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Level 45
152 St Georges Terrace
Central Park
Perth WA 6000

Postal Address:
PO Box 7096
Cloisters Square
Perth WA 6850

T 08 9469 9800

Mr John Pierce
Chairman
Australian Energy Market Commission
PO Box A2449
Sydney South NSW 1235

By online submission

Dear ~~Mr Pierce~~ John

Frequency Control Frameworks Review: Issues Paper

Thank you for the opportunity to respond to the AEMC's Frequency Control Frameworks Review (Review) Issues Paper dated 7 November 2017.

This Review provides a timely opportunity to undertake a wide-ranging review of frequency control in the National Electricity Market (NEM). The frequency control framework currently employed in the NEM was established when conventional plant and passive load was the norm. With the power system undergoing widespread changes, it is timely and indeed necessary to re-examine needs and capabilities to ensure that the NEM has a robust, efficient and cost effective frequency control framework that will be able to adapt to the needs of the grid in the coming years.

AEMO believes that contemplating the needs of the system in the coming years is best done by examining plausible future scenarios and assessing what the technical requirements of such a system will be and how they might be delivered. As an example of this approach, AEMO is developing the likely topology of the NEM in the next 10 to 20 years through its Integrated Grid Plan and also engaging with international system operators through the GO15 to examine what will be required to operate such a grid successfully and efficiently. System service requirements such as frequency control will be a particular focus. It would be useful for the Review to adopt a similar approach so that the frequency control framework can be tested in the context of a tangible future system, rather than a narrow focus of current frameworks.

AEMO strongly advocates an approach that starts from examining in detail the fundamental needs of the system in terms of frequency control. This would then feed naturally into specifying services that match these needs, and finally into an exploration of procurement options. AEMO considers that this kind of approach is best placed to deliver an outcome that achieves the over-arching objective of the Review, which should along the lines of ensuring that the NEM has a frequency control framework that is robust, efficient and cost effective in light of a rapidly evolving power system. Our proposed approach is detailed in the attached submission.

There is a risk that progressing too quickly to 'solutions mode' or to procurement options will not deliver a framework that meets the underlining objectives of the Review, and the National Electricity Objective (NEO). In light of this, AEMO's submission focuses on the Review approach and methodology in particular, leaving discussion of the advantages and

disadvantages of particular solutions and procurement options to a later stage when they become more relevant as they can be properly assessed against the need.

Nonetheless, it is recognised that there is a case for transitional measures to ensure the Frequency Operating Standard continues to be met. There are various measures that AEMO is considering and indeed actioning that fall within the current Rules, Standards and Guidelines. Because of the potential need for short-term as well as long-term action, AEMO urges the AEMC to consider a staged approach to any changes to the NEM's frequency control framework. Appropriate staging would allow suitable measures to be put in place while a comprehensive program of work to develop suitable longer-term frameworks is progressed. In this staging approach, AEMO will provide key direction on the performance standards required and relevant services so that procurement options can be considered by the Review.

Should you have any queries regarding this submission please do not hesitate to contact Matthew Holmes, Principal – Future Energy Systems via matthew.holmes@aemo.com.au or (07) 3347 3039.

Yours sincerely

Cameron Parrotte
Executive Group Manager – Strategy and Innovation

ATTACHMENT

AEMO SUBMISSION ON FREQUENCY CONTROL FRAMEWORKS REVIEW ISSUES PAPER

1. Context and need for frequency control

AEMO, as the market and system operator of the NEM, has the role of running the electricity market, while ensuring system security is appropriately managed. One of the fundamental aspects of system security is the control of frequency.

Frequency control is essentially the second-to-second, minute-to-minute balancing of supply and demand in the power system. Any imbalance in supply and demand manifests as a frequency deviation from the NEM's nominal level of 50 Hertz (Hz). If frequency departs too much from the nominal level, the system can very quickly suffer loss of load and generation as systems act to isolate and thus protect themselves. Frequency control services, which can actually be considered to be structured and carefully timed supply-demand balancing services, are procured to deal with these issues. If this is not carefully planned and managed, or the services do not deliver effectively, the system can very quickly end up with loss of generation and indeed major blackouts.

While prevention of these major consequences is the ultimate purpose of frequency control, it is also important for a range of other reasons. For example, most network equipment including protection systems and harmonic filters, are designed to operate around 50 Hz. Poor frequency control may call into question their effectiveness. Frequency control is also important for interconnector control; poor frequency control causes increasing volatility on network element flows, challenging assumptions that are factored into their design and management. There is also an element of overall system efficiency and waste reduction as traditional generators are generally designed to operate most efficiently at 50 Hz, and poor frequency control may result in additional fuel usage and increased emissions.

The frequency control framework currently employed in the NEM was established when conventional (synchronous) plant and relatively passive load was the norm. However, the NEM, like most mature grids around the world, is undergoing a number of changes such as:

- A significant shift from passive to active load.
- Fundamental changes in consumer behaviour.
- A shift from fully-scheduled synchronous generation to variable non-synchronous generation with varying levels of controllability.

These fundamental changes will affect both what is required from and able to be delivered by the current frequency control services in the NEM. In particular, in the absence of changes to address it, this can be expected to result in a simultaneous increase in the volatility of underlying load and a significant reduction in the availability of sources of frequency control. This would indicate a challenging environment. However, new technologies and approaches can be exploited to address this, and could indeed lead to a better frequency control solution overall.

To get to this point though, the industry must as a whole look to challenge pre-conceived notions of what frequency control is and how it is delivered. In particular, it is important to

consider the role and relevance of frequency control in light of the power system we have now and the power system we are likely to have in the future.

Many grids across the world have noted their frequency control services tested in recent years. In the NEM, recent history has shown that frequency control performance – notably within what is referred to as the "normal operating frequency band" - has been declining. Furthermore, AEMO has concerns about whether current market and system settings will continue to meet some obligations under the Frequency Operating Standard (FOS). The reasons for this are manifold and complex, however AEMO regards that it is fair to conclude that this is a symptom of the current frequency control frameworks being sub-optimal for the current and emerging power system.

AEMO has been conducting considerable work on this issue internally and also with the assistance of key stakeholders via the Ancillary Services Technical Advisory Group (AS-TAG). This has included a key piece of work from DigSilent which highlighted a progressive but significant trend of participants widening deadbands[1] on the governor systems of their as the major factor in the deteriorating level of frequency control. This work highlighted a range of issues associated with unsatisfactory frequency control including risks to system security. Matters such as this makes for a compelling and useful launching point for this Review, and it is important that the Review is carefully scoped and managed so that its objectives may be achieved.

2. Defining the Objective

AEMO believes that the Review would benefit greatly from very clearly articulating an over-arching objective that is not dependent on the FOS. This would serve to focus the Review and provide an ultimate test for any solution coming out of the Review. AEMO notes that the Issues Paper states the following objective:

…to recommend the combination of changes that are necessary to provide a secure power system at the lowest cost to consumers.

While this objective is sound, AEMO considers that it is perhaps too focused on making changes or tweaks to the current framework. This runs the risk of being too short-sighted. AEMO suggests that a more fundamental statement of the objective could be something of the following nature:

The Review must ensure that the NEM has a frequency control framework that is robust, efficient and cost effective in light of a rapidly evolving power system.

In considering this objective, it is important to note what the terms 'robust', 'efficient' and 'cost effective' entail in the context of frequency control:

2.1. Robust

Robust is used to indicate that framework is resilient to a wide range of future outcomes. This is key because it is difficult to predict with high confidence what the generation mix in the NEM will be or how customer behaviour may change. The framework must be able to deliver a resilient power system for a range of possible futures.

[1] The 'deadband' is the frequency band within which the generator will not respond to a frequency deviation by increasing or decreasing output as appropriate.

2.2. Efficient

Efficient is used to indicate that the framework must deliver the required performance in a structured manner with a minimum of wasted effort. For example, a framework that is inflexible to changing needs is likely to result in over-specification of services. Likewise, a framework that fails to incorporate all technologies and account for their possible opportunities and challenges in terms of their potential contribution to frequency control is unlikely to deliver an efficient outcome.

2.3. Cost effective

Cost effective is used to indicate that the framework should deliver the required performance in a manner that delivers good value for money, if not necessarily absolute least cost. For example, a solution that delivers least cost but is not resilient or robust is not as good as slightly more expensive solution that does deliver these other essential properties.

3. Scope of the Review

The AEMC's Issues Paper states that the following matters will be considered in the scope of the Review:

1. Primary Frequency Control
2. Frequency control ancillary service (FCAS) markets
3. Ramping
4. Distributed Energy Resources.

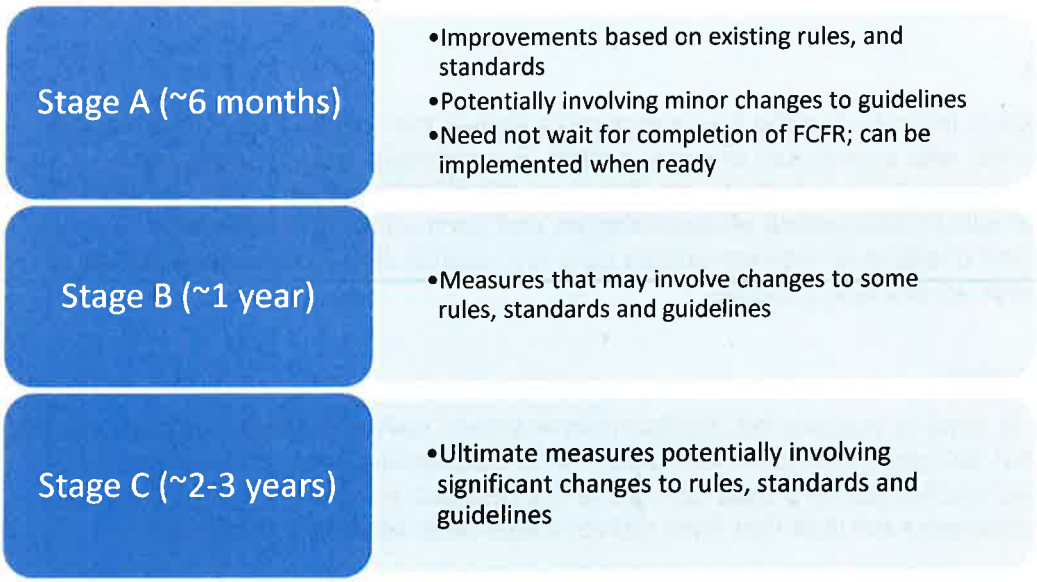
AEMO considers that describing the scope of the Review in terms of these four elements is too limited and too solution/procurement focussed. It may be better to articulate that these elements will all be specifically considered in light of their possible relevance to achieving the objective of the Review, but not limit the Review to a particular set of elements.
The scope rather should be targeting the technical needs of the power system through a staged approach that considers the current power system and its frequency control needs, and how to transition to the evolving power system and its needs.

4. Assessment Approach

4.1. Staging

AEMO believes the approach to the Review should be staged. The key reason for this would be to support short or medium term measures to be implemented while more detailed or wide-ranging analysis and design is undertaken. There is no reason why suitable and workable measures cannot be implemented quickly while the Review considers in detail what a frequency control framework fit for a low carbon grid should look like.

AEMO suggests three logical stages could be defined as follows. Indicative timeframes are shown too however this should be made sufficiently flexible so it can adapt appropriately to circumstances that may arise throughout the course of the Review:



4.1.1. Stage A

Separately to the Frequency Control Frameworks Review, AEMO has been and continues to progress a program of work analysing frequency control performance and identifying opportunities for improvement, especially in line with managing AEMO's obligation to meet the FOS. Stage A recognises that this work needs to feed into the Review, and work that the Review does should likewise feed back into AEMO's ongoing work.

Given that it is assumed that Stage A does not look to change rules and standards, potential actions could include:

- Investigation of adequacy of regulation FCAS base quantities
- Improved and expanded monitoring of frequency and quality of FCAS service delivery by providers
- Active and direct engagement with FCAS providers to improve quality of service delivery
- Investigation of alternative dynamic triggers for additional regulation FCAS procurement (i.e. changing time error trigger to an alternative trigger)
- Potential changes/tweaks to service delivery characteristics (via MASS)
- Dynamic service requirements (e.g. linking service quantities to time of day)
- Demonstration of new technical capabilities of existing or new providers
- Continuing investigation of opportunities to improve AGC performance.

4.1.2. Stage B

Stage B would be intended to examine potential changes that would entail relatively minor changes to rules and standards. This would build on Stage A and consider matters such as the following:

- Changes to FOS, for example the re-definition of bands such as the normal operating frequency band, or the addition of other bands
- Introduction of a performance-based payment scheme
- Market changes to ensure energy not unduly prioritised over system service delivery

- Introduction of primary frequency control in some form within the normal frequency operating band, including consideration of provision via FFR
- Addressing any minor regulatory barriers to non-traditional frequency control providers

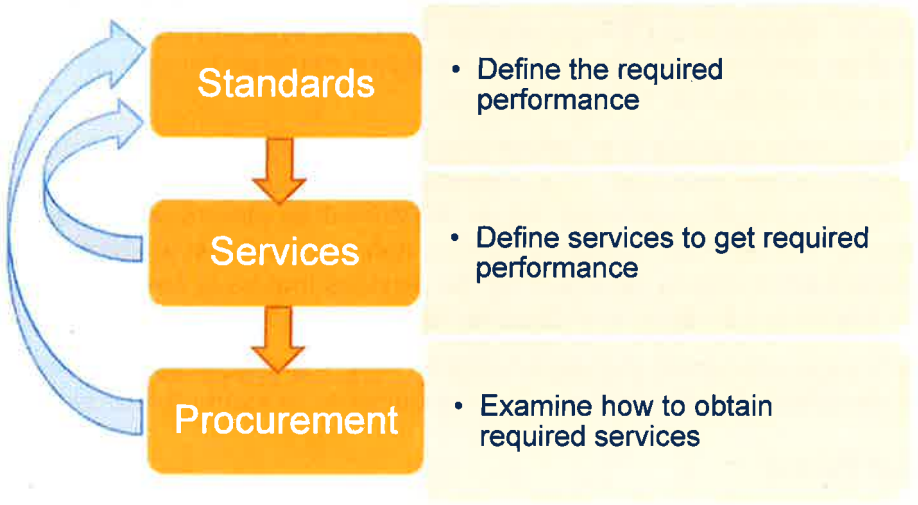
4.1.3. Stage C

Stage B would be intended to examine potential changes that could entail major changes to rules and standards. This would build on Stage A and B and consider matters such as the following:

- Further changes to FOS
- Incorporation of not yet established technologies
- Expansion of performance-based payment scheme
- Establishment of performance-based procurement scheme
- New markets, contract mechanism, etc. designed to procure identified services
- Addressing major regulatory barriers to non-traditional frequency control providers.

4.2. Workflow

In addition to this staging approach to the overall Review, AEMO considers that each Stage could adopt a 3-step process. This proposed process is shown in the diagram below:



In essence, this approach would mean repeating the same process in each of the three stages, but opening up the options at each stage regarding changes to Rules, Standards and Guidelines. That is, in Stage A, guidelines could potentially be changed, but no rule or standard changes would be undertaken. In Stage B, minor rule and standard changes would be considered. Stage C would open up the possibility of major rule and/or standard changes. Of course, each 'iteration' through this process must not be considered entirely independently, and to the extent possible, should be cognisant of the objective and direction of subsequent stages.

The process outlined above recognises that the investigation of any framework must first establish the required performance. AEMO will provide key direction on this throughout the Review. Although this first step is labelled as a 'standard', AEMO does not refer specifically

to the Frequency Operating Standard (FOS). Rather this refers to the standard of performance being sought. This may be described by the current, or potential future FOS, but should not necessarily be limited to that. Rather, it should examine the fundamental required performance or system behaviour that is desired.

It is important to specifically consider frequency control needs not in isolation of all else but to consider carefully the nature of the system. The frequency control needs of a given system will depend on many factors including but not limited to:

- The number, size and distribution of synchronous machines. This considers factors such as inertia and the proportion and distribution of potential frequency control providers in the system.
- The strength of the network
- The flexibility of the fleet
- The volatility of the load
- The general level of safety margin in the system
- The anticipated level of unknowns and potential pace of change in the system.

In particular, it must be specifically considered how the growing penetration of distributed energy resources (DER) and other non-synchronous generation will affect the needs of the system, and hence design of frameworks. Although in the next ten years there is likely to still be a number of synchronous generation in operation, there is likely to be times that they are not online due to high levels of DER generation. Directing synchronous units online or constraining other generation to increase the resilience of the power system is very unlikely to constitute a cost-effective or efficient solution.

The second step in the process is to define what services are likely to be required to deliver the defined performance 'standard', and understand the capabilities of different technologies in providing frequency control services. Again, AEMO will be able to provide significant input to the definition of the services. Following service definition, the last will be to evaluate all possible procurement methods for obtaining the services that have been defined, and to compare the relative advantages and disadvantages of these.

It is important to also recognise that depending on what the specification of the services and procurement investigation reveals, there may be cause to re-examine the 'standard'.

5. Context of Review

AEMO considers that in order to put the Review properly in context, it is vitally important to consider the kind of power system in which the frequency control framework will be expected to apply. The NEM's frequency control framework must be suitable for the system now, but also for system that might reasonably be expected in say 15 years (it is noted that the current framework has essentially been in place for around 16 years). Therefore AEMO suggests it would be useful to specifically state the nature and makeup of the system that might be reasonably likely in this sort of timeframe. This is likely to include attributes like the following which are featured in AEMO's 2016 NTNDP[2]:

[2] http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NTNDP/2016/Dec/2016-NATIONAL-TRANSMISSION-NETWORK-DEVELOPMENT-PLAN.pdf - see 45% Emissions Reduction scenario.

- Continued uptake of DER, perhaps with penetration levels of up to say 22% of total installed capacity
- Continued shift in utility-scale generation from synchronous to variable non-synchronous generation, perhaps with total penetration levels of up to 35% of total installed capacity.

AEMO considers that any proposed framework should be tested assuming the current system makeup, and also an anticipated system such as that proposed above to assess whether it is likely to deliver the stated objectives in both situations. This includes examining how such a system may vary in generation mix through the course of a day; with total penetration levels this high, it is highly likely that load will largely be served solely by DER and non-synchronous generation at times.

The following table shows one aspect of frequency control – potential providers – contrasted over the approximate timetable suggested. AEMO is documenting this in a similar fashion in its upcoming Power System Requirements Report, which is expected to be published shortly. It is also important to consider how the actual system performance desired may vary over this timeframe too as it is unlikely to be static.

Providers of frequency control	**2000**	**2017**	**Potential providers by 2030**
Synchronous generation - coal	✓	✓	✓
Synchronous generation - gas	✓	✓	✓
Synchronous generation – hydro	✓	✓	✓
Synchronous generation – solar thermal			✓
Non-synchronous generation - wind		Testing stage	✓
Non-synchronous generation – utility PV			✓
Non-synchronous - storage		✓ commencing	✓
Non-synchronous generation - other			?
DER – rooftop PV			✓
DER – demand response		✓ commencing	✓
DER – customer batteries			✓
Load – large scheduled	✓	✓	✓

Load – aggregated consumers		✓ (limited)	✓

In order to highlight this critical point of the 'context' of frequency control in the NEM, AEMO recommends that the AEMC should consider a piece of work investigating the existing FOS, assessing why it was created in the way that it was, and how it was dependent upon assumptions regarding the nature of the generation mix, control systems, and load behaviour. Contrasting this with the current and emerging power system could provide powerful insights as to why a new design could be warranted. It could be argued that the previous philosophy of frequency control was market based, and that what is required now is more 'technical needs based'. For example, frequency services of certain types were abundant in the past, and thus the focus was on creating a market where these could be readily traded. Now that the system is far more dynamic, the fundamental technical needs and the certainty of these being delivered is arguably far more the point of focus.

A second piece of work could examine the frequency control frameworks of systems that may have similar penetration of variable renewable energy systems. However, for this to be particularly useful, it would be critical to attempt to determine *why* frameworks are designed as they are in different jurisdictions; factors such as those discussed in section 4.2 must be brought out. Furthermore, a focussed examination of recent or upcoming actions jurisdictions may have taken on frequency control would also be highly useful, especially where this focuses on the underlying reason *why* these actions were implemented.

6. Assessment Principles

AEMO notes that the AEMC has outlined five assessment principles in the Issues Paper. In considering the Review, AEMO also independently drafted a set of assessment principles which are as follows:

- Frequency control requirements should be defined in terms of the fundamental power system needs. For example, this should recognise that frequency control is about correcting a supply-demand imbalance in a timeframe necessary to ensure the system is kept in a secure state, and resilient to unexpected events.
- Target flexibility and adaptability; a framework that is flexible and adaptable will be critical to a grid that is undergoing rapid and significant change in its makeup and behaviour.
- Ensure services are predictable, verifiable and assessable. Measurement is fundamental to ensuring that the services are delivered in an efficient and cost effective manner.
- Adopt a performance based approach to procurement and payment. This needs to provide a fair and transparent method for linking financial incentives to the relative usefulness of providers' frequency responsiveness.
- Be willing to implement solutions in the short and medium term while progressing longer term solutions. This is reflected in the Staging approach discussed in 4.1.
- Consider all options including minimum acquisition versus universal approaches. This means evaluating the relative benefit of solutions where the minimum amount of service is procured, versus options where some or all services may be procured universally to the extent possible.

- Inclusiveness and ease of entry/exit. In order to deliver an efficient and cost-effective outcome, it will be important to encourage the maximum level of participation and not inadvertently prevent new opportunities from being exploited.
- Ensure energy delivery is not systematically prioritised over system service delivery. This means addressing any actual or perceived precedence over the supply of energy compared with supplying frequency control services.

AEMO notes that there is a reasonable amount of overlap in the assessment principles that the AEMC and AEMO have developed independently. AEMO suggests that the AEMC and AEMO collaborate to ensure that the set of principles that are ultimately adopted provide comprehensive guidance to the Review in supporting the overall objectives.