AUSTRALIAN ENERGY COUNCIL

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By Email: Ben.Hiron@aemc.gov.au
CC: Andrew.Paver@aemo.com.au

Dear Ben,

Primary Frequency Response Incentive Arrangements
Reference: ERC0263

The Australian Energy Council (AEC) has developed the attached contribution to the Frequency Control lines of work that are presently being undertaken within the AEMC and AEMO. Whilst this contribution is intended to be used broadly, please accept it also as an out of session submission to ERC0263

The AEC is the industry body representing 22 electricity and downstream natural gas businesses operating in the competitive wholesale and retail energy markets. These businesses collectively generate the overwhelming majority of electricity in Australia, sell gas and electricity to over ten million homes and businesses, and are major investors in renewable energy generation.

The contribution was developed by the AEC's "Frequency Control sub-group" which is keen to see implemented an economically sustainable procurement of Primary Frequency Control (PFR) within the narrow-band frequency characteristic of the National Electricity Market (NEM). The group felt it would be beneficial to describe and qualitatively analyse the key candidates. This enabled the group to narrow down the candidates to those the members felt had most promise.

This is described in the attached report which we are pleased to contribute.

Any questions about this submission should be addressed to the writer, by e-mail to Ben.Skinner@energycouncil.com.au or by telephone on (03) 9205 3116.

Yours faithfully,

Ben Skinner
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Economic procurement of Primary Frequency Response

September 2020

1. Executive Summary

The Australian Energy Council (AEC) has engaged closely with the question of how to procure National Electricity Market (NEM) Primary Frequency Response (PFR) for several years. Whilst it accepts the decline in frequency performance in recent years required correction, the AEC does not consider that the current rule – unrewarded mandatory PFR from all capable plant to a near-zero deadband – is sustainable in the long-term. That rule sunsets in June 2023 and should be seen as purely an emergency measure. In the meantime the industry must find a long-term economically sustainable PFR mechanism.

The 2018 AEMC Frequency Control Frameworks Review (FCFR) and other activities have proposed a range of possible models. The industry's failure to move ahead on these is perhaps because there are too many options, and it is unclear where to focus. In response to this, the AEC Frequency Control Sub-Group has completed a desktop exercise to winnow down the options to help focus the market bodies.

This exercise defined and considered in detail seven PFR procurement options and their pros and cons. These then were evaluated against each of:

- Economic efficiency;
- Practicality of implementation; and
- Power System Security confidence, from the perspective of the System Operator.

From this, two equally ranked "pathways", that involve a combination of options and steps were ultimately selected as most promising. These are described below.

Both pathways involve an initial stage that incorporates the existing mandatory PFR rule, which provides effectively a "soft-start" to the new regime. These initial stages are guaranteed to provide at least equal, and most likely superior, system security to the current rule, but are themselves not economically sustainable in the long-term. They are then replaced with a long-term design that will provide the correct signals for investment and performance. The preferred timing of stage 1 is at least a year before the sunset, with stage 2 taking effect from the sunset.

Pathway A: PFR Frequency Control Ancillary Service (FCAS)

This pathway involves:

- **Initial mandatory stage**:
  - Continued mandatory provision of near-zero deadband PFR without stored energy; and
  - A new raise and lower PFR FCAS, designed as per existing FCAS markets, with enabled providers supporting their narrow-band PFR response with stored energy.
- **Long-term design**:
  - Continued mandatory provision of wide-band PFR without stored energy to provide a system security safety-net for non-credible power system events.
  - A raise and lower PFR Frequency Control Ancillary Service (FCAS), designed as per existing FCAS markets, with enabled providers providing narrow-band PFR response supported with stored energy.

Pathway B: Double-sided Causer-Pays (DSCP)

This pathway involves:

- **Initial mandatory stage**:

    - Continued mandatory provision of near-zero deadband PFR without stored energy; and
    - Implementation of the DSCP mechanism.
- **Long-term design**:
    - Continued mandatory provision of wide-band PFR without stored energy to provide a system security safety-net for non-credible power system events.
    - Operation of the DSCP mechanism to provide a natural incentive to deliver disaggregated narrow-band PFR with stored energy.

The AEC recognises that DSCP is not yet fully technically described and modelled. To this end, the AEC is seeking to co-fund with the Australian Renewable Energy Agency (ARENA) work by Intelligent Energy Systems (IES) to deliver this advice in early 2020.

Whilst the AEC recommends that the focus now narrow down to these two pathways, the AEC does not have a preference between them at this time. The AEC notes however that Pathway B is dependent on a successful conclusion of the IES research in early 2021.

2. Introduction

2.1 Purpose

This paper evaluates options to procure National Electricity Market (NEM) Primary Frequency Response (PFR) in an economically and technically sustainable manner as a long-term alternative to the present mandatory provision of narrow band PFR.

This paper was developed:

- With broad engagement and consensus of the Australian Energy Council (AEC) frequency control subgroup;
- To assist thinking and focus for all parties;

2.2 Background

The NEM is presently under a temporary rule of mandatory provision of PFR to a 15mHz deadband from all capable providers, without a requirement for stored energy and without financial recompense.

Whilst this has been brought in to manage a problematic frequency characteristic, the AEC considers that in the long-term, uncompensated mandatory narrow-deadband PFR is a poor long-term solution as it[1]:

- Places an unreasonable operational burden and cost upon generators capable of PFR;
- Fails to recruit a known level of PFR and headroom[2] at any time, creating the risk of future shortfalls as the system changes;
- Does not attempt to find the optimal balance between system security benefit versus cost (i.e. cost to all parties, including PFR suppliers);
- Provides no incentive to invest in new PFR supply, especially batteries;
- Creates perverse incentives to under-invest in PFR capability to seek exemption;
- Distorts the value of the Frequency Control Ancillary Services (FCAS) markets; and

[1] These concerns are explained in the AEC submission to the mandatory rule change https://www.energycouncil.com.au/media/17393/20191031-erc0274-aec-submission-to-primary-frequency-response-final.pdf

[2] In this document "headroom" implies the ability to increase output (stored energy) AND reduce output (footroom)

- Affects the expected performance of the FCAS markets.

2.3 Defining Frequency Response Bands

For this paper, frequency control has been presented as three parts of the spectrum:

- *Narrow-band* being techniques used to correct the frequency when it sits within the Normal Operating Frequency Band (NOFB) of 50 ± 0.15Hz. This responds to continuous power system swings caused by natural movements in demand and variable generation sources. Regulation FCAS is designed to activate secondary frequency control for this purpose.
- *Contingency-band* being that range outside the NOFB beyond ± 0.15Hz as expected following credible contingencies such as the loss of a large generator or potline. The Contingency FCAS acts within this range.
- *Wide-band* being that range beyond about ± 0.50Hz which should only emerge following non-credible contingencies such as the loss of an interconnector.

2.4 Developing sustainable options

The Australian Energy Market Commission's (AEMC) 2018 Frequency Control Frameworks Review floated several broad designs but did not develop them ahead of the mandatory rule. This paper describes the leading (non-exclusive) options that the subgroup has considered, and describes their individual costs and benefits.

In summary these are:

	PFR Option
(a)	Mandatory uncompensated narrow-band PFR without headroom
(b)	Mandatory uncompensated wide-band PFR without headroom
(c)	Voluntary narrow-band PFR via an enablement based FCAS market;
(d)	Use of existing "Contingency" FCAS markets to achieve a narrower Normal Operating Frequency Band (NOFB)
(e)	Double-sided Causer Pays (the IES / Creative Energy Consulting approach);
(f)	Mandatory narrow-deadband PFR with a regulated payment;
(g)	Modifying Regulation service for providers to supply both secondary and PFR

Note that several of these options are not mutually exclusive. For example, a regulated payment could be applied to resources not included in a PFR market (option (c) above) or not eligible to deliver Regulation FCAS (option (g) above).

A comparative analysis is presented at the end of the report which ultimately concludes in favour of two preferred alternative "pathways" which apply combinations of options in two stages: a "soft-start stage" followed by a long-term arrangement.

3. Option (a) Mandatory narrow-band PFR

This is the existing mandatory rule that the AEC does not consider sustainable in the long-term. It is presented here purely to provide transitional security confidence towards the economically sustainable models discussed further on.

3.1 How presently operates

Design element
All capable units are required to maintain PFR with active deadbands down to ±0.015Hz.
Headroom is not obliged and is purely opportunistic.

3.2 Advantages and Disadvantages

Advantage	*Disadvantage*
Theoretically activates the greatest possible number of governors for the current fleet and operating condition and provides AEMO operational confidence	Provides no certainty of number of active governors nor level of headroom.
Does not require Reliability Panel or AEMO to specify a desired outcome.	Likely to be operating an inefficiently high amount of PFR.
Shares deviation burden across a wide number of providers	Drawing inefficiently low volume from low cost providers and inefficiently high volume from high cost providers
No explicit costs passed through to customers	Costs inefficiently emerge in other ways, e.g. barrier to entry
	Distorts the value of FCAS services as AEMO buys less regulation and the marginal cost of being enabled for contingency services revealed through bids is suppressed.
	Frequency support will be insufficient during periods when conventional generators are de-committed during high renewable output.
	Not a long-term solution given the coming retirements of the conventional generators that it relies upon.

4. Option (b) Mandatory wide-band PFR

In their report into the 25 September 2018 event, AEMO desired all capable resources participating in frequency control to respond to extreme (particularly non-credible) frequency events. However, this does not need a very narrow 15 mHz deadband (which will require even more expensive resources to respond to small disturbances). In parallel with other options, a mandatory requirement could be maintained purely for extreme events. This would ensure that, in the event of non-credible contingencies, opportunistic headroom may act to reduce the level of automatic load or generation shedding.

4.1 How this could work

Design element	*Options*
All capable units would be required to maintain active deadbands at a level well outside the operation of FCAS markets.	Propose [±500 mHz]. Must be wide enough to only activate in extreme events, noting very wide has lower security benefit.
Headroom would not be obliged.	System protection based on opportunistic headroom available from energy market.

4.2 Advantages and Disadvantages

Advantage	*Disadvantage*
Low burden on providers – rare governor movement or battery cycling required. No requirement to maintain headroom. Where unsuitable for plant, exemptions can be granted.	Provides no certainty of response for AEMO.
25 Aug 2018-type events will have a better frequency outcome, therefore providing greater confidence of the system surviving non-credible contingencies	Assists only in very extreme events.
Even if uncompensated, distortion to market-based options is very minor	Can only act as a safety net to other options.

5. Option (c) Voluntary narrow band PFR recruited via an enablement based competitive FCAS market

Under this approach, the Reliability Panel, under advice from AEMO, would determine a new NOFB Frequency Operating Standard, and the Rules would establish an enablement market for NOFB PFR analogous in design to the existing FCAS contingency services. The additional resources procured under this market would maintain the frequency tightly around 50 Hz.

The MASS would describe expected performance. Providers would register their PFR capability and bid PFR reserves (effectively headroom in MW). AEMO would convert the new NOFB standard into a required enablement volume and dispatch via NEMDE.

5.1 How this could work

Design element	*Options*
The Reliability Panel would determine a revision to the Frequency Operating Standard, presumably defining a new "narrow band" standard.	Standards could include: • Frequency must be within [±50mHz] for [95%] of the time, and then within ±150mHz for [99%] of the time • Retain cumulative deviation target (time error)
A new market for a tight deadband primary frequency control would be developed, and a new service defined	• Eligibility could be the 15 MHz PFR response currently required as a mandatory response, with some associated droop setting. • Alternatively, MASS could permit multiple classes of eligibility based on size of deadband with a scaler to payments. E.g., the deadband must be set at less than 50 mHz, but setting the deadband to 15 mHz would receive a [2x] multiplier on payments, reflecting the additional value of that service – with some scaling. • Could have a single maximum droop setting, or also allow variable droop settings with enablement value calculated through an expected average energy response expectation calculation similar to how MASS determines contingency FCAS. • Alternatively, multiple distinct services (with differing deadbands, etc.) could be defined, procured, and traded off by AEMO – but this would likely be complex. • Quantities could be co-optimised across all FCAS services, and, depending on service definitions, the same resource could deliver multiple services – e.g., NOFB PFR could also

	deliver Regulation (a local response updated to a central target; i.e., a general case similar to AEC's Option (g))
AEMO would determine the quantity of Narrow PFR to procure in order to meet the new FOS. This would likely be an empirical calculation.	• Procurement would likely be for a specific quantity (MW) of reserves at any one time • A "demand curve" approach could also be used to trade off the volume of services (e.g., more response could be purchased if prices are low, a "minimum spend" could be implemented, allowing AEMO to purchase up to some maximum, etc.). However, this approach creates more complexity and uncertainty and has not been pursued in FCAS to date.
Resources that were enabled for the service would be required to perform according to MASS and ex-post assessed similarly to the Fast Raise/Lower Contingency FCAS services.	• To maintain headroom in order to be able to deliver the offered capacity • To deliver a proportional response to the frequency (given the likely frequent utilisation, stricter requirements might be needed here) • In order to maintain headroom, scheduled providers would bid a trapezium-based offer structure as per the existing FCAS markets which would be co-optimised with energy.
Cost Recovery	• Could be like contingency FCAS: Socialised payments from generation for PFR raise and load for PFR lower. • Could be like regulation FCAS: Ex-post causer pays factors

5.2 Advantages and Disadvantages

Advantage	*Disadvantage*
The Reliability Panel defines a clear, acceptable and economically justifiable standard that the market can work towards meeting	Reliability Panel and AEMO have been reluctant to specify a standard & required PFR quantity to date – will be criticised for either gold plating or being insufficiently secure
Market driven approach, with price transparency, economically efficient use of resources, and a clear link to consumer preferences.	AEMO will need to accept the voluntary nature of participation. Incentives for resources not dispatched in the new market to participate in frequency control are limited to the existing Causer Pays (or minor modifications thereof)

Is arguably more secure than mandatory approach as it ensures a known quantity of headroom always remains available to support narrow-band PFR, including if changes to the system reduces the quantity of “free” headroom available. Better than existing arrangement that provides no guarantee of headroom availability as the system evolves – with a risk of future shortfalls.	Requires a relatively narrow definition of the service, which may not allow maximum participation.
Provides renumeration for services with a marginal price based on bids that (presumably) reflect the cost of provision.	New costs ultimately passed through to consumers in a largely socialised manner
Availability payments provide certainty to providers, with bids into the various markets co-optimised within the dispatch interval	.
Preserves existing FCAS markets, and builds on established co-optimised FCAS services approach	
By procuring “ahead” of time (i.e. through registration and at the start of the dispatch interval), provides certainty to AEMO that a known quantity and quality of PFR will be operational, assisting with system modelling	
Co-optimised trapezium bidding approach can be copied from the other FCAS and is well understood in the market.	

6. Option (d): Narrow band PFR enablement market operating with compulsory narrow band PFR

Noting the first two disadvantages in (c), a soft-start to a narrow-band enablement market could be created by initially requiring mandatory uncompensated narrow-band PFR to continue as per the existing rule.

The result of being enabled for the market would be a guarantee of headroom from units that were otherwise continuously PFR active. This would result in a system that was *at least as* secure than the existing rule in all circumstances and *more secure* in most circumstances.

Inevitably the existence of the mandatory requirement would distort the market, as the marginal cost of being enabled would usually be quite small, especially with respect to downrange response. Therefore the price would be expected to clear below the efficient value of PFR. Whilst that is distortionary, it could represent a “no-regrets soft-start” period to gain broad acceptance.

7. Option (e) Use of existing FCAS mechanisms via change to NOFB

Under this approach, the Reliability Panel would tighten the NOFB bounds from ±150 mHz to [±50mHz] and oblige AEMO to achieve it under their FCAS existing markets within the existing (post sunset) rules.

7.1 How this could work

Design element	*Options*
Existing Regulation FCAS (secondary frequency control)	AEMO would increase procurement and tighten AGC tuning targeting the more conservative NOFB standard.
Existing Contingency FCAS (PFR)	AEMO would respecify FCAS Contingency Services MASS to operate from the narrower edge of new NOFB. Contingency FCAS' would activate in what is presently considered "normal" (i.e. non-contingency) conditions.

7.2 Advantages and Disadvantages

Advantage	*Disadvantage*
Uses existing frameworks, and potentially requiring minimal regulatory and AEMO system changes.	AEMO is sceptical of secondary frequency control effectiveness and may be disinclined towards greater use of the Regulation service.
Would use contingency-based FCAS providers to support frequency performance in non-contingency conditions	Providers of the services formerly known as "contingency" would have to respond much more frequently than previously. This would likely cause some to withdraw, e.g. smelters.
Would provide remuneration to providers of PFR	Requires a relatively narrow definition of the service, which may not allow maximum participation.
Bids into the various markets are co-optimised within the dispatch interval	Prices of all FCAS services would go up (arguably closer to their true value).
Preserves existing FCAS markets, and builds on established co-optimised FCAS services approach	
Is arguably more secure than mandatory approach as it ensures a known quantity of headroom always remains available to support narrow-band PFR, including if changes to the system reduces the quantity of "free" headroom available.	
This has, to some extent, already been implemented by requiring a primary response from *generator* contingency providers at the	

mandatory deadband (15mHz), ahead of the 150 mHz NOFB trigger.	

8. Option (f) Double Sided Causer Pays (DSCP)

In this approach, a new ancillary service would operate entirely under a four-second SCADA causer-pays logic. Although the design is drawn from that used to recover FCAS Regulation costs, FCAS Regulation would remain as is.

8.1 Description of existing Regulation Causer Pays

In the existing Causer Pays calculation, if participants deviate from their dispatch trajectory in a way that makes the frequency worse (i.e. they are below target when the frequency is low, or vice versa), then a penalty is determined for the participant. The penalty is the product of the volume of the deviation and the size of the frequency error measured during that four second interval.

These penalties are then accumulated over four weeks. Participants then must fund AEMO's FCAS regulation costs in the following four weeks' in proportion to the size of the penalty they previously accrued.

The logic of this allocation is that it charges those who "caused" the deviations that created the need for the FCAS regulation service in the first place. There are obvious limitations to that existing arrangement, such as:

- The four-week lag means that participants are not paying in proportion to their current performance, but rather based on an assumption that historical performance will continue; and
- Only penalties are recorded, i.e. deviations from target that assist in correcting the frequency are not rewarded.

8.2 DSCP - how this could work

IES[3] and Creative Energy Consulting have both proposed alternatives to the causer pays concept, but without the two limitations above. Specifically:

- All deviations from linear dispatch targets are calculated every four seconds (though not actually in real time)
- Those participants who are making the frequency worse (i.e. the penalty described above) pay those participants who are making the frequency better.
- As with the existing causer pays, the payment quantities are a product of the deviation and frequency error (with some pricing function), but the transaction is resolved in the four second interval, i.e. there is no four-week accumulation.

This way, generators mandated by the new rule to provide PFR can be rewarded in accordance to their actual observed performance, thereby creating an incentive to perform. Alternatively, the mandatory provision could be removed and the DSCP payment relied upon as the sole signal for narrow deadband PFC.

Unscheduled demand also contributes to the frequency error. AEMO's demand forecast is effectively a "dispatch target" and to the extent actual demand varies from it, this affects frequency in the same way as a generator missing its target. In both the existing process and IES' approach, demand is treated the same way as a generator. Demand causer-pays costs (or possibly rewards) are passed on to customers as a class.

[3] https://www.csenergy.com.au/news/new-report-proposes-options-for-incentivising-frequency-services#:~:text=IES%20proposes%20a%20double%2Dsided,who%20cause%20the%20frequency%20deviations.

8.3 DSCP Pricing Options

Having worked out the volume of causer pays or causer support, there is the key question of what price to apply to these volumes – there is no obvious value to draw upon.

- IES recommends using a centrally determined estimate of the opportunity costs of supporting frequency from a standard thermal generator. However, this is likely to be difficult to determine accurately, will vary over time, and may not reflect provision from other sources.
- Creative Energy Consulting suggests that the price of the FCAS Regulation market as a proxy for the opportunity cost of either withholding energy from the energy market (Raise) or generating above minimum load (Lower).

Pricing functions could:

- Be flat, such deviations are priced/penalised the same regardless of frequency performance
    - This would encourage participants to deliver a response (or meet their dispatch target) regardless of frequency performance, with no price discrimination between resources
- Increase with the size of the deviation – providing greater penalties [payments] for deviations from dispatch trajectories that lead to [help mitigate] large frequency deviations.
    - The status quo Causer Pays pricing function has a linear trajectory.
    - This function would allow low-cost resources to support small frequency deviations (e.g., +/- 50mHz) while more expensive resources could have a wider deadband but receive a higher payment
- (While early response to deviations is desired, a pricing function that pays a higher price at small deviations but less when deviations are worse does not seem appropriate)

8.4 Advantages and disadvantages

Advantage	*Disadvantage*
Can be introduced without requiring any overtly new “outcome” objectives or standards: AEMO does not have to specify a quantity of PFR to be procured.	Pricing function may be difficult to determine efficiently and itself requires a trade-off between security and cost.
Provides strong real-time signals to participants to maintain headroom, which could provide the incentive for much of the PFR to voluntarily continue to be provided after the obligation sunsets in 2023.	If mandatory requirement is maintained, may not allow for price discovery or for the least-cost mix.
During the mandatory rule, frequency will tend to operate closer to 50.00Hz than it has previously, so the deviations payments would presumably be small: a consequence of the obligation forcing an oversupply of PFR.	Lack of a standard may make assessing effectiveness of the approach difficult.
Some designs would allow for Regulation Causer Pays to be incorporated into the scheme and to put performance incentives onto Regulation providers.	Complex to model and forecast (both on planning and operational timescales).

	Risk of adverse behaviours or frequency outcomes if participants respond quickly to swings in frequency (particularly if there is response lags).
	Places greater reliance on 4s data, which is typically low quality; this is currently used for Causer Pays, but errors may currently be less material (i.e., not as correlated with specific price events).
	Settlement during contingency events could be quite extreme and create risks, in particular following separation events.
	Relies on uncertain usage payments to incentivise availability, e.g., no opportunity for AEMO to acquire prudent reserves.
	Does not allow price discovery through bids for the provision of the service; the price function must be externally imposed and hopefully set at a level that encourages response – this could be adjusted empirically by AEMO (as with the current Regulation volume), however this may lag investment needs.

9. Option (g) Mandatory provision with regulated payments (Norway approach)

If mandatory PFR was maintained a regulated payment could be made to PFR providers to:

- Reflect the cost of provision from existing units, and
- Provide an incentive for future investment in PFR capable plant

9.1 How this could work

Design element	*Options*
Regulator determines fair payment based on costs of provision.	Assess based on a theoretical model unit.
Regulator recognises different quality of service.	Develop a method to assess equivalent PFR effectiveness across activated plants and adjust the payment accordingly.
Headroom provision and performance.	• Do not oblige headroom, and withdraw payment only if repeated unexplained non-delivery. • Do not oblige headroom but take note of actual response (e.g., based on 4s deviations that help the frequency, possibly only for providers not delivering FCAS Regulation). This could be used as part of the method to assess effectiveness described above, or it could be an ongoing small regulated payment to provide some compensation to those who elect to hold headroom. However, this would be complex.

9.2 Description and experience of Norwegian Arrangements[4]

Summary of key observations from Ramboll:

- The generation mix in Norway is predominantly hydro and wind.
- In the Nordic region, the balancing markets are divided into primary reserves (FCR), secondary reserves (FRR-A) and tertiary reserves (FRR-M). Primary and secondary reserves are activated automatically in response to changes in frequency, while tertiary reserves are activated manually by the Nordic TSOs. The Norwegian TSO, Statnett, is responsible for ensuring that there are always sufficient primary reserves.
- Norway has a mandatory PFR service, but payment is at a fixed nominal (administratively determined) cost for “residual” service.
- Value is low 2 kr/MW/h (~AUD$0.30/MW/h) for “activation”.
- The transmission system operator (TSO) requires that generators above 10 MVA can have a maximum of 12% droop if they are not active in the market. During summer this requirement is strengthened to a maximum of 6%.
- There is a financial penalty should you not comply however little detail on it. In the joint Nordic system (Finland, Sweden, Norway and East Denmark), the obligations

[4] See Ramboll: Ancillary Services from New Technologies Dec 2019

for maintaining reserves have been agreed in System Operation Agreement between the Nordic Transmission System Operators (TSOs).

- More renewable generation resulting in more frequent, less predictable and large imbalances within the operational hour.
- The frequency quality in the Nordic power system has still deteriorated particularly in low inertia situations with:
    - Larger imbalances caused by forecast errors and HVDC ramping presenting a challenge for the TSOs (which includes Norway).
    - Increased need for, though reduced access to, reserve capacity in the current market situation.
    - Concerns in the availability of transmission capacity for frequency and balancing reserves.
- In 2025 the inertia is estimated to be below the required volume of 120–145 GWs 1-19 per cent of the time depending on the climate year. The Nordic operators note that the main challenge lies in maintaining sufficient inertia in the system to guarantee operational security.
- Results indicate that during some periods and especially summer periods availability of the rotating generation can be limited. During some periods of time the level can be insufficient for securing of the system frequency in case of disturbances in the system.
- The technical requirements for primary reserves are being redesigned, at the end of 2019, to guarantee sufficient primary response in the future. Initially, rather strict requirements were proposed which were able to secure frequency stability down to rather low inertia without having to reduce the reference incident nor introduce a faster reserve. This, however, came at the price of having difficulties of pre-qualifying enough reserves. Some units could not prequalify at all or had their reserve capacity heavily reduced.

9.3 Advantages and Disadvantages[5]

Advantage	*Disadvantage*
Provides some compensation for the burden of the mandatory requirement.	Does not necessarily deliver headroom, particularly as the grid transitions.
Somewhat lessens the perverse incentive in the mandatory requirement to intentionally not build or maintain quality PFR capability.	There is no available “fair” price, it will almost certainly be arbitrarily decided based on regulatory bargaining.
Potentially very simple to implement (aside from determining the price and equivalent effectiveness).	Whilst the mandatory provision remains, providers’ bargaining position is very weak so price will likely end up being a nominal quantity, in which case industry acceptance will remain poor.
Could be implemented immediately.	Does not discriminate between low- and high-cost providers – no opportunity to incentivise the most efficient system.
Maintains the mandatory provision satisfying AEMO.	Does not on its own target an efficient level of frequency control.
Could be implemented in conjunction with other schemes, e.g., as a payment to	As seen in Norway, the mandatory approach with some remuneration does

[5] See Ramboll: Ancillary Services from New Technologies Dec 2019 and ENTSOE Fast Frequency Reserve – Solution to the Nordic inertia challenge 13 December 2019

participants that help the frequency even when not accepted into a market.	not necessarily prevent frequency issues, the changing generation mix still causes problems.
	Norway shows this requires frequent adjustment and update.
	Not providing sufficient investment to handle future primary frequency control. Hence why Norway technical arrangements are being reviewed at the end of 2019.
	The remuneration does not appear to be sufficient to remunerate investment. Norway is investigating a market approach which suggests this is not a long-term proposal.
	Wear and tear on Norway plant with changing requirements over the summer periods.

10. Option (h) Modify Regulation service to include PFR

Require Regulation FCAS providers to also provide a limited quantity of narrow deadband PFR.

AEMO would adjust the MASS to include PFR in the processes arranged for bidding, pre-dispatch, dispatch, settlements, performance review and reporting.

Regulation providers are already required to reserve headroom, which would be required to also be made available for PFR. Any PFR response would transition into a Regulation response once the secondary frequency control systems (AGC) took over.

10.1 How this could work

Design element	*Options*
Obligations on providers: 3 variants	1. Delivery of PFR could be a mandatory requirement for Regulation providers; this would reduce the pool of FCAS providers but provide certainty over the quantity; 2. Delivery of PFR could be mandatory if (and only if) the provider has the capability; this would maximise FCAS participation, but leave uncertainty in the quantity of PFR; or 3. Providers could indicate their capability (either through economic bid bands, or through a mandatory-if-capable provision requirement) and AEMO could procure Regulation services to meet minimum requirements for PFR and the original Regulation service (effectively, a constraint equation that must be satisfied). In all approaches providers would need to indicate to AEMO the quantity of standardised PFR that could be delivered (based on stored energy, droop, etc.).
Procurement quantity	• opportunistic (as much as possible), • sufficient to meet a standard (e.g., a % of demand), or • a fixed quantity Delta has proposed a method assigning a need for PFR based on a fixed percentage of real-time demand in a region with adjustments for the demand to include 50% of rooftop solar generation and for regional export/import quantities (for raise/lower PFR demand calculation). For dispatch, regional import/export support (for raise/lower PFR dispatch) would be ignored and in this way the dispatch would aim to always have PFR in case of sudden unexpected interconnector loss.

Dispatch and Pricing	In dispatch, AEMO would dispatch FCAS regulation conventionally and some or all Regulation providers would provide PFR support. The FCAS bidding trapezium naturally reserves a level of headroom (up and down). In the third variant (PFR constraint) the price of Regulation could either be determined by the highest price dispatched unit (similar to other constraint equations – meaning PFR incapable Regulation providers could be constrained off), or there could be a framework for AEMO to select units out of merit order such that only the price of the last required conventional regulation would be used to set the price. In this case, some pricing function would be needed for the higher cost units. Delta proposed preserving the existing Regulation service procurement but have a parallel procurement for additional PFR with a form of price adder if required.

10.2 Advantages and Disadvantages

Advantage	*Disadvantage*
Only MASS change required, no Rule change requirements for variants 1 or 2, but possibly for 3 if new pricing function.	Not all providers of Reg FCAS are suited to PFR and vice versa.
Uses existing headroom procurement, and *many (but not all)* FCAS providers could deliver PFR.	Variant 1 would exclude Regulation FCAS providers who could not met the PFR requirement, while the others might not provide certainty of PFR procured.
No mandatory procurement.	PFR providers without an AGC/Regulation capability would be unable to participate.
No major system architectural changes except a need to calculate a continuously required PFR demand based on an assigned percentage of energy demand.	
Can be blended with both the development of a standard and double-side causer pays to provide the overall solution.	The cost of Regulation FCAS and PFR may not be aligned, or more than efficient levels of one service may be procured due to only a single “lever” (in some designs).
Only MASS change required, no Rule change requirements for variants 1 or 2, but possibly for 3 if new pricing function.	May not be palatable to AEMO, who wants wider participation.

	Outcome could be costly and may need divisors on settlement and regular economic review to have adjustments set right to compromise providing satisfactory incentives whilst not imposing unreasonable expense. (However, as FCAS is generally paid for by causers, if the causer assessment process is fair, unreasonable costs should provide incentives to improve performance and reasonable rewards provide incentives to over perform).
	May depend on artificial cost ramps to stimulate new PFR delivery (the option potentially could overcome this).

11. Comparative Analysis

As noted, the above options need not (and likely should not) be implemented in isolation. A combination of these options can lead to more effective overall outcomes – balancing economic efficiency with "backstop" system security. Several combinations of options are considered below, and evaluated against:

- Economic Efficiency & Competition – how likely are these options to deliver efficient economic outcomes, making the best use of resources?
- Implementation practicality – how complex or costly will these reforms be to implement, and will there be potential challenges?
- Comparison to AEMO position – how do these options compare against AEMO's positions to date on addressing the immediate need for improved frequency control?

(We consider that all these options, to greater or lesser degree, could be used to improve frequency performance and therefore the Economic Efficiency criteria is the primary performance evaluation metric.)

A ranking of 1 – 5 was chosen as a way of providing comparisons within the categories.

	PFR Option
(a)	Mandatory uncompensated narrow-band PFR without headroom
(b)	Mandatory uncompensated wide-band PFR without headroom
(c)	Voluntary narrow-band PFR via an enablement based FCAS market;
(d)	Use of existing "Contingency" FCAS markets to achieve a narrower Normal Operating Frequency Band (NOFB)
(e)	Double-sided Causer Pays (the IES / Creative Energy Consulting approach);
(f)	Mandatory narrow-deadband PFR with a regulated payment;
(g)	Modifying Regulation service for providers to supply both secondary and PFR

Combinations	Economic Efficiency & Competition 1-5	Implementation practicality 1-5	Comparison to AEMO position 1- 5
A: (c) only	5 –Voluntary competitive common clearing price market with headroom√	3 – New FCAS narrow band service to be created×, but largely along lines of other services√	2 – AEMO has expressed low confidence in relying only on market processes for security. × AEMO has resisted defining the volume of service required. × Purchases known quantity of headroom as per contingency and regulation√
B: (b) + (c)	4 – Voluntary competitive market for narrow band PFR√, Supported by mandatory wideband backstop for major contingencies which will distort competitive contingency FCAS markets×.	3 – Like A	3 – As with A, but wideband backstop gives some comfort√.
C: (a) + (c)	3 – Voluntary competitive market for narrow band PFR with headroom√, Distorted by mandatory requirement to provide continuous PFR ×.	3 – Like A	4 – Gives a *more* secure system than current rule (a) because it is both mandatory and guarantees some headroom √ AEMO has resisted defining the volume of service required. ×
D: (d)	3 – Competitive bidding√ Design will exclude efficient provision of contingency FCAS from those who can't do PFR and vice versa×	4 –New FOS required×, No systems changes: achieved by adjusting MASS criteria to require "contingency" providers to also respond to narrow band frequency movements√	1 – AEMO has expressed low confidence in relying on market processes for security× Will need to specify a secure volume – likely determined empirically, like existing Regulation. × No wide-band backstop. ×

Combinations	Economic Efficiency & Competition 1-5	Implementation practicality 1-5	Comparison to AEMO position 1- 5
E: (b)+(d)	2- Like D Mandatory backstop further distorts contingency services×.	4 – Like D.	3 – Like D but backstop provides some comfort√.
F: (e)	4.5 – Pays according to actual performance√. Pricing function must be centrally determined rather than based on bids, or drawn from Regulation services as a proxy×.	2 – New settlement system based around causer pays must be developed. × Pricing function to be developed. ×	2 – AEMO may be fearful that most PFR gets withdrawn×. Will need to be convinced that system is functional and stable×. Does not require AEMO to specify a secure volume√.
G: (e) + (b)	4 – Like F but mandatory wideband backstop for major contingencies which will distort competitive contingency FCAS markets ×.	2 – Like F	3 – Like F but backstop provides some comfort√
H: (e) + (a)	3. – Like F but mandatory PFR continues×. Mandatory provision makes regulator happy to bias pricing function to under-reward×.	2 – Like F	4.5 – AEMO will consider mostly an extension of mandatory arrangements√. Will need to be convinced that system is functional and stable×.
I: (f)	1 – Mandatory PFR continues× Regulated payments known to be inefficient and clunky×.	3 – No operational changes √ Complex regulatory determination× Moderately complex new settlement system ×	5 – AEMO will consider mostly an extension of mandatory arrangements√. Toughest task given to AER.

Combinations	Economic Efficiency & Competition 1-5	Implementation practicality 1-5	Comparison to AEMO position 1- 5
J: (g)	3 - Like D. Competitive bidding√ Design will exclude efficient provision PFR from those who can't do secondary frequency response and vice versa×	5 – No systems changes√.	2 – No mandatory PFR×. Will need to specify secure quantity – regulation and PFR procured together ×. Concern about decline in regulation providers×.
K: (g) + (b)	2 – Like I. Mandatory backstop further distorts contingency services×.	5 – No systems changes√.	3 Like I but backstop provides some comfort√.

11.1 Results of comparative Analysis

Weakest Combination

Combination **I** (Mandatory PFR with regulated payment) – scored weakest and should not be pursued.

Medium-scoring Combinations

D (Extending Contingency FCAS into NOFB) and **E** (with wideband backstop) had design simplicity attractions, but there was fear that it would confuse the existing FCAS markets and exclude some existing contingency providers from the market.

J (Regulation FCAS providers must also deliver PFR) and **K** (with wideband backstop) also had simplicity attractions, but there was fear this could exclude good Regulation providers who can't presently provide PFR. The variants that attempt to correct for these exclusions lose the benefit of simplicity.

Highest-scoring Combinations

Pathway One

A (New PFR FCAS market) was the highest from an economic efficiency point of view but weak in comparison to AEMO's position. If this is combined with the wide-band backstop **B** it would be a little less efficient but provide some more apparent security. If combined with mandatory narrow-band PFR **C** it would be much less efficient, but would, due to known headroom, have even greater security than the current rule (a).

From this a view was formed that a pathway was to begin briefly with **C** in order to gain confidence, say for one year, and then move to **B**.

Pathway Two

F (Voluntary double-sided causer-pays) scored amongst the highest for economic efficiency. When combined with the wide-band backstop **G** it was somewhat less efficient but could provide more security confidence. When combined with mandatory narrow-band PFR **H** it was less efficient again, but the same or even more secure than the current rule (a) because it incentivises performance.

From this a view was formed that a pathway was to begin briefly with **H** to gain confidence, say for one year, and then move to **G**.

11.2 Conclusion

The process has been useful in filtering out many of the options which hold less promise and focussing on two mutually exclusive main themes:

- A new narrow-band PFR FCAS service; and
- DSCP

These can each be phased in through a period of overlap with the current rule, providing a safe environment to develop confidence in the performance. However after a brief demonstration period, mandatory narrow-band PFR must end, but the regime may continue to be supported by mandatory wide-band, to assist in saving the system from extreme non-credible contingencies.

Pathways One and Two each looked roughly equivalent in terms of our assessment criteria and the AEC is presently unable to identify a preference. If the technical results emerging from IES' detailed DSCP analysis prove problematic, then Pathway One would become the AEC preference.