment of the BRP's. In the case that asset A has a different BRP than asset B, the BRP of asset A will receive an imbalance adjustment of 0,5 MWh and the BRP of asset B will receive an imbalance adjustment of 0,25 MWh not resulting in an imbalance because of aFRR activation.

Overdelivery

In case of overdelivery, when the activated energy by the BSP is higher than the requested energy based on the setpoint(s) of TenneT, the settlement with the BSP is capped by the requested energy. The imbalance adjustment at the BRP is still based on the activated energy, since this is the energy what the BSP activated on the individual assets. This way, TenneT will not remunerate the BSP for delivering more energy than requested, while correcting the BRP in a way that reflects as close as possible the real situation (as it is not possible for TenneT to determine which assets contributed to the overdelivery).

Traditionally the extra activated energy (overdelivery) would result in passive balancing, but with the new method TenneT cannot choose which assets and therefore which BRP should receive less imbalance adjustment than communicated by the BSP.

Example:

- *TenneT sends a setpoint of 4 MW to the BSP during a complete ISP (requested energy is 1 MWh);*

[9] More information see imbalance pricing system: https://www.tennet.eu/fileadmin/user_upload/SO_NL/Imbalance_pricing_system.pdf

- *BSP sends a setpoint of 2 MW to asset A with BRP X (delivering 0,5 MWh) and 3 MW to asset B with BRP Y (delivering 0,75 MWh);*
- *The activated energy of the BSP is 1,25 MWh.*

	Traditional method (BSP = BRP X = BRP Y)	***New method (independent BSP, BRP X = BRP Y)***
Settled energy with BSP	1 MWh	1 MWh
Imbalance adjustment BRP[10]	1 MWh	1,25 MWh
BRP imbalance because of aFRR activation	+0,25 MWh	-

The BSP will have no incentive to overdeliver because the BSP will only be remunerated for 1 MWh and he will need to remunerate the assets for 1,25 MWh. In this case a new activated energy message is expected, giving the BSP a possibility to reallocate the activated energy.

Non-delivery by asset

Both cases describe different aFRR delivery of the BSP. Also the asset can react differently than requested by the BSP. Possible settlement of this imbalance is a matter between BRP and asset owner. Possible settlement of penalties because of non-delivery is a matter between BSP and asset owner.

7.2 BRP information

As explained in chapter 4.4 the BSP is responsible for sending the BRP information (which asset has which BRP) via the pool configuration message to TenneT as input for imbalance adjustment at the BRP. Within the pilot was experienced that the pilot partners have no access to information on the BRP in case of household customers. Household customers have a contract with their supplier, but the BRP information is not available. Therefore some pilot partners were not able to send the BRP information in the portfolio message needed for the imbalance adjustment. During the pilot TenneT solved this gap in information stream by receiving the EAN-codes from the BSP and request the BRP information at the DSO. This process proved to be very time consuming and sensitive to errors. For example in the cases where a BRP switch took place, the BSP was not updated about it and send pool configuration message containing wrong BRP information. This method therefore is not workable in the regular market and a solution has to be found for delivering the right information to TenneT and the BSP.

7.3 BSP-BRP agreements

The asset owner is responsible for contracts with the BSP and BRP. When an asset owner decides to deliver aFRR via an independent BSP, he is responsible to inform his BRP and to make additional agreements with the BRP on the handling/settling of aFRR (or other ancillary services) delivery. The asset owner can

[10] In case BRP X and BRP Y are not the same entity (new method), 0,5 MWh will be corrected at BRP X and 0,75 MWh will be corrected at BRP Y.

delegate this responsibility to the BSP, which will be the case when the asset owner has less knowledge about the energy system (for example a household) and it will take too much effort for him to arrange the right contracts with the BSP and the BRP.

Within the pilot the discussion was started up between the BSP and the BRP on is topic. As it is important for the BRP to receive the information about the imbalance adjustment per connection. But the BRPs have to put effort in a connection to TenneT to receive this information and to integrate this addition information in their system.

In the future there can be many BSPs and BRPs active in the market. It will take a lot of effort for the BSP and the BRP to set-up agreements with every BSP/BRP separately. Additional discussions between the different market roles have to take place to arrange agreements, how this can be set-up without too much effort for the different market parties.

7.4 Smart meter allocation

A prerequisite of the pilot was that only assets with individual smart meter allocation at the connection can be used in the aFRR portfolio. An imbalance adjustment takes place at the BRP of the activated assets. The additional/less electricity consumed/produced should be measured at the allocation point and therefore allocated to the BRP of the allocation point. If an end consumer is a profiled customer and is joining in a aFRR portfolio of a BSP this is not the case. The additional/less electricity consumed/produced is only measured in the consumption/production of all profiled customers together and therefore divided over all BRPs of profiled customers together. In this case the imbalance adjustment is done incorrectly and the aFRR activation is not neutral for the BRPs imbalance position. Smart meter allocation solves this problem and makes the aFRR activation neutral for the BRPs imbalance position. Unfortunately smart meter allocation is not that common yet and the BSP is not authorised to activate smart meter allocation for his customers. The customer has to activate this via the supplier, but the process of smart meter allocation is not standardly embedded at every supplier and takes a lot of effort to be activated. This, together with the fact that smart meter allocation has impact on the contract between the customer and the supplier, brings a barrier for end consumers to join an aFRR portfolio of BSPs.

Collective smart meter allocation (phase out of profiled customers) will solve this, but will take some additional time. An intermediate solution will need to be found for this and additional discussions between BSPs and suppliers will be undertaken on this subject. The requirement of smart meter allocation is added in the aFRR manual as before there was no experience with household customers as part of an aFRR portfolio

8. Audit

TenneT deems data integrity and data security highly important also in the delivery of aFRR. As the aFRR delivery within the pilot is based upon new aFRR concepts, TenneT has decided to audit the pilot partners by an independent auditor to verify the aFRR delivery and the reliability of the data aggregation.

The focus of the audit was therefore to assess the aFRR delivery with smaller scale assets, renewable generation and demand response assets and the data aggregation within the current product specifications. The following topics were investigated:

- Construction of the reference signal;
- Real-time power measurements and construction of the aggregated measurements;
- Assurance of aFRR delivery;
- Design of processes and dataflows.

8.1 Process

As a first step during the audit the pilot partners were requested to fill a questionnaire, which contained questions on topics as described in the previous paragraph. This questionnaire together with TenneT data on registrations of which the pilot partners were not able to follow the aFRR delta-setpoints, were used as a guideline for the interview of the pilot partners.

The pilot partners who were able to deliver aFRR were invited by the auditor for an interview, where they were asked to elaborate on the answers in the questionnaire and the registrations on delivery. During this interview the auditor made observations. An audit report was made to give insights in the observations and improvement possibilities.

Due to Covid-19 interview were held via virtual meetings to ensure a safe working environment for both the auditing party and the pilot party.

8.2 Pools and setpoint following

The results of the audit showed how all flexibility sources participating in the pilot do have a degree of unpredictability, which directly affect the capability of the pool to follow the aFRR setpoint. Cars may unexpectedly be used for driving during an aFRR delivery, IT connections can be temporarily be lost, CHP's may be used for generating heat/CO2 for horticulture and wind gusts are not predictable. BSPs need to deal with that unpredictability. They do that on one hand by accepting the unpredictability and on the other hand by having spare capacity at hand (having a bigger portfolio than the energy bid send in) or use different kinds of assets in one pool.
All BSPs use the assets in the aFRR pilot only for aFRR delivery, as it is not allowed to deliver aFRR and mFRRda with the same assets at the same time.

8.3 Individual assets

CHP's

The audit confirms the view that CHPs are suitable for providing aFRR as they are reliable and can ramp-up and down quickly when in operation. It also confirms the statements made in 5.1.3 on monitoring that delivery with CHP is not so stable during start-up of the asset. The other aspect the BSP has to take into account is that in some cases the aFRR delivery is overruled by the climate system. So not activated assets (spare capacity) needs to be in the pool to be able to cover for that.

Cars and charging poles

For BSPs it is hard to predict, when charging is taking place at individual cars/charging station level. When cars are charging (not fast charging) it takes a while so they can be used as base for the energy bids.
The cars and charging poles are dependent on the behaviour of the owner, who might decide to start using the car for its primary purpose during aFRR delivery. To ensure a correct aFRR delivery and response this behaviour needs to be taken into account, it can be counteracted by the size of the pool by keeping (not activated) assets at hand to be able to keep following the setpoint.

Wind

Also the audit concludes that reference signal power output prediction, one minute ahead, is not possible, due to the fluctuating nature of wind. A wind farm is good at predicting the average power output baseline for the moment of delivery (based on for instance wind speed measurements). However it cannot predict the wind gusts.
The audit confirms it is a good idea to use the power output signal with a zero minute lead time as reference signal for monitoring as already accepted by TenneT on individual basis, also stated in paragraph 5.1.1

8.4 Control and software

The audit confirms for all aggregator BSPs that it takes significant effort to create the aggregated reference signal and the aggregated measurement. But in the end the information created was correct and reliable and could be used for verification of monitoring. Construction of the reference signal was done correctly and was reliable. The aggregation of power measurements with underlying measurements with a 4 second resolution is not feasible, but building up aggregated power measurements with measurements with a lower resolution has a high enough quality for verification purpose.

8.5 Conclusion audit

All assets were technically able to deliver aFRR. Although some challenges were faced with building up the aggregated measurements, developing a baseline and having enough power available for delivery with the pool. These points should get extra attention during the prequalification process.

9. Conclusion

9.1 Conclusion on goals

TenneT opened the aFRR market for independent aggregator BSP and concluded that aggregation, renewables and demand response are technically perfectly able to deliver aFRR. Of the seven pilot partners, four are now prequalified as BSP at the time this report is published.

TenneT implemented the necessary alternative options to connect to the LFC through a private mobile network and the Crowd Balancing Platform. The aFRR energy bid data model is slightly changed to facilitate single bid including multiple BRPs. Furthermore, a new process is implemented for imbalance adjustment and settlement, where TenneT receives the activated energy of individual assets that are activated. TenneT perceives this as a big step forward towards unlocking flexibility.

9.1.1 Assess technical feasibility of aFRR delivery with new flexibility sources

Investigating power output, baselines and input from the audit, TenneT concluded that new technologies are technical able to deliver aFRR. The assets could show a reaction within 30 seconds and they were able to increase/decrease their power output with the requested ramp rate.
The technically difficulty delivering aFRR with demand response, renewables and aggregation of small assets is mainly the set-up of the aggregated power output and the reference signal according to the requirements in the product specifications. Industrial steer-boxes appeared to have default interaction frequencies of about 30 seconds, which could be lowered but with increase of data acquisition and processing cost. Measurements of EVs, smart meters or other decentral assets have even lower measurement resolutions. Extrapolation is a way to deal with this as we just require the pool to react fast. The audit confirmed that indeed this a suitable method.

Therefore the following changes were made on these requirements:

- The aggregated power output still has to be delivered on a 4 second resolution, but the underlying measurements are allowed to have a lower resolution (> 4 seconds) and can be inter/extrapolated. The BSP has to show TenneT during the prequalification process why the aggregated power output is a good representation of the reality.
- Next to the current method of a reference signal with 1 minute lead time a reference signal without lead time is allowed if the BSP can explain why a 1 minute lead time is too difficult, for example generation with renewables. The BSP has to show TenneT during the prequalification process how the reference signal without lead time is constructed, using input signals independent of the aFRR setpoint and current power output.

9.1.2 Data communication between TenneT - BSP

Within the pilot two new possibilities for the data communication between TenneT and the BSP are implemented: private mobile network and Crowd Balancing Platform. Both technologies are evaluated and TenneT concluded that they were able to meet the security and reliability requirements and therefore TenneT accepted both methods for BSPs in the aFRR market. TenneT will continue to monitor the reliability of both implementations and when the reliability is dropping TenneT serves the right to freeze connecting new BSPs until the risk on reliability is mitigated.

The two methods are added in the product specifications as possibility to connect to TenneT, although the Crowd Balancing Platform is not yet accepted for capacity bids (and therefore contracted energy bids) as it does not comply to the requirements of the critical infrastructure yet. TenneT is in process of review if the Crowd Balancing Platform can also facilitate contracted bids.

9.1.3 Open the aFRR market for independent aggregator BSP

Within this pilot TenneT created the possibility for an independent aggregator BSP to deliver aFRR. For this the following changes were made in the product specifications

- The imbalance adjustment at the BRP is not solely based anymore on the activation of the bid, but also on additional information from the BSP
- The BSP has the responsibility to divide the activation signal of TenneT over the assets
- After activation the BSP send in the activated energy per allocation point
- The imbalance adjustment of the BRP is the aggregation of all activated energy of the allocation points in his portfolio

This process is implemented via the application PASAR using webservices. PASAR is the aFRR implementation of IRIS (which implemented the same framework only for mFRRda)

Next to this additional requirements are added for the BSP with decentral assets to keep operating within the current balancing market setup:

- No profile customers are allowed in the portfolio
- BRPs have to be informed about the possible delivery of aFRR via allocation points in their portfolio.

9.1.4 Hurdles in aFRR delivery with new flexibility sources

The pilot partners gave insights on the hurdles in aFRR delivery. The information about aFRR delivery had to be found in many different documents. Therefore the product specifications are adjusted to the aFRR manual containing all relevant information around aFRR delivery.
Insights were given on the complexity on creating the BSP backend system, gaining information needed for the aFRR process and the relation with suppliers and BRPs. The remaining hurdles are identified in the next paragraph.

9.2 Remaining hurdles

The pilot solved the main hurdles, but still some hurdles keep existing.

9.2.1 Access to information for the BSP

The BSP is no role yet in the Dutch information model and therefore has no access to data need for aFRR delivery, such as has the customer smart meter allocation and who is the BRP behind the customer. The BSP is dependent on the information given by the customer. Unfortunately practice showed this information cannot always be found by the customer, or in some case it did not result to be up to date. For example in the case of household customers the BRP is not known, or the BSP is not always updated by the customer when a BRP switch takes place. For this the BSP has to become a formal role in the Dutch information model, for example mentioned in the C-AR or CERES.

9.2.2 Independent BSP

As described in chapter 7.3 the independent BSP faces barriers in the relation with the BRP and the supplier. During the pilot the discussion started with the different market roles but these discussions will keep taking place also after the pilot. The discussions will focus on the information exchange of activation between the BSP, BRP and supplier, the compensation of delivered energy and the usage of smart meter allocation. As a conclusion there will be a clear picture on how the independent BSP fits in the Dutch electricity market and how contractual and administrative burden can be as low as possible and bringing fair compensation between the different roles, anchored in the new Dutch energy legislation.

9.2.3 Effort on creating backend system

While the new IT-connections options lowered the barriers for BSPs for connecting to TenneT systems, some challenges remain for the BSPs in setting up their back-end. This includes, for example, the connection to the different types of assets, dispatching them according to the setpoint received by TenneT, constructing the aggregated signal on a 4-seconds basis, based on the measurements of the assets in the pool. Additionally to these more technical challenges, also realizing a bidding strategy based on the pool availability and the market prices and integrating it together with the rest of the signals, is part of the key tasks of the BSP for delivering aFRR.

Following further developments can help, like for example"

- Connection to the devices (protocol standards)
- Standard allowed method on aggregation of measurements

9.2.4 Minimum bid size of 1MW

Using many small assets to deliver aFRR can make it difficult to reach the minimum bid size of 1MW as many assets are needed before the minimum delivery of 1MW is reached. It is difficult to bind customers when a BSP is not prequalified yet, but it is not possible to get prequalified before the 1MW threshold is reached. TenneT understands the difficulty for the minimum bid size, but concluded to keep the requirement. Some reasons behind this conclusion are:

- It is very hard for aggregators to have a positive business case with volumes below 1MW
- The minimum bid size of 1MW is an European requirement and cannot be easily changed
- New market parties can start with a service to their customers on passive balancing.

Another difficulty that was faced was the requirement of maximal 3 bids lower than 4 MW. As the delta-setpoints sent to the BSPs have integer values there is no smooth aFRR activation when many small bids have to be activated. This is due to technical limitations of the LFC. In the upcoming years this will change, and therefore in the future TenneT will also allow more small bids.

9.2.5 Capacity bids

Within this pilot the barriers for the aFRR market in relation to the energy bids were investigated as a first step. The Crowd Balancing Platform currently only services voluntary energy bids. The energy revenues are not sufficient to cover all the necessary investments and capacity remuneration would strongly increase the business case. Therefore TenneT will investigate if and how it can expand the Crowd Balancing Platform with aFRR capacity bids.
Another barrier mentioned of capacity bids is the daily product. Wind assets, electric vehicles, solar parks and demand response can possible expand their bidding volume when the capacity bids will evolve to smaller building blocks. For example the 4 hour blocks such as the FCR market.

9.2.6 Portfolio constraints for BSPs

Currently BSPs need to manage their portfolio, taking into account different constraints of activation of the different assets in the pool. Examples of this can be the cooling down period of heat pumps or the limited energy in a battery, which make it challenging to activate and deactivate in a rapid sequence or activations in consecutives ISPs. These issues can be solved by the BSP by having a large pool of assets, possibly with different technologies, but could also be facilitated by the possibility of adding additional parameters in an aFRR bid. For this reason, TenneT finds it valuable to further investigate this possibility in the future.

9.3 Experiences and conclusions of pilot partners

9.3.1 Engie

During the pilot Engie built up a lot of knowledge on how to incorporate renewable assets in the aFRR landscape, which came with some challenges. Luckily there was a big commitment within Tennet and Engie to succeed in this pilot. And thanks to the strong willingness and efforts of different teams within Engie the project was successfully delivered. The experience that was gained during this pilot will help Engie to enhance delivering aFRR with other types of flexible capacity in the Netherlands and to roll out similar solutions in other countries where Engie is active.

9.3.2 Enova

An internal process of continuous improvement has now determined that it is possible to get into range of TenneT's response requirements. The key question that still needs answering is whether aFRR is a valid alternative for the passive imbalance, being the traditional short term market on which our customers trade their power production and consumption.

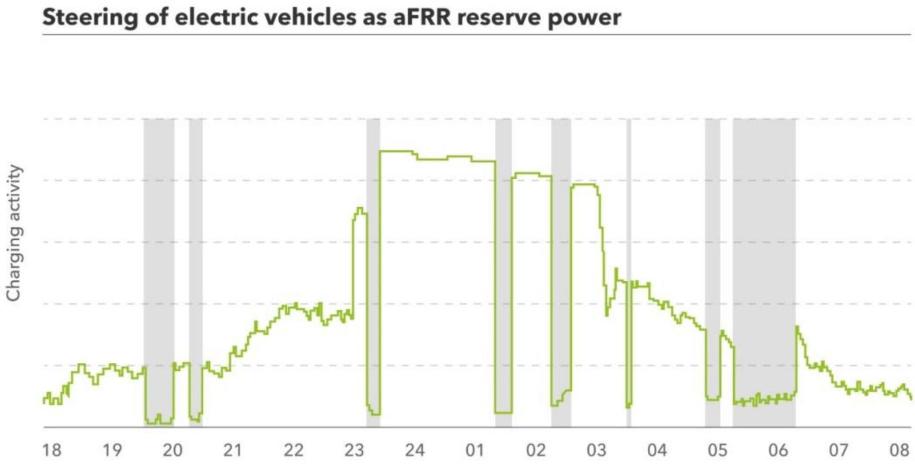
At the end of the pilot Enova hopes to come up with an affirmative answer to this challenge.

9.3.3 Escozon & Energie samen

It is a very interesting challenge to be able to control a solar park together with a battery for the aFRR market. There is a lot to consider that we did not realize in advance. It is actually a whole new and exciting world that we have entered. We have not had any experience with this before. We appreciate the good support we receive from TenneT very much.

9.3.4 Next Kraftwerke & Jedlix

We have shown that electric vehicles can be integrated into our virtual power plant and deliver aFRR successfully. When a large imbalance occurs in the grid and TenneT requires aFRR power, Next Kraftwerke stops or starts the charging of the EVs to counter deficits or excesses of electricity respectively. This is shown in the graph below for a typical night, where several upward aFRR activations occurred. Upon activation by TenneT (grey colored time blocks), the charging activity is drastically reduced.



Working with household flexibility (the charging of the EVs is controlled to deliver aFRR when they are parked at home) requires smart meter allocation ('slimme meter allocatie'). Households have to request this at their supplier. They also have to report when they switch to a new supplier. Such processes make it more cumbersome to participate. It is important to keep working towards a hassle-free process for flexibility resources, especially if it concerns citizens. This is also in line with the spirit of the Clean Energy Package

9.3.5 Scholt Energy & Envervalis

Wind energy controlled flexibly

The implementation was challenging because the electricity production of the wind farm (and other renewable assets) fluctuates and is difficult to predict. Therefore a state-of-the-art power forecast based on weather data is needed. This forecast is translated into offers to bid on the aFRR market.
CEO Wim Boonen from Envervalis: "In this pilot, we are showing that volatile energy sources such as wind energy can be controlled flexibly. This contributes to the stability of the electricity grid, despite the fact that volatile sources previously caused imbalance.''

The full integration at the wind farm is successful. Scholt Energy makes daily bids on the market, which are activated by TenneT. These activations are directly linked to the asset. Several activations have already been delivered successfully. At the moment, the pilot project is finished and investigations are ongoing regarding the possible future scope and scale of the aFRR product. We are thankful to have had the support of Tennet during the pilot which was important in making the project a success.

9.3.6 Sympower

Within Sympower the unanimous conclusion is that the pilot has proved to be of great value to improve our flexibility services for our customers in the Netherlands. We gained a lot of new customer insights and experience how to create value with assets participating in the aFRR market. And we are proud of our inhouse developed digital RTU as part of setting up the communication for aFRR with Tennet.

Furthermore, the pilot has also been an opportunity to emphasize the position of independent BSP's and the barriers within the current market framework to operate and help unlocking new sources of flexibility. For example, it is currently mandatory for independent BSP's to have some sort of bi-lateral agreement with a BRP if flexibility is to be unlocked on behalf of a customer by a BSP. This is not only severely impacting the ability to compete but also in conflict with the Clean Energy Package. If independent BSP's are to have a future in the Dutch balancing market, the position of the independent BSP needs to be strengthened within the regulatory framework accompanied with a fair central settlement model for all aFRR deliveries. This cannot be stressed enough because it is fundamental for the future of flexibility and a healthy balancing market.

Last but not least, Sympower wants takes this opportunity to thank Tennet for all their help, expertise, time and patience to make the pilot a success. They have truly been the best pilot partner you can wish for.

9.3.7 Vandebron

Technically, we have been happy to contribute development to the Crowd Balancing Platform and felt our growing expertise in the aFRR was valued by TenneT while doing so. With the solid documentation provided, careful collaborative testing and overall eagerness to turn the product into a success, developing, testing and bringing to life the required interfaces has been as smooth a ride as software development allows for.

Future perspective

Vandebron is exploring expanding the assets types to several different consumer assets. Within our mission, the aFRR market is an indispensable part of the energy transition, and scale within the platform is essential. A number of different asset types could be interesting for application on the CBP for both their technical as well as business accessibility.

Electric hot water boilers are a good example of a consumer asset that is quickly growing in popularity, and could prove valuable as an aFRR asset, being both already IoT enabled and flexible in usage with minimal reduced comfort for the end user. After all, Vandebron provides services that should benefit their clients both in contributing to the energy transition as well as adding to life comfort.

9.4 Follow up work

The aFRR pilot was concluded reaching the goal of opening the aFRR market to new flexibility sources. But development of aFRR will always take place. Therefore TenneT will continue investigation of the aFRR product also after the pilot.

Some of the remaining hurdles are picked-up in a working group concentrating on the remaining hurdles for aFRR delivery with EVs. Topics that will be addressed are:

- *Market (information) design*
  - Information stream to the BSP, such as information of smart meter allocation and BRP
  - BSP – BRP – supplier agreements
  - Activation of smart meter allocation
- *The prequalification and activation of mobile assets*
  Prequalification takes place on allocation point (EAN18), this brings the following issues; Cars that are prequalified can only deliver via the allocation point they are prequalified on and, only one aFRR BSP is allowed on an allocation point. This conflicts if there is a BSP steering charging poles and a BSP steering cars.
- *The extrapolation method for metering data*
  The aggregation of assets brings complexity if the resolution of measurements is lower. TenneT wants to give BSPs the freedom in creating the aggregation, but we can explore the possibility of expanding standard allowed methods.

Also further investigation on usage of device measurements for verification purpose will take place.
Next to that TenneT will investigate the possibilities in improvement of the PQ process and therefore also the information to the BRP and the DSO

And off course TenneT is always open for discussion and improvements!