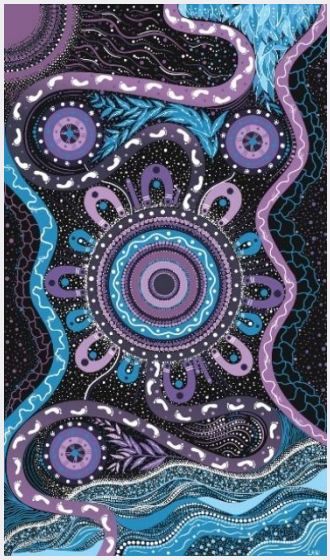
Frequency Performance Payments (FPP) – Factor Calculation Guide

9 December 2024

A resource for NEM market participants and other stakeholders preparing for FPP's implementation



We acknowledge the Traditional Custodians of the land, seas and waters across Australia. We honour the wisdom of Aboriginal and Torres Strait Islander Elders past and present and embrace future generations.

We acknowledge that, wherever we work, we do so on Aboriginal and Torres Strait Islander lands. We pay respect to the world's oldest continuing culture and First Nations peoples' deep and continuing connection to Country; and hope that our work can benefit both people and Country.

'Journey of unity: AEMO's Reconciliation Path' by Lani Balzan

AEMO Group is proud to have launched its first Reconciliation Action Plan in May 2024. 'Journey of unity: AEMO's Reconciliation Path' was created by Wiradjuri artist Lani Balzan to visually narrate our ongoing journey towards reconciliation - a collaborative endeavour that honours First Nations cultures, fosters mutual understanding, and paves the way for a brighter, more inclusive future.

Important notice

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1. Introduction

1.1 Background and context

The National Electricity Market (NEM) is experiencing a period of significant change. The progressive replacement of thermal, synchronous generation with variable inverter-connected resources, such as wind, solar and batteries, makes the task of managing the power system securely more complex.

The Australian Energy Market Commission (AEMC) recognised the need for a new framework of incentives for NEM participants regarding primary frequency response (PFR). The AEMC made a final determination in the Primary Frequency Response Incentives rule change[1] on 8 September 2022. The key effects of the rule change are to:

- Extend the requirement for all scheduled and semi-scheduled generators to provide automatic PFR (by removing the sunset clause that would have seen that obligation lapse in June 2023).
- Introduce a new system of incentives and penalties that will see generators and scheduled generators, scheduled loads and semi-scheduled loads either receive or be liable for payments, based on whether they have had a helpful or unhelpful impact on system frequency. These are the frequency performance payments (FPP) that give their name to the overall reform.
- Use the performance values determined for FPP, which are calculated for every five-minute interval, to allocate the cost of Regulation Frequency Control Ancillary Services (FCAS). The cost of Regulation FCAS is currently allocated via the Causer Pays framework.

1.2 Purpose of this document

National Electricity Rules (NER) 3.15.6AA(f) stipulates that AEMO must develop and publish the Frequency Contribution Factors Procedure (FCFP), containing specified parameters and other elements of the calculations that will be performed as part of FPP operation.

This FPP Factor Calculation Guide has been produced as an explanatory resource to accompany the FCFP, to assist market participants and other stakeholders during the implementation phase of the reform. It is consistent with, and should be read with, the FCFP.

[1] See https://www.aemc.gov.au/rule-changes/primary-frequency-response-incentive-arrangements#:~:text=Rule%20Change%3A%20Completed&text=Confirmation%20that%20the%20mandatory%20primary,changes%20in%20power%20system%20frequency.

2 Primary Frequency Response Incentive Arrangements rule change – purpose and key elements

The changes AEMO is implementing in the FPP reform initiative are the result of the AEMC's final determination in the Primary Frequency Response (PFR) Incentives Arrangements rule change[2].

This section summarises the AEMC's stated purpose for the new PFR Incentive Arrangements and identifies the key elements of the reform.

2.1 Purpose of the new rules

As the adoption of inverter-based resources (IBR) continues to increase, new measures are required to support the operation of the power system in accordance with the standards stipulated in the Frequency Operating Standard (FOS).

The AEMC mandated a suite of measures, outlined in Section 2.2, below, which would both:

- "*give AEMO the tools it needs to manage the secure operation of the power system*" in accordance with the FOS, and
- "*deliver more efficient operation of power system plant and encourage innovation and investment in new capability to help control power system frequency, thereby lowering costs for consumers over the long term*", through a system of incentives and penalties based on individual unit performance.

2.2 Key elements of the new rules

The AEMC characterised the changes as fitting into three categories:

1. **The extension of mandatory PFR requirements** for all scheduled and semi-scheduled generators and scheduled loads (removing an existing June 2023 sunset to such arrangements).
2. **Introducing the new FPP process**, which creates a double-sided system of incentive payments and penalties based on units' impact on system frequency.
3. **New reporting obligations** on AEMO and the Australian Energy Regulator (AER), related to the aggregate level of frequency response and the total cost of the scheme[3].

The focus of this document is the implementation of initiatives in the second category. AEMO will use four-second supervisory control and data acquisition (SCADA) system data to measure the impact of each eligible market participant and assign contribution factors (CFs) to apply in each five-minute NEM dispatch interval. These CFs are then used to:

[2] See https://www.aemc.gov.au/rule-changes/primary-frequency-response-incentive-arrangements. Final decision made 8 September 2022.

[3] AEMC, Primary Frequency Response Incentive arrangements - Final Determination, 8 September 2022, p1.

- Calculate outcomes in the two-sided FPP scheme, where penalties for market participants making unhelpful contributions to system frequency equal incentive payments to participants having a helpful impact, in each five-minute interval. This reform creates a new financial flow in NEM ancillary services.
- Allocate the cost of used Regulation FCAS, replacing the current Causer Pays arrangements that assign new CF once every 28 days.

The calculation of CFs is explained in further detail in the next section.

3 The FPP calculation process

This section identifies the factors and values used in the FPP calculation, as well as outlining the process by which AEMO will take measurements, produce input values and calculate final settlement amounts.

3.1 Elements of the calculations

The table below lists the different values that are used in the process, to determine and allocate both FPP and Regulation FCAS recovery. Please note that, to make this document as helpful as possible, the definitions below are more descriptive than those provided in the Glossary of the NER.

Table 1 Key terms and elements of the FPP calculations

Term	Definition
Cost recovery market participant	Collective term for the different categories of market participants who are subject to the NER. In the case of FPP, primarily generators, bi-directional units (such as energy storage systems) and some loads.
CF (Contribution Factor)	A factor calculated in respect of, and applied to, an eligible unit with appropriate metering.
DCF (Default Contribution Factor)	A factor calculated based on the historical performance of an eligible unit with appropriate metering.
DRCF (Default Residual Contribution Factor)	A DCF applied to the residual.
DUID (Dispatchable Unit Identifier)	The unique identifier for a dispatchable unit. A dispatchable unit is either a net producer of electricity or net consumer of electricity that is registered to participate in the centralised dispatch and pricing processes operated by AEMO.
Eligible unit with appropriate metering	A generator or large load that will be assigned individual CFs (because it can provide the necessary data).
FM (Frequency Measure)	The indicator of a need to raise or lower frequency.
FPP (Frequency Performance Payment)	A trading amount payable by, or to, a Cost Recovery Market Participant, determined in accordance with NER.
Historical Performance Period (HPP)	A seven-day period, starting at 12:00 AM on a Sunday and ending at 12:00 AM on the following Sunday, which concludes 14 days prior to the commencement of the billing period, inclusive of the 5 business days' notice period.
NCF (Negative Contribution Factor)	A CF that is less than zero.
NRCF (Negative Residual Contribution Factor)	A residual CF that is less than zero.
Performance	Collectively refers to Raise Performance and Lower Performance of all units.
P_regulation	The marginal price of meeting the global market ancillary service requirement or local market ancillary service requirement for the regulating raise service or regulating lower service in that trading interval. Calculated in $ per megawatt (MW) per hour (NER 3.15.6AA(b)(1)).
RCF (Residual Contribution Factor)	The contribution factor calculated in respect of, and applied to, the residual.
RCR (Requirement for Corrective Response)	The total volume in MW that contributed to reducing the deviation in frequency of the power system. The RCR is used to scale FPPs and is determined separately for trading amounts for regulating raise services and regulating lower services.
Reference Trajectory	The expected active power output or consumption of an eligible unit with appropriate metering.
Residual	All units without appropriate metering.

Term	Definition
Residual Deviation	The aggregate deviation of the Residual.
Residual Performance	The aggregate performance of the Residual.
SCADA	Supervisory control and data acquisition.
TSFCAS	The total amount of Regulation Raise FCAS or Regulation Lower FCAS in a trading interval.
Usage (U)	The proportion of Regulation FCAS that is deemed to be Used Regulation FCAS.
Unused Regulation FCAS	Regulation FCAS that is deemed to be unused and for which costs are determined in accordance with NER 3.15.6AA(d).
Used Regulation FCAS	Regulation FCAS that is deemed to be Used and for which costs are determined in accordance with NER 3.15.6AA(c).

3.2 Description of the FPP process

Broadly, the process undertaken for each five-minute trading interval is as follows.

1. For each eligible unit with appropriate metering (that is, units that will receive an individual CF), compare SCADA measurements with a Reference Trajectory to determine deviations from that trajectory. Calculate Residual Deviations based on the sum of deviations of eligible units with appropriate metering.
2. Determine the FM, which indicates whether there is a need to raise or lower power system frequency.
3. For each eligible unit with appropriate metering and the Residual, calculate Performance based on the FM and the deviations for Raise and Lower Services.
4. Calculate CFs for eligible units with appropriate metering and for the Residual.
5. Determine the RCR, which is then multiplied by the Regulation FCAS Requirement price (P_regulation) to calculate the total amount of FPPs for each Regulation FCAS Requirement.
6. Use the CFs for each Cost Recovery Market Participant to apportion FPPs.
7. Apportion FPPs to eligible units without appropriate metering pro rata, based on their total energy output (or consumption) and RCF.
8. Calculate Usage.
9. Apportion the cost of Used Regulation FCAS to each Cost Recovery Market Participant on the basis of NCFs.
10. Apportion the cost of Unused Regulation FCAS to each Cost Recovery Market Participant using DCFs.

Figure 1 below shows the general workflow of this process, excluding the application of any exceptions.

Figure 1 Flowchart of the general workflow of FPP process

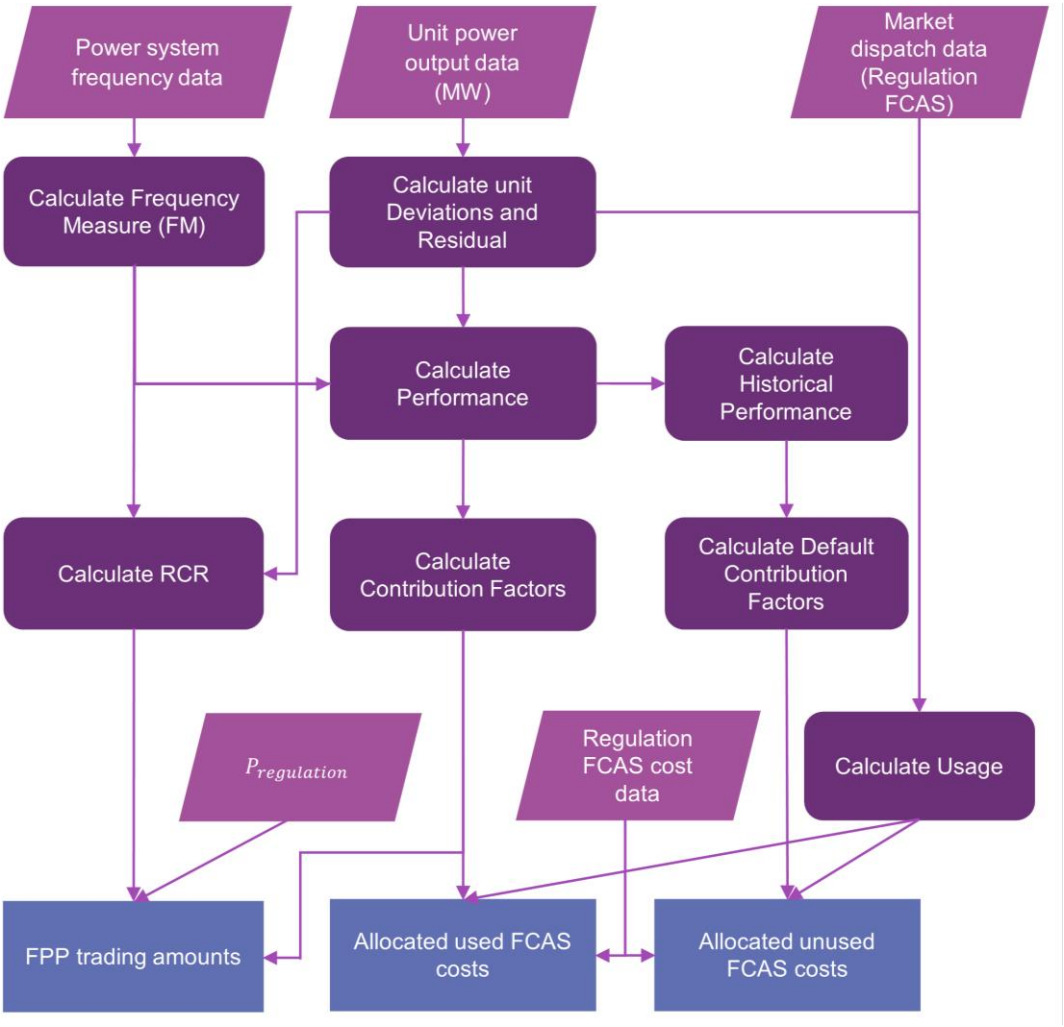


Table 2 below details the equations that are used to determine the FPPs and the recovery of Regulation FCAS costs.

Table 2 Settlement equations

Trading amounts	Eligible unit	Residual deviation
FPPs	$TA = \boldsymbol{CF} \times \frac{P_{regulation}}{12} \times RCR$	$TA = \boldsymbol{RCF} \times \frac{P_{regulation}}{12} \times RCR \times \frac{TE}{ATE}$
Recovery of Used Regulation FCAS	$TA = TSFCAS \times U \times \boldsymbol{NCF}$	$TA = TSFCAS \times U \times \boldsymbol{NRCF} \times \frac{TE}{ATE}$
Recovery of Unused Regulation FCAS	$TA = TSFCAS \times (1 - U) \times \boldsymbol{DCF}$	$TA = TSFCAS \times (1 - U) \times \boldsymbol{DRCF} \times \frac{TE}{ATE}$

It should be noted that this document will not focus on Trading Amount calculations, but rather the outputs calculated by the FPP Application that these equations require. A separate document outlining the Settlement equations will be issued at a later stage.

4 FPP data sources

This section outlines the input data used in the FPP calculations and the AEMO systems from which the data will be sourced.

4.1 Registration data

4.1.1 Unit data

AEMO maintains unit and interconnector master data in its Registration system. Registration data is required by the FPP Application so an active data set of FPP participants can be maintained.

FPP participants are classified as the following, based on their functions and participation in the market:

- Units:
  - Generators: Scheduled, Semi-Scheduled, and Non-scheduled.
  - Loads: Scheduled and Non-Scheduled Loads.
  - Bi-Directional Units (BDU).
- Interconnectors.

For units that are registered as hybrid systems, the FPP Application will assess the system according to the registration arrangement which details the allocation of Dispatchable Unit Identifiers (DUIDs) and SCADA metering.

Registration master data will be ingested by the FPP Application daily, to account for master data changes in the Registration system and used to generate FPP Unit master data.

The FPP Application will validate all Registration data ingested to ensure units meet the eligibility criteria for FPP calculations.

4.1.2 Master data maintained in FPP

For scenarios where master data is not available via the Registration system, unit data can be created and managed directly in the FPP Application. Power system units can be created and managed within the FPP application, enabling their frequency data to be ingested for FPP calculations. Non-scheduled generators and loads will be managed between the FPP application and Registrations database.

4.1.3 ADC Groups

Aggregated Dispatch Conformance (ADC) was introduced by the Integrating energy storage systems into the NEM Rule[4] and operationalised through AEMO's Dispatch Procedure. ADC allows the units in an Aggregate System to conform in aggregate with their dispatch instructions, excluding any scheduled resource for which individual dispatch conformance or Resource

[4] AEMC, Rule determination, 2 December 2021, pp. 34-36.

Level Compliance is required for system security. Accordingly, ADC provides the Aggregate System with the flexibility to manage its electricity flows behind the connection point.

In AEMO's market systems, DUIDs are registered for ADC by linking those DUIDs to an Aggregate Dispatch Group (ADG_ID). Those participating in ADC will be assessed as a single eligible entity by the FPP Application, using the Primary DUID assigned to the Aggregation Dispatch Group (ADG_ID).

When calculating the Reference Trajectory and Unit Deviations for a unit, these calculations will be applied to each DUID within the group. Once calculated, the Unit Deviations will be aggregated to the Primary DUID. FPP CF and Unit Performance will be calculated for the Primary DUID.

4.2 Dispatch data

The NEM Dispatch Engine (NEMDE) used in the central dispatch process determines the optimal solution for efficient and economic dispatch of electricity in the NEM.

NEMDE produces a single physical run for each trading interval where each scheduled resource (scheduled generating unit, semi-scheduled generating unit, scheduled bidirectional unit, scheduled load or scheduled network service) will receive a dispatch instruction. Dispatch instructions to produce, consume, reduce, or transfer active power are issued via AEMO's Electricity Market Management System (EMMS) every five minutes. Within the instruction is the Dispatch Target, which is the active power outcome specified for a scheduled resource which represents the level to be achieved at the end of the relevant trading interval.

In addition to the physical run, the dispatch run includes one or more pricing runs used to set the spot and ancillary service prices. These prices are used to determine the cost of constraints.

The FPP Application will ingest dispatch and constraint data for each trading interval from the physical run to calculate the reference trajectory for each FPP participant using the dispatch targets issued.

4.2.1 UnitSolution

The UnitSolution table stores dispatch run data for each dispatchable unit on a trading interval basis. The FPP Application will use a unit's Dispatch Target (TOTALCLEARED) from the physical run to calculate the reference trajectory. The FPP Application will also use the amount of Regulation FCAS enabled (LOWERREG and RAISEREG) as an input into the Usage Calculation.

4.2.2 RegionSolution

The RegionSolution table stores dispatch run data on a regional level for each trading interval. The FPP Application will use OPERATIONAL_DEMAND amounts to calculate the weighted average Frequency Measure per Regulation constraint, and in the calculation of Estimated Used and Unused Regulation FCAS Residual Amounts for FPP Participant reports.

Once stored, the FPP Application will curate the data and check for any missing intervals which will be identified by a flag set in NEMDE against a dispatch run. The FPP Application will flag the data as bad quality, and the quality flag will be used as an input check to downstream FPP calculations.

4.3 SCADA data

The FPP Application will ingest SCADA data measurements to calculate unit and residual deviations and calculate the Frequency Measure. SCADA measurements are taken every four seconds, resulting in 75 data values per trading interval. The following two SCADA data types will be used as inputs into these calculations.

4.3.1 Unit measurements and curation

Unit Power Output data (in megawatts [MW]) will be used to calculate unit deviations and residual deviations with respect to each unit and region.

The FPP Application will retrieve the data for each active FPP unit stored in the system, with the data being applicable to previously mentioned FPP participants in Section 4.1.1 (units and interconnectors).

The data will be ingested 'raw' (i.e. prior to any curation process) with associated measurement interval, trading interval, MW value, and data quality flags for each 4-second time interval.

Once stored, the FPP Application will then curate the data, and apply configurable curation rulesets to the data which will then be stored for calculation purposes. Curation rules within the system will be used to ensure a data quality and address any system flagged discrepancies.

4.3.2 Frequency and curation

Frequency data (in hertz [Hz]) will be used to calculate the Frequency Measure with respect to each region and each Regulation FCAS Requirement.

The FPP Application will retrieve SCADA frequency data for each active Power System measurement stored in the FPP system.

Similarly to Unit Measurements, the data will be ingested 'raw' with associated measurement interval, trading interval, Hz value, and data quality flags for each 4-second time interval.

Once stored, the FPP Application will then curate the data, and apply configurable curation rulesets to the data which will then be stored for calculation purposes. Curation rules within the system will be used to ensure a data quality and address any system flagged discrepancies.

4.4 Regulation FCAS

To maintain frequency within the NEM frequency standards, FCAS have been developed to alter generation and demand, thus ensuring generation and demand balance is always maintained. These services can be either regulation or contingency services.

Regulation frequency control corrects the supply or demand balance in the NEM in response to minor deviations to load or generation[5]. These services are continually used to correct for minor changes in the supply/demand balance and are controlled centrally from one of AEMO's two control rooms (known as Automatic Generation Control [AGC] systems).

The two FCAS services relevant to FPP reform are:

- Regulation Raise (used to correct a minor drop in frequency).
- Regulation Lower (used to correct a minor rise in frequency).

4.4.1 Structure of a constraint

Constraints are used to manage power system limitations and FCAS requirements within the NEM. They are important to market participants as their formulation determines the influence or variation in output from that which might be expected from a consideration of offer prices alone.

Constraints can be thought of as an 'enforcement tool' used to keep the power system operating within the limits. Constraint equations are used by NEMDE to ensure market operation solutions are within the physical limits of the power system. These equations are constructed based on network information and are used to determine generation loading levels and regional energy prices.

Constraints that are input into NEMDE have the following components:

- Left Hand Side (LHS).
- Operator.
- Right Hand Side (RHS).

The LHS of a constraint consists of the variables that can be optimised by NEMDE, including scheduled/ semi-scheduled generators, scheduled loads, bidirectional units, interconnector flow or regional FCAS requirements. The operator of a constraint can either be 'equal to', 'less than equal to', or 'greater than equal to'. It simply equates the LHS and RHS components. The RHS of a constraint is pre-calculated and presented to NEMDE as a constant.

FCAS constraints predominantly have regional FCAS enablement term variables in the LHS, but in some situations, other terms such as Interconnector flow or unit MW targets or FCAS enablement can be included in the LHS.

4.4.2 Pricing and recovery

FCAS Payments are made on a regional basis, using regional FCAS prices. The costs of these payments are however recovered at the constraint level since regional dispatch is based on bid prices but benefits all regions.

To calculate FCAS payments, the price for the region is calculated by adding the marginal costs of all constraints included in that region. Regional payments can then be calculated for a trading interval and specific FCAS service by multiplying the Regional FCAS price by the amount of FCAS that was enabled in the region. The regional payments are then recovered on a constraint level (Base cost).

[5] Although not applicable to the FPP Reform, contingency FCAS corrects the supply or demand balance following a major contingency event, such as the loss of a generating unit, major industrial load, or large transmission element. While they are always enabled to cover contingency events, contingency services are only occasionally used.

In cases when additional Regulation service is enabled to meet 5-Minute FCAS requirements, the Base cost of each 5-Minute FCAS constraint is split into the cost to be recovered through Regulation and 5-Minute FCAS recovery mechanisms. This recovery cost split is also known as the Adjusted cost.

For more details, refer to the *Efficient Dispatch and Localised Recovery* or the *Guide to Constraint Outcomes for FCAS Cost Recovery*[6].

4.4.3 P_Regulation

P_Regulation (also referred to as adjusted marginal value) is a calculated value for regulation FCAS services that has been introduced by the FPP reform to be used in the calculation of FPP trading amounts.

P_Regulation is calculated per constraint, for regulation services. This can be for both regulation FCAS constraints and 5-Minute FCAS constraints (that have Regulation terms on the left hand side (LHS)). For all other FCAS services, P_Regulation will be zero. The respective P_Regulation formulas are illustrated in Table 3.

Table 3 P_Regulation formula

	P_Regulation formula
Regulation service	$Regulation = \frac{Base\ Cost}{\sum Regulation\ Enabled} \times 12$
5-Minute service	$5\ Minute = \frac{Base\ Cost}{\sum(Regulation\ Enabled + 5\ Minute\ Enabled)} \times 12$

where:

- Base cost is the cost calculated for each constraint.
- 12 represents the number of dispatch intervals in an hour. For Pre-Dispatch, this would be 2.

When there is no ex-post price change, the value of P_Regulation is equal to the marginal value (marginal cost of the constraint). However, P_Regulation value will differ to marginal value when an ex-post price change event or price adjustment[7] occurs.

As outlined in Section 3.2, the P_Regulation value will be used in the FPP Trading Amount formulas for both eligible units and the Residual.

More details on P_Regulation calculation can be found in the *Guide to Constraint Outcomes for FCAS Cost Recovery*.

4.5 System outages

In the unlikely event of a system outage to either the FPP Application or an upstream system mentioned in the above sections, the FPP Application has configuration to ensure that trading intervals can still be processed once the outage has been restored. For any outage longer than 30 minutes, AEMO will issue a market notice.

[6] https://aemo.com.au/-/media/files/initiatives/frequency-performance-payments-project/AEMO-Guide-to-Constraint-Outcomes-for-FCAS-Cost-Recovery.pdf & https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/0160-0049-pdf.pdf

[7] Price adjustment can happen due to reasons including Intervention, OCD, MII price revision, MPF/MPC capping, APC, and Market Suspension

As per the procedure, if Dispatch or SCADA data is unavailable, the FPP system will wait for 30 minutes to receive and ingest the data should it become available during that time period. If the data is not received, the FPP Application will proceed with calculation and performance values will be null (covered in Section 5 in more detail).

If the FPP Application has an outage, it will be unable to ingest dispatch, SCADA, and FCAS requirement data, and execute calculations to determine participants' performance during the outage period. Once the system has been restored, the FPP Application based on a pre-configured time duration will 'look back' from the point in time the system is restored (currently set as one hour) and commence calculating participant performance. The full functionality to handle various outage scenarios will become available in the February 2025 FPP release. In addition, the participant data model will be extended to inform participants via additional flags which data was used in FPP the calculation, and which was not.

5 FPP calculations

This section outlines the calculations performed by the FPP Application for each five-minute trading interval. These calculated outputs will be stored in the FPP Application database and consumed by downstream settlement systems and published to FPP participants via public and private reports.

5.1 Frequency Measure

Formulation of Frequency Measure is covered in Section 4.1 of the *Frequency Contribution Factors Procedure*[8]. Frequency Measure Conditions, which outlines scenarios of unreliable data, is covered in Section 4.3 of the document.

5.1.1 Regional Frequency Measure Calculation

The FPP Calculation Process begins with the calculation of the Frequency Measure, which is calculated using power system frequency data (Hz). System frequency is an integral component of the FPP reform, allowing AEMO to determine if a participant's contribution to system frequency was helpful or unhelpful.

The Frequency Measure reflects the need to raise or lower power system frequency towards 50 Hz:

- A positive frequency measure means the frequency should be increased.
- A negative frequency measure means the frequency should be decreased.
- The larger the magnitude of the frequency measure, the bigger the need.

For every region, the FPP Application will calculate a frequency measure value for each 4-second interval, using the frequency deviations within that region and the previous 4-second interval's calculated Frequency Measure. This measurement will be derived by applying an exponential weighted moving average filter (a lowpass filter) to the negative of the frequency deviations in the region.

When calculating the Frequency Measure, the application will begin calculating using the data from the last two minutes of the previous interval. This duration of two minutes is configured in the system and is used to eliminate any dependency on the previous interval's calculation.

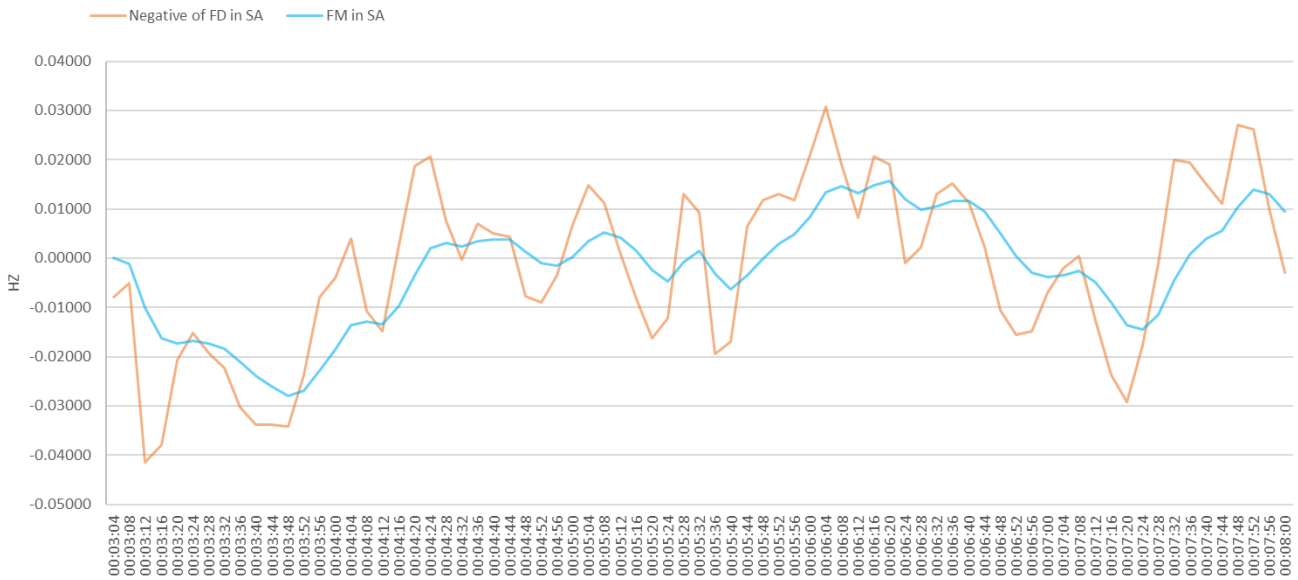
The Frequency Measure for the first 4-second interval will be assigned as 0 and the second 4-second interval will be assigned the calculated FM value.

If the calculated Frequency Measure is positive, then the value will be saved in the FPP Application as a Raise FM value and the Lower FM value will be zero for the 4-second time interval. If the Frequency Measure is negative, then it will be saved as a Lower FM value with the Raise FM value as zero for the 4-second interval.

[8] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/frequency-contribution-factors-procedure/final-documents/final-frequency-contribution-factors-procedure.pdf?la=en

This means that for each 4-second interval within the 5-minute trading interval, each Frequency Measure will be saved against either Raise FM or Lower FM, with one value as zero and the other as the calculated Frequency Measure, as shown in Figure 2 (the supporting data can be found in the appendix of this document).

Figure 2 Frequency Measure for trading interval



It should be noted that under some conditions, the Frequency Measure may not be a reliable indicator of the need to raise or lower the frequency. For example, there may be a signification number of frequency data points that are bad quality or missing within a trading interval. In this case, a trading amount for a participant would not be calculated.

The FPP Application will perform reliability checks once it has calculated the Frequency Measures for a trading interval, which will be applied to both Raise and Lower FMs within the interval.

The application will execute three reliability rule checks:

- **Unavailability of minimum number of reliable Frequency Measures**.
  - The reliability check will be applied to both Raise FM and Lower FM calculated values in a trading interval.
  - The application will consider all Raise FM values for an interval and validate the minimum number of reliable frequency measure values allowed within the interval. This value is a configurable value, and the application currently checks for a minimum of seven 4-second intervals. If this check fails, the interval will be marked as unreliable. The check will be similarly applied to all Lower FM values and repeated per region.
- **Dead-band check**.
  - The dead-band check will be applied to both Raise FM and Lower FM calculated values in a trading interval.
  - The application will consider all Raise FM values for an interval and validate there is at least one Raise FM value above 0.01 Hz against the trading interval.

- If successful, the trading interval will be marked as reliable. If there are no 4-second intervals within a trading interval where the Frequency Measure is above 0.01 Hz, then the interval will be marked as unreliable for raise service by the application. The check will be similarly applied to all Lower FM values and repeated per region.

- **Significant volume of 'bad' raw frequency data in a trading interval**.
  - When there is a significant number of 'bad' SCADA data values within a trading interval, the FPP Application will mark the values with a data curation flag of 'Bad(0)'. The application will mark the Frequency Measure for both Raise FM and Lower FM values in that region as unreliable. The check will then be repeated per region.

5.2 Constraint Frequency Measure Calculation for RCR

For calculation of the Requirement for Corrective Response (Section 5.7), the Frequency Measure will be calculated by the FPP Application at the constraint level using a weighted average formula. For each region associated to the constraint, the OPERATIONAL_DEMAND and a configurable weight constant[9] for each region will be considered. The application will then calculate the FM value. If the FM value is positive, then this will be stored as the Raise FM value, and the Lower FM value stored as zero. If the FM value is negative, then this will be stored as the Lower FM value, and the Raise FM value will be stored as zero.

The calculation is repeated for every 4-second interval and for each requirement to obtain the Frequency Measure value for the requirement

System separation test

After the calculation of Frequency Measure and reliability checks, the FPP Application will check for the occurrence of system separation for a trading interval. The system separation check will be carried out between all mainland Frequency Measures to verify if the Frequency Measure in one region corresponding to the trading interval is aligned with the Frequency Measure in another region corresponding to the trading interval. This check will be carried out by applying Pearson's correlation coefficient formula. If the occurrence of system separation is determined for a Frequency Measure within a trading interval, a system exception will be logged to notify the FPP Application user for review as the Frequency Measure is not automatically tagged as unreliable.

Alignment test

Misalignment of frequency measures and real-time frequency deviation occurs when the frequency measure and frequency deviations indicate the opposite need to raise or lower power system frequency. This can occur when the frequency measure and frequency deviation value in a 4-second interval have the same sign (that is, both are positive or both are negative), and the power system frequency is outside the primary frequency control band.

The FPP Application will perform a misalignment check against every 4-second interval of frequency measure data, with an alignment check flag being set for frequency measure raise and frequency measure lower values.

[9] Will be available in Tuning Parameters and Input Sources (https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/frequency-contribution-factors-procedure/final-documents/turning-parameters-and-input-sources.pdf?la=en)

For example, if the frequency measure is a positive value, the Raise FM will be positive and the Lower FM will be 0. The frequency deviation is then validated against the primary frequency control band value, currently set to 0.015 Hz. If the value is greater, then the alignment flag will not be set against the frequency measure value as the frequency measure and deviation are not aligned. If lower, then the alignment flag will be set.

Similarly, if the frequency measure is negative, the Lower FM will be negative and the Raise FM will be 0. The same validation will be applied however the check against the frequency control band will be checking the frequency deviation is less than the control band value.

5.3 Unit deviations

Reference Trajectory and deviation calculation is covered in Section 5 of the *Frequency Contribution Factors Procedure*[10].

5.3.1 Reference Trajectory

The Reference Trajectory of a unit show its *expected* active power output or consumption within a trading interval. The trajectory is determined by analysing the previous dispatch target and current dispatch target for a given interval.

Scheduled and Semi-scheduled Units, Interconnectors, and BDU

The Reference Trajectory of scheduled generating units, semi-scheduled generating units, scheduled loads, scheduled bidirectional units, and interconnectors is a straight line between the previous and current dispatch targets.

Figure 3 Reference Trajectory scheduled and semi-scheduled

Reference trajectory	Actual measurement	Example
Straight line between previous NEMDE *dispatch target/dispatch level* and current NEMDE *dispatch target/dispatch level*.	SCADA data for the eligible unit, load, or interconnector.	

The Reference Trajectory is calculated for each 4-second interval within a 5-minute trading interval using the dispatch target data from NEMDE, resulting in 75 calculated values stored in the FPP Application for a single trading interval. The FPP Application will use both the previous dispatch target and current trading interval dispatch target to calculate the trajectory for each FPP unit.

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The below example shows a sample (condensed) data set and plotted graphical output of a reference trajectory for a semi-scheduled generator.

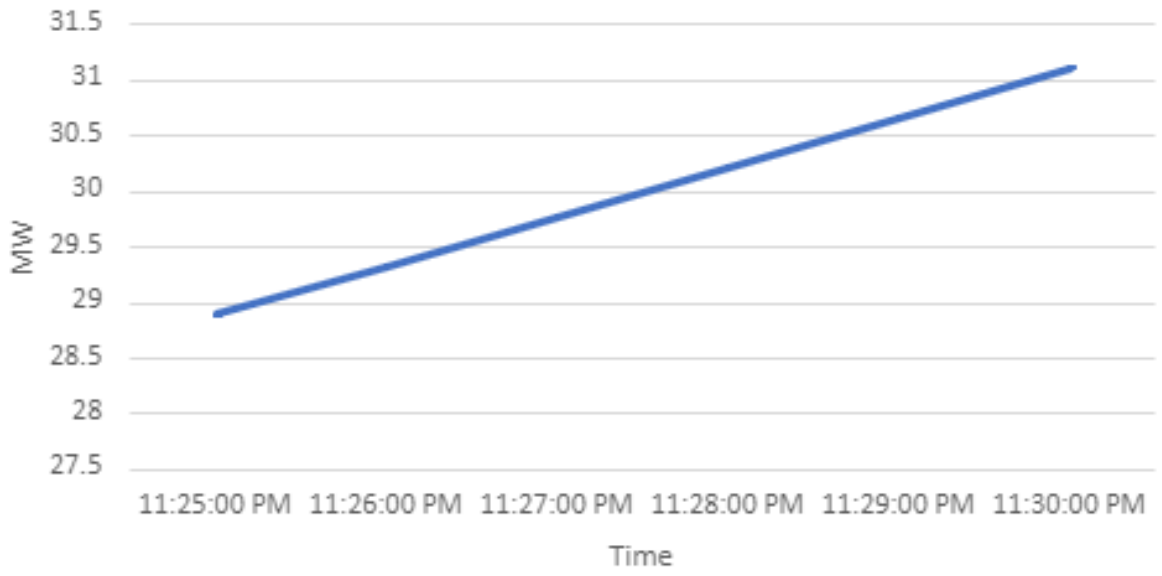
Table 4 Condensed dispatch targets, per minute of a trading interval

Time	MW
1/09/2023 11:25:00 PM	28.89
1/09/2023 11:26:00 PM	29.334
1/09/2023 11:27:00 PM	29.778
1/09/2023 11:28:00 PM	30.222
1/09/2023 11:29:00 PM	30.666
1/09/2023 11:30:00 PM	31.11

Table 5 Dispatch targets

Trading interval	Total cleared
1/09/2023 11:25:00 PM	28.89000
1/09/2023 11:30:00 PM	31.11000

Figure 4 Graphical example of Reference Trajectory for a trading interval (MW)

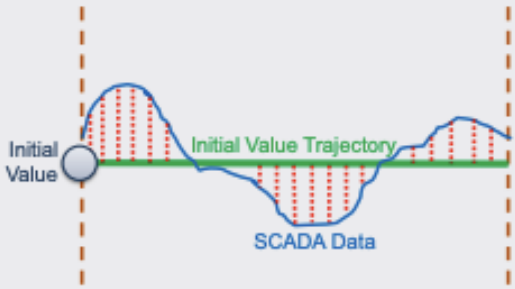


Non-scheduled units

The Reference Trajectory of non-scheduled generating units, non-scheduled bidirectional units, and non-scheduled market loads is a continuation of the unit generation/consumption at the start of the current trading interval, due to non-scheduled units not having a dispatch target.

The Reference Trajectory is calculated for each 4-second interval within a 5-minute trading interval using the SCADA metered value at the start, resulting in 75 calculated values stored in the FPP Application for a single trading interval.

Figure 5 Reference Trajectory non-scheduled

Reference trajectory	Actual measurement	Example
Continuation of SCADA metered value at the start of the current *trading interval*.	SCADA data for the *eligible unit* or *load*.	

Missing data

There may be instances where dispatch data is not received or partially received by the FPP Application, for example, due to a technical reason. For such scenarios when no dispatch data is received, the FPP Application will wait 30 minutes and then proceed with the FPP calculation for the trading interval, assigning a NULL against all FPP units including Non-scheduled units and Interconnectors.

For scenarios where partial data is received, the FPP Application will proceed with calculations for the trading interval with no delay. The Reference Trajectory will be calculated for Units and Interconnectors with dispatch data, and a NULL assigned to Units and Interconnectors that have missing dispatch data. An exception will also be logged to notify system users.

In the rare case of a missed dispatch run in NEMDE, no dispatch targets would be ingested into the FPP Application. The application will be unable to calculate the Reference Trajectory for the specific interval and will assign a NULL against the FPP units including Non-scheduled units and Interconnectors.

5.3.2 Unit deviations

Unit deviations are calculated at each 4-second interval, similar to the Frequency Measure, and will be used to help in understanding if the unit has contributed to an increase or decrease in the net amount of energy within the power system for a trading interval.

A positive deviation is one that increases the net amount of energy in the system (more generation or less load), and a negative deviation has the opposite effect.

The FPP Application will calculate unit deviations (in MW) by comparing curated unit power output measurements against the Reference Trajectory. Unit deviations will be calculated for all active, eligible FPP units and will use curated SCADA data that is not flagged as bad quality.

If the 4-second interval data has been flagged by the system as bad quality then a unit deviation of zero will be assigned to the unit. In the case where no 4-second interval data is available for the unit, then a unit deviation of NULL will be assigned. Lastly, if the calculated Reference Trajectory for a unit is NULL, then the unit deviation will also be assigned as NULL.

The calculation steps are repeated for each 4-second interval for the entire trading interval.

Figure 6 shows the Reference Trajectory, 4-second SCADA measurements, and deviations of a unit over eight trading intervals.

Figure 6 Reference Trajectory and unit deviation example (MW)

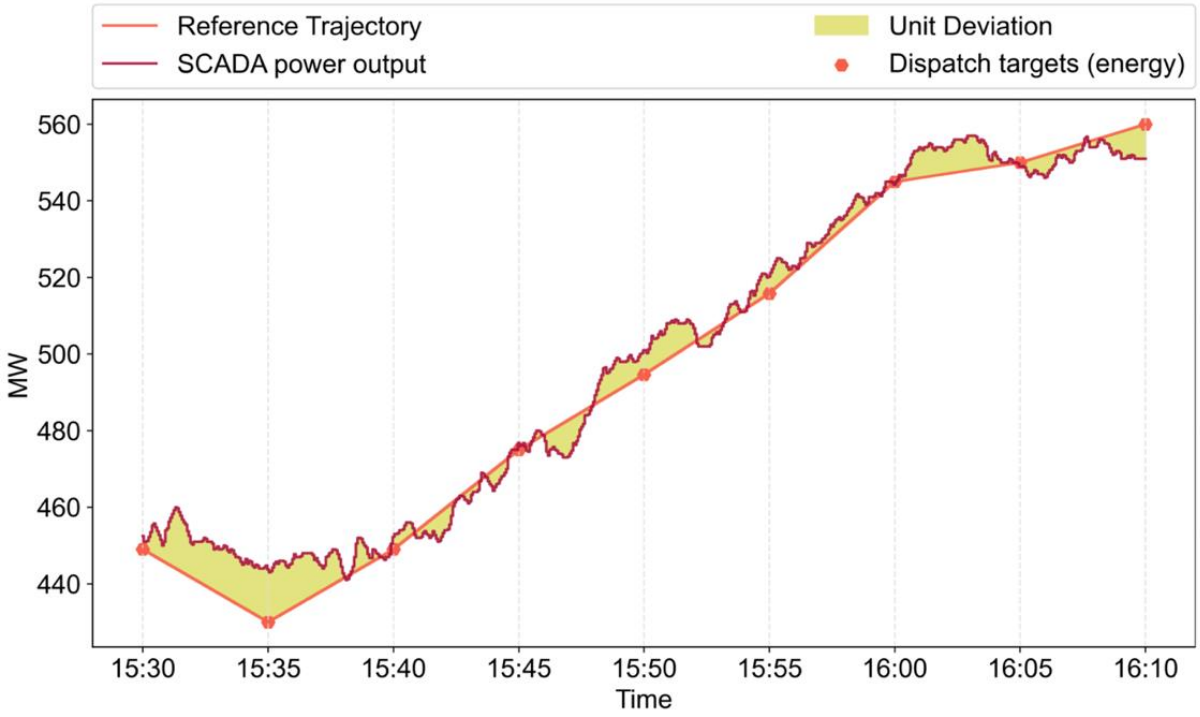
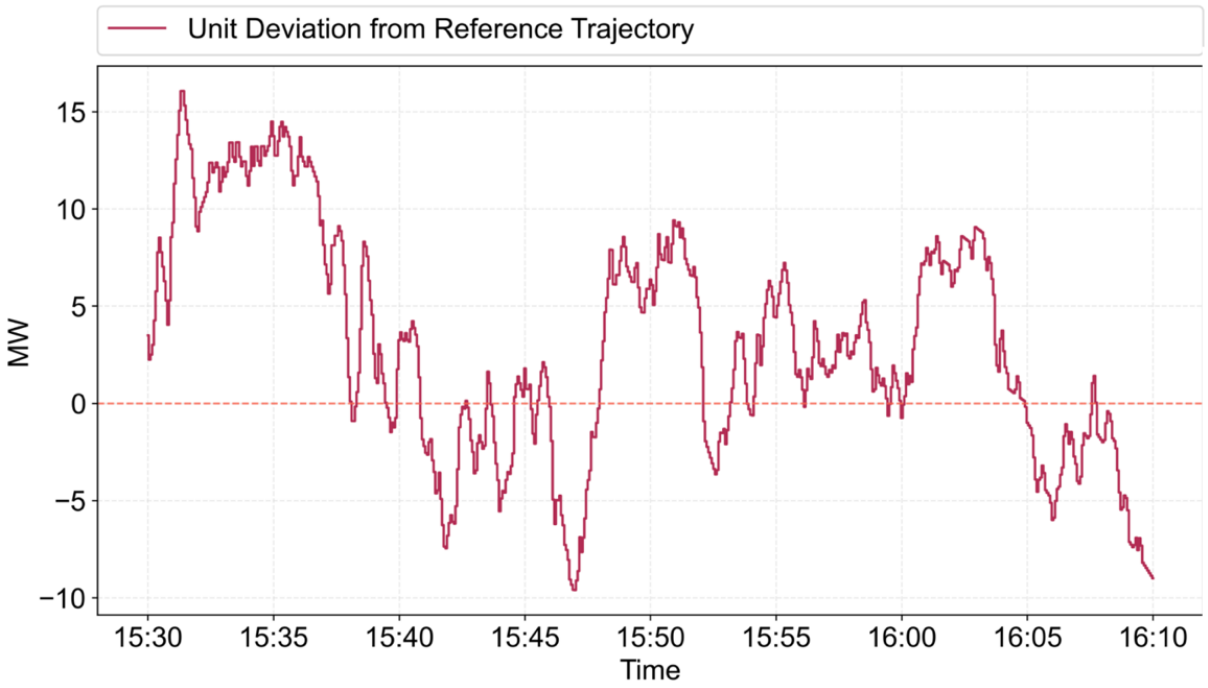


Figure 7 Unit deviation for the above Reference Trajectory (MW)

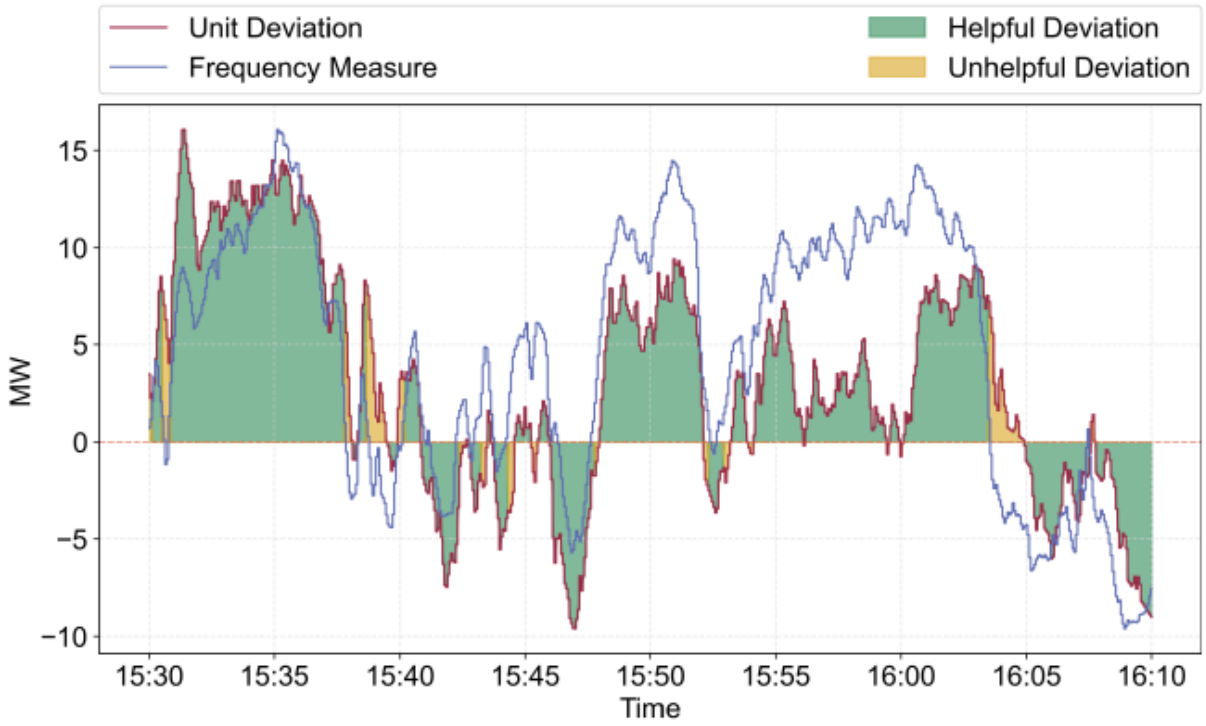


It should be noted that a positive deviation does not necessarily mean that unit helped, as it will depend on the frequency measure at the time. Similarly for a negative deviation being unhelpful. A deviation that shares the same sign as the Frequency Measure is deemed helpful, and results in good performance, and vice versa for a deviation that opposes the Frequency Measure.

Figure 8 illustrates this for a generating unit with PFR capability over eight trading intervals.

An example of helpful deviation can be seen at the 15:35 timestamp (green highlight), where both the unit deviation and the frequency measure share the same positive sign. An example of unhelpful deviation can be seen just before the 16:05 timestamp, where the unit deviation is positive, but the frequency measure is negative.

Figure 8 Figure caption (MW)



5.3.3 Residual deviation

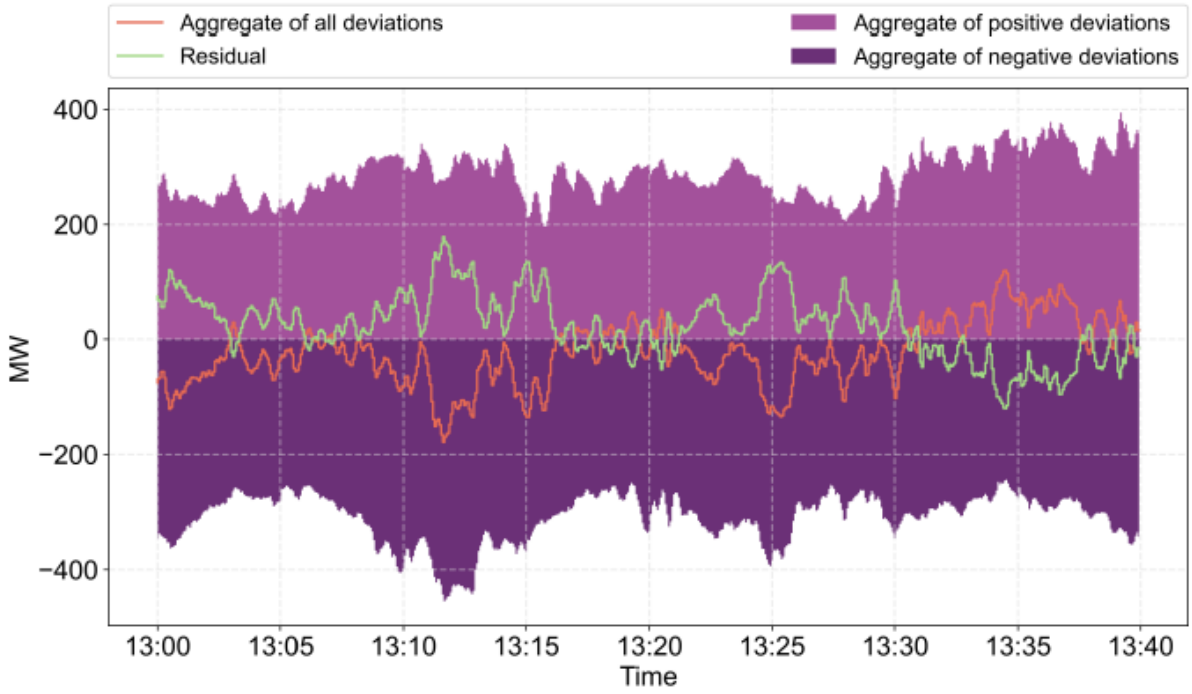
The Residual refers to all facilities connected to the grid without appropriate real-time telemetry (4-second SCADA measurements), including small consumers and distributed resources. Due to no SCADA data being available for these facilities to calculate their performance, a different approach is required.

The FPP Application will calculate the Residual by aggregating the Deviations of all units with appropriate metering and the interconnectors within the region, and then take the opposite of that sum to determine the Deviation of the Residual. The Residual Deviation will be calculated once the Reference Trajectory, Unit Deviation, and aggregated Unit Deviations have been calculated for FPP Units and Interconnectors.

For each 4-second interval within a trading interval, all positive deviations and negative deviations will be summed for FPP units, along with connected interconnector deviations. If there is a scenario where all units and interconnectors in a region have a unit deviation of NULL due to SCADA data not being available, the residual deviation against the region will also be assigned as NULL.

As shown in Figure 9 below, all positive deviations of all units (without 4-second SCADA measurements) for mainland are aggregated as well as all negative deviations. These deviations are then summed, providing an aggregate of all deviations (orange line), which the negative value can then be calculated, giving the residual value of the mainland regions.

Figure 9 Mainland regions' Residual visualisation (MW)



5.4 Performance

Performance refers to the degree to which a unit contributes to the need to raise or lower the frequency of the power system. The Raise and Lower Performance calculation is covered in Section 6.2.1 and 6.2.3 of the *Frequency Contribution Factors Procedure*[11].

5.4.1 Unit performance

For each FPP unit, two performance values are calculated for every 4 second data segment by the FPP Application:

- One value for when there is a need to increase the system frequency.
- One value for when there is a need to lower the system frequency.

The aggregates of these 4 second performance respectively form the unit's Raise and Lower performance values over the 5-minute trading interval.

A positive value of performance, regardless of whether it is for raise or lower, would indicate that the unit helped the frequency of the power system. A negative value of performance would indicate that the unit did not help.

A unit's 4-second performance is calculated based on the Frequency Measure and the deviation of the unit from its Reference Trajectory.

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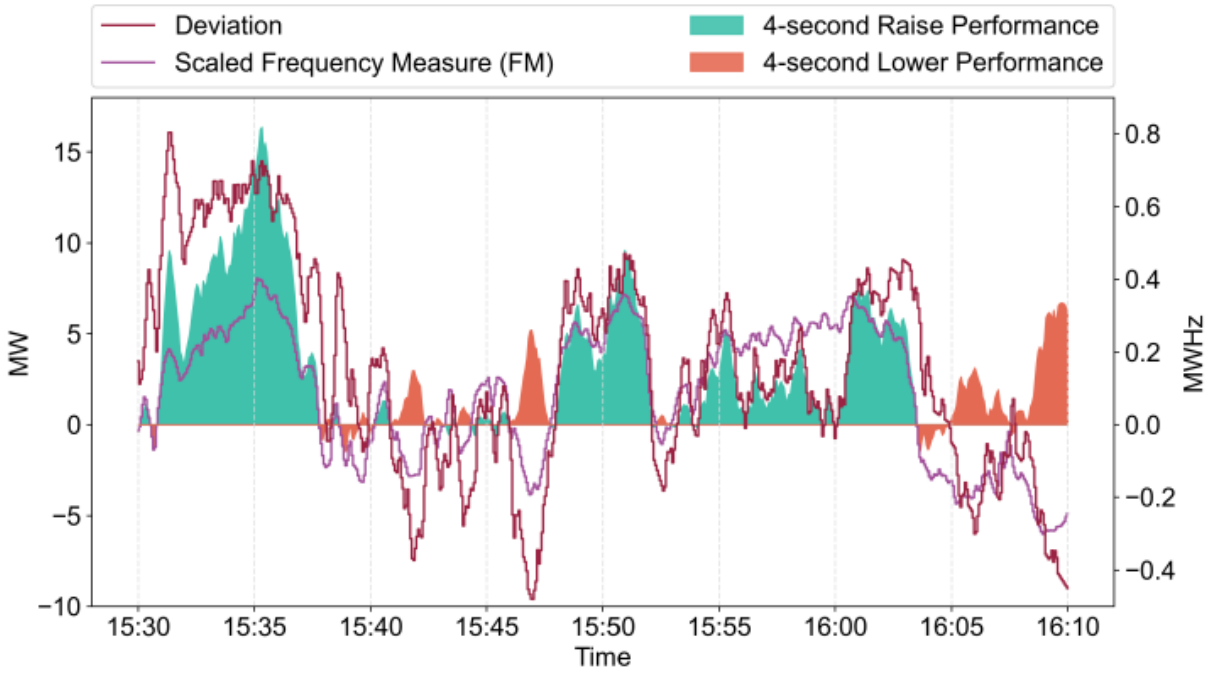
Figure 10 Figure caption (MW)



The FPP Application will calculate both Raise Performance and Lower Performance for FPP Units and Primary DUIDs for an Aggregate Dispatch Group (ADG), and the residual.

The Raise and Lower performance calculations will be completed once the application has calculated the unit and residual deviation, and the frequency measure per region. The application will verify that the frequency measure data for both raise and lower has no bad data quality flag attached and then calculate the performance values. If the data is flagged as unreliable, then the performance calculation will be set to NULL for the unit within the trading interval.

5.4.2 Residual performance

The FPP Application will calculate the residual performance for each region for a trading interval. Similar to unit performance, the residual performance will be calculated for both raise and lower once the application has calculated the unit and residual deviation, and the frequency measure per region. The application will verify that the frequency measure data for both raise and lower has no 'bad data quality' flag attached and then calculate the performance values.

Once the raise and lower performance values are calculated, the application will aggregate them to obtain the Raise Residual Performance and Lower Residual Performance values for the trading interval.

If the data is flagged as unreliable, then the performance calculation will be set to NULL for the residual within the trading interval. Furthermore, performance for the residual can be NULL if the raise or lower frequency measure values for a region are unreliable, or dispatch or SCADA data is unavailable. In case of the latter, this would be due to reference trajectory, unit and residual deviation all being NULL in the FPP system meaning performance could not be calculated.

5.5 Contribution Factors

Raise Contribution Factor and Lower Contribution Factor calculation is covered in Section 6.2.2 and 6.2.4 of the *Frequency Contribution Factors Procedure*[12]. The Application of Default Contribution Factors and Calculation of Default Contribution Factors is covered in Sections 6.3 and 6.4.

5.5.1 Contribution Factors and Residual Contribution Factors

Following the calculation of Raise and Lower Performances of all units in a trading interval, the FPP Application normalises the Performances in each Regulation FCAS Requirement to determine Contribution Factors (CFs).

Contribution Factors will be calculated for a unit in relation to each Regulation FCAS Requirement, for each trading interval. This means that if the Regulation FCAS Requirement is a raise requirement, 'raise' performance values will be used to calculate the Contribution Factor. Similarly, for a 'lower' requirement, lower performance values will be used.

This factor is determined based on the unit's performance in a trading interval, compared to all other units' performance in the same trading interval that had the same sign.

$$CF = \frac{Unit's\ Performance}{Total\ Performance\ of\ all\ units\ in\ the\ requirement\ that\ have\ the\ same\ sign}$$

For example, if a unit had positive performance, the contribution factor would be determined against the total performance of all other units that had a positive performance for a specific FCAS requirement.

Similarly, if a unit had negative performance, the contribution factor would be determined against the total performance of all other units that had negative performance for a specific FCAS requirement.

As shown in the example below, the performance of a unit is used to determine its Contribution Factor, which can be determined for different requirements.

The unit's performance, shown on the left Y-axis, is divided by the total performance for the requirement, shown on the right Y-axis.

Note that a Mainland requirement is a requirement that contains all regions except Tasmania, whereas a Global requirement contains all Mainland regions and Tasmania.

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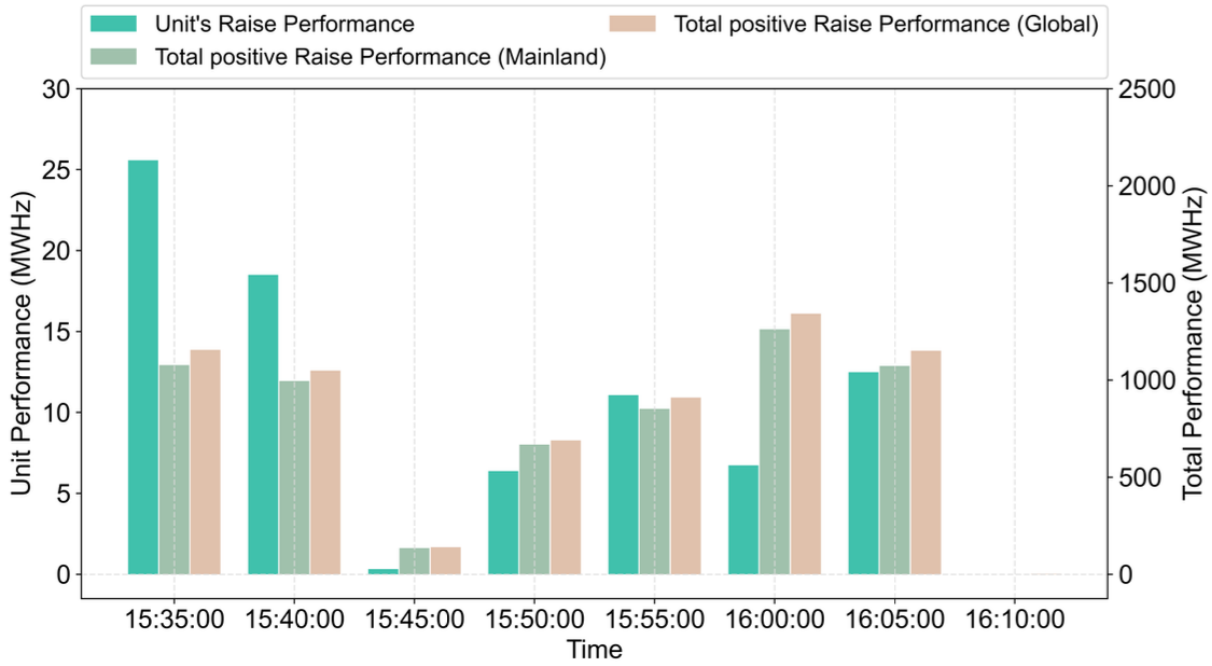
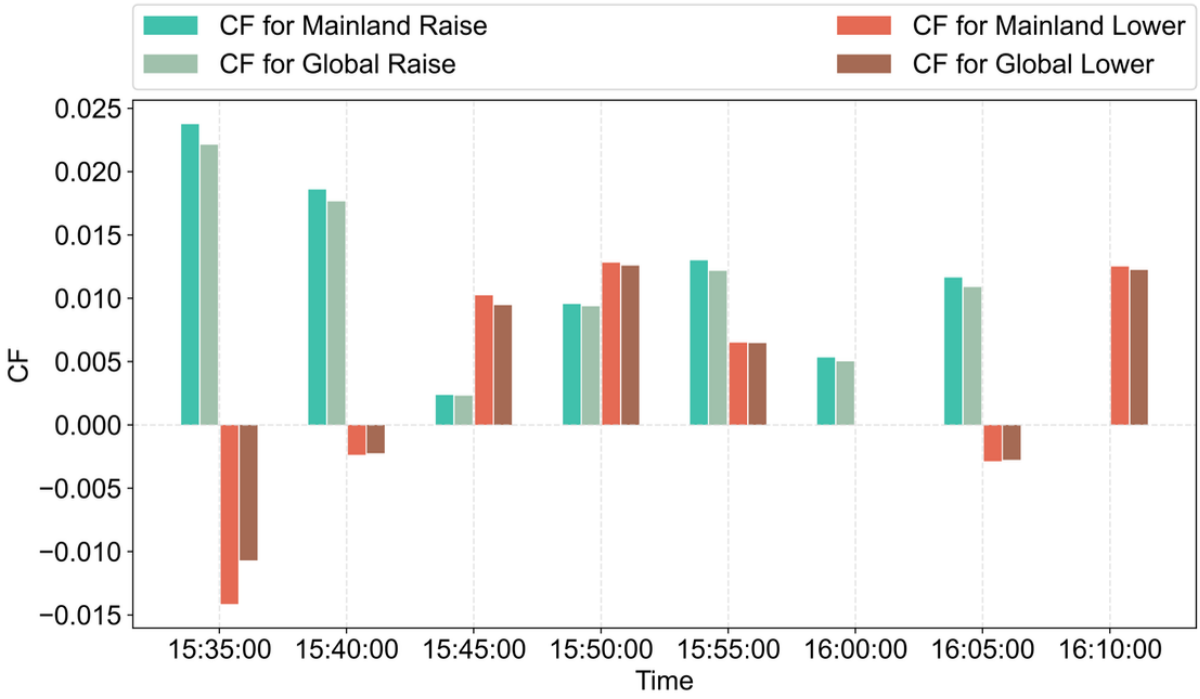
Figure 11 Raise Performance of the unit versus all units in two different requirements (MWHz)



The Contribution Factors are calculated for both the Mainland Requirement and the Global Requirement, for both raise and lower, per trading interval.

In the example below, the raise requirement has positive contribution factors due to positive performance, whilst the lower requirement has negative contribution factors due to negative performance.

Figure 12 Raise and Lower Contribution Factors for Mainland and Global



Contribution Factor values will be between -1 and 1, where negative values show a unit's unhelpful frequency performance and positive values reflect a unit's helpful performance in frequency control. The positive and negative CFs will respectively be used to determine the incentives or penalties in the FPP system.

It should be noted, there is no difference in how Contribution Factors or Residual Contribution Factors will be calculated by the FPP Application for either eligible units with appropriate metering or for the Residual.

Below is an example Contribution Factor calculation for a Regulation Raise requirement (RAISE_REQ1) with two associated regions.

Raise and Lower Performance values have been calculated for eligible units in two regions associated with the regulation requirement. The residual for each region has been calculated. In this example, **Raise Performance** will be used to calculate the contribution factors for the Regulation Raise requirement.

Table 6 Performance of units in two regions, for a trading interval

Region	Eligible unit	Raise Performance (MWHz)	Lower Performance (MWHz)
A	GA1	120	50
	GA2	-50	150
	GA3	100	-100
Residual in region A		**-120**	**-100**
B	GB1	-120	-100
	GB2	100	-50
	GB3	100	100
Residual in region B		**-80**	**50**

The residual values for each region are aggregated to calculate the residual performance against the requirement.

Table 7 Aggregated residual values

Region	Eligible unit	Raise Performance (MWHz)
A	GA1	120
	GA2	-50
	GA3	100
B	GB1	-120
	GB2	100
	GB3	100
Residual for RAISE_REQ1		**-200**

The absolute sum of all Positive Raise Performance values and the absolute sum of all Negative Raise Performance values is calculated.

Table 8 Absolute sum of Positive and Negative Raise Performance

Region	Eligible unit	Raise Performance (MWHz)
A	GA1	120
	GA2	-50
	GA3	100
B	GB1	-120
	GB2	100
	GB3	100
Abs Sum(Positive Raise Performance)		**420**
Abs Sum(Negative Raise Performance)		**370**

Contribution factors are then calculated for each eligible unit, along with negative and negative residual contribution factors (see next section).

Table 9 Contribution Factor calculation

Region	Eligible unit	Raise Performance (MWHz)	CF	NCF and NRCF
A	GA1	120	0.285714286	0
	GA2	-50	-0.135135135	-0.135135135
	GA3	100	0.238095238	0
B	GB1	-120	-0.324324324	-0.324324324
	GB2	100	0.238095238	0
	GB3	100	0.238095238	0
Residual for RAISE_REQ1		**-200**	**-0.540540541**	**-0.540540541**

5.5.2 Negative Contribution Factors and Negative Residual Contribution Factors

For AEMO to recover Used Regulation FCAS costs, Negative Contribution Factors will be calculated for a unit in relation to each Regulation FCAS Requirement, for each trading interval.

At the time of calculating the Contribution Factor for a unit, the FPP Application will calculate both a positive and negative Contribution Factor, per Requirement (as outlined in Table 9).

Negative Residual Contribution Factors will also be calculated and used to determine how much Used Regulation FCAS costs should be recovered for the Residual.

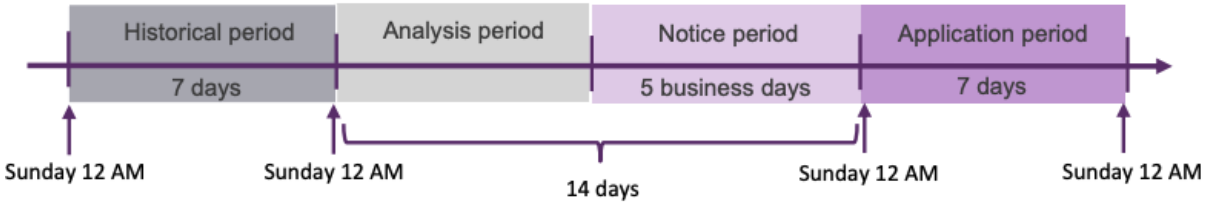
There is no difference in how Negative Contribution Factors or Negative Residual Contribution Factors will be calculated by the FPP Application for either eligible units with appropriate metering or for the Residual.

5.5.3 Default Contribution Factors and Default Residual Contribution Factors

A Default Contribution Factor (DCF) is a contribution factor that is calculated by looking at a unit's historical performance. The Historical Performance quantifies how helpful or unhelpful a unit's frequency performance was over the seven-day Historical Performance Period (HPP).

The Historical Performance Period is a seven-day period starting at 12:00 AM Sunday and ending at 12:00 AM on the following Sunday, which concludes 14 days prior to the commencement of the billing period, inclusive of the five business days' notice period as referred to in NER 3.15.6AA(i). Figure 13 shows the timing of the HPP.

Figure 13 HPP and DCF calculation timeline



The FPP Application will calculate the Raise and Lower Historical Performances for each unit, every week, based on the unit's Performance values over a seven-day historical period. Historical Performances are calculated differently for Regulation FCAS cost and FPP:

- For FPP, performances are averaged over the historical period and then capped at zero.
- For Used and Unused Regulation FCAS Recovery, performances at each 5-minute trading interval in the historical period are capped at zero and then averaged.

Because the historical performance values will be used to determine trading amounts that will be paid by participants, the values cannot be positive and hence they are capped at zero.

DCFs can be used in two different ways:

- For Unused Regulation FCAS cost allocation, DCFs are always used (refer to Table 2 in Section 3.2 for the equations).
- For Used Regulation FCAS cost allocation and FPP, DCFs are used only when the Performance of a unit cannot be calculated in a trading interval.

The DCF calculation for the Historical Period will be scheduled to be executed and published at the end of the Analysis Period. Post the notice of the five business days, the calculated values will be used during the Application Period.

The DCFs will have an assigned effective start and end date, which correlates to the start and end dates of the Application Period, where the calculated DCFs against the Historical Period will be used.

For each Settlement week, once the historical performance has been calculated, the FPP Application will calculate both Raise and Lower Default Contribution Factor values for all units with appropriate metering and for the Residual. The DCFs will be calculated with respect to each Raise and Lower Regulation FCAS Constraint, and associated region to the unit.

The Application will also calculate DCF for Primary DUIDs. However, DCFs will not be calculated against Non-Primary DUIDs of an ADG set, they will be assigned as zero. A DCF of zero will also be assigned against a unit that has zero Historical Performance due to the unavailability of performance data during the historical duration.

5.5.4 Substituted Performance

There may be instances during FPP calculation processing where data is flagged as bad quality or unavailable for specific calculation steps. In this case, the FPP Application will have set a data flag in a previous calculation or curation process when the data was ingested.

Rather than performing a series of recalculations, the FPP application at times will substitute historical data to ensure that Contribution Factors can be calculated for a particular unit. Substitution will only occur if a system threshold for the number of units with bad data is not exceeded. If the number of units with unavailable or bad data in a region associated to a constraint exceeds the system threshold, the FPP application will automatically assign the CF's of all units as zero, and no substitution takes place. Similarly, if a region associated to a constraint is deemed unreliable, all CF values will be assigned as zero and no substitution takes place.

Units and residuals that have substituted performance will be flagged by the system to show that a substituted value was used for the CF calculation. This flag will be visible in the contribution factor participant report.

Calculating CF/RCF substituting null performance with FPP historical performance

When calculating Raise and Lower Contribution factors, the FPP Application will check if the associated unit has null performance values. If null values are found, the application will replace the null values with the calculated FPP historical performance values for both raise and lower CFs.

FPP historical performance will be calculated by summing the real time performance of a unit and taking the average. The value will be capped to 0 as substituted values can only be used for cost recovery. FPP historical performance will be calculated for both raise and lower performance. The Contribution Factor can then be calculated for that unit.

When calculating the Raise or Lower Residual Contribution Factors for a requirement, the FPP Application will check for any unit with null performance values for the requirement and will substitute the performance values when calculating the absolute sum of the performance values with the same sign.

Non-primary DUID with null performance in an ADC group will not have their performance values substituted.

Calculating NCF/NRCF substituting null performance with Regulation historical performance

Once the Raise and Lower Contribution factors have been calculated, the FPP Application will also calculate the Negative Contribution Factors for the units and the residual. If null performance values are found, the application will replace the null values with calculated Regulation historical performance values.

Regulation historical performance will be calculated by capping the unit's real time performance at every five minute trading interval, and then taking the average.

When calculating the Raise or Lower Negative Residual Contribution Factors for a requirement, the FPP Application will check for any unit with null performance values for the requirement and will substitute the performance values when calculating the absolute sum of the performance values with the same sign.

Non-primary DUID with null performance in an ADC group will not have their performance values substituted.

5.6 Usage

Raise and Lower Usage calculation is covered in Section 8 of the *Frequency Contribution Factors Procedure*.

Usage reflects the proportion of enabled Regulation FCAS that was used within a trading interval that contributes to reducing the deviation in power system frequency. The Usage value will determine the percentage of Regulation FCAS costs to be recovered on the basis of Negative Contribution Factors (NCFs), the 'used Regulation FCAS' methodology, and the percentage to be recovered on the basis of DCFs, the 'unused Regulation FCAS' methodology.

For each trading interval, the FPP Application will calculate usage for each Regulation FCAS Requirement, for both raise and lower regulation requirements. Raise usage is the maximum of the sum of units' positive deviations that are enabled for a Raise Regulation requirement. Lower Usage is the maximum of the absolute sum of units' negative deviations that are enabled for a Lower Regulation requirement.

Post calculation of Unit and Residual deviations, and summing of respective positive and negative deviations, the application will calculate the total amount of enabled Regulation FCAS for both raise and lower requirements with respect to all associated regions, per trading interval. Any unit associated with bad SCADA data will be ignored from the calculation, as will any unit in an ADC group that has bad SCADA data. The application will then determine the amount of Regulation FCAS used associated to both raise and lower requirements for the respective regions by considering the highest of the summed values for a trading interval. Once these values have been determined the application will calculate both Raise and Lower Usage values per requirement.

If Frequency Measure data is unreliable, or bad or unavailable input data exceeds the configured threshold in a region associated to the requirement, then the Usage will be assigned as zero based on the validity checks performed by the system and data quality flags.

The example below shows a sample data set of calculated Usage values for a single constraint and associated Enabled Regulation FCAS and Used Regulation FCAS amounts.

Table 10 Calculated usage data

Trading Interval	MWEnabled	MWUsed	Usage
03/10/2024 09:05:00	267.4587	128.038	0.4787
03/10/2024 09:10:00	224.6652	87.5151	0.3895
03/10/2024 09:15:00	270.2525	88.389	0.3271
03/10/2024 09:20:00	290.0217	102.7773	0.3544
03/10/2024 09:25:00	241.4836	90.9618	0.3767
03/10/2024 09:30:00	240.0065	96.2577	0.4011
03/10/2024 09:35:00	295.9224	110.8949	0.3747
03/10/2024 09:40:00	240.9173	109.4554	0.4543

Trading Interval	MWEnabled	MWUsed	Usage
03/10/2024 09:45:00	254.7261	110.54	0.434
03/10/2024 09:50:00	295.0108	182.4438	0.6184
03/10/2024 09:55:00	304.6106	179.571	0.5895
03/10/2024 10:00:00	218.414	102.0184	0.4671

Figure 14 Raise usage graphic example

5.7 Requirement for corrective response

Before Trading Amounts can be determined for Participants, the scale of payments needs to be determined. To do this, the Requirement for Corrective Response (RCR) is calculated.

Raise and Lower Requirement for Corrective Response calculations are covered in Section 7 of the *Frequency Contribution Factors Procedure*[13].

5.7.1 Constraint deviations for RCR

The Requirement for Corrective Response is the measure of the total volume in MW of helpful response that contributed to reducing the deviation in frequency of the power system. It represents the peak volume of helpful response provided by all units in a given trading interval.

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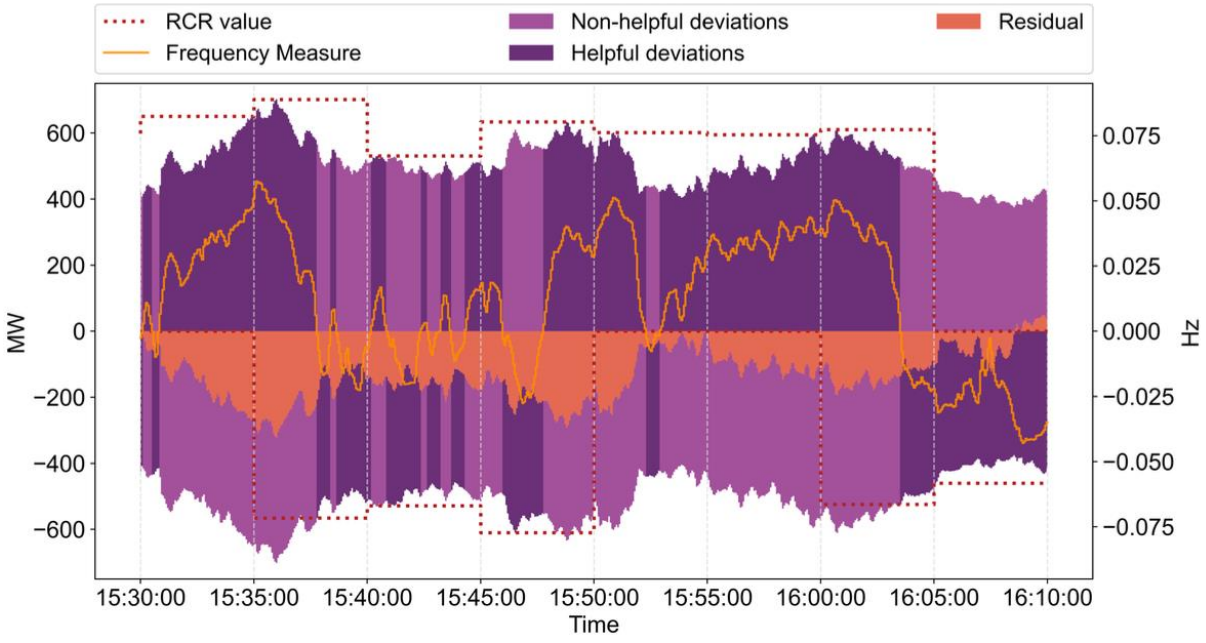
The RCR is determined with respect to each Regulation FCAS Requirement and is used to scale the monetary value of FPP trading amounts. For Raise Requirements, the Raise RCR value will be calculated. Similarly, for Lower Requirements, a Lower RCR value will be calculated.

The larger the RCR value is, the larger the value of FPP trading amounts.

Figure 15 depicts how the RCR corresponds to the maximum of the sum of all helpful deviations (including both units and Residual) during eight trading intervals interval.

Deviations that are helpful during a trading interval are shown in a darker purple, while deviations that are unhelpful during a trading interval are shown in a lighter purple. Following the frequency measure across the intervals shows the positive deviations are helpful when the frequency measure is positive, and the negative deviations are helpful when the frequency measure is negative.

Figure 15 Requirement for Corrective Response for a Mainland requirement (MW, Hz)



The maximum of the sum of all positive deviations where the Frequency Measure is positive for the interval will give the Raise RCR value, whereas the maximum of the sum of all negative deviations where the Frequency Measure is negative for the interval will give the Lower RCR value.

The positive and negative deviations are symmetrical, as it is assumed that residual deviations (deviations of units without appropriate metering) is the opposite of the sum of all other deviations.

The FPP Application will calculate the RCR value for Raise and Lower requirements when the Frequency Measure, verification of the Frequency Measure reliability per requirement, Unit Deviation and Residual Deviation per requirement have been calculated.

For each Regulation Raise Requirement, the application will sum all positive deviations of all units and the positive residual values for each 4-second interval, within a trading interval. Raise Frequency Measure data for each 4-second interval will then be considered, where the Raise FM values are greater than zero. The Raise RCR value is then

calculated by considering the maximum of the summed “helpful” positive deviations when the frequency measure is positive within the 4-second time interval. The calculation is repeated for each requirement.

The same calculation approach will be taken for Lower RCR, however the sum of all negative deviations of all units and the negative residual values for each 4-second interval, within a trading interval will be considered, where the Lower FM values are less than zero. The Lower RCR value will be calculated by considering the minimum of all summed “helpful” negative deviations when the frequency measure is negative within the 4-second time interval.

An example of RCR values and supporting data can be found in the Appendix of this document.

Units with a bad data quality flag will be ignored for the calculation of Raise or Lower RCR. Similarly, if there are units within an ADC group with a bad data quality flag, they will be ignored for calculation.

If Frequency Measure data is determined by the system to be unreliable or the percentage of units with bad or unavailable data exceeds to the configured system threshold, then the RCR value will be zero for the associated requirement within the trading interval.

RCR values will be flagged by the system to show that FM data was unreliable or the percentage of units with bad or unavailable data exceeded the threshold. This flag will be visible in the RCR participant report.

6 Financial estimates

AEMO is planning for a six-month non-financial operation period from December 2024. It is important to note that this follows, and is different from, system testing. AEMO will have all FPP systems in production before the commencement of non-financial operation and recommends that participants do likewise.

During the non-financial operation period, the FPP calculations will be completed and data reported to participants, but settlement of these amounts will not be undertaken. Non-financial operation will allow participants to observe what their outcomes would be under the new FPP regime, without the actual financial consequences. This information will give participants the option to start to respond (or plan to respond) to the new financial incentives that the FPP scheme will send.

Participants will be able to view FPP outcomes for their registered units via the following reports.

6.1 Estimates for a unit with CF

Report name: FPP_EST_COST

This report will show the *estimated* cost for each FPP unit, per constraint and bid type for a five-minute trading interval.

The report is triggered at the completion of an FPP calculation run for a closed trading interval.

Table 11 Estimated cost report example

INT DATE TIME	CONSTRAINTID	BIDTYPE	FPP	INT DATE TIME	CONSTRAINTID	BIDTYPE	FPP
6/09/2024 10:05:00 AM	F_I+BIP_ML_L5	LOWERREG	DUID1	NSW1, QLD1, SA1, TAS1, VIC1	-269.14	-7.28	-0.33
6/09/2024 10:05:00 AM	F_I+BIP_ML_L5	LOWERREG	DUID2	NSW1, QLD1, SA1, TAS1, VIC1	-181.40	-4.91	-0.33
6/09/2024 10:05:00 AM	F_I+BIP_ML_L5	LOWERREG	DUID3	NSW1, QLD1, SA1, TAS1, VIC1	-143.82	-3.26	-0.34
6/09/2024 10:05:00 AM	F_I+BIP_ML_L5	LOWERREG	DUID4	NSW1, QLD1, SA1, TAS1, VIC1	-259.08	-3.14	-0.38
6/09/2024 10:05:00 AM	F_I+BIP_ML_L5	LOWERREG	DUID5	NSW1, QLD1, SA1, TAS1, VIC1	-116.02	-3.14	-0.33
6/09/2024 10:05:00 AM	F_I+BIP_ML_L5	LOWERREG	DUID6	NSW1, QLD1, SA1, TAS1, VIC1	-111.01	-2.924	-0.33

The FPP Payment Amount (estimated) value can be either positive (a credit) or negative (a debit).

The USEDFCAS and UNUSEDFCAS (estimated) values will either be zero (nil) or a negative value (a debit) only.

The name of the participant will be published in the report. It has been omitted from the above example.

6.2 Estimates for residual

Report name: FPP_EST_RESIDUAL_COST_RATE

This report will show the *estimated* residual cost rate, per constraint and bid type for a five-minute trading interval.

The report is triggered at the completion of an FPP calculation run for a closed trading interval.

Table 12 Estimated residual cost report example

INT DATE TIME	CONSTRAINTID	BIDTYPE	REGION	FPP	USEDFCAS	UNUSEDFCAS
6/09/2024 10:05:00 AM	F_TASCAP_RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	-25.90765512	-0.5665665	-0.48600595
6/09/2024 10:05:00 AM	F_TASCAP_RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	1.39450141	0	-0.01733273
6/09/2024 10:05:00 AM	F_MAIN+RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	-25.14490453	-0.69028279	-0.61251971
6/09/2024 10:05:00 AM	F_MAIN+RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	5.46281254	0	-0.06700862
6/09/2024 10:05:00 AM	F_MAIN+RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	-30.72377839	-1.14905654	-0.34273909
6/09/2024 10:05:00 AM	F_MAIN+RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	-32.94698521	-1.05694706	-0.43228119

The FPP Payment Amount (estimated) value can be either positive (a credit) or negative (a debit). The USEDFCAS and UNUSEDFCAS (estimated) values will either be zero (nil) or a negative value (a debit) only.

The amounts published are $ per MWh. It is calculated by dividing total residual payment/recovery by the estimated total energy relevant to that constraint. In this calculation it is estimated as the regional operational demand plus a weight constant[14].

6.3 Recovery rates

Report name: FPP_EST_PERF_COST_RATE

This report will show the *estimated* performance cost rate, per constraint, for a five-minute trading interval.

The report is triggered at the completion of an FPP calculation run for a closed trading interval.

[14] Will be available in Tuning Parameters and Input Sources (https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/frequency-contribution-factors-procedure/final-documents/turning-parameters-and-input-sources.pdf?la=en)

Table 13 Recovery Rate Report example

INT DATE TIME	CONSTRAINTID	BIDTYPE	RELEVANT REGION	FPP PAYMENT	INT DATE TIME	CONSTRAINTID	BIDTYPE
6/09/2024 10:05:00 AM	F_TASCAP_RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	0	0	0	2.44614916
6/09/2024 10:05:00 AM	F_I+RREG_0220	RAISEREG	NSW1, QLD1, SA1, TAS1, VIC1	28.87521287	28.74246255	0.09562376	1.43144495
6/09/2024 10:05:00 AM	F_I+RREG_0220	RAISEREG	NSW1, QLD1, SA1, TAS1, VIC1	0	0	0	0.01824828
6/09/2024 10:05:00 AM	F_TASCAP_RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	17.88340686	18.04180746	0.02245924	0.77222205
6/09/2024 10:05:00 AM	F_TASCAP_RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	84.46114049	86.68023228	0.00232091	1.99149212
6/09/2024 10:05:00 AM	F_TASCAP_RREG_0220	RAISEREG	NSW1, QLD1, SA1, VIC1	306.7310365	314.3074475	0.00940337	2.0345053

The FPP Payment Rate Amount (estimated) value will be either zero (nil) or a positive (a credit). The FPP Recovery Rate Amount (estimated) value will be either zero (nil) or a negative (a debit). The USEDFCAS and UNUSEDFCAS rate (estimated) values will either be zero (nil) or a negative value (a debit) only.

The amounts are published in $ per MWh.

7 Further information and engagement opportunities

7.1 List of relevant documents

The table below lists relevant documents that provide further information about how the FPP system will run and how data will be communicated.

Table 14 Relevant documents

Reference	Title	Location
N.A.	Frequency Contribution Factors Procedure	https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/frequency-contribution-factors-procedure/final-documents/final-frequency-contribution-factors-procedure.pdf?la=en
160-0392	Efficient Dispatch and Localised Recovery of Regulation Services Business Specification	https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/0160-0049-pdf.pdf
N.A.	Power System Data Communication Standard	https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/aemo-standard-for-power-system-data-communications.pdf
N.A.	Frequency Contribution Factor Tuning Parameters and Input Sources	https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/frequency-contribution-factors-procedure/final-documents/turning-parameters-and-input-sources.pdf?la=en
N.A.	Guide to Ancillary Services in the National Electricity Market	https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/guide-to-ancillary-services-in-the-national-electricity-market.pdf
N.A.	MMS Data Model Reports	https://visualisations.aemo.com.au/aemo/di-help/Content/Data_Model/MMS_Data_Model.htm
N.A	Guide to Constraint Outcomes for FCAS Cost Recovery	https://aemo.com.au/-/media/files/initiatives/frequency-performance-payments-project/AEMO-Guide-to-Constraint-Outcomes-for-FCAS-Cost-Recovery.pdf

7.2 How to stay engaged with the implementation of the FPP reform

7.2.1 Online resources

AEMO is implementing FPP as part of the NEM Reform Program. Information about the NEM Reform Program can be found at: https://aemo.com.au/initiatives/major-programs/nem-reform-program.

The FPP Project age can be found at https://aemo.com.au/initiatives/major-programs/frequency-performance-payments-project. This page includes links to all consultation materials and other resources developed as part of the FPP implementation process.

The NEM Reform Program also publishes a bi-monthly newsletter. Stakeholders can register to receive that newsletter at https://aemo.us10.list-manage.com/subscribe?u=eae433173c2b1acb87c5b07d1&id= 9c87409bb5.

7.2.2 Regular forums

As part of the NEM Reform Program, AEMO operates a number of stakeholder forums. The implementation of FPP is regularly discussed at the following open monthly forums:

- **Program Consultative Forum** (see https://aemo.com.au/consultations/industry-forums-and-working-groups/list-of-industry-forums-and-working-groups/program-consultative-forum).
- **Implementation Forum** (see https://aemo.com.au/consultations/industry-forums-and-working-groups/list-of-industry-forums-and-working-groups/implementation-forum).
- **Electricity Wholesale Consultative Forum** (see https://aemo.com.au/consultations/industry-forums-and-working-groups/list-of-industry-forums-and-working-groups/electricity-wholesale-consultative-forum).

To join the invitation list for any of the above forums, email NEMReform@aemo.com.au.

A1. Supporting data

This section contains supporting data for the examples outlined in Section 5 of this document.

A1.1 Frequency Measure example

Supporting data for Figure 2 Frequency Measure in Section 5.1.1.

Table 15 Frequency Measure for sample region (SA-1)

4-second interval	Region Freq. Deviation	Negative of Freq. Deviation	Frequency Measure	Raise FM	Lower FM
12:03:04 AM	0.00800	-0.00800	0.00000	0	0
12:03:08 AM	0.00500	-0.00500	-0.00111	0	-0.0011111
12:03:12 AM	0.04150	-0.04150	-0.01009	0	-0.0100864
12:03:16 AM	0.03800	-0.03800	-0.01629	0	-0.0162894
12:03:20 AM	0.02075	-0.02075	-0.01728	0	-0.0172807
12:03:24 AM	0.01525	-0.01525	-0.01683	0	-0.0168294
12:03:28 AM	0.01925	-0.01925	-0.01737	0	-0.0173673
12:03:32 AM	0.02225	-0.02225	-0.01845	0	-0.0184524
12:03:36 AM	0.03025	-0.03025	-0.02107	0	-0.0210741
12:03:40 AM	0.03375	-0.03375	-0.02389	0	-0.0238909
12:03:44 AM	0.03375	-0.03375	-0.02608	0	-0.0260818
12:03:48 AM	0.03425	-0.03425	-0.02790	0	-0.027897
12:03:52 AM	0.02375	-0.02375	-0.02698	0	-0.0269754
12:03:56 AM	0.00800	-0.00800	-0.02276	0	-0.0227587
12:04:00 AM	0.00400	-0.00400	-0.01859	0	-0.0185901
12:04:04 AM	-0.00400	0.00400	-0.01357	0	-0.0135701
12:04:08 AM	0.01075	-0.01075	-0.01294	0	-0.0129434
12:04:12 AM	0.01475	-0.01475	-0.01334	0	-0.0133449
12:04:16 AM	-0.00275	0.00275	-0.00977	0	-0.0097682
12:04:20 AM	-0.01875	0.01875	-0.00343	0	-0.0034308
12:04:24 AM	-0.02075	0.02075	0.00194	0.001942683	0
12:04:28 AM	-0.00750	0.00750	0.00318	0.003177642	0
12:04:32 AM	0.00025	-0.00025	0.00242	0.002415944	0
12:04:36 AM	-0.00700	0.00700	0.00343	0.003434623	0
12:04:40 AM	-0.00500	0.00500	0.00378	0.003782485	0
12:04:44 AM	-0.00425	0.00425	0.00389	0.003886377	0
12:04:48 AM	0.00775	-0.00775	0.00130	0.001300516	0
12:04:52 AM	0.00900	-0.00900	-0.00099	0	-0.0009885
12:04:56 AM	0.00350	-0.00350	-0.00155	0	-0.0015466

4-second interval	Region Freq. Deviation	Negative of Freq. Deviation	Frequency Measure	Raise FM	Lower FM
12:05:00 AM	-0.00675	0.00675	0.00030	0.000297088	0
12:05:04 AM	-0.01475	0.01475	0.00351	0.003508846	0
12:05:08 AM	-0.01125	0.01125	0.00523	0.005229103	0
12:05:12 AM	-0.00075	0.00075	0.00423	0.004233746	0
12:05:16 AM	0.00825	-0.00825	0.00146	0.001459581	0
12:05:20 AM	0.01625	-0.01625	-0.00248	0	-0.0024759
12:05:24 AM	0.01225	-0.01225	-0.00465	0	-0.0046479
12:05:28 AM	-0.01300	0.01300	-0.00073	0	-0.0007262
12:05:32 AM	-0.00925	0.00925	0.00149	0.001490772	0
12:05:36 AM	0.01940	-0.01940	-0.00315	0	-0.0031516
12:05:40 AM	0.01700	-0.01700	-0.00623	0	-0.006229
12:05:44 AM	-0.00650	0.00650	-0.00340	0	-0.0034004
12:05:48 AM	-0.01175	0.01175	-0.00003	0	-3.362E-05
12:05:52 AM	-0.01300	0.01300	0.00286	0.002862743	0
12:05:56 AM	-0.01175	0.01175	0.00484	0.004837689	0
12:06:00 AM	-0.02100	0.02100	0.00843	0.008429313	0
12:06:04 AM	-0.03075	0.03075	0.01339	0.013389466	0
12:06:08 AM	-0.01900	0.01900	0.01464	0.014636251	0
12:06:12 AM	-0.00825	0.00825	0.01322	0.013217084	0
12:06:16 AM	-0.02060	0.02060	0.01486	0.014857732	0
12:06:20 AM	-0.01900	0.01900	0.01578	0.015778236	0
12:06:24 AM	0.00100	-0.00100	0.01205	0.012049739	0
12:06:28 AM	-0.00225	0.00225	0.00987	0.009872019	0
12:06:32 AM	-0.01300	0.01300	0.01057	0.010567126	0
12:06:36 AM	-0.01525	0.01525	0.01161	0.011607765	0
12:06:40 AM	-0.01125	0.01125	0.01153	0.011528262	0
12:06:44 AM	-0.00225	0.00225	0.00947	0.009466426	0
12:06:48 AM	0.01050	-0.01050	0.00503	0.005029442	0
12:06:52 AM	0.01550	-0.01550	0.00047	0.000467344	0
12:06:56 AM	0.01475	-0.01475	-0.00291	0	-0.0029143
12:07:00 AM	0.00700	-0.00700	-0.00382	0	-0.0038222
12:07:04 AM	0.00200	-0.00200	-0.00342	0	-0.0034173
12:07:08 AM	-0.00050	0.00050	-0.00255	0	-0.0025468
12:07:12 AM	0.01275	-0.01275	-0.00481	0	-0.0048142
12:07:16 AM	0.02375	-0.02375	-0.00902	0	-0.0090221
12:07:20 AM	0.02925	-0.02925	-0.01352	0	-0.0135172
12:07:24 AM	0.01775	-0.01775	-0.01446	0	-0.0144578
12:07:28 AM	0.00100	-0.00100	-0.01147	0	-0.0114672
12:07:32 AM	-0.02000	0.02000	-0.00447	0	-0.0044745

4-second interval	Region Freq. Deviation	Negative of Freq. Deviation	Frequency Measure	Raise FM	Lower FM
12:07:36 AM	-0.01950	0.01950	0.00085	0.000853175	0
12:07:40 AM	-0.01500	0.01500	0.00400	0.003996914	0
12:07:44 AM	-0.01100	0.01100	0.00555	0.005553155	0
12:07:48 AM	-0.02700	0.02700	0.01032	0.010319121	0
12:07:52 AM	-0.02625	0.02625	0.01386	0.013859316	0
12:07:56 AM	-0.01000	0.01000	0.01300	0.01300169	0
12:08:00 AM	0.00300	-0.00300	0.00945	0.009445759	0

A1.2 RCR Example

This data example is mentioned in Section 5.7 Requirements for Corrective Response.

The data example in Table 16 shows the calculated deviation values, Residual Deviation, Frequency Measure values for both Raise and Lower and "helpful" positive and negative deviations, for a trading interval. Using this data, the RCR Raise and RCR Lower values can be calculated using the "helpful" positive and negative deviations. The maximum of positive deviations and minimum of negative deviations has been highlighted in Table 17 in the "helpful" columns and shown in the summary table below.

Table 16 Summary of deviations and RCR values

Category	Value
Max of positive deviations	497.8181
Min of negative deviations	-545.20
RCR RAISE	497.8180934
RCR LOWER	545.2043025

Table 17 RCR Data example for a trading interval

Time	Sum of pos deviations of metered units	Sum of negative deviations of metered units	Residual deviation	Sum of positive and residual deviations	Sum of negative and residual deviations	FM	FMRAISE	FMLOWER	"Helpful" positive deviations	"Helpful" negative deviations
1:30:04 PM	329.80	-545.20	215.40	545.20	-545.20	-0.0294	0.0000	-0.0294	0.0000	*-545.20*
1:30:08 PM	331.80	-529.92	198.12	529.92	-529.92	-0.0262	0.0000	-0.0262	0.0000	-529.92
1:30:12 PM	334.83	-506.06	171.23	506.06	-506.06	-0.0289	0.0000	-0.0289	0.0000	-506.06
1:30:16 PM	328.20	-487.65	159.45	487.65	-487.65	-0.0348	0.0000	-0.0348	0.0000	-487.65
1:30:20 PM	320.55	-498.21	177.66	498.21	-498.21	-0.0339	0.0000	-0.0339	0.0000	-498.21
1:30:24 PM	324.31	-497.58	173.28	497.58	-497.58	-0.0249	0.0000	-0.0249	0.0000	-497.58
1:30:28 PM	321.92	-507.50	185.59	507.50	-507.50	-0.0237	0.0000	-0.0237	0.0000	-507.50
1:30:32 PM	322.69	-511.00	188.30	511.00	-511.00	-0.0205	0.0000	-0.0205	0.0000	-511.00
1:30:36 PM	331.40	-512.12	180.72	512.12	-512.12	-0.0295	0.0000	-0.0295	0.0000	-512.12
1:30:40 PM	343.03	-503.36	160.33	503.36	-503.36	-0.0342	0.0000	-0.0342	0.0000	-503.36
1:30:44 PM	342.93	-497.68	154.75	497.68	-497.68	-0.0342	0.0000	-0.0342	0.0000	-497.68
1:30:48 PM	349.96	-489.52	139.56	489.52	-489.52	-0.0205	0.0000	-0.0205	0.0000	-489.52
1:30:52 PM	345.73	-494.61	148.88	494.61	-494.61	-0.0172	0.0000	-0.0172	0.0000	-494.61
1:30:56 PM	357.22	-489.91	132.69	489.91	-489.91	-0.0163	0.0000	-0.0163	0.0000	-489.91
1:31:00 PM	349.51	-479.61	130.10	479.61	-479.61	-0.0135	0.0000	-0.0135	0.0000	-479.61
1:31:04 PM	347.41	-473.03	125.62	473.03	-473.03	-0.0134	0.0000	-0.0134	0.0000	-473.03
1:31:08 PM	354.99	-462.73	107.73	462.73	-462.73	-0.0058	0.0000	-0.0058	0.0000	-462.73
1:31:12 PM	367.42	-444.96	77.55	444.96	-444.96	0.0105	0.0105	0.0000	444.9620	0.00
1:31:16 PM	377.39	-432.65	55.26	432.65	-432.65	0.0085	0.0085	0.0000	432.6467	0.00
1:31:20 PM	385.35	-437.42	52.08	437.42	-437.42	-0.0035	0.0000	-0.0035	0.0000	-437.42
1:31:24 PM	364.36	-446.45	82.09	446.45	-446.45	-0.0099	0.0000	-0.0099	0.0000	-446.45
1:31:28 PM	348.33	-474.53	126.20	474.53	-474.53	-0.0129	0.0000	-0.0129	0.0000	-474.53

Time	Sum of pos deviations of metered units	Sum of negative deviations of metered units	Residual deviation	Sum of positive and residual deviations	Sum of negative and residual deviations	FM	FMRAISE	FMLOWER	"Helpful" positive deviations	"Helpful" negative deviations
1:31:32 PM	340.82	-478.43	137.62	478.43	-478.43	-0.0207	0.0000	-0.0207	0.0000	-478.43
1:31:36 PM	337.18	-489.02	151.83	489.02	-489.02	-0.0232	0.0000	-0.0232	0.0000	-489.02
1:31:40 PM	327.35	-503.00	175.65	503.00	-503.00	-0.0216	0.0000	-0.0216	0.0000	-503.00
1:31:44 PM	326.70	-509.86	183.16	509.86	-509.86	-0.0251	0.0000	-0.0251	0.0000	-509.86
1:31:48 PM	325.32	-513.00	187.68	513.00	-513.00	-0.0257	0.0000	-0.0257	0.0000	-513.00
1:31:52 PM	326.09	-517.88	191.79	517.88	-517.88	-0.0234	0.0000	-0.0234	0.0000	-517.88
1:31:56 PM	319.36	-520.56	201.20	520.56	-520.56	-0.0266	0.0000	-0.0266	0.0000	-520.56
1:32:00 PM	312.70	-511.52	198.82	511.52	-511.52	-0.0307	0.0000	-0.0307	0.0000	-511.52
1:32:04 PM	313.86	-511.40	197.53	511.40	-511.40	-0.0152	0.0000	-0.0152	0.0000	-511.40
1:32:08 PM	324.02	-495.57	171.55	495.57	-495.57	-0.0063	0.0000	-0.0063	0.0000	-495.57
1:32:12 PM	325.54	-488.71	163.16	488.71	-488.71	-0.0057	0.0000	-0.0057	0.0000	-488.71
1:32:16 PM	328.30	-474.68	146.38	474.68	-474.68	-0.0106	0.0000	-0.0106	0.0000	-474.68
1:32:20 PM	338.56	-460.95	122.39	460.95	-460.95	-0.0037	0.0000	-0.0037	0.0000	-460.95
1:32:24 PM	354.48	-451.29	96.80	451.29	-451.29	0.0048	0.0048	0.0000	451.2862	0.00
1:32:28 PM	361.09	-445.41	84.32	445.41	-445.41	0.0068	0.0068	0.0000	445.4066	0.00
1:32:32 PM	354.03	-464.66	110.63	464.66	-464.66	0.0050	0.0050	0.0000	464.6590	0.00
1:32:36 PM	349.43	-474.28	124.85	474.28	-474.28	0.0069	0.0069	0.0000	474.2805	0.00
1:32:40 PM	345.13	-485.49	140.36	485.49	-485.49	0.0076	0.0076	0.0000	485.4874	0.00
1:32:44 PM	339.84	-480.92	141.08	480.92	-480.92	0.0138	0.0138	0.0000	480.9169	0.00
1:32:48 PM	345.57	-483.67	138.09	483.67	-483.67	0.0118	0.0118	0.0000	483.6652	0.00
1:32:52 PM	344.10	-482.00	137.90	482.00	-482.00	0.0036	0.0036	0.0000	482.0022	0.00
1:32:56 PM	322.40	-497.82	175.42	497.82	-497.82	0.0011	0.0011	0.0000	*497.8181*	0.00
1:33:00 PM	321.19	-497.12	175.93	497.12	-497.12	-0.0078	0.0000	-0.0078	0.0000	-497.12

Time	Sum of pos deviations of metered units	Sum of negative deviations of metered units	Residual deviation	Sum of positive and residual deviations	Sum of negative and residual deviations	FM	FMRAISE	FMLOWER	"Helpful" positive deviations	"Helpful" negative deviations
1:33:04 PM	320.34	-486.79	166.45	486.79	-486.79	-0.0138	0.0000	-0.0138	0.0000	-486.79
1:33:08 PM	325.97	-473.63	147.66	473.63	-473.63	-0.0105	0.0000	-0.0105	0.0000	-473.63
1:33:12 PM	326.57	-471.64	145.08	471.64	-471.64	0.0037	0.0037	0.0000	471.6443	0.00
1:33:16 PM	334.28	-457.77	123.49	457.77	-457.77	0.0025	0.0025	0.0000	457.7701	0.00
1:33:20 PM	335.12	-461.92	126.81	461.92	-461.92	0.0018	0.0018	0.0000	461.9233	0.00
1:33:24 PM	332.68	-459.00	126.32	459.00	-459.00	0.0033	0.0033	0.0000	458.9996	0.00
1:33:28 PM	328.91	-454.14	125.23	454.14	-454.14	0.0089	0.0089	0.0000	454.1445	0.00
1:33:32 PM	341.33	-448.08	106.75	448.08	-448.08	0.0150	0.0150	0.0000	448.0756	0.00
1:33:36 PM	370.87	-450.03	79.16	450.03	-450.03	0.0056	0.0056	0.0000	450.0299	0.00
1:33:40 PM	358.03	-455.71	97.68	455.71	-455.71	-0.0077	0.0000	-0.0077	0.0000	-455.71
1:33:44 PM	341.36	-455.85	114.49	455.85	-455.85	-0.0046	0.0000	-0.0046	0.0000	-455.85
1:33:48 PM	329.58	-472.09	142.51	472.09	-472.09	0.0015	0.0015	0.0000	472.0888	0.00
1:33:52 PM	328.85	-471.37	142.52	471.37	-471.37	-0.0011	0.0000	-0.0011	0.0000	-471.37
1:33:56 PM	336.78	-451.32	114.53	451.32	-451.32	-0.0025	0.0000	-0.0025	0.0000	-451.32
1:34:00 PM	338.80	-452.25	113.45	452.25	-452.25	0.0024	0.0024	0.0000	452.2530	0.00
1:34:04 PM	350.29	-442.36	92.06	442.36	-442.36	0.0039	0.0039	0.0000	442.3562	0.00
1:34:08 PM	346.27	-446.75	100.48	446.75	-446.75	-0.0020	0.0000	-0.0020	0.0000	-446.75
1:34:12 PM	350.18	-449.38	99.19	449.38	-449.38	-0.0037	0.0000	-0.0037	0.0000	-449.38
1:34:16 PM	365.71	-453.41	87.71	453.41	-453.41	-0.0023	0.0000	-0.0023	0.0000	-453.41
1:34:20 PM	367.45	-446.77	79.32	446.77	-446.77	-0.0025	0.0000	-0.0025	0.0000	-446.77
1:34:24 PM	364.91	-441.44	76.53	441.44	-441.44	-0.0021	0.0000	-0.0021	0.0000	-441.44
1:34:28 PM	361.38	-446.82	85.45	446.82	-446.82	0.0035	0.0035	0.0000	446.8241	0.00
1:34:32 PM	350.08	-440.64	90.56	440.64	-440.64	0.0061	0.0061	0.0000	440.6408	0.00

Time	Sum of pos deviations of metered units	Sum of negative deviations of metered units	Residual deviation	Sum of positive and residual deviations	Sum of negative and residual deviations	FM	FMRAISE	FMLOWER	"Helpful" positive deviations	"Helpful" negative deviations
1:34:36 PM	364.07	-436.84	72.78	436.84	-436.84	-0.0021	0.0000	-0.0021	0.0000	-436.84
1:34:40 PM	375.45	-438.24	62.79	438.24	-438.24	-0.0071	0.0000	-0.0071	0.0000	-438.24
1:34:44 PM	369.68	-433.09	63.41	433.09	-433.09	-0.0145	0.0000	-0.0145	0.0000	-433.09
1:34:48 PM	366.31	-442.33	76.02	442.33	-442.33	-0.0169	0.0000	-0.0169	0.0000	-442.33
1:34:52 PM	362.22	-452.25	90.03	452.25	-452.25	-0.0131	0.0000	-0.0131	0.0000	-452.25
1:34:56 PM	362.66	-451.21	88.55	451.21	-451.21	-0.0085	0.0000	-0.0085	0.0000	-451.21
1:35:00 PM	368.45	-441.82	73.36	441.82	-441.82	0.0013	0.0013	0.0000	441.8151	0.00