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Guideline for variable production and consumption in automatic reserves

1 Introduction

This document is an additional guideline for variable generation and consumption participating in automatic reserves (FFR, FCR, aFRR). The document provides guidance on how to apply reserve product requirements to units where variability in generation or consumption needs to be considered. It focuses on topics related to the baseline and reporting of maintained reserves.

Examples of variable production include weather-dependent sources such as wind and solar power. Variable consumption may include, for instance, electric vehicle charging systems where the reference power depends on the number of users, or electric boilers whose operating power is determined by the needs of the district heating network. The necessity of applying this guideline shall always be agreed upon with Fingrid.

The examples in this document focus on weather-dependent production, however, the same requirements apply equally to variable consumption.

The general technical requirements and the prequalification tests, applicable for all technologies, are described in the following documents:

- The technical requirements and the prequalification process of Frequency Containment Reserves (FCR)
- The technical requirements and the prequalification process of Fast Frequency Reserve (FFR)
- The technical requirements and the prequalification process of Automatic Frequency Restoration Reserve (aFRR)

The documents are available on Fingrid's website, see the attachments on the product specific pages.

2 Definitions

2.1 Definitions for generation units

Available power ($P_{available}$) is the highest power that would be possible to produce under the current operating conditions. For example, for wind power the available power depends on variables such as wind speed and air density, and for solar power on variables such as solar irradiation and temperature of the panels. The available power is a calculated value. The plant may be producing less than the available power if the power has been limited (market-based curtailment or a restriction by the grid operator).

Power limitation (P_{limit}) is the power level to which the production is currently restricted.

Baseline power ($P_{baseline}$) is the power that the plant would produce if no reserves were activated.

Minimum power (P_{min}) is the lowest power that the plant can currently operate at.

Maximum power (P_{max}) is the highest power that the plant can currently operate at. It equals $P_{available}$ unless the power is restricted by the grid operator in which case it equals the power limitation.

Instantaneous active power is the measured power exchange with the grid. The value is positive for injected power and negative for absorbed power.

Activated reserve is the change in power due to activation of a reserve. It is calculated as the difference between the measured instantaneous active power and the baseline.

Maintained reserve is the capacity that the plant has available for activating a reserve, limited to the prequalified capacity. The maintained reserve shall not be decreased if the capacity is used to activate the reserve.

2.2 Definitions for consumption units

Available power ($P_{available}$) is the active power that would be possible to consume under the current operating conditions. For example, the power consumed by electric boilers may follow the needs of district heating. Therefore, the available power may depend on the conditions of the district heating network. The available power is a calculated value.

Power limitation (P_{limit}) is the power level to which the consumption is currently restricted, if the power of the unit can be restricted.

Baseline power ($P_{baseline}$) is the power that the plant would produce if no reserves were activated. The value is positive for injected power and negative for absorbed power.

Minimum power (P_{min}) is the lowest power that the unit can currently operate at. The value is positive for injected power and negative for absorbed power. It equals $P_{available}$ unless the power is restricted in which case it equals the power limitation.

Maximum power (P_{max}) is the highest power that the unit can currently operate at. The value is positive for injected power and negative for absorbed power.

Instantaneous active power is the measured power exchange with the grid. The value is positive for injected power and negative for absorbed power.

Activated reserve is the change in power due to activation of a reserve. It is calculated as the difference between the measured instantaneous active power and the baseline.

Maintained reserve is the capacity that the unit has available for activating a reserve, limited to the prequalified capacity. The maintained reserve shall not be decreased if the capacity is used to activate the reserve.

3 Baseline

3.1 General guidelines

A baseline with sufficient accuracy is needed

- for BSP to use as the reference power for control actions,
- for Fingrid to perform ex-post verification of reserve activations, and
- for BSP to calculate the maintained reserve capacities for real-time monitoring and invoicing of capacity.

Reserves shall be activated as a power deviation from the baseline. The baseline is always related to the actual production or consumption, as the need to activate automatic reserves is based on the physical imbalance between production and consumption in the power system. Production forecast or traded volumes cannot be used as a baseline for activating automatic reserves, as they may deviate from the actual production and hence not represent the physical state of the system.

If the plant has a controllable setpoint, the baseline power equals the setpoint (production setpoint excluding setpoint changes due to activation of reserves). For intermittent generation or consumption the baseline is:

a) $P_{available}$, if the plant is operating without power limitation

b) For generation units min($P_{available}$, P_{limit}), if a power limitation is active

c) For consumption units max($P_{available}$, P_{limit}), if a power limitation is active

If the power of a generation unit is limited to provide upregulation, the limitation must ensure that the available upregulation capacity is always equal to or greater than the offered upregulation capacity (contracted capacity and voluntary energy bids). Either the limit must be applied in relation to the momentary $P_{available}$, or if an absolute power output limit is used, it must have enough margin towards variations of $P_{available}$. The same conditions apply for consumption units when consumption is restricted to provide downregulation. If the power of a unit has been restricted by the grid operator, activation of reserve must not lead to exceeding this power limitation. In this case reserves can be provided by setting the limitation, so that the margin between the applied limitation and the level given by the grid operator is at least equal to the offered reserve capacity.

In FCR-D and FFR the reserve may alternatively be activated in relation to the instantaneous power right before the activation, assuming this is the baseline during the activation. FCR-D and FFR are activated in disturbance situations, and the duration of the activation is typically short. Therefore, variations in the baseline during the activation can be neglected. With this method FCR-D downwards provision from generation units and FCR-D upwards and FFR provision from consumption units do not require use of the available power. The BSP can derive the baseline from the power measurement, freezing the baseline during activation. The available power is not needed for reporting either. For providing FCR-D upwards and FFR from generation units the available power is still needed for calculating and reporting the maintained reserve capacity, even if the control

action uses the instantaneous power measurement as the reference. For providing FCR-D downwards from consumption units the available power is still needed for calculating and reporting the maintained reserve capacity, even if the control action uses the instantaneous power measurement as the reference.

3.2 Quality criteria for the available power calculation

If the available power is used as the baseline and/or for calculating the maintained reserve capacity, its quality is verified in the prequalification process. An inaccurate calculation can cause lacking or excessive activations, distort the monitoring of the available reserves and lead to incorrect payments and penalties.

For verification the BSP shall submit the information listed below. It shall be submitted per reserve providing entity. For aFRR provision the information can be submitted per portfolio if the nominal power of the reserve providing entities is maximum 10 MW.

- Description of the calculation of the available power
    - What measurements, assumptions, models etc. are used?
    - Is machine learning or other similar techniques used?
    - How does the calculation consider exceptional circumstances, such as icing of wind turbines or maintenance?
- 1 month of data with a resolution of at least 10 s including:
    - Timestamp (column name ‘DateTime’), according to standard ISO 8601, e.g. '2024-11-28T12:18:21Z'
    - Calculated available power [MW] (column name ‘P_available’)
    - Measured instantaneous power [MW] (column name ‘P_measured’)
    - .csv, .xlsx or .xls file
- The data shall be from a period without reserve activations or power limitations
    - If necessary, the data can be gathered from several non-consecutive periods, totalling 1 month. The minimum duration of the non-consecutive periods shall be 1 hour.
- The data shall be a representative sample of the conditions where the entity would maintain reserve capacity. If necessary, Fingrid can request additional data to conduct the analysis.
- Note: the calculation cycle may be longer than 10s if the quality criteria are still met, but the data shall be sampled to 10s resolution

The quality of the available power is evaluated as follows.

1. The deviation of the available power is calculated for each timestep:

   $$P_{deviation}(t) = P_{available}(t) - P_{measured}(t)$$

2. The normalization power is calculated as the average of the available power values:

   $$P_{normal} = \frac{\sum P_{available}}{N}$$

   where N is the number of timesteps in the dataset.

3. The normalized root-mean-square error is calculated as:

   $$NRMSE = \frac{\sqrt{\frac{\sum P_{deviation}(t)^2}{N}}}{|P_{normal}|}$$

4. The NRMSE shall not be higher than 5 %.

The quality criteria shall be fulfilled with the conditions under which reserves are to be maintained. In other words, access to the reserve markets does not require the quality criteria to be met at all times. If certain conditions (e.g. bad wind conditions) negatively affect the calculation of reference power, they can be replaced by periods of higher quality (e.g. good wind conditions). The maintenance of the reserve shall be scheduled at times when the conditions are such that the reference power quality criteria is met.

Fingrid reserves the right to further develop the quality criteria, the data requirements and the verification process, as more experience is gained.

4 Calculation of maintained reserve

Maintained reserve is the capacity that the entity has available for activating reserves, calculated separately for each product. The maintained reserve shall not be decreased if the capacity is used to activate the reserves.

Figure 1 illustrates how the capacities of different reserves are added when providing multiple products at the same time. It does not indicate which reserves have the highest priority for the power system. Instead, it describes a typical behaviour of a reserve providing entity when the control is active for all sold reserves. If there is not enough headroom for all the sold capacities, the maintained FCR-D capacity is limited first, then the FFR capacity, then FCR-N, then FRR. The reasoning behind this is that FRR and FCR-N can be fully activated when a disturbance that activates FCR-D and FFR occurs. When the disturbance occurs, FFR will activate faster than FCR-D, and therefore it is FCR-D that will not be delivered fully. With regards to FCR-N and FRR, any of these reserves can be activated before the other. However, since FCR-N is typically located after FRR in the control chain (FCR works as a difference to the setpoint including FRR), the FRR reserve takes priority over the FCR-N.

If the reserve providing entity does not behave as described here, the calculation of the maintained capacities shall be adjusted to reflect the actual behaviour. This may be the case if the controller logic is different than assumed here, or the BSP proactively turns off

the control of any of the reserves in case of insufficient headroom. The BSP shall ask Fingrid to approve the solution.

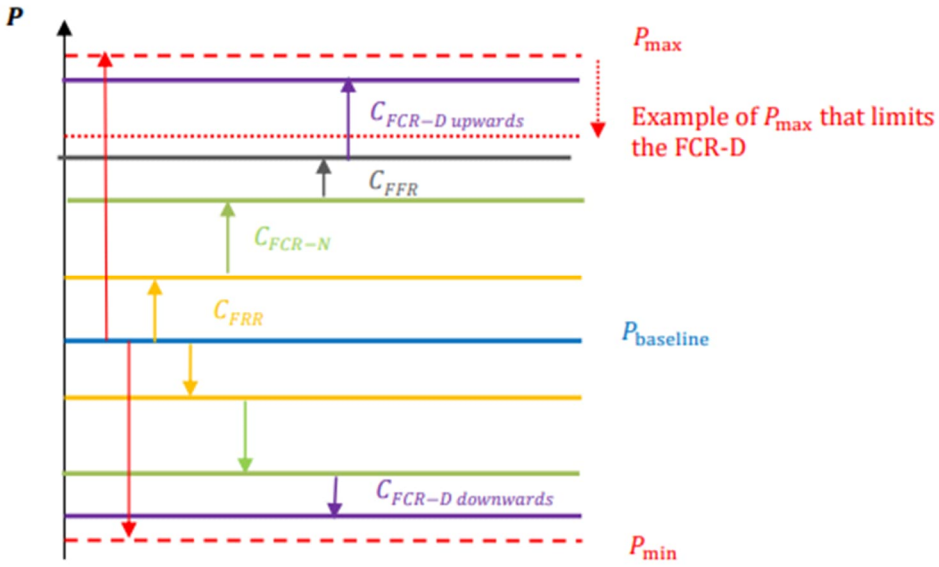

Figure 1 Maintained reserve capacities

Maintained reserve capacities must be reported to Fingrid in real-time. Fingrid uses the data for real-time monitoring and in the invoicing process to verify the BSP has delivered all invoiced capacity. The BSP must also save the data in order to calculate their delivered capacity for the invoice.

The maintained aFRR is calculated as:

$$C_{aFRR,upwards,maintained} = \max\left[\min\left(P_{max} - P_{ref} - C_{other\ reserves}, C_{prequalified}\right), 0\right]$$

$$C_{aFRR,downwards,maintained} = \max\left[\min\left(P_{ref} - C_{other\ reserves} - P_{min}, C_{prequalified}\right), 0\right]$$

If the BSP has multiple aFRR providing entities, the maintained capacity is reported for the portfolio instead of the individual entities.

The maintained FCR is calculated as:

$$C_{FCR-N,maintained} = \min\left(P_{max} - P_{ref} - C_{other\ reserves}, \ P_{ref} - C_{other\ reserves} - P_{min}, \ C_{FCR-X}\right)$$

$$C_{FCR-D,upwards,maintained} = \max\left[\min\left(P_{max} - P_{ref} - C_{other\ reserves}, \ C_{FCR-X}\right), 0\right]$$

$$C_{FCR-D,downwards,maintained} = \max\left[\min\left(P_{ref} - C_{other\ reserves} - P_{min}, \ C_{FCR-X}\right), 0\right]$$

The maintained FFR is calculated as:

$$C_{FFR,maintained} = \max\left[\min\left(P_{max} - P_{ref} - C_{other\ reserves}, \ C_{FFR}\right), 0\right.$$

In the equations above,

P_{max} is the current maximum power output (available power for generation units if power is not limited). The value is positive for injected power and negative for absorbed power,
P_{min} is the current minimum power output (available power for consumption units if power is not limited). The value is positive for injected power and negative for absorbed power,

P_{ref} is the current power baseline, the value is positive for injected power and negative for absorbed power,

$C_{other\ reserves}$ is the capacity of the other potential reserves sold in the direction of question, considering the priority order of reserve maintenance. mFRR capacity should consider both contracted capacity and currently activated voluntary mFRR energy bids.

$C_{prequalified}$ is the prequalified capacity of the aFRR reserve product,

C_{FCR-X} is the steady state response of the Frequency Containment reserve at the selected operating point and/or the amount of FCR-X accepted based on the prequalification test, whichever of the values is lower at that moment,

C_{FFR} is the steady state response of the Fast Frequency Reserve at the selected operating point and/or the amount of FFR accepted based on the prequalification test, whichever of the values is lower at that moment.

5 Data exchange requirements

The participation in the automatic reserves requires real-time data exchange as well as logging of historical data.

For a list of signals to be included in the data exchange, please refer to “Reserve information exchange – signal list”, available on Fingrid’s website.

Fingrid also recommends logging variables that affect the available power (wind speed, solar irradiation etc.).

6 Examples

6.1 aFRR downwards

A wind park provides 10 MW of aFRR downwards. It is operating without power limitations, i.e. producing the available power if aFRR is not activated. The baseline is the available power.

Figure 2 illustrates the ideal behaviour of the wind park. When 10 MW of aFRR is activated, the measured power should run 10 MW below the baseline. The maintained capacity is calculated as the difference between $P_{available}$ and P_{min}, independent of currently activated aFRR.

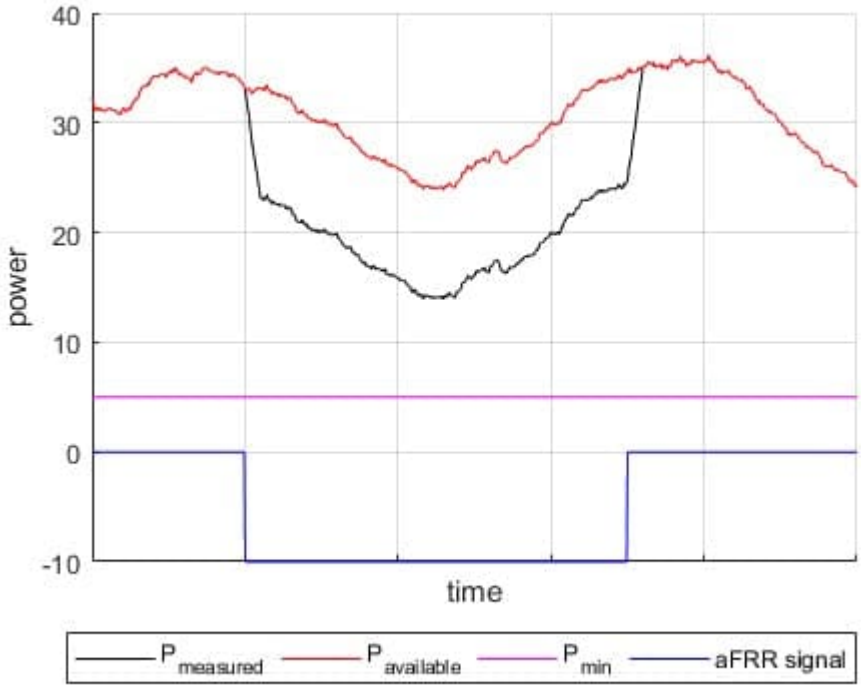

Figure 2 aFRR downwards, example

6.2 aFRR upwards

6.2.1 Operating at constant power limit

A wind farm provides 10 MW of aFRR upwards. The production has been limited to a constant power output to leave enough margin for upregulation. The baseline is the power limit.

Figure 3 illustrates the ideal behaviour of the wind park. There is enough margin between P_{limit} and $P_{available}$ to active the full aFRR capacity.

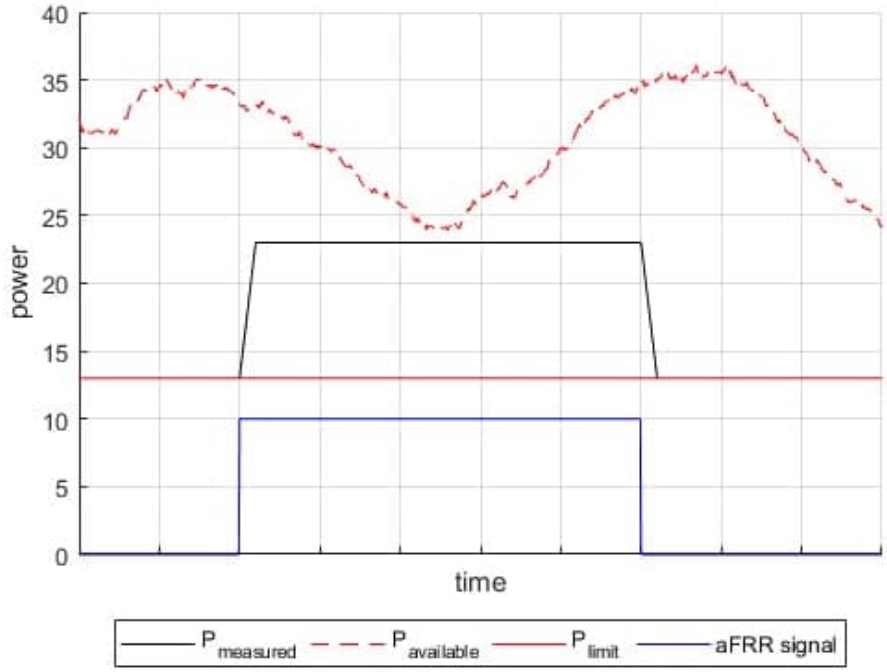

Figure 3 aFRR upwards, example 1

Figure 4 illustrates the behaviour of the wind park if the margin between P_{limit} and $P_{available}$ is not sufficient. During activation the measured power should remain 10 MW above the baseline, but this is not possible due to the decrease in the available power. The requested aFRR capacity is only partially activated.

The maintained capacity is calculated as the difference between $P_{available}$ and P_{limit}, independent of currently activated aFRR. In the latter example when the margin is insufficient, the maintained capacity will also decrease.

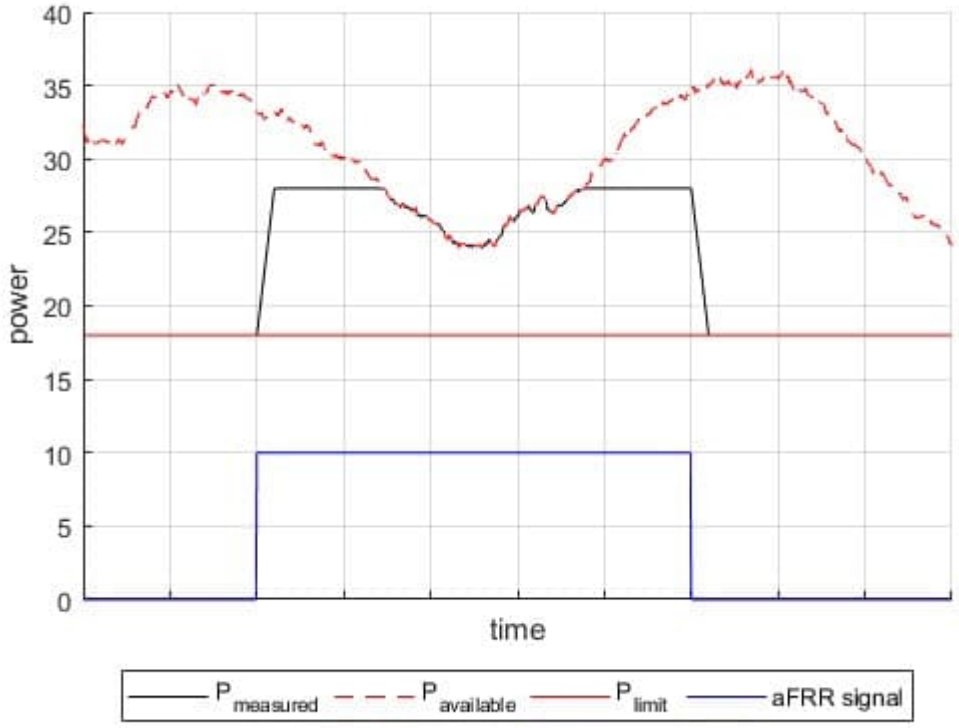

Figure 4 aFRR upwards, example 2

6.2.2 Operating at varying power limit

A wind farm provides 10 MW of aFRR upwards. The production is limited in relation to the available power to give a constant margin of 10 MW. The baseline is the limited power.

Figure 5 illustrates the ideal behaviour of the wind park. When no aFRR is activated, the measured power runs 10 MW below the available power. When aFRR is fully activated, the measured power equals the available power. The maintained reserve is calculated as the difference between $P_{available}$ and P_{limit}, independent of currently activated aFRR.

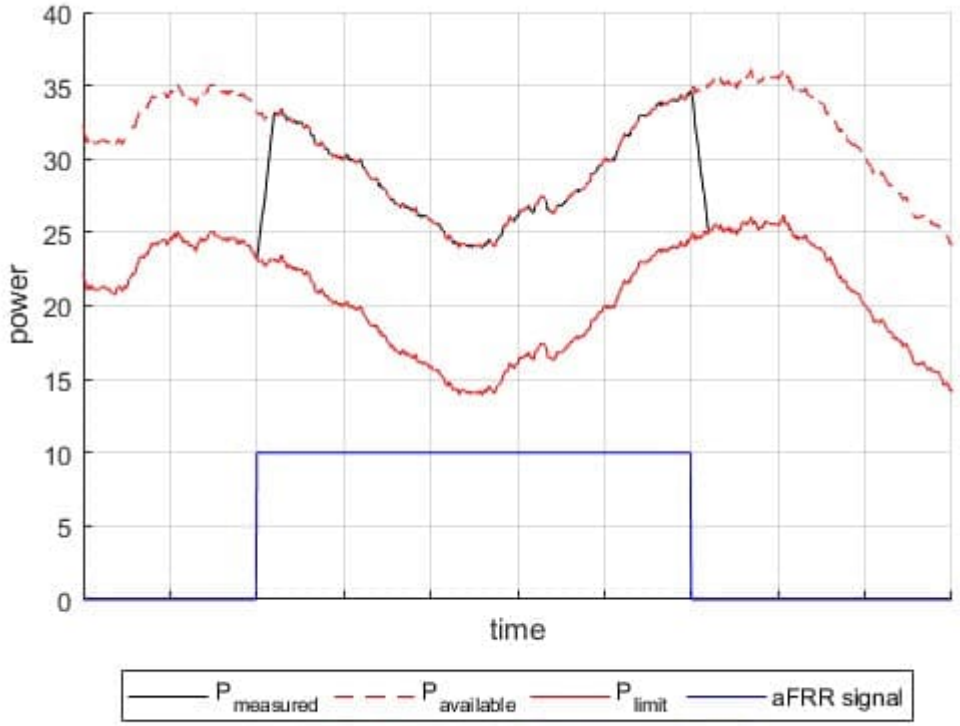

Figure 5 aFRR upwards, example 3

6.3 FCR-D downwards

A wind park provides 20 MW of FCR-D downwards. It is operating without power limitations, i.e. producing the available power if FCR-D is not activated.

Figure 6 illustrates the ideal behaviour of the wind park when the baseline is the available power. When a frequency deviation occurs, FCR-D downwards is activated accordingly. During activation changes both in the frequency and in the available power affect the measured power. The maintained capacity is calculated as the difference between $P_{available}$ and P_{min}, independent of currently activated FCR-D.

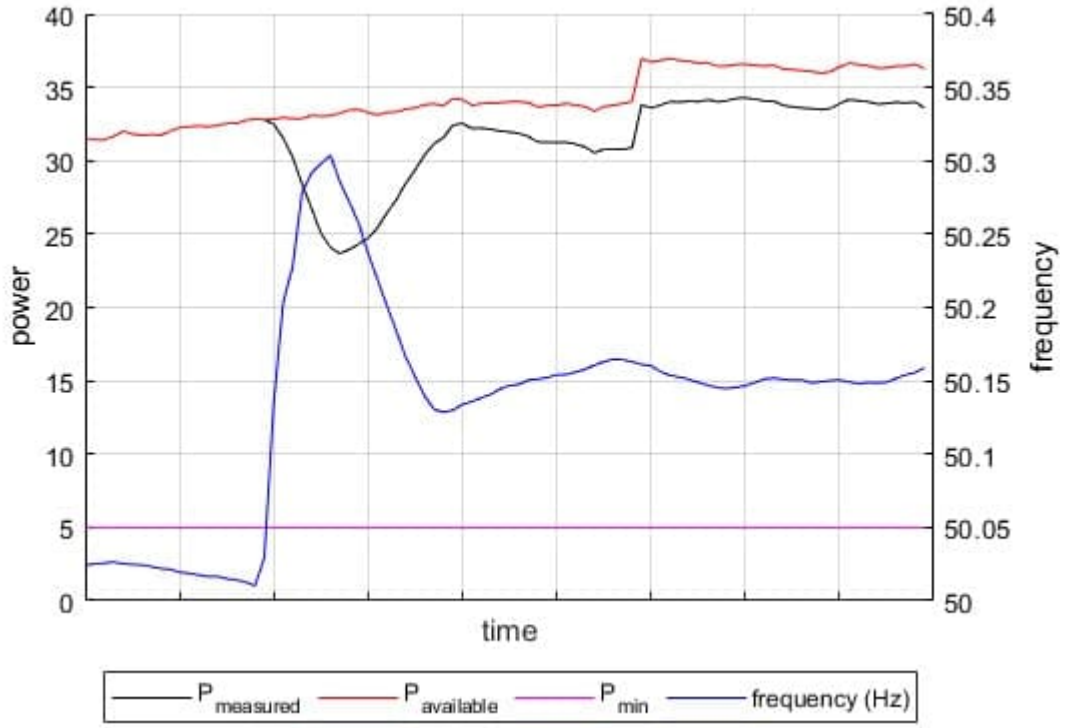

Figure 6 FCR-D downwards, example 1

Figure 7 illustrates the ideal behaviour of the wind park, when the baseline is the instantaneous power right before the activation. When a frequency deviation occurs, FCR-D downwards is activated accordingly. During activation the baseline is frozen and only changes in the frequency affect the measured power. The maintained capacity is calculated as the difference between $P_{baseline}$ and P_{min}, independent of currently activated FCR-D.

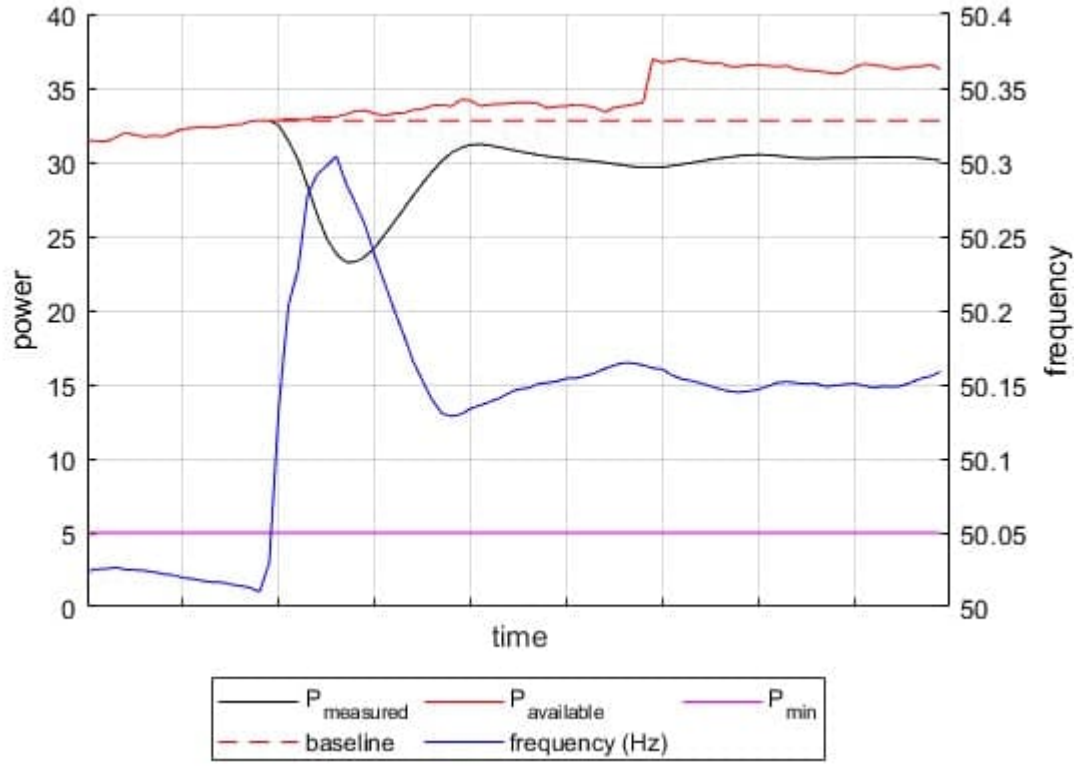

Figure 7 FCR-D downwards, example 2