15. Symposium Energieinnovation, 14. bis 16. Februar 2018, Technische Universität Graz, www.EnInnov.TUGraz.at
ISBN 978-3-85125-586-7 DOI 10.3217/978-3-85125-586-7

The FutureFlow project: Promoting TSO-TSO cooperation in operation of balancing systems

Christoph GUTSCHI[1], Andraž Andolšek(*)[2], Mitja Kolenc[3], Radovan Sernec[4]

1 Introduction

Load-frequency control operated by the TSOs is a crucial system to maintain the grid frequency within a stable bandwidth. According to European legislation, balancing reserve is procured by the European TSOs via market based approaches. The balancing markets are usually operated by the TSOs and proofed to be functional for provision of reserves in the last years. Nevertheless, the procurement of reserves causes considerable costs, which must be borne by the TSOs. For instance, Austrian Power Grid (APG) published costs for reserve provision of 92 Mio. EUR for the year 2016 [1]. TSOs wants to reduce those costs by TSO-TSO cooperation in procurement and activation of reserves. For this purposes several regional cooperations have been established during the last years, e.g. between German TSOs and some interconnected TSOs as well as between Slovenia, Croatia and Bosnia [2].

Since development of new approaches and platforms for balancing purposes is representing an interesting and relevant research topic on European level, several European-founded projects such as FutureFlow[5] are launched.

The FutureFlow project aims to investigate the cooperation in aFRR (automatic frequency restoration reserves) markets between Austria, Slovenia, Hungary and Romania. Main goals are to gather theoretical and practical experience in aFRR and netting cooperation to prepare the project members to assess later participation in upcoming European initiatives like PICASSO, who has been endorsed as reference project for the aFRR plafrom by the ENTSO-E Market Committee [3].

This paper discusses methods for measurement and validation of the provided aFRR services taking into account the national characteristics and requirements of the TSOs involved: ELES, MAVIR, TRANSELECTRICA and APG. These topics were investigated and summarized in the Deliverable D1.1 [4] of the Futureflow project, which is the basis for the present paper.

In the FutureFlow project, the system architecture is implementing the TSO-TSO-model, as described in the European guidelines for electricity balancing [5]. According to the TSO-TSO model each TSO operates the national balancing markets and establishes the technical rules and guidelines for the connected balancing reserve providers. The balancing service provider (BSP) provides balancing services to the connecting TSO using the national framework; the connecting TSO forwards these balancing services to the requesting TSO in the international framework. Each TSO procures the required amount or reserves in the own grid area, but the real-time-dispatch is performed within the whole grid area of all participating TSOs by means of a least-cost optimization taking into account limited transmission capacities between the control areas.

Historically, each TSO developed individual rules for connection of BSP and evaluation of the provided services. In order to approach towards a level playing field for BSPs, some harmonization between the national rules should be considered. It is the aim of this paper to discuss and explain the proposals for harmonization of rules developed in the FutureFlow project. This includes: types of applicable generation units, baseline algorithms, level of online-data measurement, communication of online-data and evaluation of service provision.

1 cyberGRID GmbH & Co KG, Weimarer Straße 119/1, AT-1190 Wien, Tel. +43 664 855 6991, cg@cyber-grid.com, www.cyber-grid.com
2 cyberGRID GmbH & Co KG, andraz.andolsek@cyber-grid.com
3 ELES, d.o.o., Hajdrihova 2, 1000 Ljubljana, Slovenia, mitja.kolenc@eles.si
4 Milan Vidmar Electric Power Research Institute, Hajdrihova 2, 1000 Ljubljana, Slovenia, Radovan.Sernec@eimv.si
5 See http://www.futureflow.eu/

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2 Requirements to aFRR measurement and verification methodologies

In an aFRR control system the behavior of the units providing the service must be monitored in real time for several reasons. Since most units applicable to aFRR are used for more than one purpose at the same time, e.g. generation of power for the electricity market and provision of aFRR to the TSO in parallel, it is essential to define and monitor two values: the current measurement of generation or consumption power and the baseline, which represents the planned point of operation if the unit would not be in activation (i.e. it would not provide aFRR power in that moment). In many cases the baseline is not identical with the minimum or maximum of available power of the unit but between those two values. The difference between measurements and the baseline is the activated power provided for aFRR service, as show in Figure 1. In the verification procedure, the activated power has to be compared with the set-point which is continuously calculated and sent out by the TSO. The same principle is applied whether a unit is considered as a net generator or a net consumer. The TSOs will use the values of activated aFRR submitted by the units to evaluate if the unit provides the requested power output within a tolerances band and if the unit reaches the requested power within the predefined full activation time (FAT).

The methods for verification which are discussed in this section can be applied on unit level or on portfolio level. In general, there should not be a difference between the evaluation of a single unit with large capacity or a portfolio of units with lower capacity; from TSO's perspective the portfolio should be treated like a single unit.

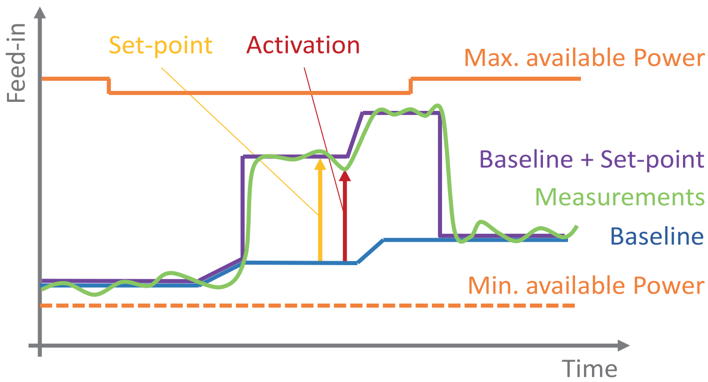

Figure 1: Definition of the aFRR power provided by a unit as the difference between current measurement and baseline. Generation is considered as positive and load is considered as negative.

In the FutureFlow project reserved flexible capacities can be activated by a TSO to reduce the area control error (ACE) of the own control zone or of another control zone. Since the TSO-TSO-model [5] will be applied, it is always the task of the connecting TSO to verify the aFRR provision.

Hereinafter, some common practices for taking measurements and calculation of the baseline values are presented. Focusing on the four control zones, currently applied rules and methods are explained in brief to provide a deeper understanding of the challenges of aFRR measurement and verification. It is not indented to propose a general rule or recommendation but rather to show several good practices which are applicable in different cases. Furthermore the different approaches in different control areas are discussed.

Primarily the power activated for aFRR is used for the P/f-control process but the data measured on-side of the unit and submitted to the TSO will also be used for further purposes like monitoring of the units performance and its compliance with the TSO's requirements, the accounting and financial compensation of the service, ex-post correction of power market schedules (power market clearing), calculation of imbalance costs on system level and balance group level and even calculation of grid fees.

To be applicable to the above mentioned purposes the verification methodology must fulfil the following requirements:

- Transparent calculation rules.

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- Accuracy, including lack of bias and appropriate handling of weather-sensitive resources.
- Reproducibility.
- Consideration of characteristics of different resource types.
- Simplicity and as a consequence low computation effort.
- Prevention of gaming.

While the measurements must be submitted in real time (i.e. 2 s interval time for submission of measurements) some TSOs require that the baseline will submitted in advance of several hours or minutes (at least equal to FAT) while other TSOs prefer to receive the baseline in real time.

Initially the rules for aFRR markets have been developed for large generation units but in the past years new sources of flexible capacities have started to enter aFRR markets and proven to be reliable providers. These units are distributed generators and distributed loads which are characterized by a smaller unit size and smaller flexible capacity compared to conventional generation units and are therefore aggregated into pools of flexibilities. With respect to aggregations of units into pools additional rules have proven to be good practices in some control zones:

- The TSO treats a pool of distributed units like being one large physical unit. The control of the distributed units inside the pool is duty of the pool operator.
- Pool values are the sum of individual values (measurements, baselines, etc.) of the units in the pool.
- An individual baseline should be defined for each unit.
- In most cases it makes sense to use a dedicated baseline only during a called activation of the unit, during the rest of time the baseline should be identical with the measurement in order to prevent unintentional indication of delivery.
- Close to real-time verification is usually done by TSO on pool level.
- Verification of individual units is done by BSP for the purpose of internal accounting.
- Recurring validation of measurements is duty of the aggregator.
- BSPs or TSOs archive data of each individual unit but only the pool values are sent to the TSO periodically (e.g. in 2 s time interval).
- BSPs may be required to archive data of individual units for several months for ex-post verification of the whole pool; TSO may use archived values for random verification of an activation. Archive data must be stored for several months or until the second clearing.
- Verification is performed by TSO with respect to the following characteristics:
- Activated power during at a stable operation point (activation with constant power for a duration longer than the FAT)
- Ramping behaviour of pool: Ramping-up and ramping-down behaviour must comply with the FAT.
- If a single generation unit or a pool will provide more than one service at the same time (e.g. participating in RR, aFRR and mFRR market during the same period) the baseline must be the same for all markets. Specific rules of the TSO have to be taken into account in order to distribute the deviation from ideal delivery amongst the provided products.
- Depending on the characteristics of a unit inside a pool, the unit can be activated only in discrete steps or follow to continuous set-points (received from BSPs). It is the duty of the BSP to arrange the portfolio of units and control the individual units in such way that the set-point received from the TSO can be fulfilled by the BSP.

2.1 Accuracy of measurement devices

In many control zones the required precision of the measurement devices (voltage transformers, current transformers and power transducers) is given with an accuracy class of 0.5% related to the maximum measurement range. Some TSO even require devices with an accuracy of 0.2 %. These requirements are derived from the historic fact that rather large units were used to provide aFRR.

Nowadays, distributed RES and industrial resources can also be applied in aFRR systems and are already accepted by some European TSOs. With respect to industrial applications, the tight accuracy requirement represents a barrier for some facilities, since internal power measurement in industry often

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only has a precision of 1% and a replacement of existing devices with more accurate ones is not economic in the usual case.

BSPs argue that a relative accuracy of 1% would be sufficient because of the lower capacity of decentralized units. As shown in Table 1 the range of absolute error of a small unit is very low compared to the absolute error of a conventional generation unit. Further BSP claim that due to the high number of units inside the pools there is an averaging effect which should reduce the relative error of the pool compared to the accuracy class of the individual units.

Table 1: Comparison of measurement accuracy and range of absolute error

	Nominal power	Accuracy	Range of absolute error
Combined cycle gas turbine (CCGT) block	400 MW	0.5 %	±2 MW
Gas turbine	50 MW	0.5 %	±0.25 MW
Industrial steam turbine	10 MW	1 %	±0.1 MW

As a compromise, the TSO may agree to use data from a measurement device with an accuracy worse than 0.5% if the unit commits to over-perform at least with an amount covering the maximum expectable error caused by the lower precision of the applied measurement infrastructure. For example, if a unit with a nominal capacity of 20 MW is equipped with a meter with an accuracy of 1% instead of 0.5%, the over-performance could be either 0.5% of the requested power or 0.1 MW over the whole range of operation.

On the other hand, if a TSO defines tight requirements for under-performance and over-performance, this requirement can present a barrier to the participation of demand response units in aFRR markets.

2.2 Filtering of measurements

As mentioned above, some units may show significant fluctuations on the power measurement signal. This can have an impact on the aFRR activation calculated as difference between actual (fluctuating) generation and (constant) baseline value. In order to reduce the short-term power fluctuations on the aFRR activation signal the measurements could pass a low pass filter. It has to be taken into account that many simple filtering methods like moving average calculation will result in a signal delay, which must be kept short because of the general requirement of maximum 5 s of signal transmission delay [6]. This correction method might be questionable in some cases and requires an agreement between TSO and flexibility provider in the prequalification procedure.

3 Online data requirements of TSOs

In order to maintain the closed control loop and for close-to-real-time verification, the aFRR providers have to send online data of the flexible resources to the TSOs during periods of active participation in the aFRR market. In case of a pool or portfolio only the pooled values must be submitted in order to keep the data traffic to be processed by the TSO in manageable limits. Usually TSOs require that data must be submitted in intervals of 2 s or spontaneously if a change appears. According to ENTSO-E [6] the sample interval should not exceed 10 s and the largest transmission delay (between field measurements and secondary controller of the TSO) should not exceed 5 s. But in some cases this time can be shorter since this requirement, this is up each TSO.

Usually required data:

- **Actual Measurement Value:** Representing the current sum of all actual measurement values of units in the pool

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- **Baseline of the pool:** This signal represents the current sum of all actual baseline values of all units in the pool.
- **Baseline Forecast:** The (indicative) baseline forecast is defined as the baseline value in 5-15 min (in the future). In an interval of 2 s a single value is sent to the TSO representing the (expected) value of the baseline in a future moment (e.g.5 min in the future). This "forecasting time" is a predefined constant value and must be at least equal to the required full activation time. This method is usual in Austria and Germany and can also be used to submit a binding baseline.
- **Provided active power (aFRR activation):** This value represents the sum of activated power in the pool, which is calculated on unit level by the difference between measured value and baseline.
- **Returned Set-point:** The TSO sends the set-point for the aFRR activation of the pool to the VPP. The VPP must return this value to the TSO in order to monitor the correct function of the control loop, the communication line and signal delay.
- **Status of the pool:** A binary value indicating the availability of the pool to provide aFRR
- **Available Positive Capacity for aFRR:**. The currently existing (reserved) capacity to provide positive direction aFRR out of the pool is sent to the TSO.
- **Available Negative Capacity for aFRR:** The currently existing (reserved) capacity to provide negative direction aFRR out of the pool is sent to the TSO.
  Depending on TSO's specifications; these may be fixed values representing the reserved capacity based on accepted bids or a dynamically calculated value based on reserved capacity and current activation, e.g. a pool reserved 10 MW positive capacity and 5 MW negative capacity, and the current activation is -2 MW. In that moment the available pos. capacity is 12 MW and the available neg. capacity is 3 MW. Depending on the TSO's requirements the available positive and negative capacity should be sent as an absolute value or relative value.

Actual measurements are required by all TSOs in the FutureFlow project. Most TSO additionally require the *currently provided active power (aFRR activation)*, the *returned set-point* and *status of the pool*. Further online signals as explained above may be required by some TSO.

Some TSO require the submission of a baseline (schedule) some hours in advance instead of a real-time value. This requirement is limiting the applicable methods for baseline calculation.

4 Baseline methodologies

4.1 Overview

A baseline is a way to express the expected consumption or generation profile of a unit and it is a basis for all monetary settlement of aFRR provision. Observed resource consumption or generation values during an activation are compared to baseload prediction in absence of an activation like shown in Figure 2. Based on data or algorithms to calculate the behaviour without activation a baseline is constructed which makes it possible to evaluate the effect of the activation.

There are several standard ways to calculate a baseline, each having its advantages and weaknesses in terms of simplicity or practicality.

In this section some frequently used baselines methodologies and fields of application are described. The order of appearance in the text does not mean a ranking of better or less suitable methods. A qualitative comparison of different methodologies is not intended because the special characteristics of different sources of flexibilities, the TSO's approach for P/f-control and the national clearing rules for the power market will require the application of different baseline methodologies.

Awareness must be raised that there is no general baseline methodology which could cover all the different needs. Many TSOs accept different baseline methodologies in order to adapt to the characteristics of various sources of flexibilities. As long as the requirements for baselines and aFRR provision are met by a resource the provider should be free to define a baseline on unit level appropriate for the behaviour of the specific unit. This approach is already supported by several European TSOs and has been proven as a driver for the participation of new sources of flexibilities like RES and industrial generators or loads.

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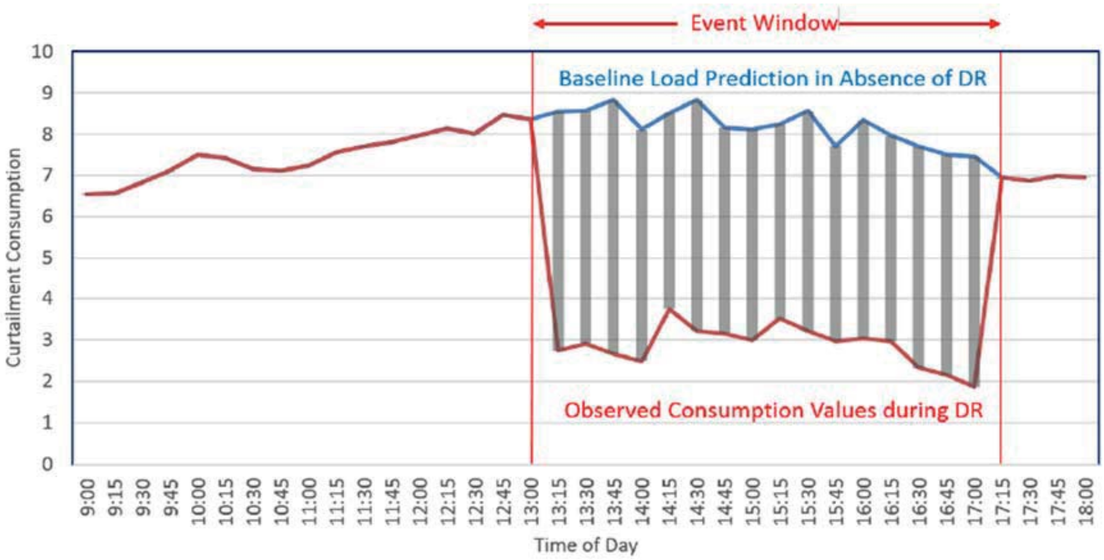

Figure 2: Conceptual diagram of consumption reduction estimation [7].

It has proved to be good practice to calculate baselines on the level of individual resources. If several resources are aggregated to build up a pool the baseline of the pool is the sum of the baselines of the individual resources. If this rule is applied, then there is no need that the baseline calculation method must be identical for all resources in a pool.

In the following, fundamental baseline methodologies are described. To illustrate the methods some simplified figures with a constant activation profile are added to explain the main principles. It has to be taken into account that in real aFRR activations the set-points can change continuously. In systems with pro-rata activation it is very unlikely that a unit will receive a constant aFRR set-point over a longer period.

4.2 Baseline correction

Some baseline methods, e.g. if the calculation is based on historic profiles or on the power market trading schedule, will usually show a gap between the forecasted profile and the real generation or consumption of a resource. In fact many units will operate with a certain level of imbalance in relation to the power market schedule. If a unit participates in an aFRR system the level of the baseline is of higher importance because of the impact on the calculation of the aFRR activation, as explained schematically in Figure 3. In case (1) no baseline correction is applied. A unit, which was imbalanced before the command for activation, would only change the generation until the difference between generation and baseline are equal to the requested activation. The net effect of generation change is depending on the level of imbalance before the start of the activation but will be different from the activation requested by the TSO and this behaviour may cause a negative impact on the quality of P/f-control. Case (1) may be favourable for some generators because the imbalance (and related costs) would disappear during the activation.

In order to provide the expected effect on the power system a correction of the baseline must be performed, e.g. as indicated in case (2). If the resource receives a command for aFRR activation the profile of the trading schedule is shifted vertically to reach the level of generation at the moment of received activation command. The amount of correction should stay constant during the whole activation. If the generation shows significant fluctuation, an average of measurement values during a short period before reception of command can be used as target value for the profile shift. Due to the baseline correction the net effect on the power system will be according to activation command. For the generator the calculated imbalance level at time of reception of activation command will continue during the whole activation. Thus the generator will be motivated to keep the initial imbalance (in times without activation) low to reduce the risk of imbalance costs.

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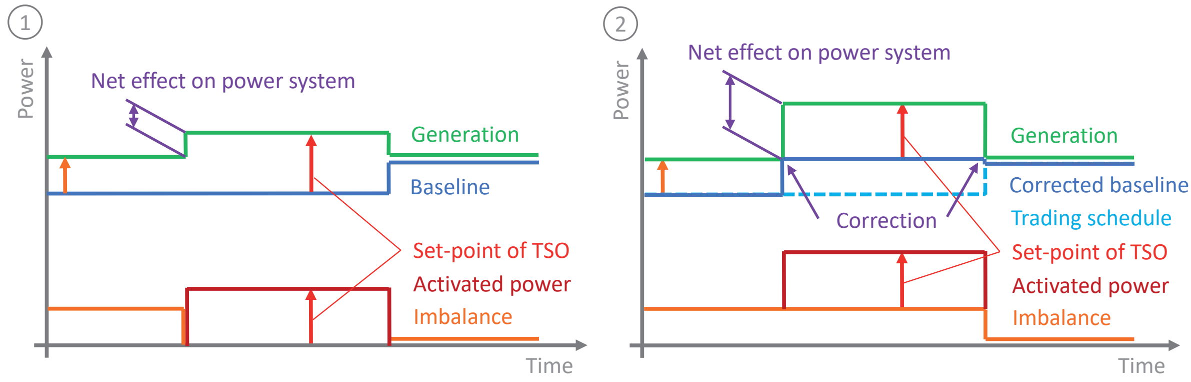

Figure 3: Impact of baseline correction: The net effect of an aFRR activation and the calculated imbalance is influenced by the baseline correction. (1) no baseline correction; (2) baseline is corrected by a vertical shift to fit to the actual generation value before the start of the activation. Correction of baseline only takes place at the beginning of an activation and eventually after the end. During the activation the baseline should not be corrected again.

If the baseline is sent to the TSO in advance the correction must be performed by the TSO as part of the verification procedure. Additionally, the provider also has to calculate the correction in order to determine the appropriate point of operation of the unit. Experience shows that even a short time delay between the baseline corrections done in parallel by two separate systems may result in a deviation which may be in the range of the tolerance band if there is fluctuation on the measurement. This is the main drawback of a baseline correction. As a countermeasure the TSO can loosen the tolerance for over-performance, which gives the provider the chance to operate on the safe side.

In case of a baseline sent in real-time the correction is only performed by the control system of the unit or the pool, thus the challenge explained above will not appear.

4.3 Baseline methodologies applicable for aFRR

4.3.1 Baseline based on power market trading schedule

The utilization of the power market trading schedule is a generic and obvious method to define a baseline. This method is applicable in many cases, especially for conventional generation units where it is feasible to follow a schedule without considerable imbalances. The schedule can be based on the day ahead market or even include the intraday trading. In the ideal case the schedule at gate closure time of the intraday market will be used as baseline. An issue can arise if the TSO requires submission of the baseline before intraday gate closure time. In such case intraday trading must be stopped for the relevant period as soon as the schedule has been submitted to the TSO.

4.3.2 Power market schedule with ramps

If the baseline is based on a power market trading schedule, it will show discrete steps, e.g. at the end of an hour or quarter-hour. In reality each spinning machine has a maximum ramping rate and cannot perform discrete steps. The aFRR activation value is calculated in short intervals as the difference between generation and baseline. As indicated in Figure 4, the application of a baseline with discrete steps will lead to significant deviations in the calculated aFRR power if the unit cannot follow a discrete step. In order to minimize this effect the steps in the baseline must be converted into ramps with gradients equal to the ramping rate of the unit.

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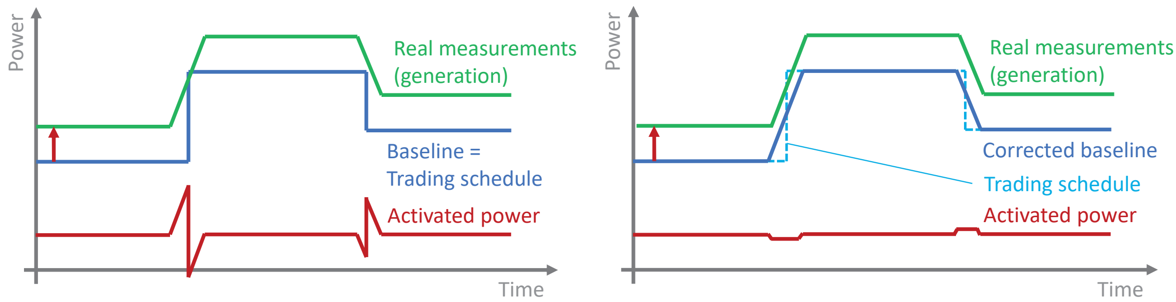

Figure 4: Effect of discrete schedules for spinning machines (left) and improved calculation of aFRR activation due to the conversion of steps to ramps (right).

Remark: A similar correction method with a total ramping duration of 10 min is defined for hourly exchange programs of cross-border exchange transfers between control areas [6].

4.3.3 Baseline values submitted with short lead time

As explained in chapter 3 some TSO require a baseline forecast value to be submitted periodically with the online data. This value indicates the baseline value at a moment in the near future, exactly a predefined timespan ahead. If this predefined timespan is equal or larger than the FAT, the value can be used as the baseline. In that case it is of importance which algorithms are used to calculate the baseline value since gaming is avoided by the criteria that an activation command will be received by the unit at the same time or shortly after the future baseline value has been reported to the TSO. This method is accepted in Germany and other European countries.

4.3.4 Continuation of the current measurement value available at reception of activation command

The easiest way to generate a baseline is simply to take the last active power measurement before the activation takes place and to consider it as a constant value during the time of activation. Such baseline is admittedly simple but it works well for generators as well as loads showing rather low generation or load volatility, e.g. in case of run-off-river power plants or large industrial consumers:

$$Baseline(t > 0) = P_{load}(t - 1) \qquad \textit{Equation 1}$$

where the time of aFRR activation is denoted by $t = 0$ and the time of one measurement before is denoted by $t = -1$.

The advantages of this method are the simplicity, transparency and rather low requirements concerning computing power. On the other hand the method is not applicable if a step in the operational schedule of the unit is expected during the time of the activation. In that case the unit would cause additional imbalance to the system due to not being able to follow the schedule.

Figure 5 demonstrates the application of the method on a generator. As soon as an aFRR activation set-point has been received the last measurement is used as the baseline value as long as there is an active aFRR set-point. The baseline stays constant if the set-point changes the values or even the sign of activation is changed. If there is no set-point different from zero received any more the baseline stays constant for some additional time in order to be able to report the down-ramping behaviour correctly.

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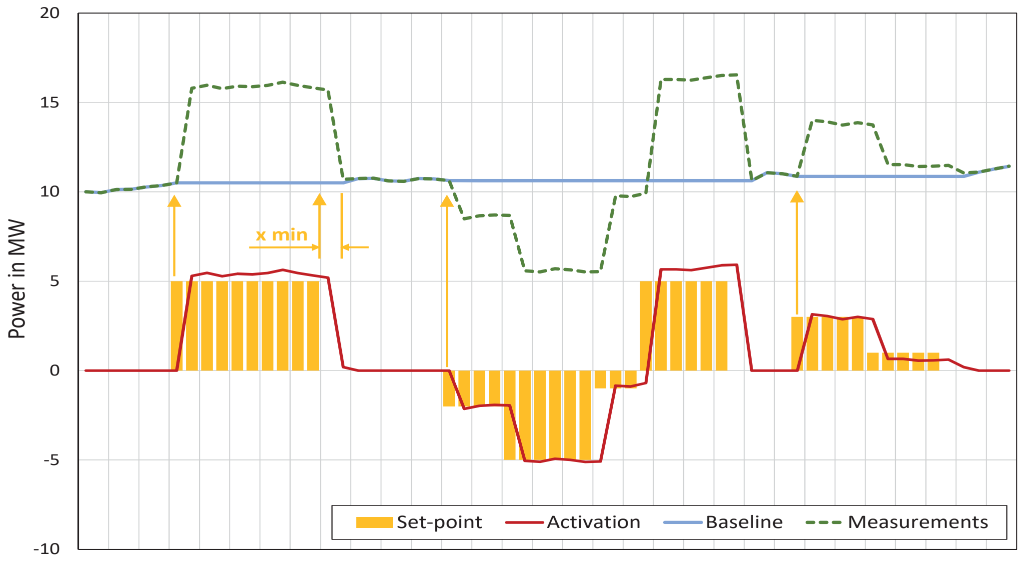

Figure 5: Example of the baseline method "continuation of the current measurements value at reception of activation command"

Instead of taking the last measurement one can take also the average of several latest measurements to eliminate noise from the data:

$$Baseline = \left(\sum_{t=-15}^{-1} Pload(t)\right)/15 \qquad \textit{Equation 2}$$

where 15 values from $t = -15$ to $t = -1$ have been taken into account. The averaging period can be chosen individually for a resource according to the time constant of noise resp. periodic fluctuations.

A sophistication of this method would be to use the ARIMA (Autoregressive integrated moving average) models where one derives a certain formula (and not a simple average value) for the calculation of next baseline values based on previous measured values. ARIMA models are based on certain autocorrelation properties of measured data that can perhaps be observed from the data. This simple baseline approach of previous paragraphs fails in the case that the last measurement was taken approximately in the local time-maximum of consumption or generation of the unit considered. In this case, the electricity consumption or generation would slowly fall anyway but by the shown approach this would be wrongly counted and also enumerated to the resource. By using the much more complicated ARIMA models the number of such cases could perhaps be minimized but could not be totally eliminated. The drawback is that these models reduce the advantages of the underlying method, namely simplicity and transparency.

4.3.5 Baselines for wind power

With the increasing share of wind power in the generation fleet there is not only a growing demand for balancing but also additional flexible capacity available. There are two main strategies to provide capacity for balancing from a wind generator. The simpler strategy is to operate the wind generator on maximum available power determined by the wind speed or according to a schedule which can be fulfilled with a very high probability. In this case negative balancing capacity can be exploited by reducing the output of the wind generator to a value lower than the maximum possible value.

If the wind generator is by default operated on a level lower than the maximum possible feed-in or possible feed-in with a high probability the output can be controlled in both directions and also positive balancing electricity can be provided. Following this advanced strategy will mean that there is a permanent loss of renewable electricity due to the reduced generation for reserving positive capacity.

In general, the exploitation of flexibility of wind generators is still in an early phase and there is no common approach across Europe so far. Two main approaches for baseline definition and verification are discussed or already applied at the moment. These approaches are shown in Figure 6.

ISBN 978-3-85125-586-7 DOI 10.3217/978-3-85125-586-7

The first method is based on a probabilistic schedule which can be provided by the wind farm with a very high probability (e.g. at least 99,5%). This probabilistic schedule requires a generation forecast which has to be calculated as close to the delivery as possible. Analysis show that the time to delivery must be lower than 4 h, but maximum 1 h is recommended to reach an adequate quality of forecast [8]).

The second method is related to real time assessment of possible feed-in based on wind speed and wind direction measurements and the given generation characteristics of the wind generator or wind park. This method has the advantage of maximum exploitation of the renewable resource. On the other hand the control of the feed-in to keep a constant difference to the potential feed-in is more challenging than maintaining a fixed level of feed-in.

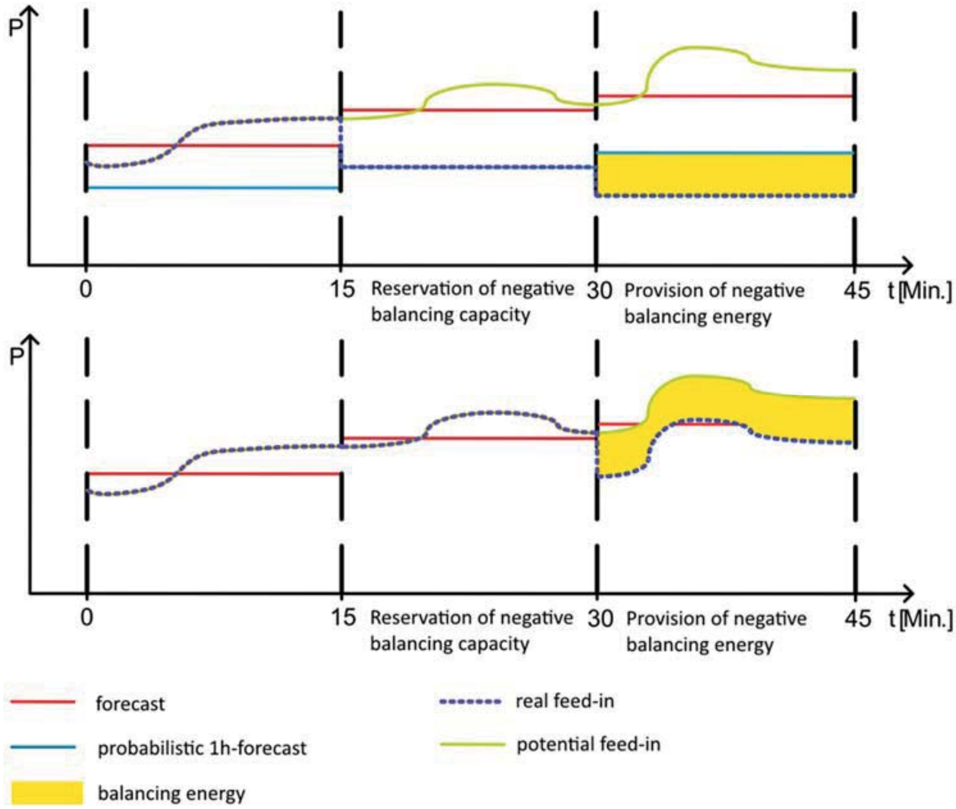

Figure 6: Different approaches for providing balancing reserve from a wind generator based on a short term schedule with high probability (above) or based on the available active power calculated in real time (below); [9]

At the current stage of implementation there is a lack of experience and some open issues still have to be solved. For instance, shadowing effects may appear if only some generators of a whole wind park would be reserved for balancing services. A crucial question is the required backup. The required backup is closely related to the quality of forecast, which is influenced by the timespan between forecast and delivery and the geographical distribution of the pool of wind generators.

Finally, a generation forecast usually provides data as an average of 15 min, a reasonable minimum interval would be 3 min because the underlying weather forecast will not be available in a higher time resolution. Interpolation methods must be applied to receive a continuous schedule in 2 s intervals as required by many TSO.

4.3.6 Proposed approaches for verification methodology

As mentioned in the beginning of the chapter there is no perfect verification method which could cover all types of units with the underlying characteristics and all the different requirements of the individual TSOs approaches and requirements of market clearing rules. In particular, the FAT requirement of the individual TSOs varies between 5 min to 15 min, and the tolerance bandwidth for aFRR activation is defined differently by each TSO. Each TSO defines some specific terms depending on the characteristics and requirements of the control zone but anyhow tries to avoid unnecessarily strict rules.

ISBN 978-3-85125-586-7 DOI 10.3217/978-3-85125-586-7

which could result in a barrier for new market participants and as a consequence the TSO or balancing market operator would have to deal with the disadvantage of low market liquidity or even too less market participants to provide the required amount of aFRR. Given to these facts it seems to be a reasonable approach to be flexible in the definition of baselines as long as a transparent and reliable method is applied. It proved to be a good practice that the provider can propose a baseline calculation method during the pre-qualification procedure which will be evaluated by the TSO. There is no known baseline methodology which could cover the specific characteristics of many industrial consumers or portfolios of industrial consumers. Usually these consumers can provide flexible capacity only for a limited time period. The integration of industrial consumers with limited availability into portfolios and the reduction of aFRR product duration should facilitate the reliable provision of flexible capacity. Some TSO and portfolio operators mention that product durations longer than 4 h are not favourable for this kind of consumers and recommend further investigations to develop a new baseline methodology for industrial consumers.

Since baselines based on power market trading schedules are a commonly used baseline method, the procedure for verification of an aFRR activation based on the analysed requirements is summed up in Figure 7.

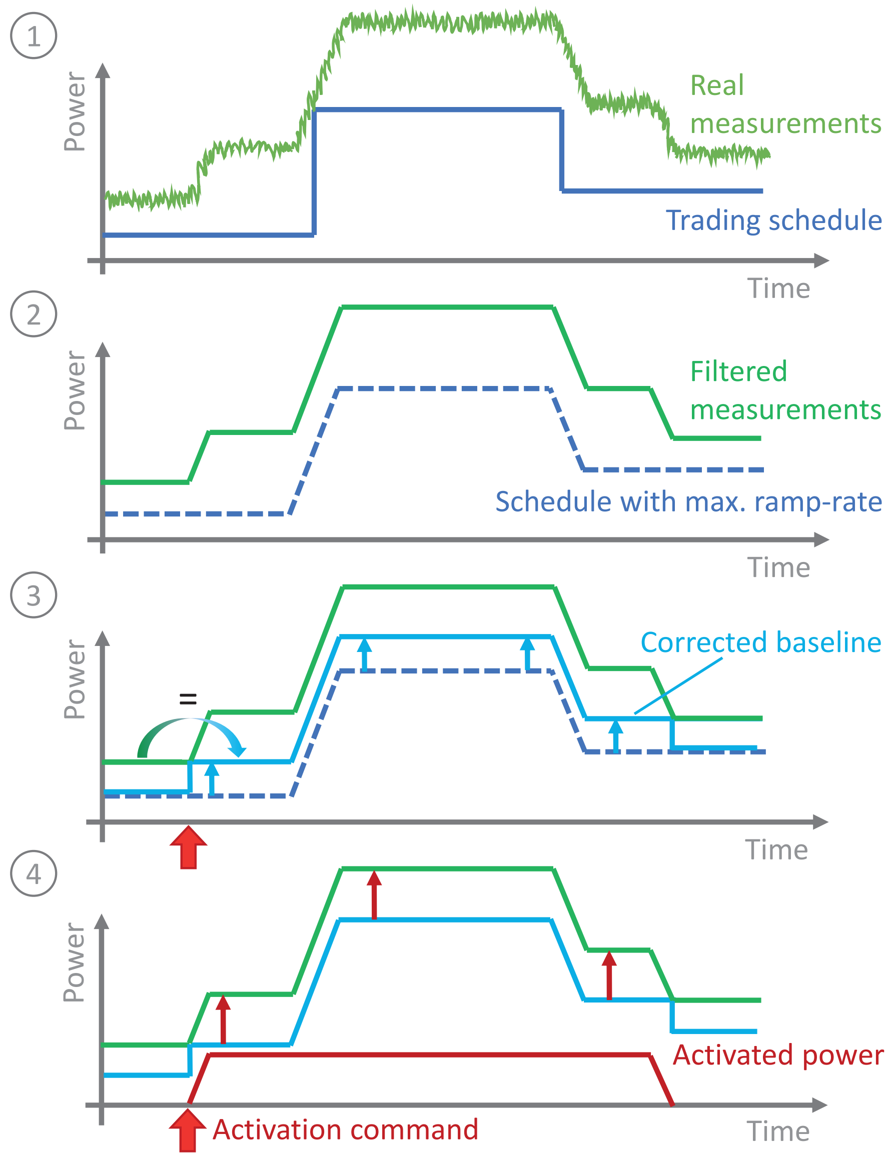

Figure 7: A general approach for verification of an aFRR activation

The basis is a data series of real measurements and the trading schedule (1). The measurements are sent to the TSO in real time (or close to real time) but the schedule can be sent in advance in some

ISBN 978-3-85125-586-7 DOI 10.3217/978-3-85125-586-7

cases. In case of too much noise on the measurements a real time filtering method might be applied before sending the data to the TSO. Additionally, discrete steps in the baseline must be converted into ramps (2). As soon as an aFRR activation command is received the baseline must be corrected to the level of the last measurements (3) and will then be fixed for the duration of the activation. If the baseline has to be send in real time in parallel to the measurements, the correction also must be performed in real time. Finally, the aFRR activation is calculated as the difference between the filtered measurements and the corrected baseline (4). Then all the required data is processed and can be send to the TSO close to real time.

This procedure provides a quite general approach. Depending on the resource characteristic, the behavior of a pool of resources and the requirements of the TSO some of the steps might be negligible in certain cases.

5 Outlook

In 2018, field tests and demonstration of the FutureFlow system will start. For this purpose, a demo site system (Figure 8) has been developed in the past two years. The tests include the preparation of real flexibility providing units in all four control areas, pooling of flexibilities in four individual virtual power plants (VPP), and separate connection of all four VPPs to the TSO-hosted FutureFlow simulation platform, where the bidding within the control area is simulated. The TSO can connect to the Futureflow cloud platform where aFRR bids are forwarded and optimization and control is performed in real-time.

A further objective is the test of aFRR provision from renewable sources. To support the integration of renewable units, an aFRR product duration of 1 h and a gate closure time of approx. 30 min will be tested.

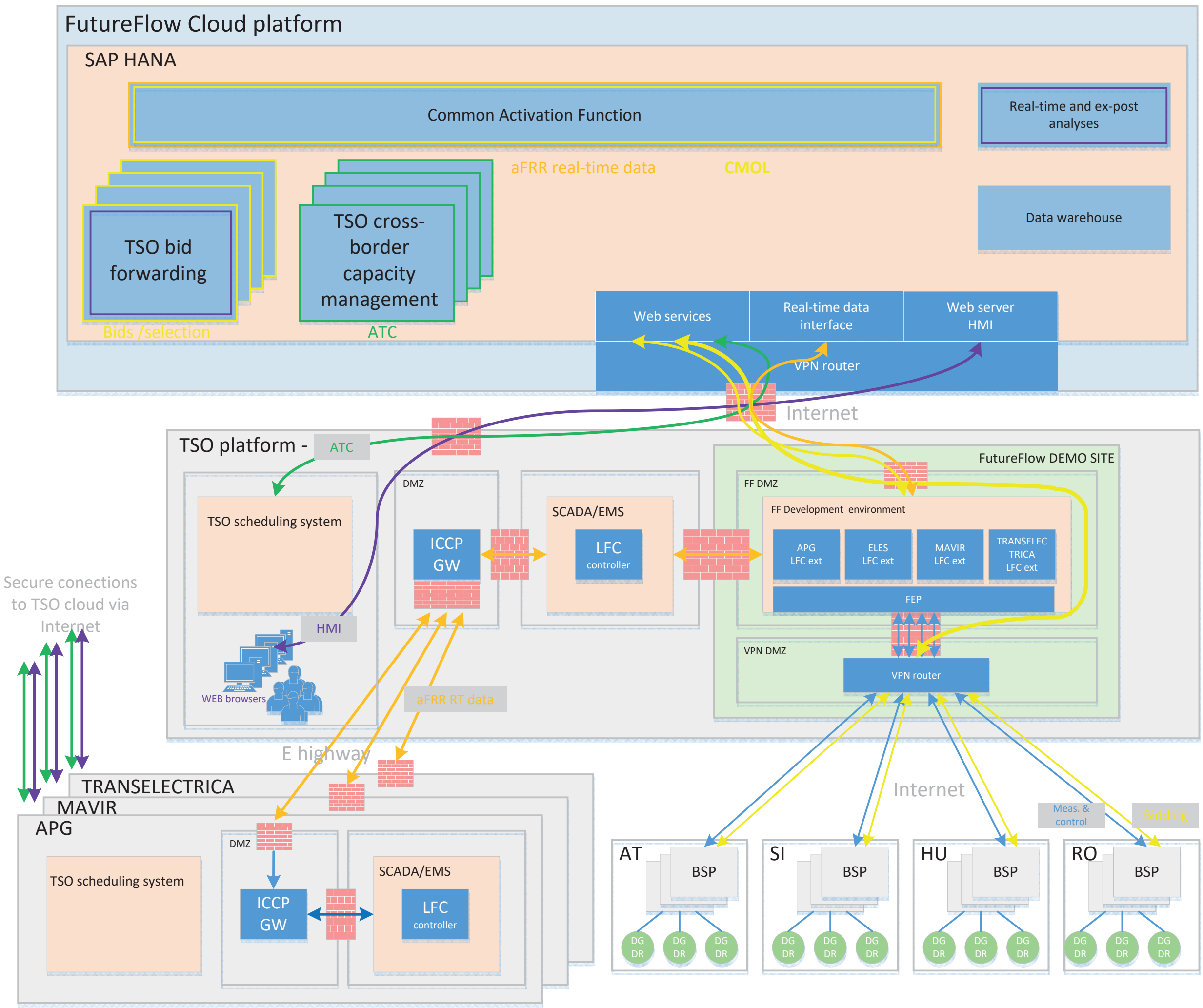

Figure 8: The FutureFlow DEMO Site System Architecture [10]

ISBN 978-3-85125-586-7 DOI 10.3217/978-3-85125-586-7

The FutureFlow DEMO site system architecture shown in Figure 8 consists of three major system blocks:

(1) TSO platforms will communicate through existing communication channels in between each other. Internal information sources can be the TSOs' scheduling systems (or any other solution, which provides the information about the available transmission capacity for balancing or redispatch purposes) and the aFRR load frequency controller (LFC) realized within SCADA/EMS and presenting measurements/variables and control within EMS.

(2) Balancing Service Providers (BSP), located in each control area (SI, AT, HU, RO) are managing pools of Distributed Resources or Distributed Generation (DR/DG) capacities. The BSPs communicate with the FutureFlow DEMO environment using data communication channels transiting over public internet paths. Each BSP relates to a single secure link, either telecom provided VPN or Internet, but with two types of data flows and separate tunnels (VLAN): measurement and control signals
   - TSO LFC (real time) and bidding
   - TSO bid forwarding function (1h).

(3) The FutureFlow Cloud platform implements several functionalities and is planned to be connected to the FutureFlow DEMO site using various communication protocols, such as REST and MQTT for real-time data flows. Functionality in the FutureFlow Cloud:
   - Selection of the matched bids
   - Real-time optimization of the imbalances in the connected countries
   - Enchaining interfaces with other platforms

6 Conclusions – Measurement and verification of aFRR provision

In general, if the TSO-TSO-model is applied, the measurement and verification of aFRR provision should be the task of the connecting TSO. Nevertheless, it turned out to be a challenging topic since there are a lot of individual rules in each control zone and in the current state there is no common standardized procedure of the four TSO. In order to deal with the existing heterogeneity, it was chosen to point out common approaches and general issues relevant for most control zones as well as good practices to verify the provided aFRR. It seems to be a promising approach of many TSO to allow any source of flexible capacity as long as the main requirements for aFRR provision are fulfilled. If a TSO wants to increase the number of aFRR providers and the market liquidity it could be helpful to re-interpret certain historically grown requirements in order to promote new sources of flexibilities like RES and industrial loads organized in pools and managed by VPPs. In the past many rules have been defined to deal with large generators only, some of these rules may become a barrier for smaller flexibilities managed by VPPs.

The definition of suitable algorithms for baseline calculation are crucial for participation of VPPs or other aggregation platforms in aFRR markets. The investigation showed that there is no common procedure for baseline calculation which could meet all the requirements related to different characteristics of various resources of flexibilities, the TSOs approach for P/f-control and verification and in some cases even the national power market clearing rules. Therefore, it is important for TSOs not to insist on too strict rules but rather to allow different verification approaches as long as the fundamental requirements are fulfilled. The paper explains five different baseline methodologies, which might fulfil aFRR requirements for sure and are proven practice in some control zones. These methods are (corrected) power market schedule, baseline submitted with short lead time (min. equal to full activation time), continuation of the current measurements, and available active power (of renewable generators). Further methods may also be applicable but are not approved by sufficient practical experience yet. In case that the real-time calculation of provided aFRR power requires a short-term baseline correction it is preferable that the provider performs the correction, which of course requires transparent rules to support ex-port verification by the TSO.

Some TSO accept new proposals for verification methods developed by the providers of flexibility as long as reliability and transparency fulfil the requirements for aFRR provision. This approach proved to be good practice to facilitate the participation of RES and VPPs in balancing markets. Alternatively, the provider could choose a baseline method from a catalogue of methods already verified by the TSO.

ISBN 978-3-85125-586-7 DOI 10.3217/978-3-85125-586-7

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Acknowledgement

The FutureFlow project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement n° 691777