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Frequency Control Frameworks Review

Engineers Australia Submission

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Engineers Australia

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Introduction

Engineers Australia appreciates the opportunity to respond to the draft report to the Australian Energy Market Commission (AEMC) Frequency Control Framework Review Draft Report (Report). The Report is welcomed and initiates reviewing the National Electricity Market (NEM) frequency control. The purpose of the Report is to set out the AEMC's analysis of the market and regulatory frameworks for frequency control in the NEM. Draft recommendations are provided in the report on improving frameworks to enhance effectiveness. Public consultation is sought from stakeholders, and Engineers Australia congratulates the AEMC on the value of the work contained in the Report. Engineers Australia believes this is an important starting point to investigating the technical consequences of changes to the frequency control framework. Electrical engineering expertise is critical in understanding the engineering solutions while making the appropriate decisions to meet the National Electricity Objective (NEO).

Overview

Power system frequency control must satisfy certain fundamental control principles. The dispatch process of the energy market and frequency control are fundamentally linked. Frequency distribution has changed over a 15-year period, however a certain cause for this change is yet to be determined or released. The Australian Energy Market Operator (AEMO) commissioned a report¹ on the Review of Frequency Control Performance in the NEM under Normal Operating Conditions which had the following key findings:

1. At least 26 out of 36 generating stations specifically discussed with market participants have:
 - a. One or more units with wide deadbands²;
 - b. Secondary control systems that inhibit frequency response within a frequency range, mimicking the impact of a deadband to a certain extent; or
 - c. Are planning to install a wide deadband on one or more units in the near future.
2. Four of eight market participants are also planning, or are in the process of making changes that will reduce frequency response at one or more stations.
3. Typically, those units for which no changes have been made to governors or secondary controls are those that are quite old, and might not have much remaining life. When these plants are retired, then there will be even less governor response available within the normal operating frequency band.

The deterioration of frequency performance has initiated examining the need for a change to frequency services and determining if the current dispatch process of the energy market is adequate,

¹ DigSILENT Pacific report (2017), *Review of Frequency Control Performance in the NEM under Normal Operating Conditions*. https://www.aemo.com.au/-/media/Files/Stakeholder_Consultation/Working_Groups/Other_Meetings/ASTAG/371100-ETR1-Version-30-20170919-AEMO-Review-of-Frequency-Control.pdf

² A governor deadband is a band of frequency deviation (input) for which the output of the governor remains zero. shown in Report Figure F.4 p. 203.

or whether that process is contributing to frequency uncertainty. The Report proposes enhancements to the existing frequency control arrangements to support the security of the power system. The draft recommendations aim to address:

1. Concerns on frequency performance in the NEM,
2. Removal of barriers to Distributed Energy Resource (DER) participation in system security, and
3. Concerns regarding reduction of natural inertia in the NEM, integration of new technologies for fast frequency control services and an inertia ancillary service market rule.

1. Concerns on frequency performance in the NEM

A current fundamental problem is that governor deadbands are allowed to be wider than accepted international best practice. Tightening these deadbands will immediately tighten frequency control. However, this may cause more wear and tear on generators, and this is where a market can provide a mechanism to compensate generators³. Providing a fast raise/lower regulation signal service would effectively cause the same amount of wear and tear on generators as the current Frequency Control Ancillary Service (FCAS), therefore the best technical solution may be to tighten deadbands on generators in conjunction with creating a new signal service market for non-generator participants. Thorough analysis should be undertaken to ensure the technical viability of such a scheme.

Without first verifying that contracted/dispatched FCAS is being delivered appropriately there is difficulty in determining whether frequency control needs to be (i) tightened, (ii) relaxed even further, or (iii) kept the same as today. Furthermore, determining the baseline against which the FCAS is measured provides a nontrivial challenge, but is fundamentally important for verification of any future DER-based FCAS.

1.1 Frequency Deviations

Control of the power system to a reference frequency (in Australia, 50 Hz) is fundamental to system reliability. Without tight frequency control, the *frequency distribution* may be affected (Report Figure 1, reproduced and corrected as Figure A). The consequences of lax frequency control include (but are not limited to):

- blades on synchronous turbines may be damaged,
- wear and tear on generator governing equipment,
- inefficient operation of generators resulting in increased emissions,
- stable control of synchronous machines may be compromised,
- system stability may be compromised,
- interconnectors may deviate from their dispatch targets and during a contingency may lead to a cascading failure,
- frequency controlled clocks will not keep time correctly,
- measurements of quantities that require a certain level of accuracy may be compromised,
- dispatch of energy and interregional loads may no longer be optimised owing to measurement error,
- load measurement and its billing may be affected,
- impedance measurement may affect stable control of voltage,
- feedback through stabilisers may affect voltage,
- harmonic dependent measurement devices may be affected, and
- harmonic filter efficiency.

The magnitude of power and frequency movements presently occurring (see Figure B) provides evidence that suggests premature wear and tear on generating plant may also be occurring.

³ There is also the counter-argument that tightening the frequency control deadband may reduce wear and tear owing to the frequency range (49.85 to 50.15 Hz) being larger than the accepted international best practice and may be beyond the optimal operating range for the NEM. This is an open question.

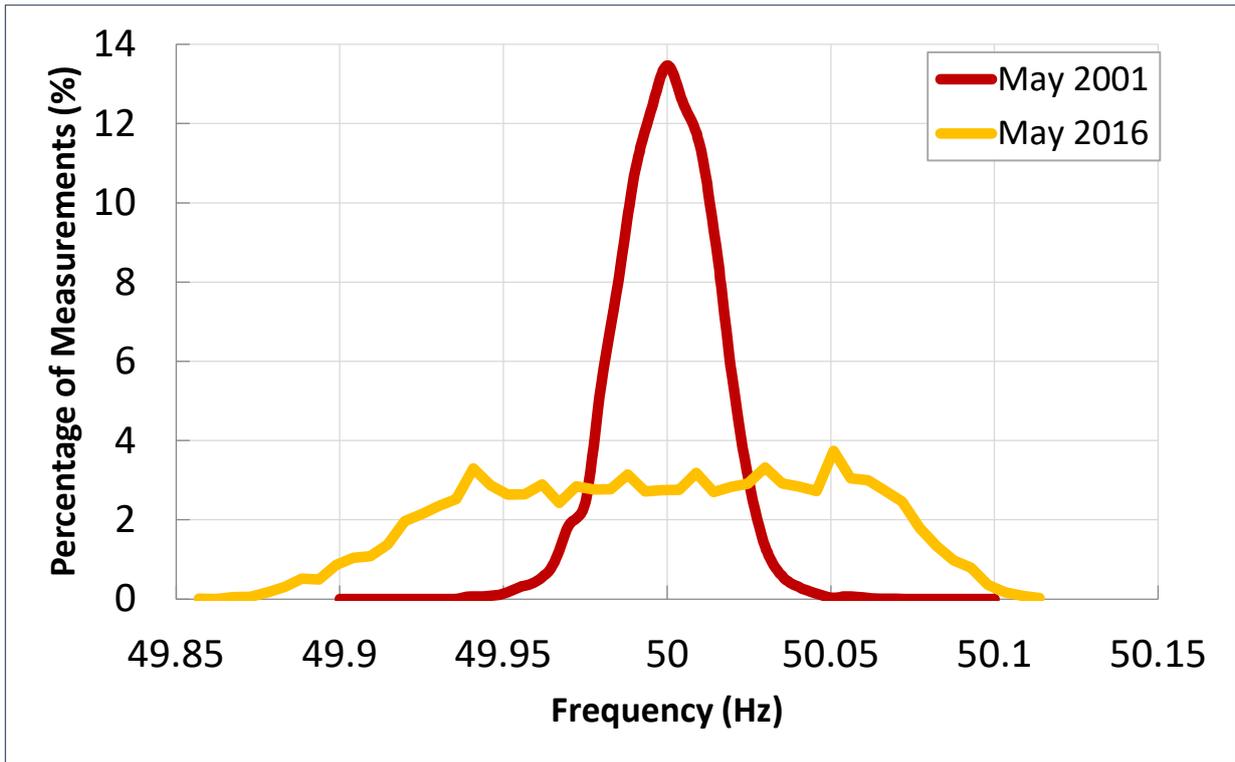


Figure A – The probability density function for frequency, measured at 4-second intervals as reported by NECA for 8 May 2001 and calculated from AEMO data for 8 May 2016 matching the 2001 distribution calculation⁴.

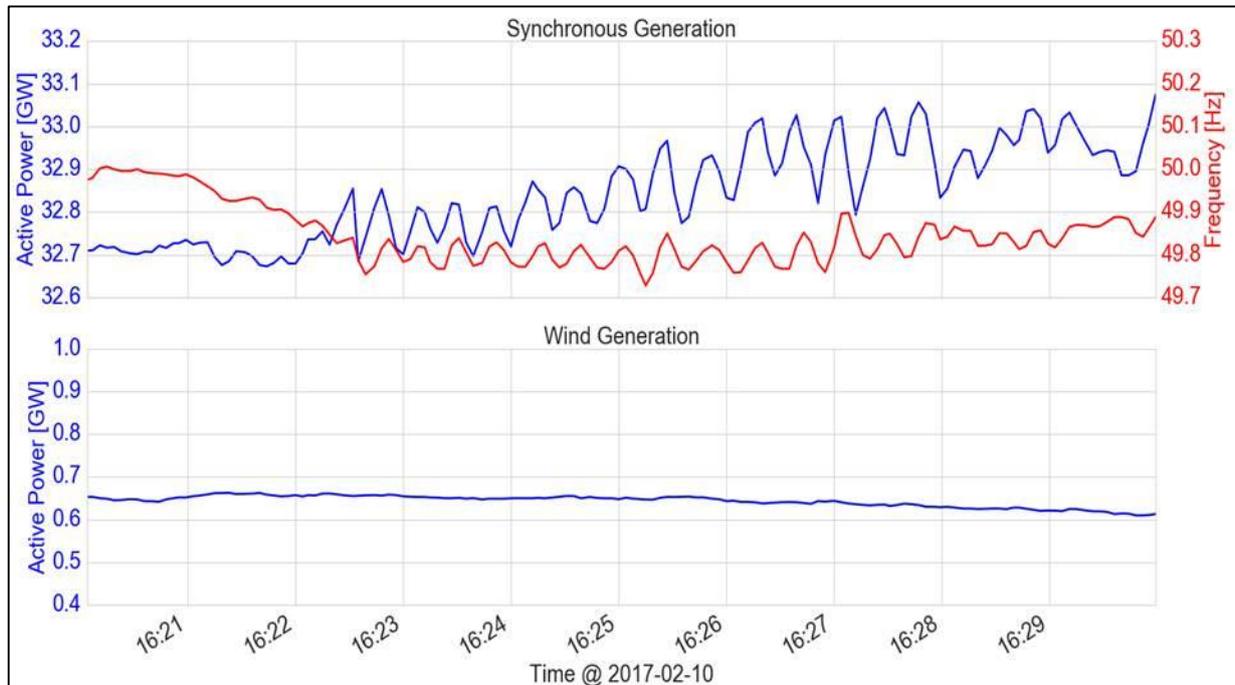


Figure B – 10 February 2017: Measurement of the NEM’s total synchronous generation active power and frequency under the current frequency control framework. Note, wind generation is almost certainly not contributing to the frequency dynamics with wind generation providing a fairly flat (and 2 orders of magnitude less) delivered active power.

⁴ Summers et al (2017), *Lessons learnt from the Australian frequency control ancillary service market*, Wind Integration Workshop, Berlin, Germany.

1.2 Power System Frequency Control

The standard approach to *power system frequency control* is based on the complementary roles of primary and secondary control. The primary system responds on a short time-scale. Generator governors measure (local) frequency and drive the generator output to a corresponding value given by the droop characteristic (see Report Figure F.4 p. 203). Importantly, governors do not try to regulate frequency to the reference 50Hz, but rather to the frequency dictated by the droop characteristic. Following a disturbance, the frequency will stabilise to a value that is not necessarily the reference frequency. Automatic Generator Control (AGC), as a secondary system with a longer time-scale, measures this frequency offset and determines appropriate raise/lower set-point adjustments for all participating generators. These adjustments effectively move the droop characteristic of each generator up/down. The time-scale decoupling between governor action (regulating power output) and AGC (regulating frequency) ensures power system stability.

Example 1 – Frequency control must satisfy certain fundamental control principles

Why is time decoupling of primary and secondary control so important?

Suppose multiple control loops, e.g. governors, all tried to regulate frequency to 50Hz. Then, the resulting interactions would cause hunting between the synchronous generators⁵. As an illustration, if two governors measured low frequency they would both respond by increasing generator output leading to an overshoot in the frequency. This would be followed by a consequent reduction in output, and the cycle would then repeat. This is an undesirable response. The power system and its various markets must be configured to prevent this.

Now suppose governors are disabled, which is effectively the case when governor dead-bands are widened. Then, the power system becomes totally reliant on AGC, and hence more sensitive to AGC parameter tuning. This is an undesirable power system configuration. The power system and its markets must be configured to prevent such sensitivity.

Recommendation EA.1

An independent study of the frequency distribution time series data is required to understand the cause and consequence of current frequency deviations. A determination of how the frequency is varying (e.g. random, cyclic) would identify any dynamics occurring in the system and whether it is ok to do nothing or solve a technical engineering problem before introducing any changes to the FCAS market.

1.3 Causer Pays

Engineers Australia welcomes the Report raising the issue regarding the *causer pays* procedure being not transparent. A stronger link between cause and issue is required to provide market participants an opportunity to respond to issues in a timely fashion and minimise any causer pays penalties. Draft Recommendations 1 and 2 raises the prospect of enhancing the causer pays arrangements to provide incentive payments in addition to penalties. Caution is brought to implementing any such changes until the consequences are fully understood from a systems perspective, and whether there is any overall benefit, or if this may be detrimental to frequency control. This requires examining the technical details to determine the technical consequences of any change.

⁵ The relevant hunting phenomenon refers to a periodic variation in the rotational speed, as shown in Figure B.

The causer pays process may induce market participants to respond in a way that could be equivalent to an *ad hoc* frequency regulating control loop.

Example 2 – Causer pays impacting power system frequency control

Consider a load that has higher demand than scheduled. If the load measures low frequency, it could seek to reduce its demand to avoid a causer pays charge. Other loads could also behave similarly, reducing their demands. In parallel, AGC makes appropriate adjustments in an attempt to regulate frequency. All participants act without information on the actions of the others. This could result in a frequency overshoot. This is similar to the multiple parallel control loops in Example 1, and may result in an undesirable hunting response.

Now suppose the causer pays process is enhanced through the provision of rewards, as well as penalties. The availability of reward incentives will encourage actions that exacerbate uncoordinated responses, increasing the likelihood of detrimental interactions.

Under the existing framework, the delay in notifying market participants of any causation prevents gaming the causer pays process for profit. The proposal to publish frequency indicator (FI)⁶ data in near real time could provide a feedback path that causes both technical issues and an increase in costs via potential gaming. However, market participants observe that without FI data, NEM frequency problems go unidentified and opportunities for wider involvement of market participants in frequency control are unachievable. Thorough analysis should be undertaken to develop a complete understanding of potentially destabilising feedback mechanisms.

The current FCAS market design is providing a coarse load following service owing to the inherent time delay in primary control to prevent causer pays penalties. Without a good frequency control scheme, there is further risk to:

- increasing system losses,
- decreasing the accuracy of load forecasting,
- losing control of interconnector flows,
- losing maintenance of a secure dispatch, and
- increasing cost of operations.

Recommendation EA.2

An independent study of the technical details is required to determine if the causer pay framework should continue, and if so, what is the best way to make this a transparent procedure without compromising frequency control or cost. Engineers Australia recommends using electrical engineers with power systems expertise and familiarity with Australia's NEM to undertake this study.

1.4. Power System Future Workforce

The technical consequences of changes to the frequency control framework must continue to be investigated for optimal outcomes. Organisations require sufficient expertise to fully understand the technical consequences of decisions being made and ensure sound judgements. Electrical power

⁶ FI is a time delayed signal calculated in causer pays.

systems engineering expertise is critical to these judgements so that appropriate decisions continue to meet the National Electricity Objective.

The *National Electricity Objective (NEO)* as stated in the National Electricity Law (NEL)⁷ is:

“to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:

- price, quality, safety and reliability and security of supply of electricity
- the reliability, safety and security of the national electricity system.”

There is risk to this objective with current evidence demonstrating the costs incurred in providing FCAS have been increasing (see Figure C) and the actual control of the frequency (see Figure B) deteriorating over a 4-year period.

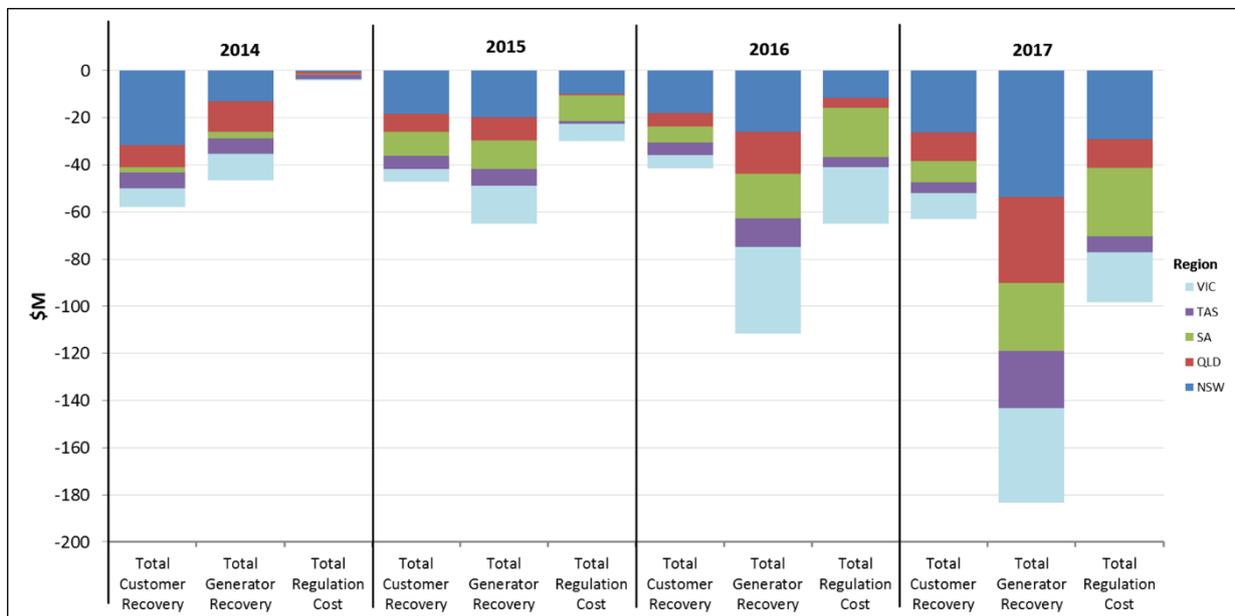


Figure C – Regulation FCAS cost and recovery⁸

Recommendation EA.3

Engineers Australia recommends that the organisations responsible for energy market design and operation ensure sufficient power systems expertise at all levels to enable optimal outcomes in the price, quality, safety, reliability and security of the national electricity system as set out in the NEL.

⁷ The NEL is set out as a Schedule to the National Electricity (South Australia) Act 1996 and applies in other jurisdictions through legislation agreeing that the NEL operate in that jurisdiction.

⁸ FCAS Recovery (2015), AEMO Settlements guide to ancillary services payment and recovery, p.10, <https://www.aemo.com.au/-/media/Files/PDF/SETTLEMENTS-GUIDE-TO-ANCILLARY-SERVICES-PAYMENT-AND-RECOVERY-V2.pdf>

2. Removal of barriers to Distributed Energy Resource (DER) participation in system security

The Report provides some focus on aggregated DER to contribute to FCAS via storage and solar PV. The potential for aggregated (distributed) demand response (DR) to also contribute to FCAS should not be underestimated. A minimum offer size of 1 MW is proposed in the Report. Baseline estimation for aggregated DER will always incur some error. Estimation processes should strike a balance so market participants are not at a disadvantage.

Recommendation EA.4

Engineers Australia recommends the minimum size for aggregated DER participation should be as small as possible to maximise contributions, taking into account baseline-related errors. Engineers Australia also recommends including aggregated demand response in the provision of FCAS.

3. Concerns regarding reduction of natural inertia in the NEM, integration of new technologies for fast frequency control services and an inertia ancillary service market rule

3.1 Reduction in inertia

Reduction in inertia is fundamentally important for future power systems where renewable generation is significant. The Report recognises the importance of inertia, however further details are required on how reduced inertia will influence the design of FCAS. The discussion in Section 8.1.1 of the Report, where inertia requirements are divided into two components, minimum level of inertia and market benefits, requires further thought from a dynamical systems perspective. Reduced inertia will have a significant effect on system response to faults, and hence on system stability. It is also likely that reduced inertia will alter inter-area modal oscillations across the NEM. In both cases, locational requirements will influence the provision of inertia.

3.2 Speed of FCAS Regulation Response and Opportunity for Service Trials

The future speed of FCAS regulation response requires careful technical evaluation with due consideration given (but not limited) to:

- the safety of DER (operational limits),
- the stability and security of the power system,
- fair opportunity to all DER and DR, and
- customer priorities.

The PJM⁹ market provides coordinated regulation by using a *RegD* fast signal (where for example batteries may respond) and a *RegA* slow signal (where for example generators respond). The Report Appendix G refers to other markets, however the PJM market has one of the most forward-looking frequency regulation markets. Engineers Australia agrees there is an opportunity for trials to test performance. PJM have published detailed procedures for certifying RegA and RegD regulation services. PJM payment for service is based on quality of performance relative to these tests.

Recommendation EA.5

Engineers Australia recommends that in considering reduced inertia, technical issues beyond frequency control should be taken into account. Furthermore, the relationship between reduced inertia and the speed of FCAS regulation response should be carefully investigated.

⁹ Pennsylvania-New Jersey-Maryland Interconnection (PJM) is a power pool in the USA and forms part of the Eastern Interconnection grid.



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