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Authors	Ben Hiron, Sebastien Henry, Julius Susanto, David Scott, Kevin Ly, Jabez Wilson, Hugh Bannister
Affiliations (optional)	Australian Energy Market Commission, Australian Energy Market Operator, Intelligent Energy systems
Email address	ben.hiron@aemc.gov.au

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Summary

As we move towards a lower emissions energy future, the provision of essential system services that support the secure and stable operation of the power system is one of the key priority areas of policy reform in the National Electricity Market (NEM). One aspect of system security is the control of power system frequency within a narrow range around 50Hz. This is achieved by achieving an instantaneous and continuous balance between electricity generation and consumption under both normal system conditions and in response to contingency events.

Following a period of degraded frequency control in the NEM throughout 2014 – 2018, there has been significant reform focussed on ways of improving the control of frequency in the NEM. These changes intend to increase the provision of primary frequency response (PFR), which acts automatically at the unit level to control system frequency close to 50Hz.

In September 2022, the AEMC made a final rule, *Primary frequency response incentive arrangements*, to support system security and deliver reduced costs for frequency control over the long term. The final rule confirmed that all scheduled and semi-scheduled generators are required to provide PFR by responding automatically to changes in power system frequency. It also introduced new arrangements for frequency performance payments to encourage and reward plant behaviour that helps control power system frequency.

The new frequency performance payments process builds on an existing performance-based approach for the allocation of costs for the enablement of regulation services. The new arrangements extend the existing process to make payments to all market participants whose plant acts to control system frequency. The associated costs will be allocated to all market participants whose plant cause the need for corrective action.

The new frequency performance payments arrangements are an innovative approach to incentivising power system frequency control. The key innovation is the development of a broad framework that creates economic incentives for any generator or load with appropriate metering to control its output to help regulate system frequency. This paper focuses on the key features of the new frequency performance payments process and presents related analysis prepared by Intelligent Energy Systems for the AEMC.

Keywords

Power system frequency control, primary frequency control, frequency regulation, electricity market design, electricity market regulation, performance-based pricing, ancillary services, power system security.

1 Introduction

As with many of the world's major power systems, Australia's National Electricity Market (NEM) is undergoing a fundamental technology transition. Lower cost, variable, inverter-connected generation such as batteries, wind and solar are displacing dispatchable synchronous generation, creating challenges for how the security of the power system is managed. This requires the development of new operating and regulatory arrangements to maintain system security and continue to deliver reliable and efficiently priced electricity.

In September 2022, the Australian Energy Market Commission (AEMC) made a final rule, *Primary frequency response incentive arrangements*, to support system security and deliver reduced costs for frequency control over the long term. (1) The final rule:

- Confirmed that all scheduled and semi-scheduled generators are required to provide primary frequency response (PFR) to help control power system frequency.
- Introduced new frequency performance payments to encourage and reward plant behaviour that helps to control power system frequency.
- Introduced new reporting obligations for AEMO and the AER in relation aggregate frequency responsiveness in the power system and the costs of frequency performance payments.

This paper describes the new frequency performance payments arrangements along with related analysis undertaken by Intelligent Energy Systems (IES) and the Australian Energy Market Operator (AEMO). IES was engaged by the AEMC to undertake analysis to inform the development of the frequency performance payments arrangements. AEMO is currently in the process of developing the detailed process and procedures to implement these arrangements. The frequency performance payment arrangements will value helpful frequency response to support system security. Over time, these arrangements will also encourage non-scheduled generation and load to become more active in the dispatch process through improved metering and information provision which will have the added benefit of improving the accuracy and efficiency of system dispatch.

1.1 Basic elements of the existing NEM frequency control frameworks

One aspect of system security is the control of power system frequency within a narrow range around 50Hz. This is achieved by dynamically balancing electricity generation and consumption under both normal system conditions and in response to contingency events, which can cause larger deviations in frequency.

During normal operation, the dynamic balance of generation and consumption is maintained through the combination of automatic generator governor response, also known as "primary frequency response", and regulation services. In the NEM, these regulation services are coordinated by the market operator's (AEMO's) automatic generation control (AGC) system. The AGC sends out control signals to generation and load enabled to provide regulation services, to modify their generation or consumption to raise or lower the power system frequency. In this way, the regulation services respond to variation differences between generation and consumption within each 5-minute dispatch interval.

As is common power system practice, the NEM also utilises contingency reserves that respond automatically to frequency disturbances caused by the failure or disconnection of transmission, generation or load elements. AEMO procures sufficient contingency services to contain and stabilise power system frequency within tolerance ranges around 50Hz. These tolerances ranges are specified in the NEM Frequency operating standard (FOS).

1.2 New frequency performance payments

The AEMC's final rule, *Primary frequency response incentive arrangements* introduced changes to the National electricity rule to create new frequency performance payments, aiming to encourage and reward plant behaviour that helps to control power system frequency. (1) These arrangements will value helpful frequency response provided in accordance with the existing generator obligations and incentivise additional voluntary PFR to support the control of system frequency into the future.

The new frequency performance payments process will commence on **8 June 2025**. This timing allows for AEMO to develop and publish a new *Frequency contribution factor procedure* by 8 June 2023, that will specify the detailed approach that it will use to assess unit performance for the purpose of frequency performance payments. AEMO published a draft *Frequency contribution factor procedure* on 7 February 2023. (2)

1.3 Background and Literature review

The existing performance-based 'causer pays' process for allocation of regulation costs

The new frequency performance payments build on existing regulatory arrangements in the NEM, including the process for 5-minute energy dispatch, procurement and enablement of regulation services and the allocation of costs for regulation services based on a performance-based "causer-pays" methodology. The causer pays framework for the allocation of regulation costs commenced in the NEM in the early 2000's under the administration of the then National Electricity Code Administrator (NECA) and the National Electricity Market Management Company (NEMMCO). (3)

The NEM causer pays framework allocates costs for regulation services based on participant contribution factors determined based on unit performance over a historical 28-day period. These contribution factors are calculated by AEMO based on a measure of the unit's contribution to "the need for regulation services" and the units active power deviation from its dispatch or reference trajectory. The unit deviations are determined based on unit Supervisory Control and Data Acquisition (SCADA) data which is refreshed on a 4 second interval for the mainland NEM. The general approach to the measurement of unit active power deviations is shown in Figure 1. (4)

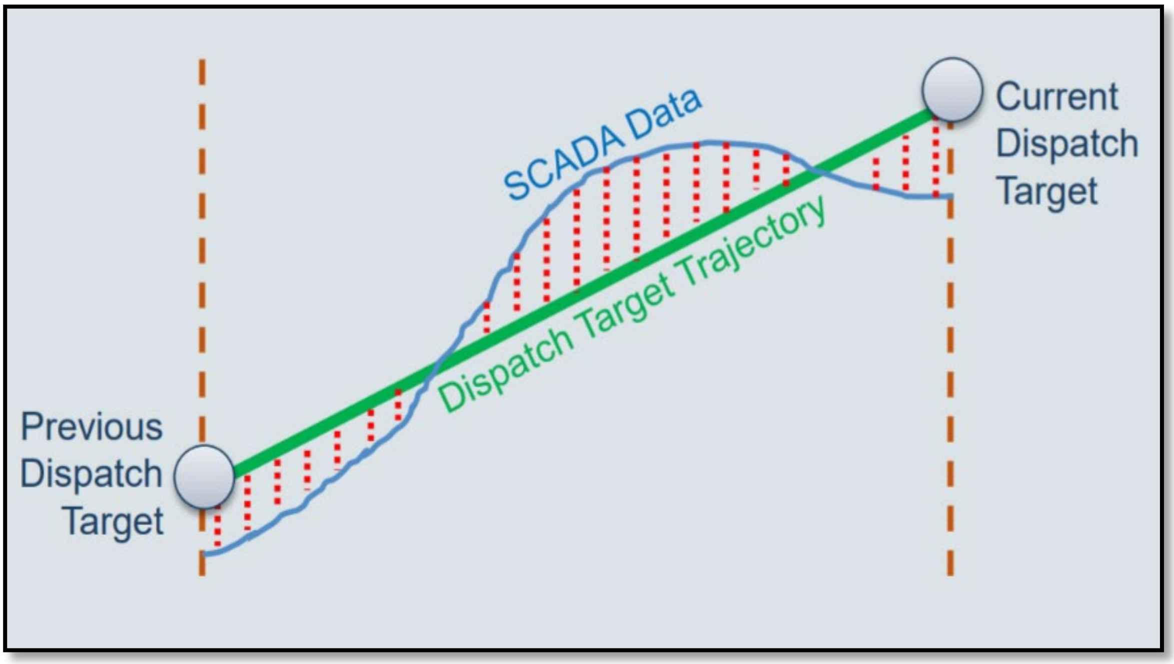

Figure 1 – Unit deviation measurement for a scheduled generator (4)

AEMO uses 'regulation requirement' as a measure of the need for regulation services, this is calculated within AEMO's central automatic generation control (AGC) system based on area control error and is also referred to as frequency indicator (FI).

The AEMC identified a number of opportunities to improve on the existing causer pays process, including valuation of positive performance, shortening and alignment of the performance measurement and financial settlement process and improved transparency for affected market participants with respect to the frequency performance measure, and the process for calculation of a unit contribution factor. (5)

History of frequency control pricing theory and application

Berger and Schweppe laid the conceptual groundwork for the real-time (intra-dispatch interval) pricing of frequency control in the late 1980s, arguing the theoretical feasibility of a real-time pricing mechanism as a means of decentralised frequency control. (6)

However, more than 30 years later, most electricity markets around the world do not have an explicit link between real-time frequency and prices. One notable exception is the Unscheduled Interchange (UI) charge, a component of the Availability Based Tariff (ABT) that was introduced in India in 2002. The primary goal of this charge is to address decades of abnormally large frequency variations (occurring on a daily basis) due to ill-discipline from both generators and loads not respecting their schedules. (6) The frequency-dependent UI charge applies to deviations from scheduled generation or load (i.e. a higher charge when deviations are detrimental to frequency control) and is one of the first examples of frequency performance payments with prices linked to (near) real-time frequency.

Several papers have proposed frequency-linked real-time spot pricing based on an expansion of the Indian UI charge model. (8) (9) (10) However, in each of these proposals (and similar to the UI charge), a fixed price-frequency curve is assumed, which may not be reflective of the dynamic underlying costs of providing PFR. For example, in the case of the UI charge, it is a statutory body, the Central Electricity Regulatory Commission (CERC), that determines the frequency-price curve. As an alternative, bid-based ancillary services markets for PFR have been proposed (for example by Jinsiwale 2019 and Zhong 2003), where generators offer price-quantity pairs in terms of a price per unit of frequency deviation and a PFR enablement volume. (11) (12)

The management of unscheduled (or inadvertent) loop flows is another area of research where frequency-linked prices have been proposed as incentives to manage unscheduled flows within balancing areas or across interconnectors. For example, the Wide-open load following (WOLF) method applies a frequency-dependent exponential scaling factor to the energy spot price to incentivise flows that support frequency. (13)

Others have investigated the potential risks associated with price-based frequency control, including Ji et al in 2019, who's work demonstrated that frequency-based pricing has the potential to either support or harm system stability, depending on the implementation approach. For example, unstable oscillations can occur when PFR providers are configured to only respond to price and not have an underlying frequency-responsive control scheme, e.g. droop control (14).

In the Australian context, frequency based performance pricing was originally proposed by IES in 1999 during the formulation of the national electricity market. (15) IES proposed a double-sided energy deviations market based on SCADA metering to price deviations from dispatch with respect to the impact of these on system frequency. While the double-sided energy deviations market was not implemented in the early days of the NEM, the concept underpinned the development of the performance-based causer pays arrangements used for the allocation of costs for regulation enablement.

The concept of energy deviation pricing or double-sided causer pays was later proposed by the AEMC in 2018 as a potential reform to deliver improved frequency outcomes by aligning economic incentives with the goal of controlling frequency to 50Hz. (14)

This concept of frequency performance pricing was further developed by Intelligent energy systems (IES) in 2022 with support from the Australian Energy Council and the Australian renewable energy agency (ARENA). The ARENA study developed a form of "double sided causer pays" using frequency linked prices to drive good frequency control outcomes by incentivising a frequency corrective response from all units. (16) The frequency-linked prices were determined based on a weighted sum of filtered frequency error signals, derived this from the marginal costs associated with a linear quadratic regulator. They proposed that the time constants of the filtered frequency signals and the procedure for calculating the weights be made known to participants ex-ante for monitoring and planning purposes. For simplicity the price of frequency regulation or the spot energy prices were suggested as options to financially weight the unit deviations for settlement purposes.

IES were engaged by the AEMC to further develop the double-sided causer pays concept in 2022 as an input to the development of the frequency performance payments arrangements. (17)

2 The new frequency performance payments process

The frequency performance payments arrangements are designed to improve on the existing performance-based arrangements for the allocation of regulation enablement costs. The objectives for the design of these improved arrangements are:

- To value positive unit performance through payments for unit performance that help to control system frequency (payments are not supported under the existing process).
- To allocate the costs of frequency performance payments to units that cause the need for corrective response (similar to the existing causer pays process).
- To shorten and align the periods for the measurement of unit performance and the application of payments or costs over each 5-minute trading interval.
- To improve on the transparency of the existing causer pays process, such that the process that is readily understood by market participants.

This section describes how the frequency performance payments process will work, including:

- the formulae that underpin the frequency performance payments
- allocation of unit contribution factors that reflect each unit's active power performance and impact on power system frequency in each trading interval
- frequency performance payments are scaled by the aggregate requirement for corrective response (RCR) - and AEMO may include parameters in relation to RCR
- frequency performance payments are valued by the relevant price for regulation services.

The AEMC's final rule set the high-level framework for the frequency performance payments transactions. It also required AEMO to develop a detailed frequency contribution factor procedure to define and publish data related to the frequency performance payments.

2.1 The formulae for Frequency performance payments transactions

A core element of the Frequency performance payments process is new transactions for frequency performance payments. These transactions establish double-sided incentive arrangements for eligible units of generation or load to provide active power response that helps control power system frequency. Under the final rule, all generation and load are exposed to new incentive arrangements in some way, with the specific application of this depending on whether a unit has "appropriate metering", which allows for individual contributions to the deviation in the frequency of the power system to be assessed.[1] The new frequency performance payments transactions will be calculated

[1] AEMO's current requirement for appropriate metering to determine individual contribution factors is Metering with the capability to record the active power output or consumption at intervals of not more than 4 seconds in the Mainland NEM, and not more than 8 seconds in Tasmania.

for every 5-minute trading interval, based on unit contribution factors determined for each trading interval – where it is practical to do so.

The frequency performance payments formula that applies for units with “appropriate metering” in each 5-minute training interval is:

$$FPP_u = CF_u \, x \, \frac{Price_{regulation}}{12} \, x \, RCR$$

Where:

- CF_u is the unit frequency performance contribution factor (between -1 and 1)
- $Price_{regulation}$ is the spot market price with respect to the regulating raise service or the regulating lower service in $/MWhr.
- RCR is the requirement (in MW) to correct the aggregate deviation in the power system.

Power system plant that do not have “appropriate metering” to support the calculation of individual unit contribution factors are allocated an aggregate contribution factor and referred to as the “residual”. The residual includes non-scheduled generation and load. Frequency performance payments for units in the residual are allocated based on the proportion of energy consumed or generated by each unit as a share of the total energy consumed or generated by the residual.

Where AEMO determines that it is not practical to determine contribution factors for a trading interval, such as where there is a lack of quality data, it may apply default contribution factors. Default contribution factors are based on historical unit performance over a longer period and may only be used for allocation of costs for frequency performance payments or regulation enablement. This approach is intended to avoid potential inconsistencies and perverse incentives could arise if payments were made to market participants based on default contribution factors.

Ex-ante vs ex-post Frequency performance payment transactions

In developing the frequency performance payments arrangements, both ex-ante and ex-post processes were considered. While the high-level objective for the mechanism was to align the economic incentives with the real-time goal of power system frequency control, it was recognised that this would require some approximation to create a workable real-world process.

An example of a real-time approach to frequency performance payment is frequency deviation pricing where unit active power deviations are multiplied by system frequency deviations and a price function to yield a price for active power deviations with respect to system frequency. Where the price function is known in advance an electricity market participant would be able to calculate their individual exposure to the frequency price in real-time and potentially use this to guide their operational decisions. However, this method of frequency performance pricing requires the development of a frequency price function in advance, that reflects the real-time value of active power response to frequency deviations. IES developed a methodology for such a real-time approach through its 2021 study on frequency deviation pricing. (18) This methodology was further investigated and documented by IES in their 2022 report to the AEMC. (17)

The frequency performance payments process described in this paper is based on an ex-post method for each 5-minute trading interval. This means that the related calculations are performed for each unit based on average unit performance and system data from the previous trading interval. This approach avoids the need for a separate frequency price function. Instead, payments are scaled based on the measured system need for corrective response (RCR) in each trading interval.

2.2 Unit performance measurement and contribution factors

A key element of the frequency performance payments process is the development of unit contribution factors for each eligible unit, including both generation and load. Positive payments are made based on positive contribution factors and the costs are allocated based on negative contribution factors.

The high-level attributes of the frequency contribution factors are described below.

Separate contribution factors are determined based on the need for raise or lower response

The NEM operates separate regulation enablement markets for raise and lower response. Therefore, the frequency performance payment process incorporates separate unit contribution factors with respect to the need to raise or lower the frequency of the power system. This supports separate valuation of unit response to raise or lower the system frequency based on the market price for the regulation raise and regulation lower services.

Contribution factors based on an energy balance approach

We demonstrated that a top-down energy balance approach could be used to account for the impact of the power system plant that do not have appropriate metering, referred to as 'the residual'. This energy balance approach is used to derive a contribution factor for the residual component and leads to a result where the positive contributions are balanced by equal and opposite negative contributions.

In addition to this, the frequency performance payments process is based on contribution factors that are averaged and normalised over each five-minute dispatch interval to determine individual contribution factors for the proportional allocation of payments and costs. This simplifies the application of the frequency performance payments formula through the allocation of proportional contribution factors for each market participant, and the residual, that range between -1 and 1 and sum to zero.

Unit performance is measured against a system frequency metric

Measuring unit performance to determine "helpers" and "causers", requires the comparison of unit performance against a system measure that reflects the need to raise or lower power system frequency. Several alternative system frequency metrics were considered as part of the investigations that informed the development of the frequency performance payments. These included raw frequency deviation and a number of functions based on system frequency. The goal of these investigations was to identify a system frequency metric that provided a transparent and consistent measure of the need to raise or lower the frequency of the power system.

Figure 2 shows a sample trace for a number of potential frequency-based metrics investigated as part of the development of the frequency performance payments: (17)

- Raw frequency deviation (Hz) — this is a measure of the real-time, unfiltered deviation of mainland system frequency with respect to 50Hz
- Smoothed Frequency (Hz) — this is a smoothed version of the real-time frequency deviation for the mainland system using a time constant of 35 seconds.
- Combined frequency (Hz) — 1:1 combination of raw and smoothed frequency
- Frequency indicator – this is a filtered measure of the requirement for corrective action by regulation units. It is determined by AEMO's AGC based on Area control error. (4)

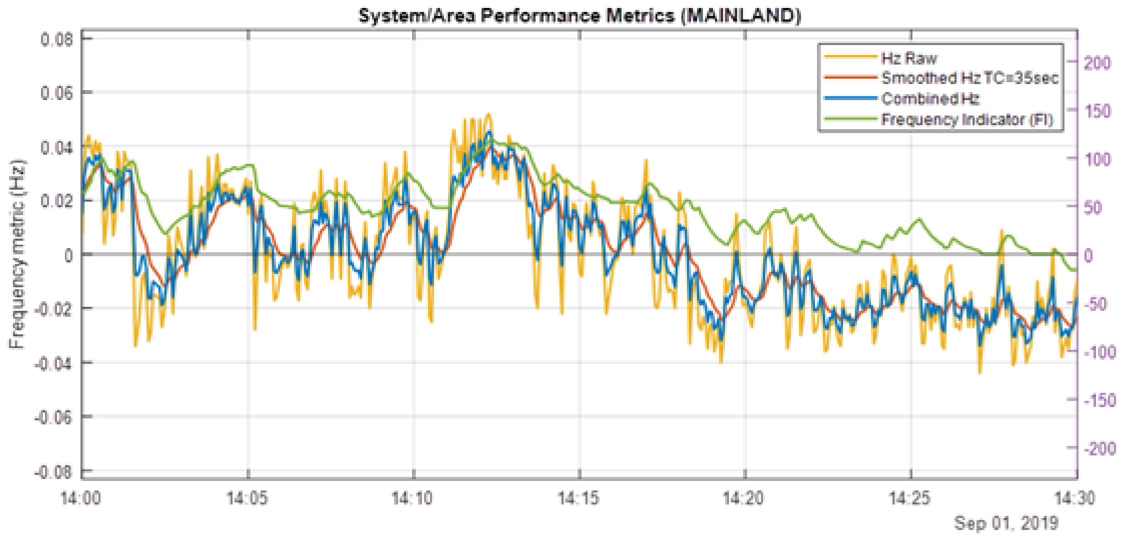

Figure 2 - Comparison of potential system frequency metrics

The AEMC recognised that there could be value in a system frequency metric being developed to reflect the need for immediate proportional active power response and also sustained response similar to the combined frequency metric shown above. Given the operational implications, the AEMC determined that AEMO would be required to define a formula for the system frequency metric and include this in its Frequency contribution factor procedure.[2]

The final rule requires that AEMO determine a measure of the need to raise or lower the frequency of the power system. This differs from the performance approach that underpins the existing causer pays process which relate to the need for regulation services. The new approach is more directly linked to the control of system frequency and allows for AEMO to determine a hybrid measure that may include multiple elements including raw frequency and a measure of the need for regulation (delayed and sustained) response.

Unit performance is measured with respect to the unit reference trajectory

As for the current causer pays process, individual unit performance is determined with respect to a reference trajectory. As shown in Figure 1, the reference trajectory represents the expected active power behaviour for each unit that receives an individual contribution factor. For scheduled and semi-scheduled generation and load, this is informed by each unit's target to target dispatch trajectory over each trading interval. For the residual component, the reference trajectory is the load forecast for the trading interval.

The new process maintains a target-to-target approach for the determination of the dispatch trajectory. This approach defines the reference trajectory based on the dispatch target at the end of a given dispatch interval and the dispatch target at the end of the previous dispatch interval. Alternative approaches were considered, including an initial to target approach, which would recognise that individual units often do not meet their dispatch target in each dispatch interval. The target to target approach was preferred as it maintains a continuous reference trajectory across multiple dispatch intervals. (17)

A key consideration was whether to require that the reference trajectory include the unit regulation component (the 4-sec signal sent by AGC for a unit that is providing regulation service to adjust load from the standard trajectory) in addition to its dispatch trajectory. It is conceivable that the

[2] On 7 February 2023, AEMO published a draft Frequency contribution factor procedure, it proposed a frequency metric based on an exponential weighted moving average, with a smoothing factor parameter (alpha) that adjusts the relative emphasis on timing of frequency deviations. (2)

regulation component should be included in the reference trajectory as the AGC-regulation signals are a form of unit dispatch, albeit delivered on a 4-second basis within the trading interval. (1)

This option was investigated and we demonstrated that the inclusion of the AGC-regulation component in the reference trajectory would be expected to lead to a 50% overall reduction in the value of net performance payments over the sample period. (17)

The long-run combined costs for regulation enablement and frequency performance payments would be expected to be relatively similar regardless of whether the reference trajectory includes or excludes the regulation component. This outcome is explained by the dynamic economic forces which would be expected to play out through market competition, noting that the fundamental costs for provision of frequency response are unchanged. (1)

Excluding the regulation component from the reference trajectory would result in more favourable performance measurement for enabled plant receiving a relatively larger share of the frequency performance payments as compared to the alternative. This approach would have the beneficial outcome of providing increased payments to regulation units that are allocated a disproportionate share of the regulation duty, due to good performance. These payments to enabled plant would be expected to put downward pressure on the market prices for regulation FCAS. It would also link the value of regulation services with the value of primary frequency response.

On the other hand, including the regulation component in the reference trajectory would result in less favourable performance measurement for enabled plant as compared to the alternative and maintain a separate valuation for regulation services and primary frequency response.

The final rule did not require AEMO to include the regulation component in the reference trajectory as the AEMC could not find sufficient justification for this approach. At the same time, the rule allows AEMO to consider “other factors” as it deems relevant in determining a unit reference trajectory. (1)

2.3 Payments scaled by the aggregate requirement for corrective response (RCR)

Another key element of the frequency performance payments arrangements is the requirement for corrective response (RCR). This is defined in the final rule with respect to each trading interval and each of the regulation services as “a measure of the total volume in MW that contributed to reducing the deviation in frequency of the power system”. RCR provides a simple representation of the ‘volume’ of corrective response required in each trading interval to raise or lower system frequency.

The concept of RCR is envisaged to include and account for the total of all helpful active power deviations across the power system. This recognises that there may be a significant quantity of active power deviations for metered plant that are balancing out harmful deviations without translating into a significant frequency error or a significant requirement for regulation services. The IES analysis developed a method for determining RCR, based on the aggregate dispatch error of all eligible units with appropriate metering. It reflects the cumulative ‘work’ done by all units acting to correct frequency deviations in the power system.

The process aggregated all deviations for metered plant (typically generation) and then presented these deviations as either above-target or below-target deviations. The above target deviations contributed to raising the frequency of the power system while the below target deviations contributed to reducing the frequency of the power system.

As shown in Figure 3, the RCR for raise is the maximum requirement to raise system frequency within a trading interval which is equal to the maximum cumulative above-target volume, when the frequency is below 50Hz. Similarly, the RCR for lower is the maximum requirement to lower system frequency within a trading interval which is equal to the maximum cumulative below-target volume when the frequency is above 50Hz.

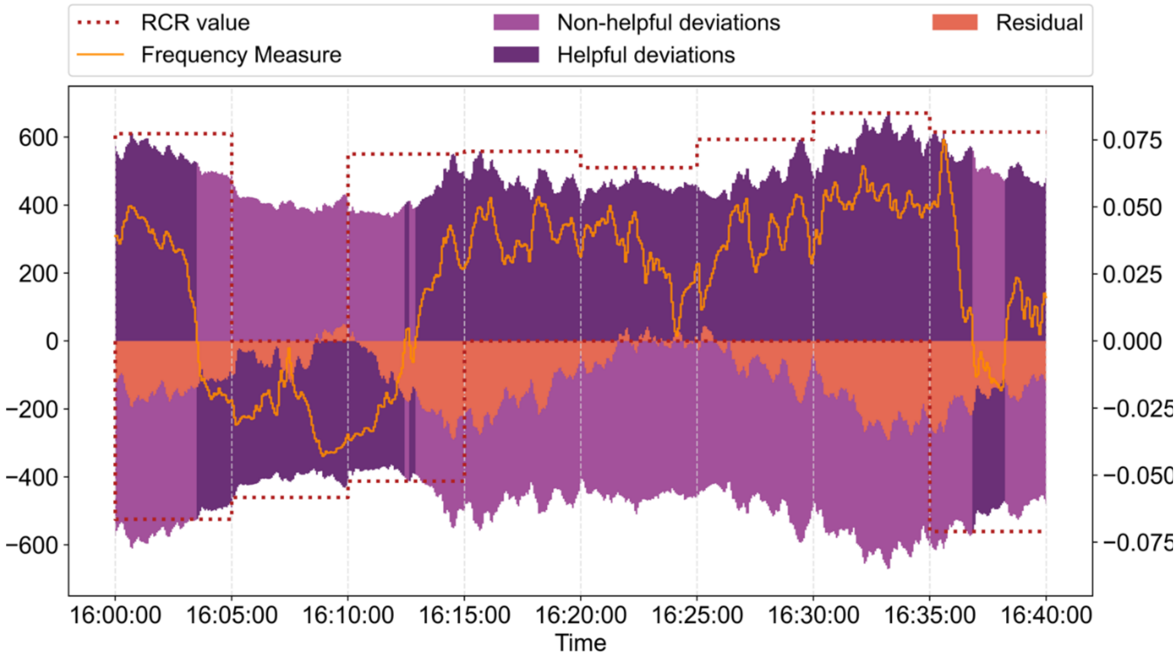

Figure 3 – Requirement for corrective response (19)

2.4 Payments valued by the relevant price for the regulation raise or lower service

Several potential approaches were considered for the financial weighting of the frequency performance payments, these included using:

1. the dispatch price for regulation raise and lower services
2. the expected price for regulation raise and lower services – based on the aggregate requirement for corrective action and the supply curve for each service
3. a combined price for both regulation services
4. the dispatch price for energy.

The Commission determined to use the dispatch prices for regulation raise and lower services as these price signals most closely matched the value of PFR over the 5-minute trading interval, including the relative value of raise and lower response. These regulation prices incorporate:

- the opportunity cost of withholding capacity for raise services, i.e. the value of energy withheld as headroom that could have been sold on the spot market
- the opportunity cost of unearned energy revenue when delivering lower services
- the utilisation cost of generating additional energy when providing raise services.

We note that the energy spot price would already be accounted for in the economically efficient short-run offer pricing for regulation services. This supports the use of the regulation price as an appropriate financial weighting. This conclusion was supported by Gilmore, Nolan and Simshauser in their 2022 work on the levelised costs of frequency control ancillary services. (19)

3 Analysis of estimated settlement outcomes

Net Frequency performance payments are expected to be around one-third of regulation enablement costs

Supporting analysis prepared by IES for the AEMC indicates that the scale of gross frequency performance payments would be expected to be similar in size to the total costs for regulation services. When taking into account payments and cost allocations that cancel out over the relevant period, the IES analysis results showed that the net value of frequency performance payments may be in the order of one-third of the costs of regulation services. In a static sense, the frequency payments would be expected to increase the aggregate costs and revenue associated with frequency regulation by about 30%. This was corroborated by analysis undertaken by AEMO in 2023. (2)

These results indicate that the scale of net frequency performance payments would be expected to be in the order of $30 million per year. As a point of reference, the historical average cost for regulation services in the NEM average over recent years (2020 to 2022) is $80 million.[3]

It is expected that the frequency performance payments will act dynamically to depress the total costs of frequency regulation by incentivising plant response that reduces the need for frequency regulation and supporting competition among market participants to be enabled to provide regulation FCAS. Following the implementation of the frequency performance payments arrangements, the price for regulation services would be expected to drop until a new dynamic equilibrium is found, where the combined revenue from frequency performance payments and regulation enablement balances out against the costs of providing PFR and regulation services.

Plant that provide PFR and/or regulation services are expected to be rewarded

Recent analysis by AEMO demonstrates that plant that is frequency responsive and/or enabled to provide regulation services are expected to profit from the frequency performance payments. Meanwhile variable renewable generation that is not frequency responsive and non-metered generation and load are expected to bear the costs of frequency performance payments. (21) These results are shown in Figure 4.

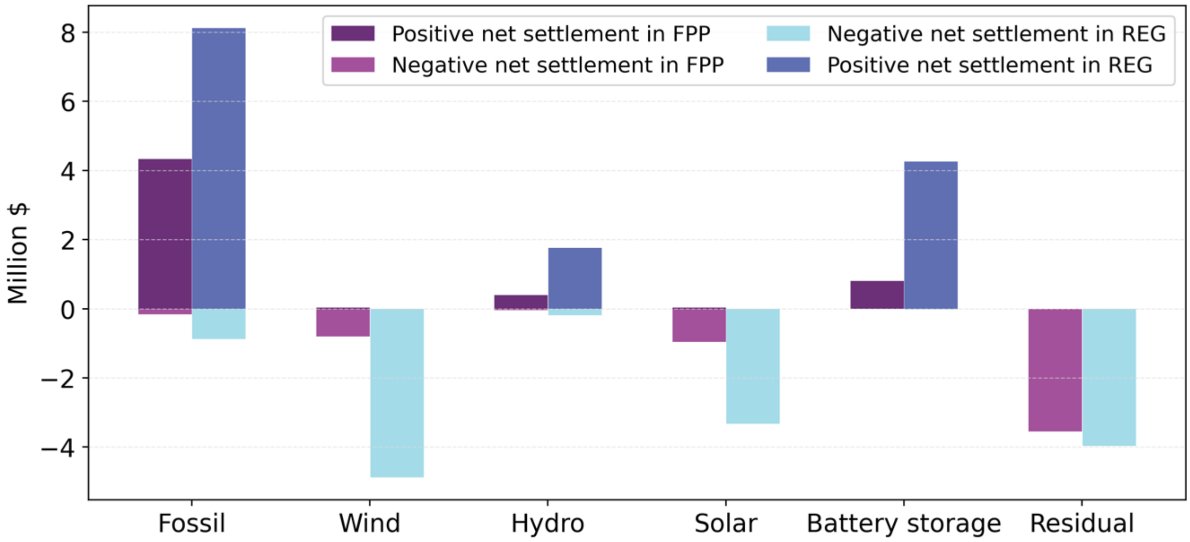

Figure 4 – Estimated net settlement outcomes based on historical performance - 20 Jul to 10 Oct 21

4 Conclusions and next steps

The new frequency performance payments build on the existing 'causer pays' arrangements for the allocation of regulation FCAS costs. They are designed to deliver improved valuation and pricing of plant behaviour that impacts on power system frequency. They will provide financial incentives to encourage innovation and investment in new capability to support the effective control of system frequency into the future.

[3] Further detail on historical costs for regulation services included in appendix A.

The new arrangements differ from the existing causer pays arrangements through:

- Valuation of positive unit performance
- The process for performance measurement and payment is shortened and aligned over a 5-minute dispatch interval.

The principles for the specification of the performance metric have been revised to more directly reflect the need to raise or lower the frequency of the power system. Under the new arrangements, plant that have appropriate metering and individual contribution factors will be incentivised to track their dispatch trajectory and respond to system frequency.

Much of the costs of the frequency performance payments will be borne by plant that are currently non-scheduled and do not have appropriate metering for individual performance measurement. This aspect of the new arrangements is expected to strengthen the incentives for non-scheduled participants to opt-in to get individual contribution factors by installing appropriate metering and registering with AEMO. They may also opt to provide self-forecasts if they think they can provide a materially more accurate forecast of their own behaviour than AEMO would do on their behalf. Two potential opportunities that could be considered to build on and expand the reach of the frequency performance payments would be:

- Ways to better incentivise plant that are currently non-scheduled, but wish to obtain individual contribution factors and improved forecasting and dispatch to become frequency response and provide self-forecast information, where it is in their financial interest to do so.
- whether and how to include distribution and customer resources, including through aggregations and virtual power plant arrangements.

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Appendix

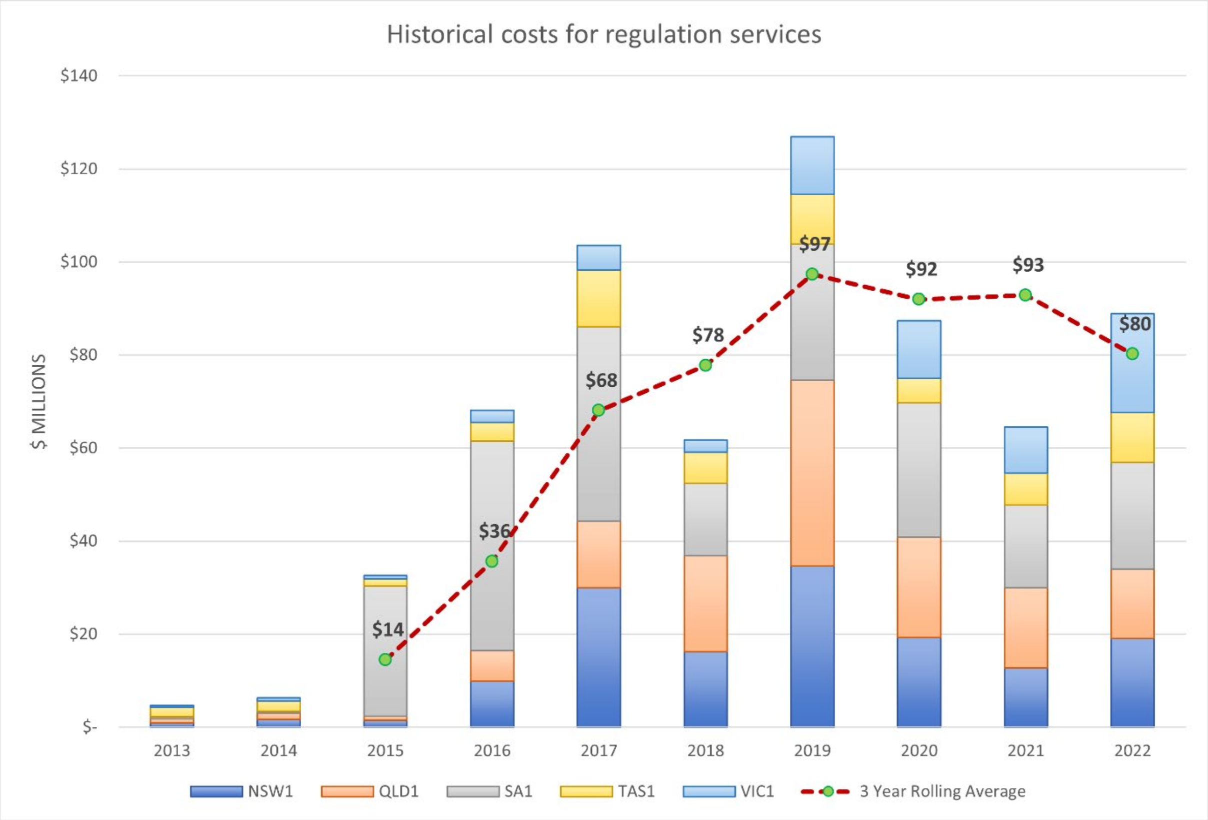

Figure 5 - Historical costs for regulation services in the NEM

Source: NEM market data - available at https://aemo.com.au/energy-systems/electricity/national-electricitymarket-nem/data-nem/market-management-system-mms-data/dispatch