RELIABILITY
PANEL AEMC

REVIEW

Reliability Panel AEMC

ANNUAL MARKET PERFORMANCE REVIEW 2016

Draft report

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About the Reliability Panel

The Panel is a specialist body within the AEMC and comprises industry and consumer representatives. It is responsible for monitoring, reviewing and reporting on reliability, security and safety on the national electricity system and advising the AEMC in respect of such matters. The Panel's responsibilities are specified in section 38 of the National Electricity Law.

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Foreword

I am pleased to present this draft report setting out the findings of the Reliability Panel's annual review of market performance.

The Panel has reviewed the performance of the national electricity market (NEM) in terms of reliability, security and safety over the 2015/16 period, in accordance with the requirements of the National Electricity Rules. We have considered both historic trends and projections of the security and reliability of the NEM.

2015/16 has seen an increased focus on the reliability and security of the NEM.

Against this background, the Panel found that the NEM performed well in terms of reliability, with no unserved energy occurring in 2015/16.

The Panel also notes there are a number of significant changes ongoing in the NEM.

Key amongst these is the ongoing trend of retirement of conventional thermal generation, with over 700MW of this type of generation capacity exiting between April 2015 and June 2016. This is coupled with the continuing entry of large volumes of newer generation technologies, particularly intermittent, renewable generation.

These changes have a number of implications for the ongoing reliability and security of the NEM.

While the NEM has performed well over the last decade in terms of reliability, projections by the Australian Energy Market Operator (AEMO) show that, in the absence of a sufficient market response, there may not be enough generation to meet demand in the medium term, in some regions. This potential shortfall highlights the need for efficient supply side and/or demand side investment so that consumer demand for energy continues to be met.

There were also a number of system security issues in 2015/16, with several resulting in interruption of supply to consumers. While the causes of these incidents are complex, they demonstrate the ongoing importance of maintaining system security in a changing environment.

In the context of these challenges, the Panel acknowledges the significant body of work underway that is currently considering how to maintain the resilience of the NEM.

This includes the Australian Energy Market Commission’s (AEMC) System Security Market Frameworks review. Working in cooperation with AEMO, this review will consider, develop and implement changes to the market frameworks to allow the continued uptake of new generating technologies while maintaining the security of the system.

The Panel also acknowledges the Independent Review into the Future Security of the National Electricity Markets, led by the Chief Scientist, Dr Alan Finkel. This project is considering a wide range of potential reforms intended to enhance the NEM’s future resilience.

The Panel has adopted a new approach to the annual market performance review for 2015/16. This annual market performance review includes increased consideration of both historic and emerging trends in the market, to provide additional context and insight to the short term trends seen within the 2015/16 reporting period.

The Panel has also structured this report to enhance usefulness for different readers. A short summary report is provided for those readers seeking a high level overview of the review and key trends. The main report provides further detail through additional commentary on the review and these key trends. Technical detail is then available in the relevant appendices.

The preparation of this draft report could not have been completed without the assistance of AEMO, the Australian Energy Regulator, network service providers, and state and territory government departments and regulatory agencies in providing relevant data and information. I acknowledge their efforts and thank them for their assistance to date.

Finally, the Panel commends the staff of the AEMC secretariat for their efforts in coordinating the collection and collation of information presented in this report, and for drafting the report for the Panel's consideration.

Neville Henderson, Chairman, AEMC Reliability Panel,

Commissioner, AEMC

Concise report

This draft report sets out the findings of the Reliability Panel's 2016 annual market performance review (AMPR) as required by the National Electricity Rules (NER). This review is conducted in accordance with terms of reference issued by the Australian Energy Market Commission (AEMC). Covering 1 July 2015 to 30 June 2016, the AMPR 2016 includes observations and commentary on the reliability, security and safety performance of the power system.

This concise report is structured as follows:

- Key concepts: reliability, security and safety are the three main concepts considered by the Panel when undertaking the AMPR.
- Market trends: the key trends in generation, interconnection and demand.
- Reliability review: an overview of reliability outcomes in the NEM.
- Security review: an overview of security outcomes in the NEM.
- Major incidents: a short review of the key power system incidents in 2015/16 that lead to interruptions in supply to consumers.
- Safety commentary: a short summary of safety in the NEM.
- Relevant policy developments: a short summary of other policy work currently underway that is relevant to the ongoing security and reliability of the NEM.

This concise report is intended to provide a high level summary of key trends in the NEM. More detailed information and commentary is provided in the main body of the report.

Key concepts

The focus of the review is the reliability, security and safety performance of the NEM. It is therefore important to understand these concepts:

- ***Reliability***: Reliability is a measure of how effectively demand for energy is supplied by generation and bulk transmission (i.e. interconnection between regions). If there is insufficient generation and bulk transmission available, this may result in an amount of energy that is not supplied to consumers, or how much "unserved energy" (USE) occurs in a given period.[1] Traditionally, there has been very little USE in the NEM.[2]

  Also relevant to the reliability of the NEM is the reliability standard. The reliability standard is an ex-ante planning standard. It feeds into the setting of various NEM wholesale pricing mechanisms, which in turn facilitate investment

1 Unserved energy excludes power system security events, network outages not associated with inter-regional flows and industrial action or acts of God. It also does not include interruptions to supply that are caused by failures the intra-regional transmission network and outages on the distribution network.

2 The demand measure used to assess the amount of unserved energy is operational demand. Operational demand refers to electricity used by residential, commercial and large industrial consumers, as supplied by scheduled, semi-scheduled and significant non-scheduled generating units.

in capacity necessary to meet consumer demand for energy. It is defined as the maximum expected amount of energy at risk of not being served, expressed as a percentage of the total energy demanded in a region over a financial year. It is currently set at 0.002% of total energy demanded.[3]

- *Security*: Security relates to the maintenance of the power system within specific technical operational limits, including specific frequency and voltage limits. To maintain the security of the NEM, AEMO uses constraints in its dispatch engine. When this is not sufficient, AEMO can direct participants or instruct load shedding.

  The power system is defined to be in a secure operating state if:

  — the power system is in a satisfactory operating state[4]

  — the power system will return to a satisfactory operating state following the occurrence of any credible contingency event[5] in accordance with the power system security standards.[6]

- *Safety*: While the general safety in the NEM is an important consideration under the National Electricity Law (NEL), there is no single national safety regulator for electricity. Instead, jurisdictions have specific provisions that explicitly refer to the safety duties of networks, as well as other aspects of electricity systems such as metering and batteries.[7] The Panel considers that the power system is safe when it is maintained and is operating in a secure condition. However, the Panel limits its consideration of safety to maintaining power system security.

Market trends

There were a number of key market trends in the NEM in 2015/16, including:

- withdrawal of significant amounts of synchronous[8] thermal generation, particularly in South Australia
- the entry of new generation capacity, mainly intermittent, non-synchronous wind and large scale solar generation

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3 The reliability standard is also used by AEMO as an input into various operational processes, such as its assessment of reserve levels. This is discussed in more detail later on in the report.

4 A satisfactory operating state is defined in clause 4.2.2 of the NER. It refers to operation of equipment within voltage and current limits as well as the frequency of the power system being within defined frequency bands.

5 A credible contingency event means a contingency event the occurrence of which AEMO considers to be reasonably possible in the surrounding circumstances including the technical envelope. For example, a credible contingency could include the failure of a single generating unit or a single major item of transmission plant.

6 The power system security standards are defined in Chapter 10 of the NER.

7 See section 2D(a) of the NEL.

8 Synchronous generators are large spinning units that have turbines that spin at the same speed as the frequency of the power system. Because the mechanical energy of the turbine is directly related to the frequency of the power system, they can typically provide what is known as "physical inertia". This inertia can assist in slowing changes in power system frequency, following a major disturbance like the loss of a transmission line.

- expansion of the capability of the Heywood interconnector between Victoria and South Australia
- significant changes in the demand side of the market, particularly in relation to residential PV and storage.

Supply side trends

2015/16 saw significant changes to the generation mix in the NEM. The region most affected was South Australia, which experienced the withdrawal of Playford B power station (240MW)[9] and Northern power station (520MW). This was in addition to the mothballing of a second Pelican Point unit[10] in April 2015. Combined, this represented a 19% reduction in the total installed generation, and a 43% decrease in the total installed synchronous generation in South Australia in a period of just over 12 months.

While no other generation was withdrawn from other regions of the NEM in 2015/16, 3.8GW of generation capacity has been announced as withdrawing in the short to medium term. All of this generation is also thermal, synchronous generation. The announced withdrawals are:

- Engie has announced the intention to withdraw Hazelwood Power Station (1600MW) (VIC) in March 2017
- Smithfield Power Partnership has announced the intention to withdraw Smithfield Power Station (170.9MW) (NSW) in July 2017
- Stanwell has announced the intention to withdraw Mackay GT Power Station (34MW) (QLD) in July 2021
- AGL has announced the intention to withdraw Liddel Power Station (2000MW) (NSW) in March 2022.

The withdrawal of synchronous generation capacity is being offset in part by the introduction of renewable, intermittent generation capacity. In 2015/16, two power plants were commissioned: Broken Hill Solar Farm (53MW) and Moree Solar Farm (56MW). Both are located in NSW.

All newly committed generation in 2015/16 was also intermittent, renewable generation. A total of 537.2MW of generation was committed by the end of 2015/16.[11]

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9 Prior to Alinta Energy retiring Playford B, it had been mothballed for an extended period of time but its capacity had not been formally withdrawn. As a result, the capacity at Playford B was available for operation until it was withdrawn. See Alinta Energy, Alinta Energy clarifies market reports, April 2012, available at https://alintaenergy.com.au/everything-alinta-energy/news/alinta-energy-clarifies-market-reports

10 A "mothballed" unit is shut down on an ongoing basis, but can be made available again, within a given amount of time. AEMO has referred to mothballed units in the Electricity statement of opportunities as 'short-term' withdrawals. This is different to closed or retired, where a unit is taken offline on a permanent basis. The mothballed capacity at Pelican Point power station represented half of its total capacity. The remaining (non-mothballed) capacity of Pelican Point remains available at 239MW.

11 Since the end of the 2015/16 reporting period, further generation projects have become committed. These are: Hornsdale Stage 2 Wind Farm (102MW, SA); Mt Gellibrand Wind Farm (66MW, Vic);

All of the committed projects are wind farms connecting in NSW, Victoria and South Australia.

Demand side trends

2015/16 also saw the continuation of a number of demand side trends.[12] Operational consumption[13] was flat. AEMO's national electricity forecasting report (NEFR) also expects operational consumption to remain flat over the 20 year forecast period.[14]

AEMO found that increasing conversion from gas heating and cooking to electric heating and cooking, as well as increasing air conditioning loads and the impact of the LNG industry[15] have all contributed to an increase in consumption of energy. However, it was also found that these increases have been offset by increasing amounts of rooftop PV[16] generation and energy efficiency gains. As a consequence, operational consumption forecasts have remained flat overall.

Rooftop PV installation rates are forecast by AEMO to remain steady until 2035/36, at which point the total installed PV capacity is projected to be 19GW.[17] Additionally, future installations of PV are projected to see an increasing coupling with integrated storage systems. In addition to the forecast 19GW of rooftop PV installed without integrated storage, another 3.8GW of PV with integrated storage is projected to be installed by 2035/36.[18] In terms of total capacity, this is equivalent to the generation capacity that has announced the intention to withdraw in the short to medium term.

AEMO has found that continued trends in uptake of rooftop PV is likely to impact on maximum and minimum operational demand in the NEM. Maximum operational demand increased in 2015/16, mostly due to the LNG facilities in Queensland.

AEMO projects summer maximum operational demand will remain flat, and by 2035/36, it will be matched by winter maximum operational demand due to increasing levels of conversion from gas to electric power heating appliances.

The timing of maximum operational demand is also projected to shift to later in the day, when PV generation is tapering off. Most regions are projected by AEMO to follow the lead of South Australia by having minimum operational demand shift from overnight

Coonooer Bridge Wind Farm (19.8MW, Vic); Williamsdale Solar Farm (10MW, NSW); Mugga Lane Solar Park (13MW, NSW); Cook Shire Solar Storage Project (28MW, QLD).

12 Consumption refers to electricity used over a period of time. Demand describes electricity usage at a particular instance.

13 Operational consumption refers to the electricity used by residential, commercial and large industrial consumers, as supplied by scheduled, semi-scheduled and significant non-scheduled generating units over a period of time. Operational consumption does not include rooftop solar PV output, that is operational consumption will decrease with increased rooftop PV output.

14 AEMO, *National Electricity Forecasting Report*, June 2016.

15 LNG exports from Gladstone, Queensland first started in early 2015 and four of the six planned LNG trains are now operational, with the remaining two due online in the first half of this year. Production is expected to reach full capacity by 2018. LNG trains consume electricity to liquefy the natural gas. More information is available at: Lewis Grey Advisory, *Projections of Gas & Electricity used in LNG Public Report,* April 2016.

16 Residential and commercial photovoltaics.

17 AEMO, *National Electricity Forecasting Report*, June 2016.

18 Ibid.

to coinciding with PV output during the day. The minimum demand in South Australia is projected to fall below zero by 2026/27.[19]

Interconnector developments

In 2015/16, the Heywood interconnector between Victoria and South Australia was in the process of being upgraded. The capacity was increased from 460MW to 650MW, providing up to 190MW of additional capacity in both directions. The upgrade was completed in July 2016 and the increased capacity was incrementally released to the market.

Reliability review

In 2015/16, there was no USE in the NEM.[20] However, USE is forecast by AEMO in the 2016 electricity statement of opportunities (ESOO)[21] to occur in Victoria, South Australia and New South Wales in the short to medium term if there is not a sufficient market response:[22]

- Victoria is projected to have unserved served energy of up to 0.0026% from 2017 to 2026.
- South Australia is projected to have unserved served energy of up to 0.0042% from 2017 to 2026
- New South Wales is projected to have unserved energy of up to 0.0009% from 2021 to 2026.

In addition to consideration of unserved energy, the Panel has reviewed historical reserve levels. This helps to illustrate the extent to which there was tightness in the balance of supply and demand.

Analysis indicates that there has been a general decline in the number of actual lack of reserve notices[23] issued over the last decade. This may indicate a historic broadening of reserve levels in the NEM.[24]

Further analysis has also shown an increase in the number of forecast lack of reserve notices that have been cancelled, before the lack of reserve condition occurs. Among other reasons, this may provide some indication that the market is increasingly

19 Ibid.

20 The Panel notes that there have been incidents resulting in USE following the conclusion of the reporting period for AMPR 2016. This will be covered in detail in AMPR 2017.

21 AEMO, *Update: Electricity statement of opportunities*, November 2016.

22 This refers to the return to service of mothballed generators in addition to changes in the supply-demand balance.

23 These notices are published by AEMO and indicate to the market that there are shortages in spare capacity in generation. If a lack of reserve is negative, it indicates that load is being shed. AEMO also publishes forecast lack of reserve notices when a lack of reserve is forecast in the short term.

24 The Panel acknowledges that unserved energy can occur under a number of circumstances and the trend in lack of reserve notices should be taken only as a general indicator; it is not sufficient in itself to suggest that reliability in the NEM, or in any of the regions, has materially improved.

responding to the need for increased generation availability at times of tight supply demand balance.[25]

There are a number of reasons why a lack of reserve notice may be cancelled. For example, AEMO may change its forecast of demand or it may indicate a response from the market to address the projected lack of reserve. The Panel considers that this trend in the cancellation of lack of reserve notices, and the potential degree of market response that it indicates, warrants further consideration. The Panel intends to consider this trend in more detail in AMPR 2017.

Security

The NEM is considered to be in a secure operating state if the power system is in a satisfactory operating state and will return to a satisfactory operating state following a credible contingency in accordance with the power system security standards.[26] The key parameters to manage in order to maintain a secure and satisfactory operating state are frequency, voltage, current flows and the operation of equipment within its limits.

In terms of the security of the NEM in 2015/16, the Panel notes:

- The frequency operating standard was met for the mainland.[27] Tasmania did not meet the frequency operating standard in February 2016.
- The time spent outside the normal operating frequency band in 2015/16 was greater than in 2014/15 or 2013/14. Over the past three years, the number of times the frequency has exceeded the normal operating frequency band in the mainland and Tasmania has increased.
- There were two instances of under frequency load shedding to maintain the power system within a satisfactory operating state; once in Tasmania in August 2015 and once in South Australia in November 2015.
- System restart ancillary services were not drawn upon.[28]
- The power system was not in a secure operating state for 174 minutes in June 2016 due to post-contingent voltages at Moorabool substation in Victoria. The cause of the incident was a combination of an unusual transmission configuration and difficulties in managing the reactive power output of Mt Mercer wind farm.

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25 The Panel acknowledges that there are a number of other reasons why a lack of reserve notice may be cancelled, such as AEMO changing its forecast of demand. The Panel therefore considers that this trend in the cancellation of lack of reserve notices, and the potential degree of market response that it indicates, warrants further consideration. The Panel intends to consider this trend in more detail in AMPR 2017.

26 The power system security standards are the standards (other than the reliability standard and the system restart standard) governing power system security and reliability of the power system.

27 The frequency operating standard is determined by the Reliability Panel and sets out the frequency bands within which AEMO must operate the system.

28 The Panel notes that system restart ancillary services were drawn upon following the South Australian system black event in September 2016. As this event falls outside of the reporting period for this 2016 AMPR, the Panel has not provided substantial comment in this report. However, the Panel intends to provide further commentary in AMPR 2017, which will cover the period July 2016 to June 2017.

The Panel notes that system security issues are the subject of a number of ongoing work programs, including the work of the AEMC and AEMO. These projects are described in further detail at the end of this concise report. These issues include, but are not limited to:

- Decreases in available system inertia, resulting in increased challenges of maintaining system frequency following disturbances: A certain level of inertia is necessary to maintain the rate of change of frequency to manageable levels.[29] The rate of change of frequency following a sudden change in the supply-demand balance is related to the level of inertia in the system and the size of the change.

  If the rate of change of frequency is sufficiently large, it can result in the failure of load or generation. This may in turn exacerbate the rate of change of frequency. If the rate of change of frequency is large enough, emergency schemes may not be able to prevent a broader system collapse.

- Declining system strength: System strength is a quantity inherent to any power system and is typically enhanced by synchronous generation. The supportive characteristics of synchronous generation are not typically provided by power electronic converter-connected, non-synchronous generation technologies.

  Declining system strength can lead to localised issues and can also have broader power system impacts. Three potential challenges for power system security are:[30]

  1. the possible reduced effectiveness of some types of network and generating systems' protection functions
  2. power electronic converter-interfaced devices such as wind turbines and solar inverters require a minimum fault level to operate in a stable and reliable condition.[31] Reduced system strength could therefore impact on their ability to ride through faults on the system
  3. voltage control in response to small and large system disturbances is also affected by system strength, with weaker systems more susceptible to voltage instability or collapse.

Major incidents

The Panel has summarised three major incidents that occurred in 2015/16 that impacted upon the security and reliability of the NEM. These major incidents are:

- **November 2015 trip of the Heywood interconnector**: On 1 November 2015 load shedding occurred in South Australia. This involved the trip of Heywood Line 1 (while Line 2 was out due to a planned outage) that resulted in South Australia being islanded from the rest of the NEM. This resulted in the loss of 160MW of customer load and 11MW of generation. Following the separation, there were

29 This is the case in the NEM currently. Future technologies may be able to substitute for inertia.

30 AEMO, *Future power system security program progress report*, August 2016, p. 45.

31 Fault levels are directly related to power system strength. A low strength system will have low fault levels.

problems controlling the frequency in the islanded South Australian power system.

- **December 2015 outage of Basslink**: On 20 December 2015 a fault occurred on Basslink, the interconnector running between Tasmania and the mainland. This fault took Basslink out of service and separated Tasmania from the mainland. At the time of the fault occurring, approximately 250MW of industrial load was disconnected under the Frequency Control Special Protection Scheme.[32] Basslink was out of service until June 2016. Coupled with very low dam storage levels for Tasmania's hydro generation, this resulted in elevated wholesale prices and reduced demand in Tasmania for the relevant period.
- **August 2015 Tasmania load shedding**: On 2 August 2015, a lightning strike tripped the two Farrell-Reece transmission lines (the FA-RE lines) in Tasmania. As a result of the line trip, two generating units at Reece Power Station were disconnected resulting in the loss of 228MW of generation in Tasmania. Both lines and the generating units at Reece Power Station were restored after 12 minutes.[33] Immediately following the event, frequency fell and was arrested mostly due to load shedding. 225MW of load was shed, consisting of 101MW at Bell Bay Aluminium and 124MW at Nyrstar.

These particular events have been selected by the Panel as they illustrate the extent of the potential supply and price impacts for consumers following major reliability or security events in the power system. These events show that in order to maintain system security, certain instances require the shedding of load. They also highlight that, while not always the case, regions can be more exposed to reliability and security issues when disconnected from the rest of the NEM.

While a number of other significant events have occurred, such as the South Australian black system event of 28 September 2016, these fall outside the reporting period of the AMPR 2016. As such, a brief overview of those events is provided in the main body of the report and a more detailed review will be provided in AMPR 2017.

Safety

The Panel's assessment of the safety of the NEM is focused on the consideration of the links between security of the power system and maintaining the system within relevant standards and technical limits. The Panel is not aware of any instances in 2015/16 where AEMO issued a direction and the directed participant elected not to comply on the grounds that complying with the direction would affect the safety of its equipment or personnel

Relevant policy developments

This draft AMPR coincides with a number of other market reform projects, including several AEMC market reviews and rule changes, as well as various AEMO projects:

32 The Tasmanian special protection schemes are market based schemes where loads are paid a fee in return for being shed following certain contingency events. This kind of commercially negotiated demand reduction is not counted towards USE or measures of load shedding.

33 AEMO, *Under frequency load shedding in Tasmania on Sunday 2 August 2015*, October 2015, pp. 4-5.

- **System security market frameworks review**: The AEMC is reviewing aspects of system security as new technologies drive a transformation of the NEM. The review aims to consider, develop and implement changes to market frameworks to allow the continued uptake of new generating technologies, while maintaining the security of the system.[34] The review is being coordinated with ongoing technical work by AEMO. An interim report was published on 15 December 2016.
- **Future power system security program (FPSS)**: AEMO has established the FPSS program to formalise and accelerate the work it has undertaken in the last few years to address operational challenges arising from the changing generation mix.[35] This work will inform and is being undertaken in cooperation with the AEMC's System security market frameworks review.
- **Emergency frequency control schemes and protected events rule change**: On 22 December 2016, the AEMC made a draft rule to facilitate enhanced emergency frequency control schemes and to introduce a new category of contingency events, the protected event. These changes are designed to help deliver a secure supply of electricity at the lowest possible cost to consumers in a changing power system environment. The Panel notes that the AEMC is currently finalising policy for the emergency frequency control rule change, and intends to publish a final determination on 30 March 2017.[36]
- **System restart standard review**: On 15 December 2016, the Reliability Panel determined a new system restart standard (SRS). The SRS specifies the time, level and reliability of generation and transmission capacity to be available for the restoration process following a major supply disruption (or black system event) that results in an uncontrolled power outage in one or more electrical sub-networks in the NEM.[37]

Conclusions

There were a number of significant changes in 2015/16, which reflected various ongoing trends in the NEM.

One such change was the significant withdrawal of conventional thermal generation coupled with the continued entry of newer generation technologies particularly wind and photovoltaics.

These changes are likely to have a number of implications for the ongoing reliability and security of the NEM.

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34 For more information, see the System security market frameworks review project page: http://www.aemc.gov.au/Markets-Reviews-Advice/System-Security-Market-Frameworks-Review

35 For more information on the Future Power System Security program, see the project page: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/FPSSP-Reports-and-Analysis

36 For more information, see the emergency frequency control schemes project page: http://www.aemc.gov.au/Rule-Changes/Emergency-frequency-control-schemes-for-excess-gen

37 For more information on the new system restart standard, see the system restart standard review project page: http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-System-Restart-Standard

While the NEM has had very little USE over the past ten years, AEMO projections suggest that, in the absence of sufficient market response, there may not be enough generation to meet demand in the medium term. This projected shortfall highlights the need for efficient supply side and/or demand side investment so that consumer demand for energy continues to be met.

There were also a number of system security events in 2015/16, several of which resulted in an interruption of supply to consumers. While the causes of these incidents are complex, they demonstrate the ongoing importance of maintaining system security in a changing environment.

In the context of these challenges, the Panel acknowledges the significant body of work underway that is considering how to maintain the ongoing reliability and security of the NEM. This includes the AEMC's System security market frameworks review, AEMO's Future power system security review and the Independent Review into the Future Security of the National Electricity Markets, led by the Chief Scientist, Dr Alan Finkel.

The body and appendices of this report provides more detail on the issues covered in this concise report.

Contents

1 Introduction

This report has been prepared as part of the Reliability Panel's (the Panel) annual market performance review (AMPR) of the National Electricity Market (NEM). It covers the 2015/16 financial year. The review is a requirement of the National Electricity Rules (NER).

1.1 Background

The functions of the Panel are set out in clause 8.8.1 of the NER. Among other things, the Panel is required to:

- monitor, review and report on the performance of the market in terms of reliability of the power system[38]
- report to the Australian Energy Market Commission (AEMC) and participating jurisdictions on overall power system reliability matters, power system security and reliability standards and the Australian Energy Market Operator's (AEMO) power to issue directions in connection with maintaining or re-establishing the power system in a reliable operating state.[39]

Consistent with these functions, clause 8.8.3(b) of the NER requires the Panel to conduct a review of the performance of certain aspects of the market, at least once every calendar year and at other such times as the AEMC may request. The Panel must conduct its annual review in terms of:

- reliability of the power system
- the power system security and reliability standards
- the system restart standard
- the guidelines referred to in clause 8.8.1(a)(3)[40]
- the policies and guidelines referred to in clause 8.8.1(a)(4)[41]
- the guidelines referred to in clause 8.8.1 (a)(9).[42]

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38 Clause 8.8.1(a)(1) of the NER. In performing this function, clause 8.8.1 (b) prohibits the Panel from monitoring, reviewing or reporting on the performance of the market in terms of reliability of distribution networks. However, the Panel may collate, consider and report information in relation to the reliability of distribution networks as measured against the relevant standards of each participating jurisdiction, in so far as the reliability of those networks impacts on overall power system reliability.

39 Clause 8.8.1 (a)(5) of the NER.

40 The guidelines referred to in clause 8.8.1 (a)(3) of the NER govern how AEMO exercises its power to issue directions in connection with maintaining or re-establishing the power system in a reliable operating state.

41 The policies and guidelines referred to in clause 8.8 .1 (a)(4) govern how AEMO exercises its power to enter into contracts for the provision of reserves.

42 The guidelines referred to in clause 8.8.1 (a)(9) identify, or provide for the identification of, operating incidents and other incidents that are of significance for the purposes of the definition of "Reviewable operating incident" in clause 4.8.15.

1.2 Purpose of the report

The purpose of this report is to set out the Panel's findings for its annual market performance review for 2015/16. In conducting this review, the Panel has considered publicly available information in addition to information obtained directly from relevant stakeholders and market participants.[43]

The Panel's findings include observations and commentary on the reliability, security and safety performance of the power system. It also provides an opportunity for the Panel to consolidate key information related to the performance of the power system in a single publication for the purpose of informing stakeholders. Among other things, this may assist governments, policy makers and market institutions to monitor the performance of the power system, and to identify the likely need for improvements to the various measures available for delivering reliability, security and safety.

1.3 Scope of the review

The Panel is undertaking this review in accordance with the requirements in the NER and the terms of reference issued by the AEMC.[44]

The AEMC has requested that the Panel review the performance of the market in terms of reliability, security and safety of the power system in 2015/16. The Panel has had regard to the following matters when conducting its review:

- **Overall power system performance**: A comprehensive overview of the performance of the power system is provided. The Panel has considered:
    - performance in terms of reliability and security from the perspective of the generation sector, the transmission and distribution sectors and impacts on end-use customers where relevant information is available
    - significant power system incidents (including but not necessarily limited to "reviewable operating incidents"[45]) that have occurred in the financial year 2015/16 including the cause of the incident (a reliability or security event),

43 The data and information gathered has been provided by a number of organisations including AEMO, network service providers, the Australian Energy Regulator (AER) and jurisdictional government departments and regulators. This data and information provided by other parties has not been verified for accuracy or completeness by the Panel. It has been assumed that those organisations have undertaken their own quality assurance processes to validate the data and information provided.

44 The terms of reference for this review are available on the AEMC Reliability Panel website.

45 A reviewable operating incident is a term defined in the NER. It refers to, among other things, a non-credible contingency event or multiple contingency events on the transmission system; or a black system condition; or an event where the frequency of the power system is outside limits specified in the power system security standards; or an event where the power system is not in a secure operating state for more than 30 minutes; or an event where AEMO issues a clause 4.8.9 instruction for load shedding an incident where AEMO has been responsible for the disconnection of facilities of a Registered Participant under the circumstances described in clause 5.9.5; or any other operating incident identified, in accordance with guidelines determined by the Reliability Panel under rule 8.8, to be of significance to the operation of the power system or a significant deviation from normal operating conditions.

the impact of the incident (on reliability or security) and the sector of origin (generation, transmission or distribution).

In particular, the Panel has provided a detailed consideration of three specific incidents in 2015/16 that it considers are particularly significant. These incidents are:[46]

1. high frequency control ancillary services (FCAS) prices and load shedding in South Australia in October and November 2015
2. load shedding in Tasmania in August 2015
3. the fault on Basslink from December 2015 to June 2016.

— Other major incidents, including the system black event in South Australia in September 2016 and the separation of the SA region from the rest of the NEM in November 2016, did not occur within the reporting period for this annual market performance review. The South Australian black system event is also the subject of a number of ongoing processes, including reviews and investigations by the AEMC,[47] AEMO[48] and AER.[49]

  Accordingly, a short summary of these events is provided in chapter 6 of this AMPR. A more detailed consideration of the system black event will be provided in AMPR 2017, which will cover the financial year 2016/17. This will allow the relevant market bodies to complete their review and assessment processes.

- **Reliability performance of the power system**: The Panel has reviewed reliability performance against of generation and bulk transmission (i.e. interconnection). In doing so, it has considered:
  — actual observed levels of maximum expected unserved energy (USE) over 2015/16
  — actual and forecast supply and demand conditions in order to form a view on whether any underlying changes to reliability performance have occurred, or are expected to occur
  — AEMO's use of the reliability safety net mechanisms over the previous financial year, including incidents of, and reasons for, the use of directions and the Reliability and Emergency Reserve Trader (RERT) mechanism.

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46 While some of these specific incidents are classed as reviewable operating incidents, others do not meet the NER specification of a reviewable operating incident. The Panel has chosen to include these incidents for consideration based on the magnitude of their impact on consumers.

47 For more information see: http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-System-Black-Event-in-South-Australi/Initiation/AEMC-Documents/Terms-of-reference.aspx

48 For more information see: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/Integrated-Third-Report-SA-Black-System-28-September-2016.pdf

49 For more information see: https://www.aer.gov.au/wholesale-markets/compliance-reporting/quarterly-compliance-report-october-december-2016

- **Security performance of the power system**: The Panel has reviewed performance of the power system against the relevant technical standards. In particular, the Panel has had regard to: frequency operating standards; voltage limits; interconnector secure limits; and system stability.
- **Safety performance of the power system**: Safety of the power system is closely linked to the security of the power system and relates primarily to the operation of assets and equipment within their technical limits. Therefore, the Panel has limited its consideration of this matter to maintaining power system security within the relevant standards and technical limits.[50]

1.4 Review process

The Panel is carrying out this review in accordance with the process set out in the NER and reflected in the AEMC's terms of reference. The following table outlines the planned timetable for the delivery of the Panel's final report to the AEMC.

Milestone	Date
Publication of draft report	4 March 2017
Close of requests for a public meeting	30 March 2017
Close of submissions on draft report	4 May 2017
Publication of final report	16 May 2017

1.5 Making a submission

Comments from interested parties in response to this draft report are invited by 4 May 2017.

In addition, any person or body may request that the Panel hold a public meeting in relation to the draft report. Any request for a public meeting must be made in writing and must be received by the Panel no later than 30 March 2017.

Electronic submissions must be lodged online through the AEMC's website www.aemc.gov.au using the link entitled "lodge a submission" and reference code "REL0060".

If choosing to make a submission by mail, the submission may be posted to:

The Reliability Panel

Australian Energy Market Commission

PO Box A2449

SYDNEY SOUTH NSW 1235

50 Safety of jurisdictional power systems is primarily administered by individual jurisdictions. As a result, the Reliability Panel has assessed safety from the perspective of operating equipment with technical limits. However, more information on individual jurisdictional considerations of safety is provided in appendix H.

All submissions must be on letterhead (if submitted on behalf of an organisation), signed, dated and quote the project number "REL0060".

All submissions will be published on the AEMC Reliability Panel website, subject to a claim of confidentiality.

1.6 Structure of this report

This report has been structured in order to assist readers seeking different levels of information and detail. The concise report provides a high level overview of the Panel's key findings, while this main body of the report provides a greater level of detail on key market trends and issues. Higher levels of detail, including tables of results and other technical information, is provided in relevant appendices.

The remainder of the document is set out as follows:

- **Chapter 2 – Key concepts and relevant standards and guidelines**: an explanation of key areas addressed by the AMPR, including an overview of the standards and guidelines published by the Panel and the operational guidelines that AEMO uses to manage the power system.
- **Chapter 3 - Market trends**: an overview of trends in the NEM for 2015/16.
- **Chapter 4 - Reliability review**: an overview of the reliability performance of the NEM in 2015/16, historical performance and assessment of emerging trends.
- **Chapter 5 - Security review**: an overview of security related issues that occurred during 2015/16.
- **Chapter 6 - Power system incidents**: a summary of some significant power system incidents that occurred in 2015/16.
- **Chapter 7 - Safety review**: a high level summary of the performance of the power system from a safety perspective.
- **Appendices**: detailed background information on various aspects of NEM power system management and performance.

2 Key concepts and relevant standards and guidelines

The focus of this review is on the reliability, security and safety performance of the power system. These concepts are discussed below, with an explanation of the relevant standards and guidelines.

2.1 Reliability

Reliability is generally associated with ensuring there is enough capacity to generate and transport electricity to meet all consumer demand.[51]

Reliability is measured in terms of unserved energy (USE) which refers to an amount of energy that is required (or demanded) by customers but which is not supplied.[52]The current reliability standard is expressed in terms of the maximum expected USE, or the maximum amount of electricity expected to be at risk of not being supplied to consumers, per financial year. The current reliability standard requires that the maximum expected amount of unserved energy in any region not exceed 0.002 per cent of the regions annual energy consumption in a financial year.

Reliability performance is measured against actual observed levels of USE for the most recent financial year.[53]The reliability of the NEM is reviewed by AEMO each year to examine any incidents that have resulted in USE.[54] The NER does not give specific direction to AEMO on how to implement the reliability standard, but it does require AEMO to perform the following functions in accordance with the reliability standard implementation guidelines.[55] AEMO operationally applies the reliability standard in the short-term and medium-term Projected Assessments of System Adequacy (PASA) through Minimum Reserve Levels (MRL) for each jurisdiction:

- PASA is a programme of information collection, analysis, and disclosure of medium-term and short-term power system security and reliability of supply prospects. The purpose of providing these assessments is to enable market

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51 Reliability is an economic construct to the extent that it must be cost-effective for generators and networks to have enough capacity to meet demand; whereas security is a technical concept as discussed in section 2.2.

52 "Unserved energy" is a defined term in NER clause 3.9.3C(a) as: The *reliability standard* for *generation* and *inter-regional transmission* elements in the *national electricity market* is a maximum expected USE in a region of 0.002% of the total *energy* demanded in that *region* for a given financial year. Importantly, the reliability standard is a planning standard that is used to identify the need for investment in generation and bulk transmission capability in the NEM.

53 This is different from the previous standard where compliance was measured against the moving average of the USE in the most recent ten financial years. The Panel made this change as a result of its review of the standard and settings in 2010. The Panel considered that it was not appropriate to assign significant meaning to individual historical outcomes or to the average of a number of outcomes over a long period of time. Rather, the reliability of the NEM should be reviewed each year to examine any incidents that have resulted in USE. See AEMC Reliability Panel 2010, *Reliability Standard and Reliability Settings Review, Final Report*, 20 April 2010, Sydney.

54 NER, clause 3.9.3D.

55 The reliability standard implementation guidelines are available on AEMO's website at https://www.aemo.com.au/Stakeholder-Consultation/Consultations/Reliability-Standard-Implementation-Guidelines

participants to be properly informed and able to make decisions about supply, demand and outages of transmission networks in respect of periods up to two years in advance. The PASA assessments are the only existing NER-based requirements on AEMO with respect to how it implements the reliability standard.[56]

- MRLs are the reserve margins that AEMO calculates are required so as not to exceed maximum expected unserved energy set in the reliability standard. MRLs function to convert the maximum allowable USE (0.002%) into a minimum reserve level in megawatts such that if reserve levels in a given region are greater than the MRLs, the reliability standard will be expected to be met.
- AEMO can also declare conditions requiring publication of notices[57] to advise when capacity reserve may be below the level needed to manage a credible contingency event.[58] There are three different lack of reserve conditions in the NEM. AEMO issues declarations that these conditions exist, in order to signal to the market either a present or future shortage of reserve:[59]
  - Lack of reserve level 3 (LOR3): this means that there is insufficient supply to meet demand. An actual LOR3 would represent load shedding.
  - Lack of reserve level 2 (LOR2): this means that a credible contingency, such as the loss of the largest generating unit, would result in there being insufficient supply to meet demand.
  - Lack of reserve level 1 (LOR1): this means that two successive credible contingencies, such as the loss of the two largest generating units, could result in there being insufficient supply to meet demand.

To assess the reliability performance of the NEM, the "bulk transmission" capacity of the NEM is taken to equate to interconnector capability.[60] Consequently, only constraints in the transmission network that affect interconnector capability are considered when assessing the availability of reserves in a region.[61]

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56 AEMO publishes PASA in two forms: medium term PASA, which forecasts peak capacity reserve conditions over a two year period; and short term PASA, which forecasts capacity reserve over a six day projection.

57 These notices include lack of reserve notices which indicate to the market various levels of shortage of reserve.

58 A credible contingency event means a contingency event of which AEMO considers to be reasonably possible to occur in the surrounding circumstances including the technical envelope. The includes, but is not limited to, the failure of a single generating unit or the failure of a single major item of transmission plant.

59 The conditions are defined in Chapter 4 of the NER.

60 The reason for this is that the reliability standard is measured on a regional basis, and the standard is met when sufficient generation capacity is available in a region. This capacity is calculated as the sum of local generation available within the region itself and of interstate generation available via an interconnector.

61 In the Comprehensive Reliability Review, the Panel clarified the definition of "bulk transmission". See AEMC Reliability Panel, 2007, Comprehensive Reliability Review, Final Report, Sydney, pp. 32-33.

Measurement of the reliability performance of the NEM does not take into account interruptions to consumer supply that are caused by outages of local transmission or distribution elements that do not significantly impact the ability to transfer power into the region. Interruption to supply caused by these kinds of events do not count towards measurements of USE.

However, the performance of distribution and transmission networks do influence the supply outcomes experienced by electricity consumers. Therefore, consistent with the AEMC's terms of reference, the Panel has also included information on the performance of the non-bulk transfer transmission and distribution networks.[62]

Measurement of the reliability performance of the NEM also does not consider any interruptions to supply that are the result of non-credible (or multiple) contingency events.[63] Interruption of consumer load in these circumstances may be due to an automatic controlled load shedding response that is initiated following a sudden change in frequency in order to prevent power system collapse, rather than the result of insufficient generation or bulk transmission capacity being made available. The consequences of these non-credible contingency events are formally classified as power system security issues and are addressed separately in this report.[64]

The reliability standard also does not include any interruptions to supply due to a black system event, such as the event that occurred in South Australia on 28 September 2017.[65] A black system can occur when non-credible contingency events cause a cascading failure of the power system, resulting in large portions of the system to collapsing to a state of zero voltage and energy. As such, the interruption to supply is not due to a lack of generation capacity or bulk transfer capability. The Panel has included a brief description of the September 2016 South Australian black system event in this 2016 AMPR, and a more detailed summary will be included in the 2017 AMPR.[66]

62 In reporting on distribution network performance the Panel has had regard to NER clause 8.8.1(b) as set out in section 1.1 of this report.

63 Contingency events are the basis of the way in which AEMO operates the power system. The NER require AEMO to undertake various actions so that the power system will be in a given frequency condition following different contingency events. A credible contingency event is an event that AEMO considers to be reasonably possible in the surrounding circumstances. For these events, AEMO is required to maintain the frequency within given limits and achieves this through procuring FCAS and constraining generation dispatch. A non-credible contingency event is a contingency event other than a credible contingency event. This includes, but is not limited to, events such as the simultaneous failure of multiple generating units or a double circuit transmission line failure. For these events, AEMO is required to maintain the frequency and achieves this through controlled automatic load shedding.

64 Power system incidents are discussed in chapter 5.

65 For more information on the event, refer to the AEMO system event report, available at https://www.aemo.com.au/Media-Centre/System-event-report-South-Australia-8-February-2017

66 Additionally, the COAG Energy Council has asked the AEMC to undertake the final stage of work by the market bodies into South Australia’s system black event on 28 September 2016. The AEMC review will build on work already underway by the market operator, AEMO, into technical matters in relation to the event; as well as the Australian Energy Regulator’s compliance review. The AEMC report is due to be provided within six months of the completion of both AEMO’s investigation report and the AER’s compliance report. For more information on this review, see:

2.2 Security

While reliability measures whether there is sufficient capacity to meet demand, security of the power system refers maintenance of the power system within specific technical limits. System security is managed directly by AEMO and network operators in accordance with applicable technical standards.

Maintaining the security of the power system is one of AEMO's key functions. The power system is deemed secure when all equipment is operating within safe loading levels and will not revert to an unsatisfactory operating state in the event of a single credible contingency. Secure operation depends on the combined effect of controllable plant, ancillary services, and the underlying technical characteristics of the power system plant and equipment.

The practices adopted by AEMO to manage power system security are defined in its operating procedures and guidelines, which have been developed from overarching guidelines defined by the Panel and obligations under the NER. AEMO is required to operate the power system within the frequency operating standards. These standards specify the frequency bands that the power system must be operated within under specific circumstances. The frequency operating standards are developed by the Panel and are published on the AEMC's website.[67]

Operations consistent with those guidelines are intended to maintain system quantities such as voltage and frequency within acceptable performance standards, as well as providing that certain equipment ratings are not exceeded following credible contingencies.

A principle tool used by AEMO to maintain power system security is the constraint equations used in the market dispatch systems. Violations of constraint equations can indicate, among other things, periods where the power system is not in a secure state.

The Panel has reviewed power system security performance by considering the following matters:

- whether the power system has been operated consistent with AEMO's published procedures and guidelines
- whether system parameters have been maintained within the range specified in the relevant standards
- the frequency and extent of any violation of constraint equations
- the frequency and extent of any violations of equipment ratings.

The Panel notes that various projects are currently underway that relate to the security of the power system. These projects include, but are not limited to the:[68]

- system security market frameworks review undertaken by the AEMC[69]

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http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-System-Black-Event-in-South-Australi#

67 AEMC Reliability Panel, *Application of frequency operating standards during periods of supply scarcity*, April 2009.

68 These projects are explained in more detail in section 2.5. Other relevant projects are detailed in appendix J.

- emergency frequency control schemes and protected events rule change undertaken by the AEMC[70]
- the future power system security program undertaken by AEMO.[71]

A description of these projects is provided in section 2.5.

In addition, the Panel has considered the various reviews of power system incidents reported by AEMO during 2015/16. This allows for an assessment of whether those incidents point to any emerging power system security issues or practices that might need to be revised to maintain future power system security.[72]

2.3 Safety

While the general safety of the NEM, and associated equipment, power system personnel and the public is an important consideration under the National Electricity Law (NEL), in general terms, there is no national safety regulator for electricity. Instead, jurisdictions have specific provisions that explicitly refer to safety duties of transmission and distribution systems, as well as other aspects of electricity systems such as metering and batteries.[73]

There are strong linkages between maintaining power system security and operating the power system safely. For example, the transfer limits and ratings that define the secure operating envelope for the power system are set at levels that maintain safety; and safe clearances from conductors are maintained by setting the thermal rating of transmission lines at an appropriate level. Safety, therefore, is supported by operating the power system within ratings and technical limits.

In this way, maintaining security of the power system could be considered as maintaining a "safe" power system to meet the requirements for safety in a general sense.[74]

In addition to considering the safety performance of the market as defined above, the Panel has included a summary of safety outcomes in each NEM jurisdiction by reference to jurisdictional safety requirements. This summary is included in appendix H.

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69 For more information, see the System security market frameworks review project page: http://www.aemc.gov.au/Markets-Reviews-Advice/System-Security-Market-Frameworks-Review

70 For more information, see the Emergency frequency control schemes rule change project page: http://www.aemc.gov.au/Rule-Changes/Emergency-frequency-control-schemes-for-excess-gen

71 For more information, see the System security market frameworks review project page: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/FPSSP-Reports-and-Analysis

72 Under NER clause 4.8.15, AEMO is required to undertake reviews of reviewable operating incidents.

73 See section 2D(a) of the NEL.

74 Although it is noted that some system security considerations do not directly relate to safety, for the purpose of our considerations where the power system has been maintained in a secure state it is considered to also be in a safe condition.

2.4 Standards and guidelines

The performance of the power system is measured against various standards and guidelines that form the technical standards framework. This framework is designed to maintain the security and integrity of the power system by establishing clearly defined standards for the performance of the system overall. The framework comprises a hierarchy of standards:

- **System standards**: define the performance of the power system, the nature of the electrical network and the quality of power. These also establish the target performance of the overall power system. AEMO's obligations to manage the power system are included in Chapter 4 of the NER and in the frequency operating standards developed by the Panel.
- **Access standards**: specify the quantified performance levels that a plant or equipment (consumer, network or generator) must achieve to allow it to connect to the power system. Access standards define the range within which parties may negotiate with network service providers, in consultation with AEMO, for access to the network. AEMO and the relevant network service providers need to be satisfied that any access granted to the power system will not negatively affect the ability of the network to meet the relevant system standards, nor impact on other network users.
- **Plant standards**: set out the technology specific standards that, if met by particular facilities allow compliance with the access standards. Plant standards can be used for new or emerging technologies where they are not covered by access standards. The standard allows a class of plant to be connected to the network if that plant meets some specific standard such as an international standard. To date, the Panel has not been approached to consider a plant standard.

The actual performance of all generating plant must also be registered with AEMO, and becomes known as a performance standard. Registered performance standards represent binding obligations on a generator. For generating plant to meet its registered performance standards on an ongoing basis, participants are also required to set up compliance monitoring programs. These programs must be lodged with the AER. It is a breach of the NER if the generating plant does not continue to meet its registered performance standards and compliance program obligations.[75]

2.5 Ongoing policy developments relevant to reliability and security

The Panel notes that various projects are currently underway that relate to the reliability and security of the power system. A summary of some of these projects is provided below.

75 The Panel developed a template in 2009 to assist generators in designing their compliance programs. This template was most recently updated by the Panel on 18 June 2015.

2.5.1 System security market frameworks review

The AEMC is reviewing aspects of system security as new technologies drive a transformation of the NEM.[76] The AEMC has set out the following three-part framework in considering the ability to maintain control of power system frequency following a contingency event, such as the loss of a large generator, load or transmission line:

- the initial rate of change of frequency
- the capacity to restore the stability of the system use of frequency response services
- the ability of generators and loads to withstand or "ride-through" changes in frequency.

The AEMC reached a preliminary view that the ability to maintain power system security in an efficient manner would be enhanced by the development and introduction of a mechanism to obtain inertia.[77] Additionally, the AEMC reached a preliminary view that the development of a fast frequency service would be beneficial in that it would provide greater flexibility in the level of rate of change of frequency that could be permitted and a more efficient amount of inertia to be procured.[78] The AEMC has identified potential mechanisms to obtain these services, including:[79]

- an obligation on generators to provide these services
- a process for AEMO to procure these services through contracts
- a process for network businesses to procure these services
- a five minute market for these services.

The review is being coordinated with ongoing technical work on these and related issues being undertaken by the AEMO. The terms of an agreement have been set out on how the AEMC and AEMO will collaborate, seeking to ensure that these activities deliver a coordinated package of measures to maintain future power system security.

The next stage of the review will be the publication of a directions paper on 24 March 2017. The direction paper outlines the AEMC's proposed approaches to managing frequency control and system strength. The Commission's proposed approach to addressing frequency control consists of two packages of complementary measures that would be implemented in a staged manner; an immediate package and a subsequent

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76 For more information, see the System security market frameworks review project page: http://www.aemc.gov.au/Markets-Reviews-Advice/System-Security-Market-Frameworks-Review

77 AEMC, *System security market frameworks review: Interim report*, December 2016, p. vii.

78 Ibid, p. viii.

79 Ibid, pp. xii-xiii.

package. The proposed approach to managing system strength is a variety of proposed rule amendments clarifying roles and obligations.[80]

2.5.2 Emergency frequency control schemes and protected events

The AEMC has made a draft rule to facilitate enhanced emergency frequency control schemes and to introduce a new category of protected contingency event.[81] These changes are designed to help deliver a secure supply of electricity at the lowest possible cost to consumers in a changing power system environment.

Emergency frequency control schemes should be able to utilise all available technologies as they evolve, in order to develop to meet future power system conditions. However, it must also be delivered at an efficient cost to consumers. The draft rule therefore sets out a governance framework in which:

- AEMO, in consultation with network service providers, will propose an emergency frequency control scheme, including estimates of potential scheme capabilities and costs to deliver those capabilities
- the Reliability Panel will undertake a cost benefit assessment of the proposal and will develop an emergency frequency control scheme standard
- AEMO will develop an emergency frequency control scheme functional design specification to meet the emergency frequency control scheme standard
- network service providers and generators (as relevant) will install and/or replace equipment that can meet these functional design specifications.

The draft rule also establishes the new category of protected contingency event and a governance framework for identifying specific protected events.

For a protected event, AEMO will be able manage the system at all times so that the frequency will stay within defined limits, if the protected event were to occur. This may include ex-ante actions, such as procuring ancillary services and constraining the dispatch of generation in the system. Some load shedding will also be allowed to limit the expected consequences of the protected event, if it occurs.

The Panel notes that the AEMC is scheduled to publish a final determination on 30 March 2017.

80 For more information see http://www.aemc.gov.au/Markets-Reviews-Advice/System-Security-Market-Frameworks-Review

81 An emergency frequency control scheme includes mechanisms that are designed to shed generation or load in a controlled and coordinated manner to arrest the sudden change in frequency that may occur following a major disturbance to the power system. Currently, these schemes include under frequency load shedding schemes. For more information, see the emergency frequency control schemes project page: http://www.aemc.gov.au/Rule-Changes/Emergency-frequency-control-schemes-for-excess-gen

2.5.3 Review of the System Restart Standard

On 15 December 2016, the Reliability Panel determined a new system restart standard (SRS).[82]

The SRS specifies the time, level and reliability of generation and transmission capacity to be available for the restoration process following a major supply disruption (or black system event) that results in an uncontrolled power outage in one or more electrical sub-networks in the NEM. As such the SRS provides a target for the procurement of SRAS by AEMO. It is a standard for procurement rather than an operational standard. Operationally, AEMO works in conjunction with generators, network service providers and JSSCs to restore the power system and customer load as quickly as possible.[83]

The Panel made some changes to the SRS in its review. These changes will apply from July 2018.

The key changes made to the SRS include:

- tailoring the level and time components of SRS for each electrical sub-network to reflect the speed at which the generation can be restored, the characteristics of the transmission network and the economic circumstances that apply to the sub-network
- specifying the minimum level of generation and transmission capacity to be restored by SRAS in each sub-network in accordance with a detailed economic assessment of procuring different levels SRAS
- including aggregate reliability of the SRAS procured for each of the electrical sub-networks. This requirement of the SRS better specifies the performance of the procured SRAS, and includes a requirement for AEMO to consider the reliability and damage to the transmission network, following a major supply disruption, when it calculates aggregate reliability.

2.5.4 Future power system security

In January 2017, AEMO published a progress report of its Future Power System Security (FPSS) program.[84] AEMO established the FPSS program to formalise and accelerate the work it has undertaken in the last few years to address operational challenges arising from the changing generation mix. If left unaddressed, AEMO considers these challenges will test the efficiency and adequacy of current operational and market processes. The FPSS program focuses entirely on power system security. It aims to adapt current processes to address immediate risks, while promoting solutions to maintain power system security over the next 10 years.

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82 For more information on the new system restart standard, see the system restart standard review project page: http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-System-Restart-Standard

83 AEMC, Review of the System Restart Standard: Final determination, December 2016, p. ii.

84 For more information on the Future Power System Security program, see the project page https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/FPSSP-Reports-and-Analysis

AEMO enlisted the expertise of a technical advisory group to inform its assessment. Four areas have been immediately progressed following this consultation:

- frequency control
- management of extreme power system conditions
- visibility of the power system (information, data and models)
- system strength.

Through its own review on power system security, the AEMC will address the related regulatory and market framework challenges that will arise, with technical input from the FPSS program.

2.5.5 ESCOSA inquiry into inverter-connected generators

In June 2016, the Essential Services Commission of South Australia (ESCOSA) commenced an inquiry into the licence conditions which ESCOSA should apply to grid-scale, inverter-connected wind-powered generators. This is the third review that the Commission has conducted into this matter, following earlier reviews in 2005 and 2010.[85]

The inquiry is driven by the need for short term adjustments to the current framework to allow for both conventional generation and newer technologies to co-exist during the transition from a generation mix with greater amounts of synchronous generation.[86]

An issues paper was published in December 2016, which seeks to facilitate discussion and debate on absence of a national framework dealing with the technical and system impacts of inverter-connected electricity generators.[87]

The draft report of the inquiry is expected to be published in May 2017, and a final report is expected to be published in August 2017.

85 ESCOSA, *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, December 2016.

86 Ibid.

87 Ibid.

3 Market trends

This chapter examines some of the key market trends in the generation mix and bulk transfer (i.e. interconnectors) in the NEM, including new entry, withdrawals and changes in interconnector capability. It examines trends in distributed energy resources (DER) as well as forecast trends in energy consumption and demand levels. It also provides some high level information on wholesale market price outcomes.

The trends in generation, bulk transfer, DER and demand play a key role in determining the present and future reliability of the NEM, as reliability is determined to be the ability of generation capacity and bulk transfer to meet demand. These trends also have consequential impacts on the security of the NEM such as the reduction in physical inertia inherent in the system and resultant changes to the rate at which frequency may change following a disturbance. The security implications of these trends are explored in chapter 5.

For the period 2015/16, the Panel notes the following key trends and outcomes:

- **Forecast consumption and demand**:[88] Electricity consumption has remained flat in 2015/16 and is forecast to remain flat until 2035/36. Regional maximum demand levels are also forecast to remain flat. Regional minimum demand levels are forecast to significantly decrease due to increased rooftop PV uptake and increased energy efficiency.
- **Generation withdrawals**: 780MW of generation capacity was withdrawn from South Australia in 2015/16, all of which was synchronous generation.[89] In addition to this, a second unit at Pelican Point (239MW) was mothballed in April 2015. Combined, this represented a 19% decrease in the total installed generation capacity, and a 43% decrease in the total installed synchronous generation capacity in South Australia, from April 2015 to July 2016.
- **New generation**: 109MW of generation was commissioned in 2015/16, all of which was large scale solar in NSW. 540MW of generation was committed; mostly wind in NSW, Victoria and South Australia. This generation was almost all non-synchronous generation.[90]

  AEMO has also forecast significant increases in rooftop solar PV, including rooftop PV combined with storage.[91]

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88 Consumption refers to electricity used over a period of time and is referred to in terms of energy measured in megawatt hours (MWh). Demand describes electricity usage at a particular point in time and is typically referred to in terms of power or demand measured in megawatts (MW). For more information see: www.aemc.com.au.

89 Synchronous generation is generation with operation that is physically 'synchronised' to the grid frequency. Conventional generation, such as coal fired power, gas fired power and hydro, is typically synchronous. Synchronous generation typically provides physical inertia and fault currents. Conversely, non-synchronous generation is typically synchronised to the grid through power electronics and does not provide physical inertia.

90 The only synchronous plant committed is Oaky Creek 2, a 15MW gas fired power station to be built in Queensland.

91 AEMO, *National Electricity Forecasting Report*, June 2016.

- **Increased bulk transfer**: the Heywood interconnector, which connects South Australia and Victoria, had its capacity increased from 460MW to 650MW.
- **Wholesale prices**: wholesale prices remained relatively flat in the NEM with the exception of Tasmania and Queensland. Both of these regions experienced relatively high wholesale prices.

3.1 Demand and consumption forecasts

Changes in the level of demand and consumption of energy are relevant to both the reliability and security of the NEM. This section identifies several of the key trends in demand and consumption.[92]

3.1.1 Key trends

The key trends in electricity demand and consumption include:

- **Households are using more electrical appliances**: Household electric appliance use, and the capacity and functionality (or "benefits") of these appliances, has increased since 2009. This trend is expected to continue in the next 20 years.[93] This has the effect of increasing both household electricity demand and consumption.
- **Consumption of electricity from the grid is expected to remain flat**: Despite increasing household reliance on electricity, the amount of electricity consumed from the grid, has declined across the NEM since 2009 as rooftop photovoltaics (PV), energy efficiency, and a range of other factors have offset increased electrical appliance use.[94]
- **New technologies are forecast to reduce energy use**: Mobile and web-connected device use is growing, while use of PCs and stationary home entertainment devices is forecast to decline resulting in reduced consumption. Battery storage technology may further offset increases in electricity consumption, by enabling households to store lower cost energy for use during peak periods.[95]
- **Energy intensive industries are a decreasing share of the Australian economy**: In aggregate, changes in the Australian economy are reducing overall energy consumption. The main growth sectors in the Australian economy are forecast to be relatively low energy intensity industries such as the services/commercial sector and food and beverage manufacturing. In contrast, growth drivers for Australian energy-intensive manufacturing are currently projected to be minimal. These energy-intensive sectors are expected to continue their relative decline in terms of consumption of electricity. The exception is Queensland's LNG export

92 The demand and consumption measured throughout this chapter is operational demand and consumption. Operational demand and consumption refers to electricity used by residential, commercial and large industrial consumers, as supplied by scheduled, semi-scheduled and significant non-scheduled generating units. Consumption refers to electricity used over a period of time. Demand describes electricity usage at a particular instance.

93 Ibid, p. 3.

94 Ibid, p. 4.

95 Ibid, p. 5.

industry, which is forecast to add 8.3% to Queensland's current electricity consumption.[96]

- **Maximum operational demand**: Regional maximum demand levels, which occur in the summer, are forecast by AEMO to remain flat. Winter maximum demand levels are forecast to increase to the point of almost matching summer maximum demand levels driven in part by the conversion of residential heating from gas to electric.
- **Minimum operational demand**: Due to increasing levels of rooftop PV, minimum demand is forecast by AEMO to shift from overnight to midday. It also forecast by AEMO that as rooftop PV capacity increases, minimum demand will continue to fall and is projected to fall below zero in South Australia in 2026/27. This would result in total customer demand being provided by rooftop PV generation, with excess rooftop PV generation remaining.

3.1.2 Consumption

Electricity consumption in the NEM peaked in 2008/09, before declining until 2013/14. AEMO considers that this decline was due to factors including:[97]

- a rapid uptake of rooftop PV
- improvements in energy efficiency
- permanent business closures.

This fall in annual consumption plateaued in 2015/16 due to consumption increases caused in part by:[98]

- a relatively cold winter and a relatively hot summer
- the start of production of LNG exports from Queensland.

Annual consumption of electricity is forecast to remain flat across the NEM until 2035/36:[99]

- Residential consumption is forecast to reduce by 16%. Consumption increases from population growth and increased uptake of appliances are offset by increases in rooftop PV output and energy efficient appliances.
- Business consumption is forecast to increase by 9.3%. Growth is mostly due to education, health and telecommunications services growth driven by population growth. Additionally, growth is driven by the continued ramping up of LNG train production in Queensland.

The forecast consumption in the NEM is shown in Figure 3.1.

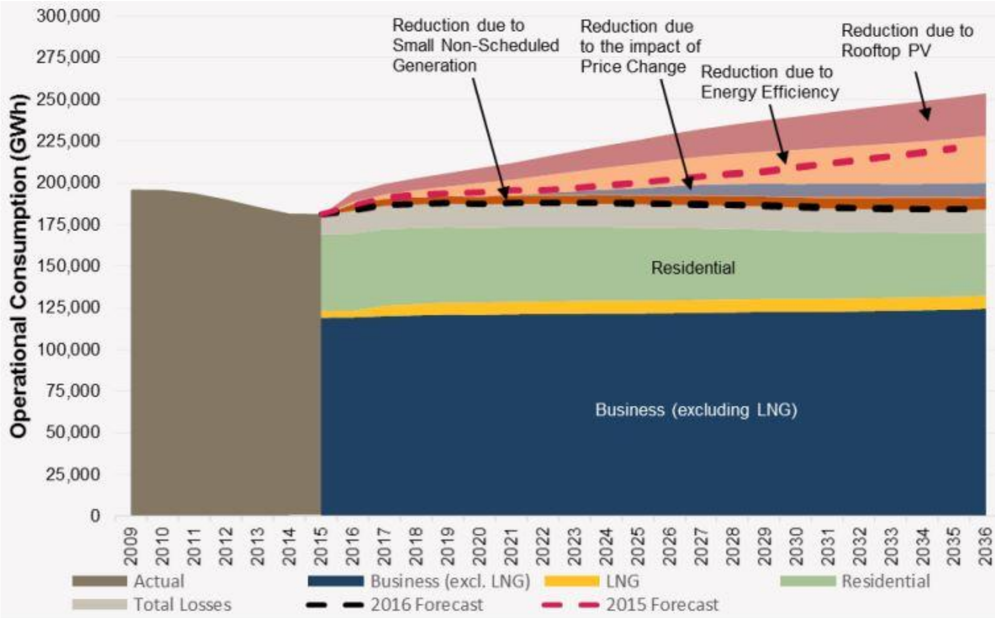
96 Ibid, p. 5.

97 Ibid, p. 5.

98 Ibid, p. 18.

99 Ibid, p. 17.

Figure 3.1 Forecast electricity consumption in the NEM



Source: AEMO, *National Electricity Forecasting Report*, June 2016.

3.1.3 Maximum and minimum operational demand

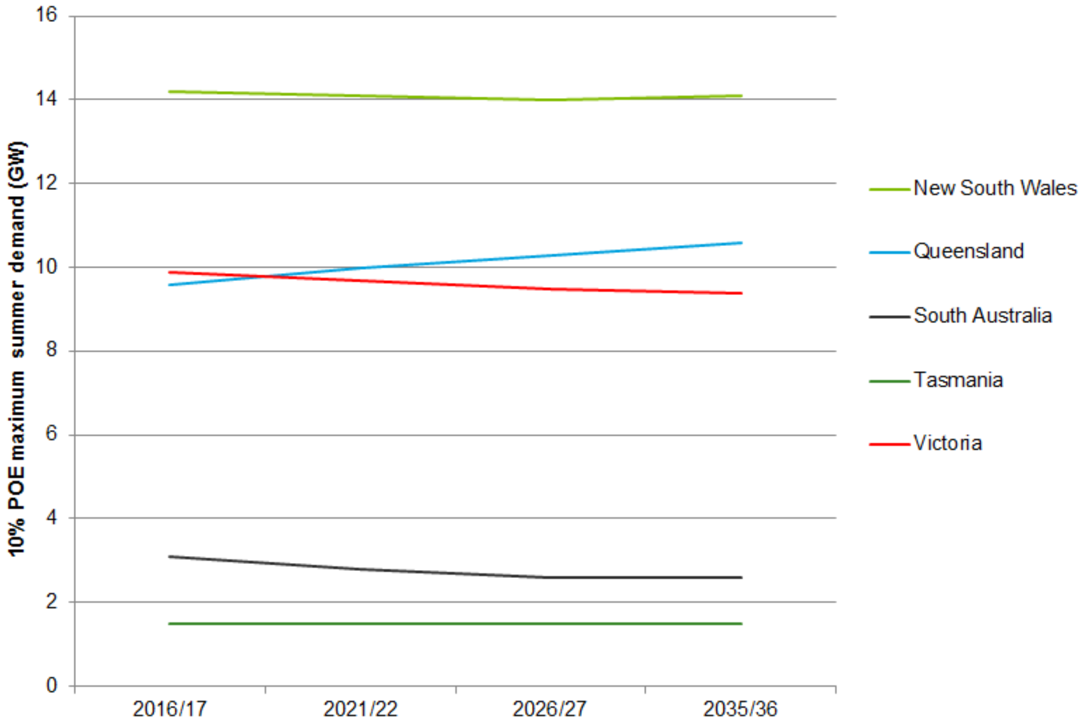
Forecasts of maximum annual demand are strongly driven by weather, and occur on different days for each region of the NEM. For this reason, a total maximum demand forecast is not estimated for the NEM. Forecasts are made on a region-by-region basis.[100]

Maximum demand is assessed for summer and winter. The distinction is made as there are different drivers of the seasonal peaks. Summer maximum demand is influenced strongly by residential air conditioning loads, whereas the winter maximum demand is being driven by an increasing switch of heating sources from gas-fuelled to electric appliances. Figure 3.2 shows the forecast 10% POE[101] maximum summer demands.

100 Ibid, p. 24.

101 Probability of exceedance is the probability, as a percentage, that a maximum demand level will be met or exceeded. For example, a 10% POE forecast of maximum demand is expected to be met or exceeded on average one year in ten.

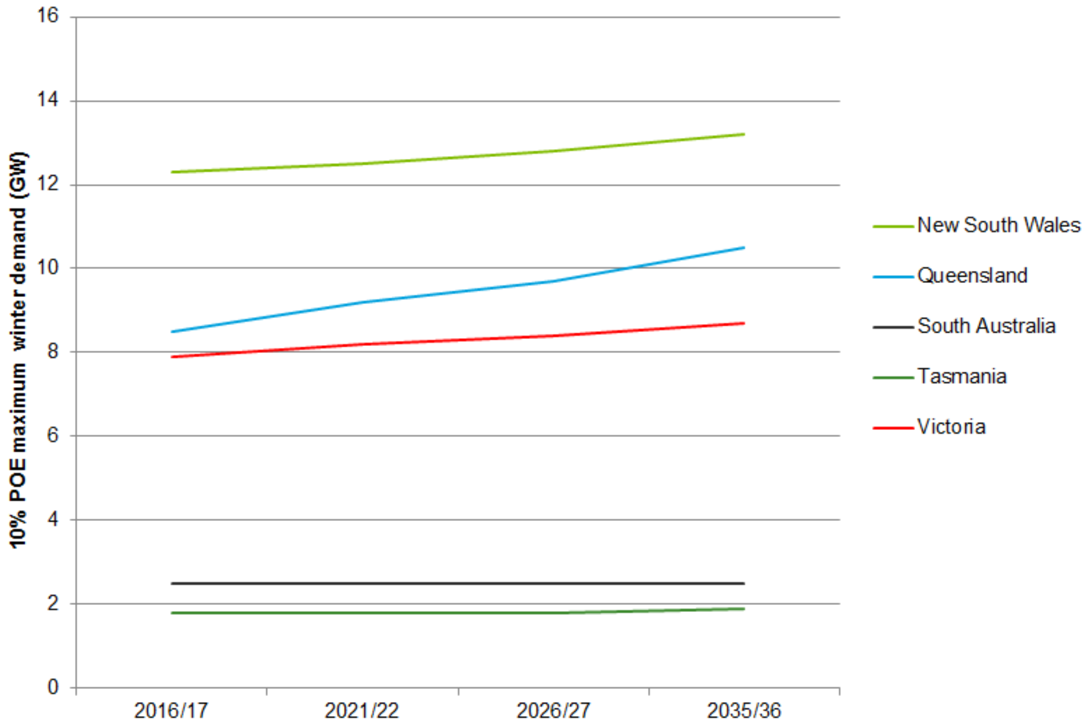
Figure 3.2 Forecast maximum summer demand



Source: AEMO, *National Electricity Forecasting Report*, June 2016.

Figure 3.3 shows the forecast 10% POE maximum winter demands.

Figure 3.3 Forecast maximum winter demand



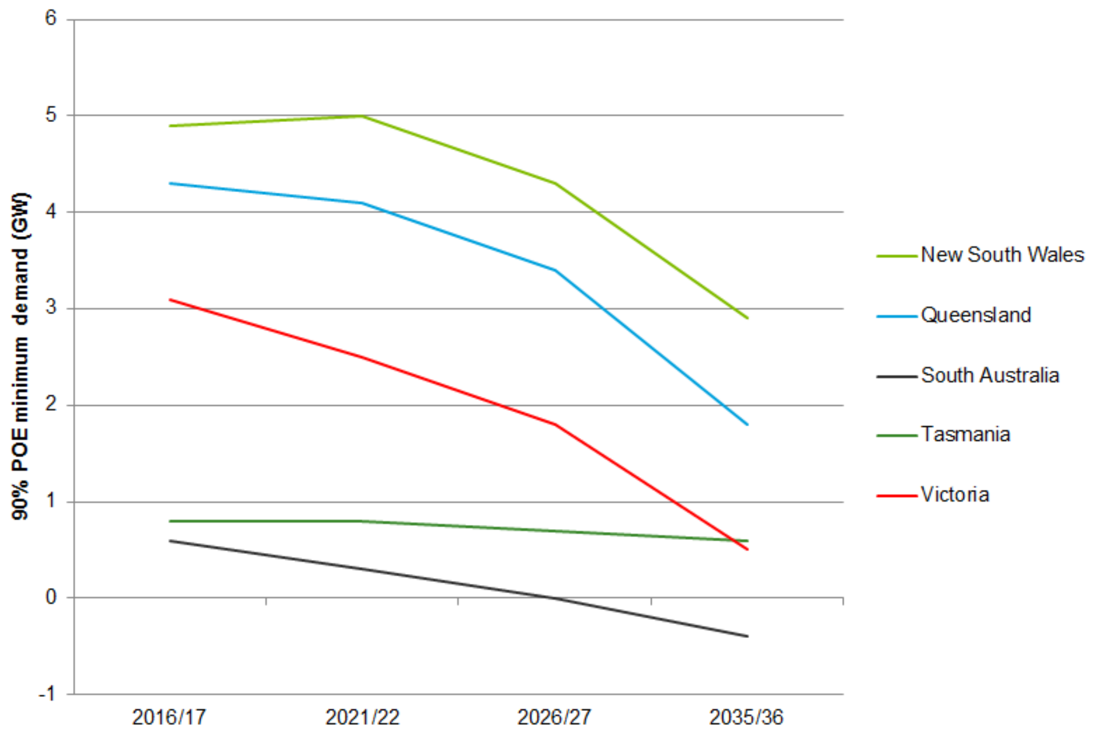
Source: AEMO, *National Electricity Forecasting Report*, June 2016.

With the exception of Queensland (forecast to grow 10% over the 20 year outlook) and South Australia (forecast to decrease by 15% over the 20 year outlook), maximum demand forecasts are generally flat. The key points for forecasts of 10% POE maximum demand are:

- Winter maximum is forecast to grow faster than summer demand and by 2030 is expected to reach similar levels. This is being driven in part by the conversion of residential heating from gas to electric.
- Continued growth in PV is forecast to offset some drivers of peak demand. It will continue to push the time of the summer peak demand to later in the day.
- Queensland's maximum demand will continue to grow due to increased LNG operations.
- South Australia's maximum demand is forecast to decline due to continued high levels of growth in rooftop PV. The lower forecast is also due to decreased consumption from the business sector.

Figure 3.4 shows the forecast 90% POE minimum demands. A 90% POE forecast is a forecast that is expected to be exceeded in nine years in 10. In Figure 3.4, this means that the minimum demand is expected to exceed the level shown for nine years in ten.

Figure 3.4 Forecast minimum demand



Source: AEMO, *National Electricity Forecasting Report*, June 2016.

Minimum demand in all NEM regions except South Australia currently occurs at night. However, minimum demand in these regions is forecast to follow trends already evident in South Australia:

- minimum demand is projected to shift from overnight to midday
- this minimum demand will then reduce in the middle of the day as PV capacity increases.

The key points for each region are:[102]

- Queensland: despite increases in demand from LNG facilities, increased PV uptake will reduce minimum demand to less than 2GW by 2035/36.
- South Australia: minimum demand is projected to fall below zero by 2026/27. This means that South Australia is projected to meet all demand with generation from distributed energy resources.
- Victoria: by 2017/18 it is expected that the time of minimum demand will switch from overnight to around midday, when solar output is at a maximum. At this point the level of minimum demand is expected to decrease further, driven by the increasing rooftop PV.
- Tasmania and New South Wales: there are similar drivers of minimum demand in these regions, where a larger fraction of the demand is insensitive to weather. As such, these regions experience smaller declines in minimum demand.

3.2 Generation capacity, retirement and investment

The changes to the NEM generation mix in 2015/16 include the following trends:

- **Retirement of thermal generation**: The NEM has experienced a significant withdrawal or mothballing of thermal, synchronous generating units, particularly coal fired power stations. Since 2008, 2.8GW of coal fired generation has been withdrawn from the NEM.

  The withdrawal of thermal synchronous generation has been particularly acute in South Australia over the last few years, with 1025MW of capacity mothballed or withdrawn between April 2015 and July 2016. This represented a 43% decrease in the total installed synchronous generation capacity in South Australia.
- **Increase in intermittent renewable generation**: The NEM has also experienced a significant growth in large-scale intermittent renewable generation. Since 2008, over 2GW of wind capacity has been installed in addition to 200MW of utility scale solar capacity commissioned in the past three years.
- **Increase in distributed energy generation**: There has been a significant increase in the amount of distributed energy generation. The vast majority is residential PV, of which the installed capacity reached over 5GW by the end of 2015/16.[103]

Changes in the generation mix may have impacts on the reliability of the NEM by influencing the supply-demand balance. While there has been significant investment in new generation capacity in recent years, much of this capacity is intermittent, semi-scheduled or non-scheduled generation. This means that during periods when this generation is unavailable, there may be increasingly tight supply demand outcomes in the market, which could have implications for reliability.

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102 Ibid, p. 27.

103 Clean Energy Regulator, *Postcode data for small-scale installations*, accessed 14 February 2017, available at http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations#Small-generation-unit-SGU-installations

These changes may also have implications for the security of the NEM. In particular, increasing levels of non-synchronous generation may decrease the amount of physical inertia available in the NEM and can also reduce system strength, both of which can impact on key system security parameters.

These reliability and security impacts of changing generation mix are explored further in chapters 4 and 5.

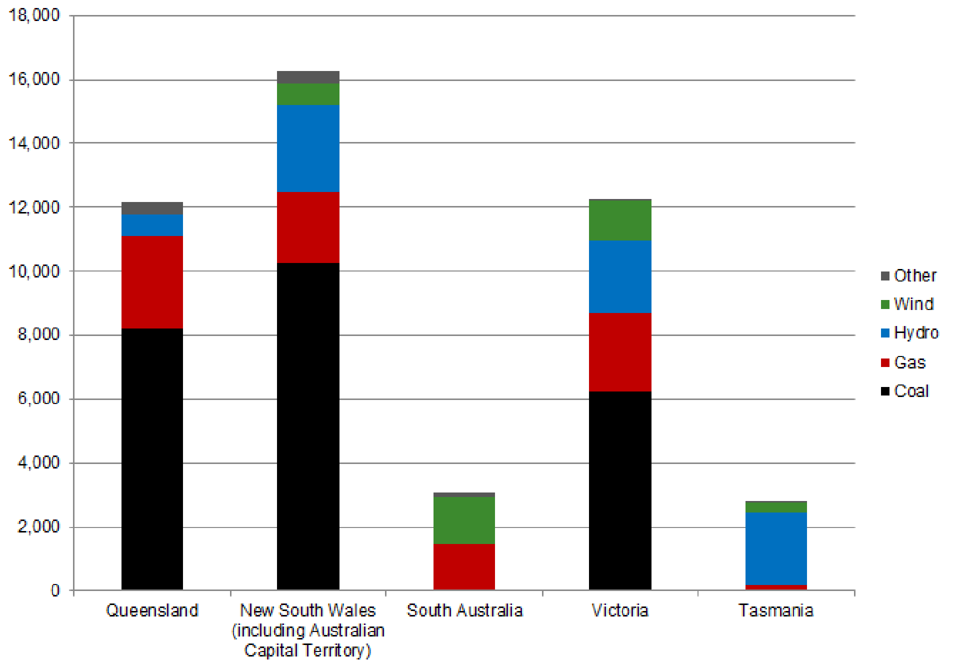
3.2.1 Generation capacity

At the end of 2015/16, the total installed generation capacity in the NEM was 46.58GW.[104] By fuel type, this generation capacity was comprised of:

- 53.0% coal
- 19.8% gas
- 17.2% hydro
- 8.0% wind
- 2.1% other, which includes 0.5% large scale solar.

The regional breakdown of generation is shown in Figure 3.5

Figure 3.5 Regional breakdown of generation by fuel type (MW)



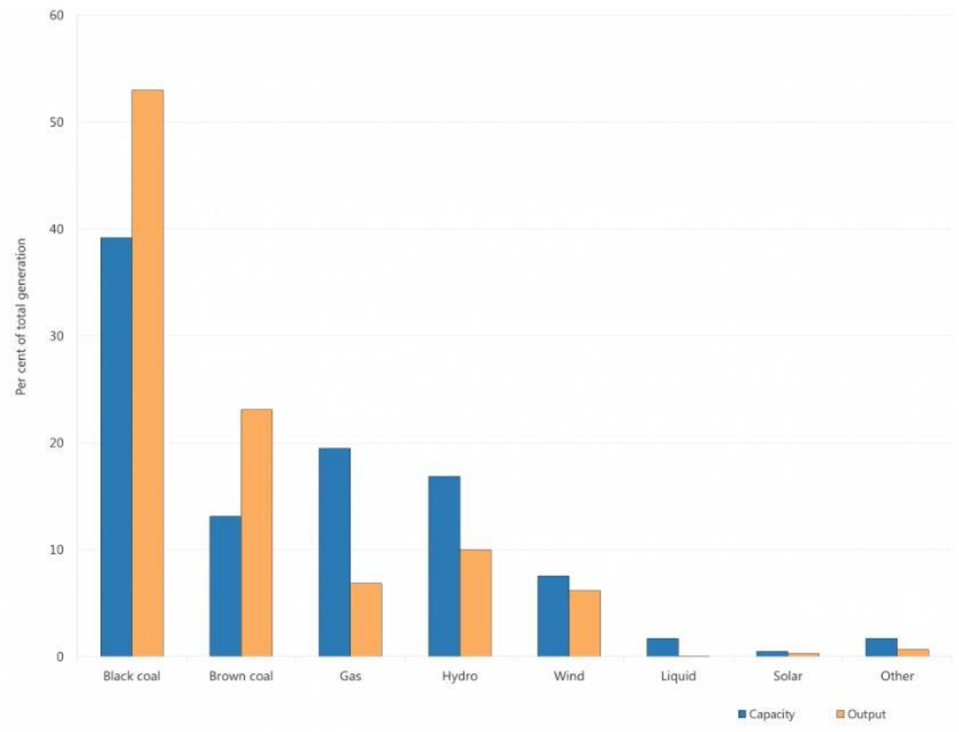
Source: AEMO, *Generator information page*.

Despite increased penetration of intermittent renewable generation and withdrawal of thermal coal-fired power generation, coal-fired power still accounts for over half the installed generation capacity in the NEM. An exception is Tasmania, where abundant hydro resources mean that over 80% of installed Tasmanian generation capacity is hydro.

104 Including scheduled, semi-scheduled, and non-scheduled installed capacity, but excluding rooftop PV and capacity currently withdrawn.

Additionally, as shown in Figure 3.6 coal-fired power also accounts for the large majority of energy generated. Coal typically operates with a high capacity factor.[105]

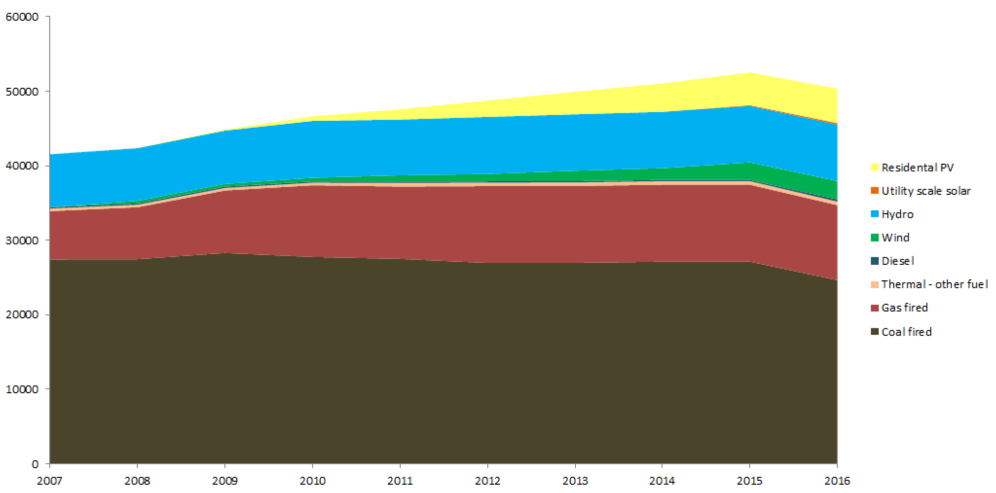
Figure 3.6 Generation compared with capacity



Source: AER, *Wholesale statistics page*, accessed 1 February 2017.

To date, the NEM has experienced a significant change in the generation mix. The changes in generation mix from 2007, shown in Figure 3.7, demonstrate that levels of intermittent generation capacity has significantly increased while coal fired capacity has decreased.

Figure 3.7 Generation mix in the NEM (MW)



Source: AEMO, *Generator information page*.

105 Capacity factor is the ratio of generation capacity to generation output often expressed as a percentage. For example, if a generator had a generation capacity of 100MW and over a year the average generation output from the generator was 80MW, that generator would have a capacity factor of 80%.

3.2.2 Generation withdrawals

In 2015/16, 780MW of generation has been formally withdrawn, all of which came from South Australia. All of the withdrawn generation was synchronous, brown-coal thermal generation.[106]

This withdrawal was in addition to the mothballing of one of the South Australian Pelican Point units in April 2015. The second Pelican Point unit had 239MW of capacity and was also synchronous.[107]

This withdrawal and mothballing represents a significant withdrawal of generation capacity from a single region within a period of just over 12 months. This represents a 19% decrease in the total installed generation capacity in South Australia, and a 43% decrease in the total installed synchronous generation capacity. The withdrawn generators are:

- Playford B Power Station (240MW) closed in May 2016[108]
- Northern Power Station (540MW) closed in May 2016
- the second Pelican Point unit was mothballed[109] in April 2015, representing a reduction of 239MW of capacity.[110]

This also represents a reduction in generation capacity in South Australia that is significantly greater than reductions in previous years.

It has also been announced that 3804.9MW of generation will be withdrawn from the NEM by 2022. All of the generation units announced for withdrawal are thermal, synchronous units. The generators announced for withdrawal are:[111]

106 Tamar Valley, a gas fired power station in Tasmania, was returned to service during 2015/16 and was re-withdrawn in the same period. Bell Bay Three Power Station, a gas fired power station in Tasmania, announced the intention to withdraw but this announcement has since been rescinded.

107 AEMO, *Electricity statement of opportunities*, August 2016, p. 15.

108 Prior to Alinta Energy retiring Playford B, it had been mothballed for an extended period of time but its capacity had not been formally withdrawn. The capacity at Playford B was available for operation until it was withdrawn. See Alinta Energy, *Alinta Energy clarifies market reports*, April 2012, available at https://alintaenergy.com.au/everything-alinta-energy/news/alinta-energy-clarifies-market-reports.

109 A “mothballed” unit is shut down on an ongoing basis, but can be made available again, within a given amount of time. AEMO has referred to mothballed units in the Electricity statement of opportunities as 'short-term' withdrawals. This is different to closed or retired, where a unit is taken offline on a permanent basis. The mothballed capacity at Pelican Point power station represented half of its total capacity. The remaining (non-mothballed) capacity of Pelican Point remains available at 239MW.

110 The Panel also notes that the mothballed Pelican Point was directed to operate by AEMO on 9 February 2017. However, the Pelican Point capacity remains withdrawn from the market. In a media statement released by Engie (the owners of Pelican Point), the second Pelican Point unit unable to be made available to the market due to the inability to guarantee supply. Supply cannot be guaranteed as the second Pelican Point has no gas contracts in place. For more information see: Engie, *Media statement: Pelican Point second unit*, February 2017.

111 AEMO, *Electricity statement of opportunities*, August 2016, p. 15.

- Smithfield Power Partnership has announced the intention to withdraw Smithfield Power Station (170.9MW) (NSW) in July 2017.
- Engie has announced the intention to withdraw Hazelwood Power Station (1600MW) (VIC) in March 2017.
- Stanwell has announced the intention to withdraw Mackay GT Power Station (34MW) (QLD) in July 2021.
- AGL has announced the intention to withdraw Liddel Power Station (2000MW) (NSW) in March 2022.

The projected impact of these retirements on the reliability of the NEM is discussed in chapter 4.

No generator in Tasmania or South Australia has announced its intention to withdraw plant. More information on generation withdrawals is available in appendix A.

The withdrawal of synchronous generation (such as coal and gas-fired generation) also has implications for system security, including through reducing the amount inertia and contributing to a reduction in the availability of ancillary services in the NEM. These ancillary services include Frequency Control Ancillary Services (FCAS) and System Restart Ancillary Services (SRAS).[112] These system security implications are discussed in chapter 5.

3.2.3 New and committed generation

In 2015/16, 109MW of new generation was commissioned.[113] This is compared to 1074MW[114] of generation commissioned in 2014/15, and 170MW of generation commissioned in 2013/14.[115]

In 2015/16, 537.2MW[116] of generation was committed.[117] This compares to 240MW of generation committed in 2014/15 and 1165MW of generation committed in 2013/14.

All generation commissioned in 2015/16 was utility-scale photovoltaics:

- Broken Hill Solar Farm (53MW) has been in full commercial operation since October 2015.

112 Ibid, pp. 3-4.

113 Commissioning represents the final stage of connecting a generator to the NEM. Immediately following commissioning, a generator can begin commercial operation.

114 This generation was predominantly wind installed in NSW, Victoria and South Australia.

115 AEMO, *Electricity statement of opportunities*, August 2016, p. 16.

116 Since the end of the 2015/16 reporting period, new generation projects have become committed. These are: Hornsdale Stage 2 Wind Farm (102MW, SA); Mt Gellibrand Wind Farm (66MW, Vic); Coonooer Bridge Wind Farm (19.8MW, Vic); Williamsdale Solar Farm (10MW, NSW); Mugga Lane Solar Park (13MW, NSW); Cook Shire Solar Storage Project (28MW, QLD).

117 AEMO considers a generation project to be committed when a number of criteria have been met. These criteria relate to; site acquisition; the components needed to build the generator being procured; relevant planning approvals obtained; financing and a final construction date. More information on the generation project commitment criteria is available in the regional generation information pages, accessible at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information

- Moree Solar Farm (56MW) has been in full commercial operation since March 2016.

The generation projects committed in 2015/16 are primarily wind farms connecting in New South Wales, Victoria and South Australia. There were no generation projects committed in 2015/16 intending to connect in Queensland or Tasmania.[118] More information on new and committed generation projects is available in appendix A.

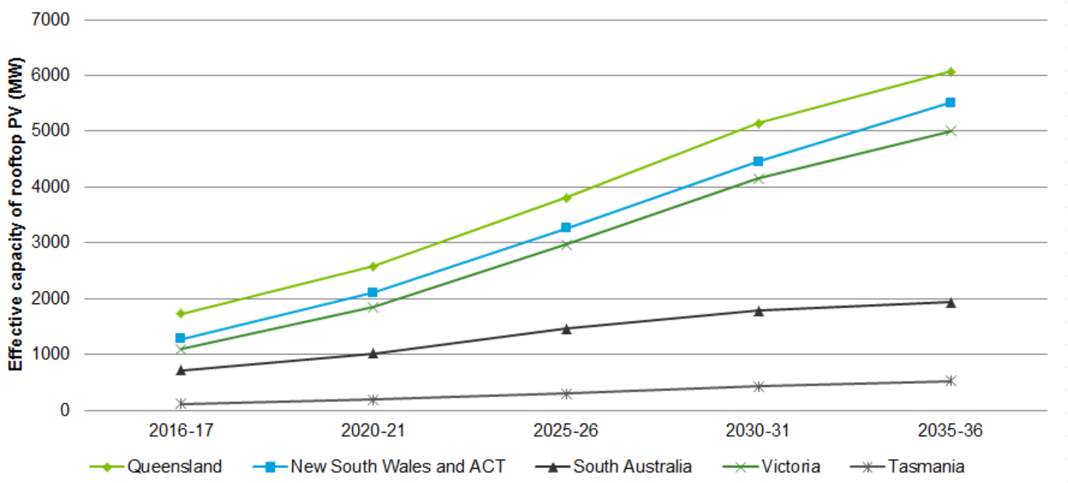
3.2.4 Increased rooftop PV and distributed storage

In response to the rapid expansion of solar generating capacity in the NEM, AEMO has produced forecasts of residential and commercial solar PV capacity. Additionally, AEMO has forecast the uptake of integrated systems consisting of rooftop PV and storage systems.

Forecast uptake

Figure 3.8 shows the AEMO forecasts of projected uptake of rooftop PV. AEMO is forecasting consistent uptake in all NEM regions and the total installed capacity of rooftop PV in 2035/36 is projected to be over 19GW.

Figure 3.8 Installed rooftop PV capacity forecasts



Source: AEMO, *National Electricity Forecasting Report*, June 2016.

Figure 3.9 shows the AEMO forecasts of projected uptake of integrated PV and storage systems (IPSS). AEMO is forecasting the rates of uptake to vary between NEM regions, with Victoria forecast to experience the fastest rates of uptake.[119] The total installed capacity of IPSS in 2035/36 is projected to be 3.8GW.

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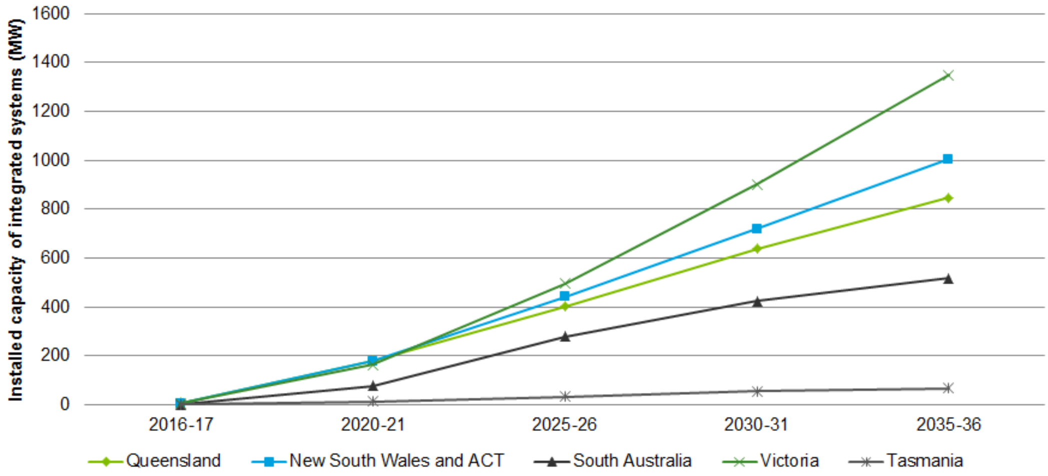
118 AEMO, *Electricity statement of opportunities*, August 2016, p. 17. The Panel notes that since the end of the 2015/16 reporting period other projects have become committed, including the Cook Shire Solar Storage Project in Queensland.

119 The model used by AEMO for forecast the uptake of IPSS does not consider the retrofitting of storage to existing PV systems. As a result, regions with current higher penetrations of PV systems experience decreased projections of uptake of IPSS as the number of potential sites is diminished.

Figure 3.9 Integrated PV and storage systems capacity forecast



Source: AEMO, *National Electricity Forecasting Report*, June 2016.

The drivers for PV and IPSS uptake in each region varies due to regionally specific characteristics:[120]

- **Queensland**: The strong growth of rooftop PV and IPSS uptake in the commercial sector is projected to offset a forecast decline of residential installations. Queensland is projected to have the highest total projected capacity of systems at the end of the forecast period.
- **New South Wales and ACT**: The steady adoption of rooftop PV systems is forecast in both residential and commercial segments, with IPSS representing almost 25% of annual rooftop PV installations after 2020.
- **South Australia**: The rate of uptake of residential rooftop PV systems in is forecast to decline as saturation is reached, with the commercial PV sector forecast to have steady growth.
- **Victoria**: Steady adoption of rooftop PV systems is forecast to continue until 2033, when saturation is expected to be reached. The assumed faster transition to a time-of-use tariff structure in Victoria contributes to forecast rapid penetration of PV systems with battery storage.
- **Tasmania** : The growth of rooftop PV installations in both the residential and commercial segments is forecast to be slowest in Tasmania among NEM regions, due to lower levels of sunshine reducing the financial attractiveness of the systems.

Impacts on consumption and maximum demand

Rooftop PV installation rates are forecast to remain steady until 2035/36, at which point the total installed PV capacity is projected to be 19GW. Additionally, future installations of PV are projected to see an increasing coupling with integrated storage systems. In addition to the forecast 19GW of rooftop PV installed without integrated storage, another 3.8GW of PV with integrated storage is projected to be installed by 2035/36. In

120 AEMO, *National Electricity Forecasting Report*, June 2016.

terms of total capacity, this is equivalent to the generation capacity that has announced the intention to withdraw in the short to medium term.

Increased rooftop PV reduces both operation consumption and the level of demand during the day. In terms of general changes in consumption, increased PV generation has been a major contributor to the historical decline in operational consumption.

In terms of demand, increased rooftop PV can exacerbate the difference in demand levels during the middle of the day, when PV output is at a maximum and therefore significantly reduces demand, and early evening, when PV output declines. This can result in a "hollowing out" of the typical daily demand curve. As discussed above, increased rooftop PV is also forecast to shift the timing of minimum demand in each region from overnight to midday. These kinds of changes in the shape and timing of the demand curve can have implications for what kind of generation is needed, and when it is needed, to meet consumer demand.

The impact of increased IPSS capacity is not as clear. However, IPSS allows for the output of PV generation to be stored during the day and then used during evening peaks. One potential implication of this is to smooth out the midday troughs and late afternoon peaks in the demand curve caused by solar PV without storage, as described above. It also provides for the opportunity to the provision of other services to the market, such as providing frequency control or other ancillary services.

3.3 Bulk transfer capability, upgrades and performance

In 2015/16, the Heywood interconnector was in the process of being upgraded.

Several other proposals for interconnector upgrades were also considered. However, these proposals occurred outside financial year 2015/16.

3.3.1 Modelled impacts of increased interconnection

The National Transmission Network Development Plan (NTNDP) included modelling of the impacts of increased interconnection of the NEM, i.e. more interconnectors between regions.[121]High level modelling suggests positive net benefits for potential interconnection developments, if they are competitively priced. These interconnection developments include:[122]

- a new interconnector linking South Australia with either New South Wales or Victoria from 2021
- augmenting existing interconnection linking New South Wales with both Queensland and Victoria in the mid to late 2020s
- a second Bass Strait interconnector from 2025, when combined with augmented interconnector capacity linking New South Wales identified above, although the benefits are only marginally greater than the costs.

121 The NTNDP is available at:

122 AEMO, *National transmission network development plan*, December 2016.

The NTNDP modelling also found that:[123]

- there are greater total net benefits when interconnection developments are combined, creating a more interconnected NEM. These benefits are also projected to increase as the energy transformation accelerates
- greater interconnection facilitates geographic and technological diversity. This diversity smooths the impact of intermittency and reduces reliance on gas-powered generation, delivering fuel cost savings to consumers
- interconnection does not necessarily solve all challenges. Local network and non-network options are also needed to maintain a reliable and secure supply. Synchronous condensers, or similar technologies, will be required to provide local system strength and resilience to frequency changes.

3.3.2 Heywood upgrade

In July 2016, the Heywood interconnector, which connects Victoria and South Australia, was upgraded to allow increased power flows between the two regions. The interconnector capacity was increased from 460MW to 650MW, providing up to 190MW of additional capacity in both directions.

The South Australian transmission network service provider (TNSP) ElectraNet and AEMO identified the classes of market benefit as material in the Heywood Interconnector regulatory investment test for transmission (RIT-T), including changes in:

- generator fuel consumption
- voluntary load curtailment
- involuntary load shedding
- costs for other parties
- network losses.[124]

ElectraNet and AEMO found that the net economic benefits arising from the Heywood upgrade were equivalent to $190.8 million ($2011/12). The upgrade comprised of the installation of a third transformer at Heywood and series compensation on 275 kV transmission lines in South Australia, a control scheme for the South East transformers and 132 kV network reconfiguration works in South Australia.

The upgrade was completed in July 2016 and the increased capacity was incrementally released to the market.

3.3.3 Proposed additional interconnector with South Australia

In November 2016, ElectraNet released a Project Specification Consultation report as a part of a RIT-T process. The report provided an economic cost benefit assessment of various network and non-network solutions to assist the management of South

123 AEMO, *National transmission network development plan*, December 2016.

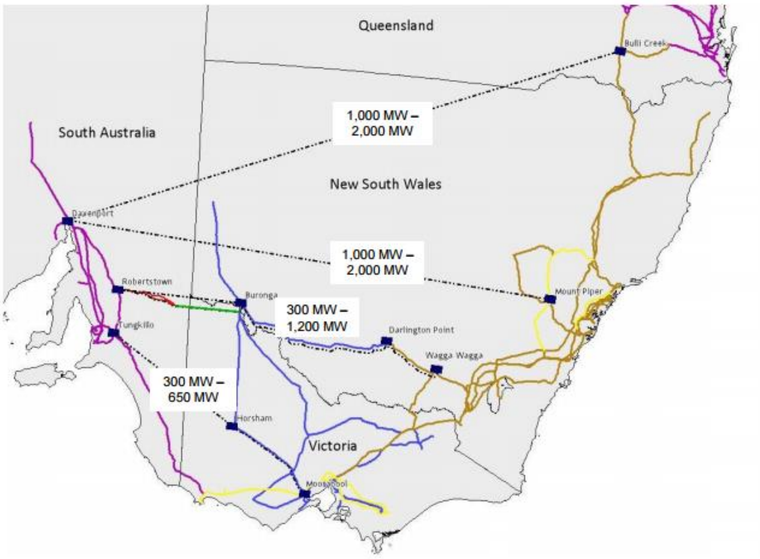
124 AER, *South Australia - Victoria (Heywood) interconnector upgrade: Determination that preferred option satisfies the regulatory investment test for transmission*, September 2013.

Australia's increasing penetrations of renewable energy. The report presented five credible options, four of which were new interconnectors:[125]

1. Interconnector linking central SA to Victoria - this line would be 350 - 600km with a capacity of 300 - 650MW. The indicative cost is $500 - 1000 million.
2. Interconnector linking mid-north SA to NSW - this line would be 300 - 800km with capacity of 300 - 1,200MW. The indicative cost is $500 - 1500 million.
3. Interconnector linking northern SA to NSW - this line would be 1,100 - 1,300km with a capacity of 1,000 - 2,000MW. The indicative cost is $1500 - 2000 million.
4. Interconnector linking northern SA to QLD - this line would be 1,450 - 1,600km with a capacity of 1,000 - 2,000MW. The indicative cost is $2000 - 2500 million.
5. Non-network solution - this would consist of a variety of non-network capabilities to provide fast frequency response, inertia and system strength; e.g. large-scale batteries, demand management, generation. This indicative cost of this option is to be informed by submissions to ElectraNet.

The four options of building an additional interconnector are shown in Figure 3.10.

Figure 3.10 Proposed interconnectors with South Australia



Source: ElectraNet, *RIT-T: Project Specification Consultation Report,* November 2016.

If the decision to construct an interconnector is made, the expected energisation would take place in 2021/22 depending on which option was chosen.

An updated discussion of the proposed augmentation will be in the 2017 AMPR, which will cover the financial year period of 2016/17. The Panel intends to publish the 2017 AMPR before December 2017.

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125 ElectraNet, *RIT-T: Project Specification Consultation Report* , November 2016.

3.3.4 Second interconnector with Tasmania

The Commonwealth and Tasmanian Governments requested a feasibility study of whether a second electricity interconnector would help to address long-term energy security issues and facilitate investment in renewable energy.

A preliminary report was released in June 2016.[126] The preliminary conclusions suggested that a second interconnector, if viable, would support long term energy security in Tasmania. The final report was completed in January 2017 but has not yet been published. Its findings will be detailed in AMPR 2017.

3.3.5 Interconnector performance

Power transfer across an interconnector is limited by the capability of network elements which make up the interconnector (thermal limitations), or the ability to maintain the system in a secure state in the event of a contingency (transient or voltage stability limitations). These limits are applied in the form of constraint equations in the National Electricity Market Dispatch Engine (NEMDE) process.[127]

During normal operation of the power system, transfer across an interconnector will ultimately be limited by constraints within the NEMDE dispatch process. However, the power system operates in a dynamic environment and there are instances where interconnector transfer can exceed their secure limit for a small period of time.

During 2015/16, the Panel has not been advised of any power system incidents where an interconnector was above its secure limit for more than one dispatch interval.

Further, during 2015/16, there were a number of significant operating incidents involving interconnectors. These included:

- the fault on Basslink impacting upon electricity supply in Tasmania from December 2015 to June 2016
- outages on Heywood, both planned and unplanned, in October and November 2015.

Both of these incidents are covered in more detail in chapter 6.

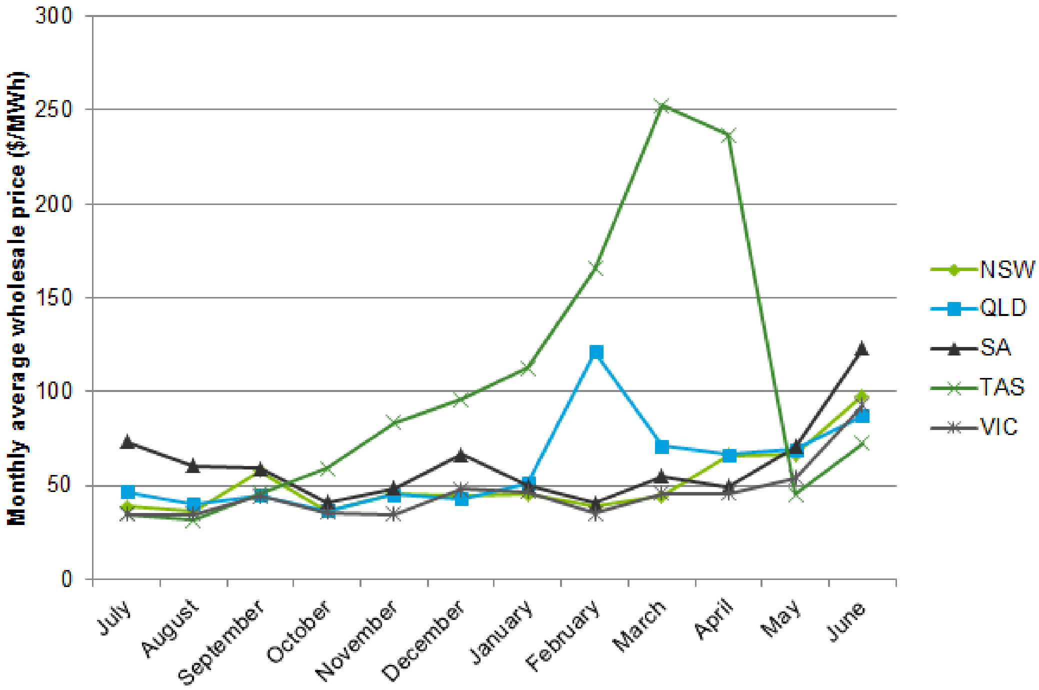
3.4 Wholesale prices

In 2015/16, wholesale prices remained relatively flat with the exception of Tasmania and Queensland. Figure 3.11 shows the wholesale monthly average wholesale prices in the NEM for 2015/16.

126 Warwick Smith, *Feasibility of a second Tasmanian interconnector*, June 2016.

127 NEMDE is the dispatch engine for the NEM. It is used by AEMO to dispatch generators. More information is available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Dispatch-information

Figure 3.11 Monthly average wholesale prices in the NEM for 2015/16



The Panel notes that:

- Tasmania experienced inflated wholesale prices in a large portion of 2015/16 due to an outage of Basslink and limited hydro resources. This is covered in greater detail in chapter 6.
- Queensland wholesale prices were also inflated in February.
- In all other regions prices remained relatively flat with the exception of June which saw increased wholesale prices NEM wide.

The Panel does also note that following the end of the 2015/16 period:[128]

- Sustained high wholesale prices were observed in South Australia in July 2016. The average price for July 2016 in SA was $229.4/MWh.
- Wholesale prices have also been significantly greater in January and February 2017 when compared to 2015/16.

3.4.1 High prices

The NEM saw a general decline in the number of wholesale price spikes up to the end of 2015/16.[129]

Figure 3.12 shows a count of trading intervals where the spot price has been above 25% of the market price cap (MPC) since 2007/08.[130] Trading intervals are settled every half

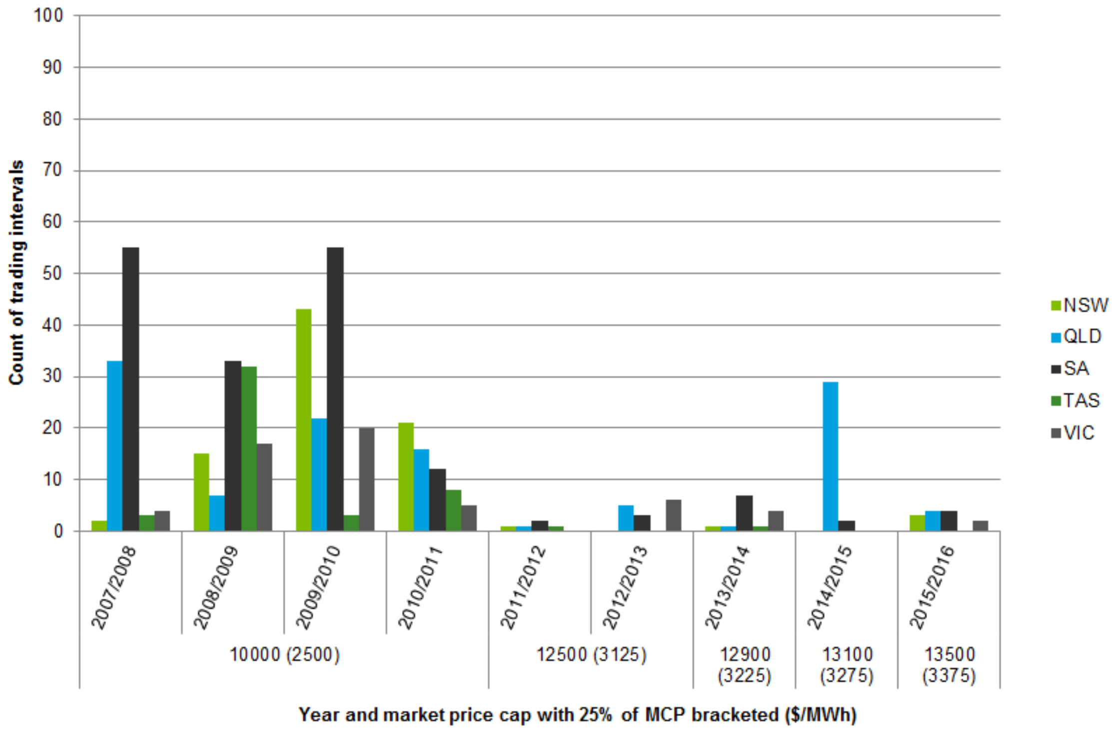
128 Prices in 2016/17 will be considered in greater detail in AMPR 2017.

129 The Panel notes that the number of price spikes may not have continued in this trend into financial year 206/17.

130 The market price cap is the maximum price that can be achieved in the NEM wholesale spot market. It has not been changed in absolute terms since 2012, but has been indexed to CPI and is increased

hour and consist of six dispatch intervals. The trading interval spot price is therefore the average of the price for each dispatch interval in that trading interval.

Figure 3.12 Count of trading intervals where the spot price was above 25% of the relevant MPC

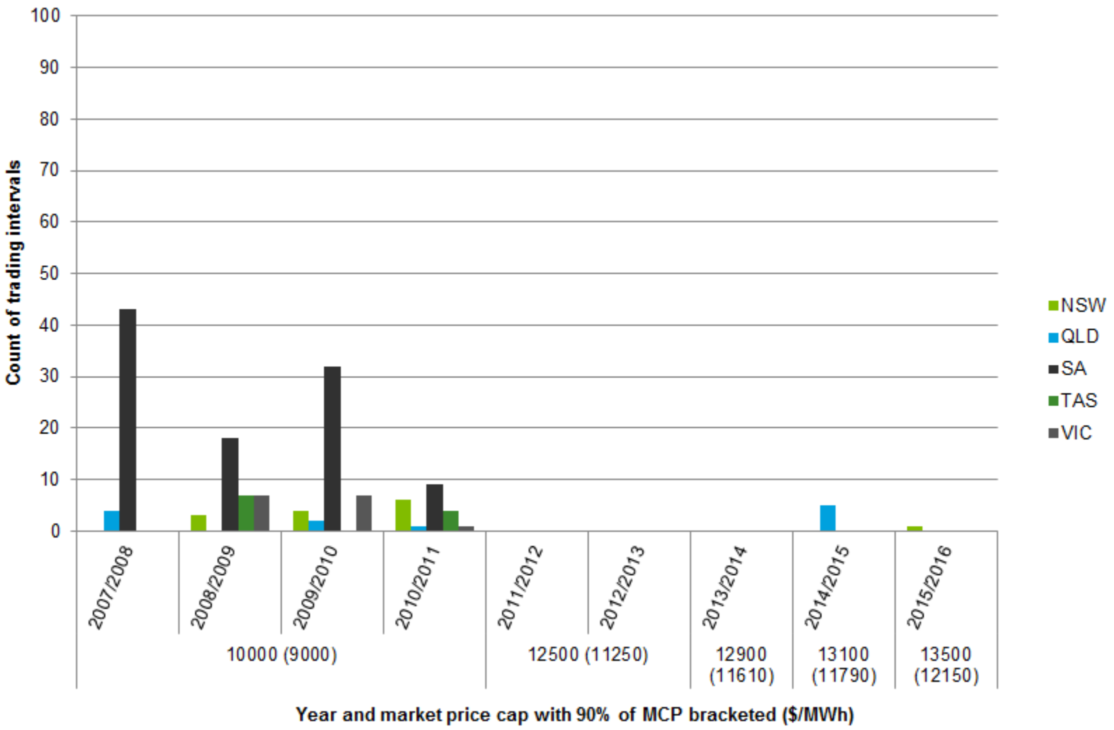


This figure demonstrates that, historically, there are very few intervals where the NEM spot market price has been at levels approaching the MPC. This is reinforced by Figure 3.13, which shows an even smaller number of trading intervals where the wholesale price has been at or above 90% of the relevant MPC.

Figure 3.13 shows a count of trading intervals where the spot price has been above 90% of the MPC, since 2007/08.

by CPI movements at the beginning of each financial year. The MPC was $13,800/MWh in 2015/16, $14,000/MWh in 2016/17 and is scheduled to increase to $14,200 on 1 July 2017.

Figure 3.13 Count of trading intervals where the spot price was above 90% of MPC



The Panel also notes that there has been a general decline in the number of trading intervals where prices have been above 25% of the MPC, up to the end of 2015/16.[131] The exception was in Queensland in 2014/15.

The Panel notes that while the trend in price spikes since 2007/08 remains similar, there are significantly less trading interval spot prices above 90% of the MPC.[132]

As noted above, the Panel acknowledges that since the end of the period covered in the 2016 AMPR there have been a number of high price incidents in several NEM regions. The Panel intends to review these incidents and provide further commentary in the 2017 AMPR.

More detail on high price events in 2015/16 is provided in appendix I.

131 The Panel does note that this trend has not continued in 2016/17 up to the end of February 2017. These wholesale market price trends will be covered in more detail in AMPR 2017.

132 The trading interval spot price is price that is paid in the wholesale market. It is comprised of the average of the six dispatch interval prices within the trading interval.

4 Reliability review

This chapter summarises the Panel's consideration of the reliability performance of the NEM in 2015/16 as well as some future projections of reliability. The consideration of future projections of reliability includes a review of projected expectations of unserved energy[133] and a review of historical reserve levels.

The Panel notes the following key reliability trends and outcomes:

- **Unserved energy**: There was no unserved energy in the NEM in 2015/16. In the past decade, there have been two occasions where there was unserved energy; once in Victoria and once in South Australia, both of which occurred in 2008/09.
- **Future reliability outcomes**: Under neutral scenarios projected by AEMO, generation withdrawals are expected to result in unserved energy in Victoria, South Australia and New South Wales before 2025/26 unless there is a significant market response to address the projected shortfall.
- **Actual lack of reserve notices**: AEMO publishes lack of reserve (LOR) notices to indicate to the market that there is a forecast lack of reserve, with the intention that the market will respond and increase the level of available generation supply. The number of actual LOR notices[134] declared has decreased over the past decade. This may be an indicator of a general improvement in generation reserve levels in the NEM up to the year 2015/16.
- **Cancelled forecast lack of reserve notices**: The forecast conditions of a lack of reserve, and the associated AEMO notice, can be cancelled by AEMO before that condition eventuates. These cancellations may be issued due to a number of reasons, including revised demand forecasts or increased amounts of generation being made available. Over the past decade the number of lack of reserve conditions that have been forecast and then cancelled have significantly increased. Amongst other possibilities, this may be an indication of the degree of market response to AEMO's issuing of LOR notices.

4.1 Reliability assessment

Reliability is a measure for determining how effectively demand for energy was met by generation and bulk transmission in a given financial year.

There are two indicators that have been used to assess the reliability of the NEM:

- **Unserved energy (USE)**: USE is a measure of the energy that was demanded and not met due to a lack of generation and bulk transmission availability.[135] Importantly, USE excludes demand for energy that was not met due to security

133 Unserved energy is a measure of the energy that was demanded and not met due to a lack of generation and bulk transmission availability.

134 LOR notices indicate to the market various levels of shortage of reserve.

135 The amount of USE is the actual indicator of reliability performance of the NERM. In contrast, the reliability standard is a planning standard, or a performance target, to which the system is designed. The reliability standard is described in more detail in section 4.1.1.

related issues or due to failures of the intra-regional transmission and distribution networks.

- **Reserve levels**: Reserve levels are a measure of the amount of "reserve capacity" that is available above forecast and actual levels of demand. For example, if forecast demand is 1000MW and there is 1200MW of capacity available, the reserve level is 200MW. Low reserve levels may indicate a heightened risk that there is insufficient generation supply available to meet demand which could result in unserved energy. Reserve levels are the amount of surplus or unused capacity of:
  - generating units
  - scheduled network services or
  - capacity arising out of the ability to reduce demand.

In previous AMPRs, the Panel has reported unserved energy in the NEM. For AMPR 2016, the Panel has introduced an assessment of reserve levels, as indicated by the number of lack of reserve notices issued by AEMO. In combination, both of these indicators are used below to demonstrate the overall reliability of the NEM.

4.1.1 Reliability standard and USE

The NEM reliability standard is an ex-ante planning standard. It is an expression of the capability of the power system to meet expected demand for energy.

The reliability standard is expressed as the maximum expected amount of energy in any region that is at risk of not being served in any given financial year. It is currently set at 0.002% of total energy demanded, meaning that the amount of USE in a region should not exceed 0.002% of the total energy demanded within that region for a financial year.

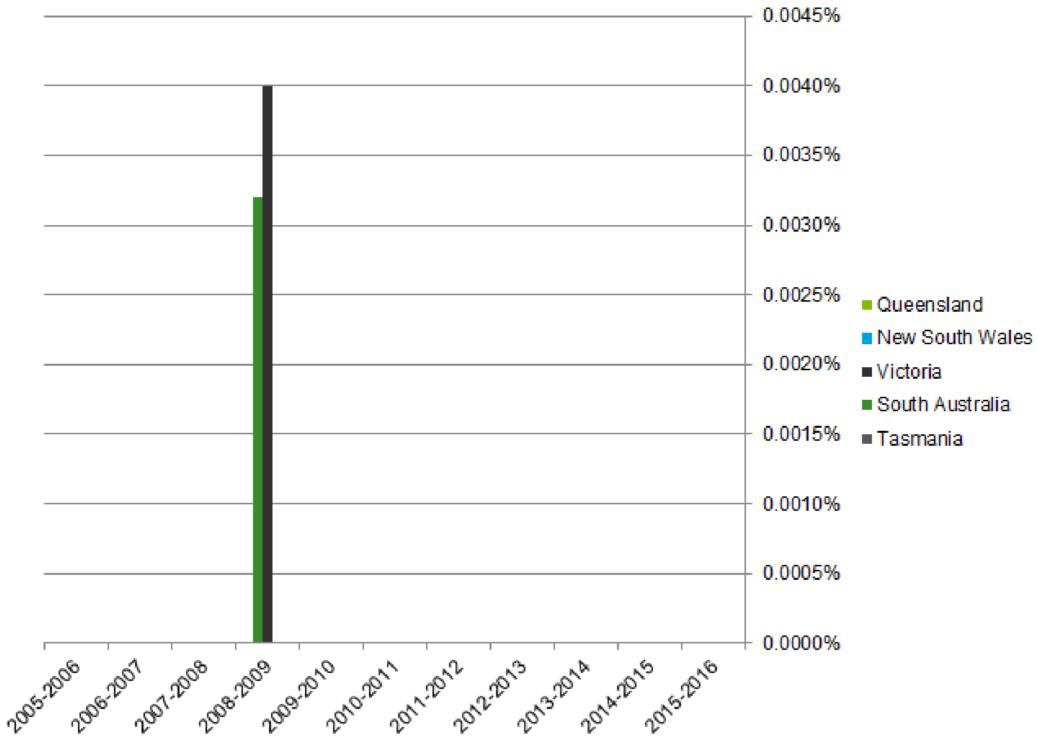
The reliability standard is defined as a target for the purposes of system planning and is not an operational standard.

The amount of USE that occurs in a region in a financial year provides an indication as to whether there is sufficient generation and bulk transfer capability to adequately meet consumer demand for energy.

Traditionally, there has been very little USE in the NEM.

Figure 4.1 compares the reliability performance of each region in terms of USE over the past decade.

Figure 4.1 Unserved energy in NEM



Over the past decade, there have only been two instances of USE on a regional basis. This USE occurred in Victoria and South Australia during 29 and 30 January 2009, due to relatively high temperatures over a prolonged period.

In all other years in the past decade, all regions have had no unserved energy. This indicates that with the exception of 2008/09, there has been sufficient generation and bulk transmission capacity to meet consumer demand for electricity.

Despite there being very little unserved energy in the past decade, individual consumers may have nevertheless experienced interruptions in supply. It is important to note that there are a number of other, non-reliability related circumstances and events that may cause an interruption to consumer supply. These include:

- distribution network outages
- transmission network outages, in the non-bulk transmission sections of the transmission network (i.e., parts of the transmission network other than interconnectors)
- imbalances in generation and demand triggered by shortages in generation capacity due to a non-credible contingency.

Non-credible contingencies may result in large disturbances to power system security, including large deviations in system frequency from the normal operating frequency of the NEM. These large deviations may trigger automatic protection systems known as under frequency load shedding schemes, which shed volumes of consumer load in a controlled manner in order to arrest the fall in frequency.

In 2015/16 there were two events where under frequency load shedding resulted in demand not being met. However, as described above, these interruptions to demand are not classified as a reliability issue and are not counted towards measurements of USE.[136]

4.1.2 Reserve levels

Reserve levels refers to the amount of spare capacity available giving consideration to amounts of generation, forecast load and load response and scheduled network service provider capability. It indicates the difference between available resources to meet demand for energy, and the level of energy demanded.

There are three different lack of reserve conditions in the NEM. AEMO issues declarations that these conditions exist, in order to signal to the market either a present or future shortage of reserve:[137]

- Lack of reserve level 3 (LOR3): this means that there is insufficient supply to meet demand. An actual LOR3 would represent load shedding.
- Lack of reserve level 2 (LOR2): this means that a credible contingency, such as the loss of the largest generating unit, could result in there being insufficient supply to meet demand.
- Lack of reserve level 1 (LOR1): this means that two successive credible contingencies, such as the loss of the two largest generating units, could result in there being insufficient supply to meet demand.

A LOR3 indicates a significant impact on the NEM, as it indicates that load is either being shed, or load shedding is imminent. A LOR1 has a less significant impact on the NEM as it means that load shedding is still only likely to occur following a multiple contingency.

Changing reserve levels may be relevant to the risk of unserved energy in a region. A narrower reserve margin may indicate that there is a greater risk of demand outstripping supply, which could in turn potentially result in unserved energy. Conversely, if the amount of generation reserve available increases, the risk of unserved energy occurring may decrease.[138]

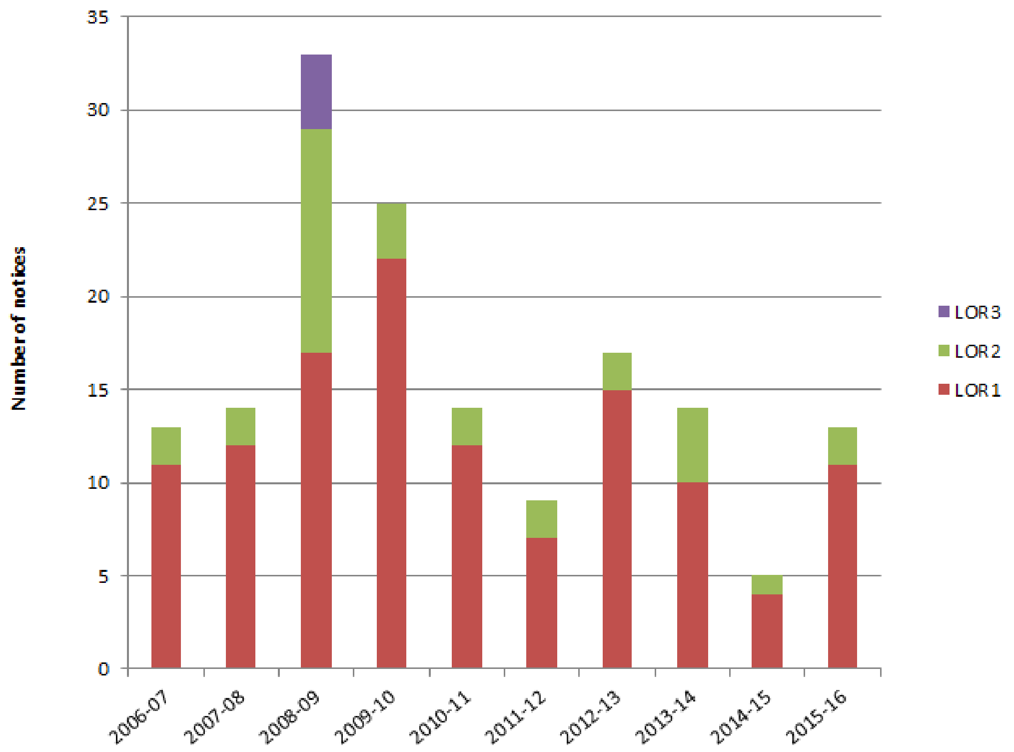
AEMO declares lack of reserve conditions through market notices. Figure 4.2 shows the number of actual LOR market notices that have been issued by AEMO over the past 10 years.

136 These security related load shedding events are discussed in greater detail in chapter 4.

137 The conditions are defined in Chapter 4 of the National Electricity Rules.

138 The Panel notes that there are a number of other factors relevant as to whether USE may occur, such as the probability of a generating unit or transmission element outage.

Figure 4.2 Lack of reserve conditions by number of LOR1, LOR2 and LOR3 notices issued



Source: AEMO, *Market notices*.

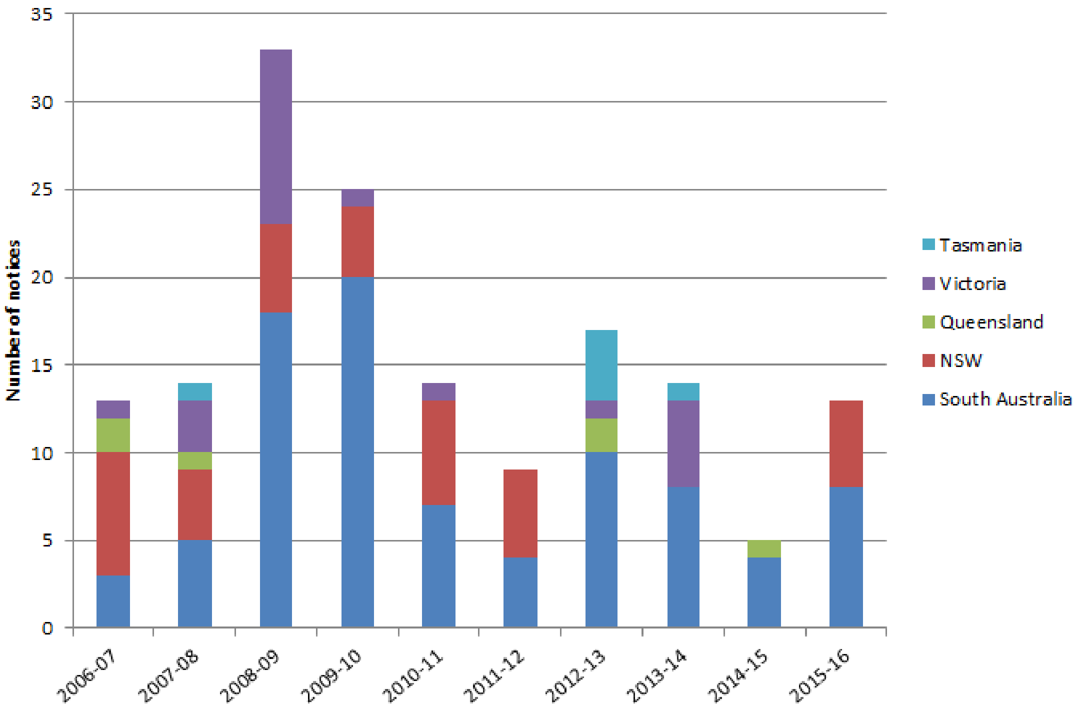
There has general decline in the number of actual LOR notices declared by AEMO. Across the NEM, the Panel notes:

- In 2008/09, the number of actual LOR notices peaked at 33. This coincides with the only instances of USE in the past decade. In 2014/15, only five actual LOR notices were declared.
- There have been no actual LOR3 notices since 2008/09.[139]

A breakdown of the regional allocation of actual LOR notices is shown in Figure 4.3.

139 The Panel notes that there was an actual LOR3 that occurred in February 2017. This occurred outside of the reporting period for AMPR 2016 and will be covered in AMPR 2017.

Figure 4.3 Lack of reserve conditions by total number of notices issued by AEMO, by region



Source: AEMO, *Market notices*.

On a regional basis, some key points to note are that:

- With the exception of 2006/07 and 2011/12, there were more LOR notices declared in South Australia than any other region.
- In 2006/07 and 2011/12 there were more LOR conditions called in NSW than any other region.
- In general terms, all regions have experienced a flat or declining number of LOR notices over the period shown.
- Queensland and Tasmania have historically experienced the least LOR notices.

The general decline in the number of LOR notices being declared could be interpreted as indicating a historic broadening of reserve levels in the NEM. As USE occurs when reserve levels fall below zero, this could in turn indicate a general reduction in the level of risk associated with the occurrence of USE. However, the Panel notes that there are a number of other factors relevant to the risk that USE will occur in any given year. Furthermore, this historic trend does not necessarily imply that the risk of USE will be lower in the future.[140]

140 Indeed, the Panel notes that there has been USE in the financial year 2016/17. In February 2017, USE occurred in South Australia. As this occurred in the reporting period for AMPR 2017, this USE, and its cause, will be discussed in AMPR 2017.

USE can occur under a number of circumstances and the trend in LOR notices should be taken only as a general indicator; it is not sufficient in itself to suggest that reliability in the NEM, or in any of the regions, has materially improved.

4.1.3 Cancelled forecasts of lack of reserve

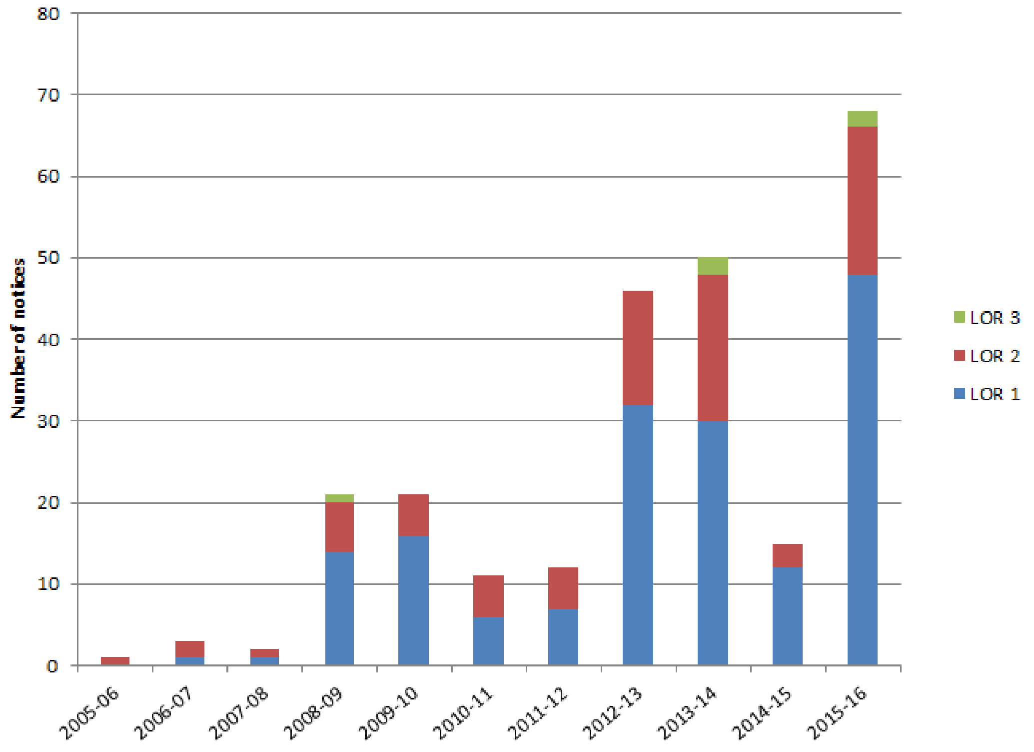
If AEMO projects a lack of reserve condition, a forecast LOR notice will be published. The intention of publishing these notices is to seek a response form the market to provide increased supply during the period where AEMO has forecast a lack of reserve. If conditions change and the projected lack of reserve condition is no longer forecast, AEMO will cancel the notice.

There are numerous reasons why AEMO would cancel a forecast lack of reserve notice, including:

- a change in forecast demand or
- an increase in the expected available generation.

Figure 4.4 shows the number of forecast lack of reserve conditions that were cancelled without becoming an actual lack of reserve condition.

Figure 4.4 Cancelled forecast lack of reserve conditions number of LOR1, LOR2 and LOR3 notices cancelled



Source: AEMO, *Market notices*.

While the actual number of LOR notices has been falling, this figure shows a general increase in the number of LOR forecast notices that have been cancelled.

As noted above, there are a number of reasons why a LOR notice may be cancelled. For example, AEMO may change its forecast of demand and find that a forecast reserve shortfall no longer exists.

However, AEMO may also cancel a LOR notice when an increase in the expected available generation results in the forecast reserve shortfall no longer existing. While other factors may be relevant, this increase in the available generation could be interpreted as a response from the market to the LOR notice, making increased amounts of generation capacity available to prevent a potential reliability shortfall.[141]

The Panel considers that this trend in the cancellation of LOR notices, and the potential degree of market response that it indicates, warrants further consideration. The Panel intends to consider this trend in more detail in AMPR 2017.

While this section has focused on the general historic trends of USE and reserve levels, the next section considers AEMO's forward projections. These projections are that there may be an increased risk of some unserved energy in future, in the absence of an adequate market response.

4.1.4 Projections of USE

AEMO publishes an Electricity Statement of Objectives[142] on an annual basis. This report provides technical and market data that informs the decision-making processes of market participants, new investors, and jurisdictional bodies as they assess opportunities in the NEM over a 10-year outlook period.

The analysis from AEMO includes projections of future potential expectations of unserved energy.

The projections of USE are signalled to the market with the intention of eliciting a response from participants to address the projected shortfall.

The projections of USE for each jurisdiction are shown under two scenarios. The first scenario assumes that there has been a response from participants to address the projected shortfall. This market response is modelled to be the return to service of three mothballed power stations, Pelican Point, Tamar Valley and Swanbank E, by 2017/18 as well as increased energy generated from existing generators. The second scenario shows projections of USE when the participants do not respond to the projected shortfall.

AEMO's projections of USE as shown are modelled with an assumption of neutral growth.[143]

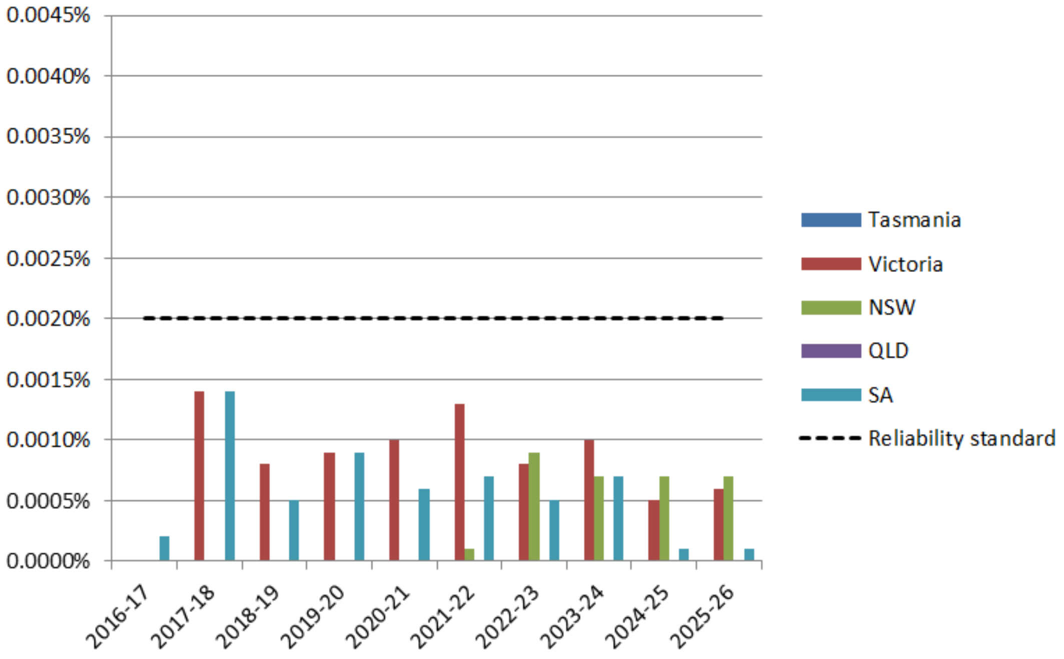
Figure 4.5 shows projections of USE under a neutral growth scenario in which a market response has occurred following the announcement of Hazelwood Power Station withdrawing from the NEM. This market response includes the return to service of the Pelican Point, Tamar Valley and Swanbank E power stations by 2017/18 and increased amount of energy generated from existing NEM generators.

141 The Panel notes that other factors may be relevant to changes in available generation, such as changes in maintenance schedules or other non-price related.

142 AEMO, *Electricity Statement of Objectives*, August 2016.

143 The neutral growth scenario modelled by AEMO assumes neutral economic and consumer growth sensitivity. AEMO, *Electricity Statement of Objectives*, August 2016, p. 14.

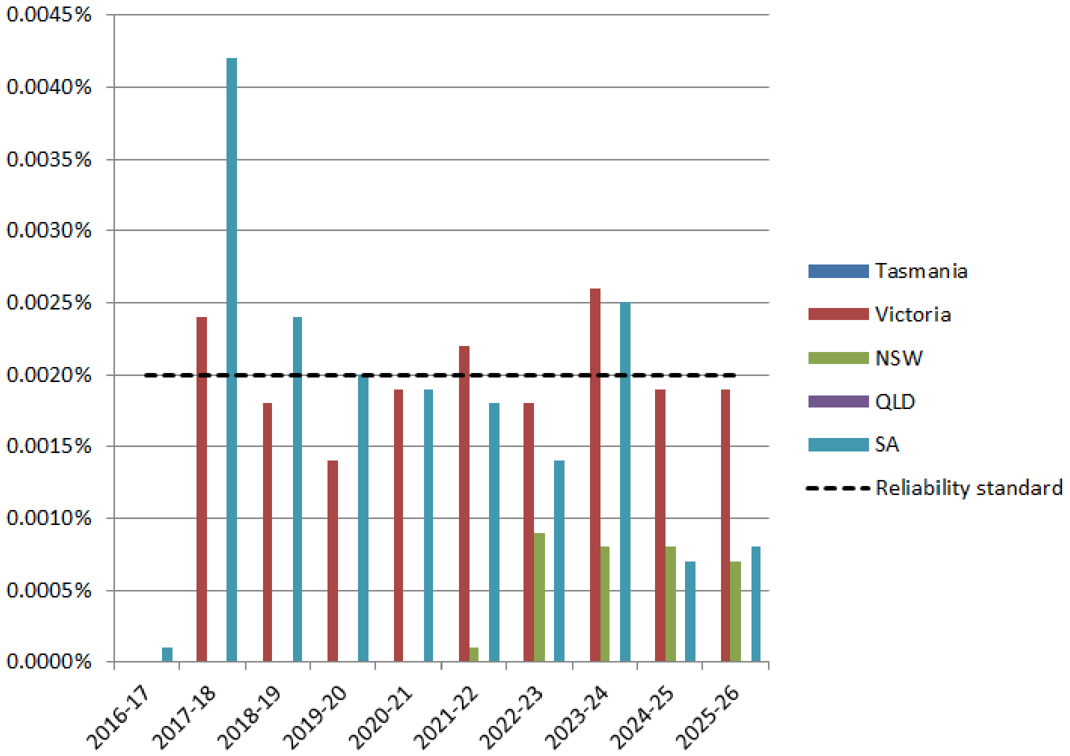
Figure 4.5 Expected USE with market response



Source: AEMO, *Electricity Statement of Objectives*, August 2016.

Figure 4.6 shows projections of USE with an assumption of neutral growth in which the withdrawal of Hazelwood Power Station has been accounted for and no market response has occurred following the announcement.

Figure 4.6 Expected USE without market response



Source: AEMO, *Electricity Statement of Objectives*, August 2016.

AEMO's projections show that, in the absence of any market response, there is a risk of USE in South Australia and Victoria that exceeds 0.002% in numerous financial years, beginning with financial year 2017/18. This demonstrates the potential impact that the withdrawal of the Hazelwood power station, and other generators, may have on reliability outcomes in multiple regions of the NEM.

AEMO also notes that market responses (in addition to the return to service of Pelican Point, Tamar Valley and Swanbank E power stations) may act to reduce the expectations of USE. These market responses include:[144]

- increasing generation from existing generators in the NEM, primarily New South Wales black coal-fired and South Australia gas-fired generation, to decrease reliance on Victorian exports
- conservation of water storage in 2016/17 for use when supply is tight in the summer of 2017/18
- demand-side participation (DSP), which can refer to a wide variety of short-term demand responses by customers to electricity price and/or reliability signals
- committing already-proposed generation, network, or non-network projects in the NEM, recognising that there are lead times for this response
- permanent demand reduction in response to anticipated increases in market prices.

Under both scenarios, the closure of Liddel power station is projected to result in some USE occurring in NSW from 2021/22 onwards. However, it is not projected that USE will exceed 0.002% in NSW.

144 AEMO, *Update: Electricity Statement of Objectives*, November 2016, p. 1.

5 Security review

The NEM is considered to be in a secure operating state if the power system is a satisfactory operating state and will return to a satisfactory operating state following a credible contingency in accordance with the power system security standards.[145] The key parameters to manage in order to maintain a secure and satisfactory operating state are frequency, voltage, current flows and the operation of equipment within its limits.

This chapter summarises the Panel's consideration of the security performance of the NEM in 2015/16, as well as some general commentary on potential future security outcomes in the NEM.

The Panel notes the following outcomes:

- **Meeting frequency requirements**: In 2015/16, the amount of time spent outside the normal operating frequency band was greater than in 2014/15 and 2013/14.

  Tasmania did not meet the frequency operating standard in February 2016.

For the past three years, the number of times the normal operating frequency band has been exceeded on the mainland and in Tasmania has increased.

- **Under frequency load shedding**: There were two instances of under-frequency load shedding in 2015/16; Tasmania in August 2015 and South Australia in November 2015.
- **Voltage limits**: In 2015/16 there was one instance of the power system being operated outside its secure operating limits for greater than 30 minutes. The cause of the incident was a combination of an unusual transmission configuration and difficulties in managing the reactive power output of Mt Mercer wind farm.
- **System Restart Ancillary Services**: System restart ancillary services were not drawn upon.[146] The Reliability Panel undertook a review of the System Restart Standard that was completed in November 2016.
- **Power system directions**: AEMO only issued power system directions once, to generators in north Queensland.
- **Power system security incidents**: there were three significant power system security incidents that have been reviewed in this report:
  - the outage on Basslink from December 2015 to June 2016
  - the outages on the Heywood interconnector in October and November 2015
  - the load shedding in Tasmania in December 2015.

These key points, and a detailed consideration of the operating incidents, are presented below.

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145 The power system security standards are the standards (other than the reliability standard and the system restart standard) governing power system security and reliability of the power system.

146 The Panel notes that system restart ancillary services were called on during the South Australian black system event of 28 September 2016. As noted earlier, this event falls outside of the reporting period of the 2016 AMPR. However, the Panel intends to provide a detailed summary and commentary on that event, and the subsequent restoration of the system, as part of the 2017 AMPR.

5.1 Power system performance

This section examines whether key power system quantities, such as frequency and voltage, were maintained at the levels required in system performance standards during 2015/16. The section also examines performance stability of the power system in 2015/16.

These system security performance indicators are explained in greater detail in appendix G.

5.1.1 Frequency

The control of power system frequency is a crucial element of managing power system security. The frequency of the power system reflects the balance between power system demand and generation. For instance, if a generator were to suddenly trip and not be available then the frequency would fall as there would be insufficient generation to meet demand.

The power system frequency is generally maintained by AEMO within a range called the normal operating frequency band. This is defined in the frequency operating standards, which are determined by the Reliability Panel.[147] When the system is operating normally (i.e. with no regions separated or being restored from a contingency event) the normal operating frequency band is the range of frequency from 49.85Hz to 50.15Hz.[148] This is described as the normal operating frequency band. The frequency operating standard requires the frequency to be within the normal operating frequency band for 99% of the time under normal operating conditions.[149]

If the frequency leaves the normal operating band, AEMO will use frequency control ancillary services to attempt to return the frequency to the normal operating frequency band as per the frequency operating standards.

The mainland and Tasmania have different frequency operating standards. The Tasmania power system is different from the mainland in that it:

- is small in terms of the size of the load and installed generating capacity
- has relatively large load, generator and network contingencies, as a proportion of the total system
- is predominantly supplied by hydro generating units
- can have a relatively low inertia, particularly when Tasmania is importing energy via Basslink at a time of low Tasmanian demand

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147 The frequency operating standards for the mainland and for Tasmania are available on the AEMC's website, http://www.aemc.gov.au/Australia-s-Energy-Market/Market-Legislation/Electricity-Guidelines-and-Standards

148 It is important to keep the power system frequency as close to 50Hz as possible, as generation units and some load equipment are designed to work most efficiently when frequency stays within this band. In addition, significant variations from the normal operating frequency band can cause generating units to "trip" and lose synchronism with the system.

149 Reliability Panel, *Application of Frequency Operating Standards During Periods of Supply Scarcity* , April 2009.

- experiences shortages of fast acting FCAS because of the slow response of hydro generators to frequency disturbances.[150]

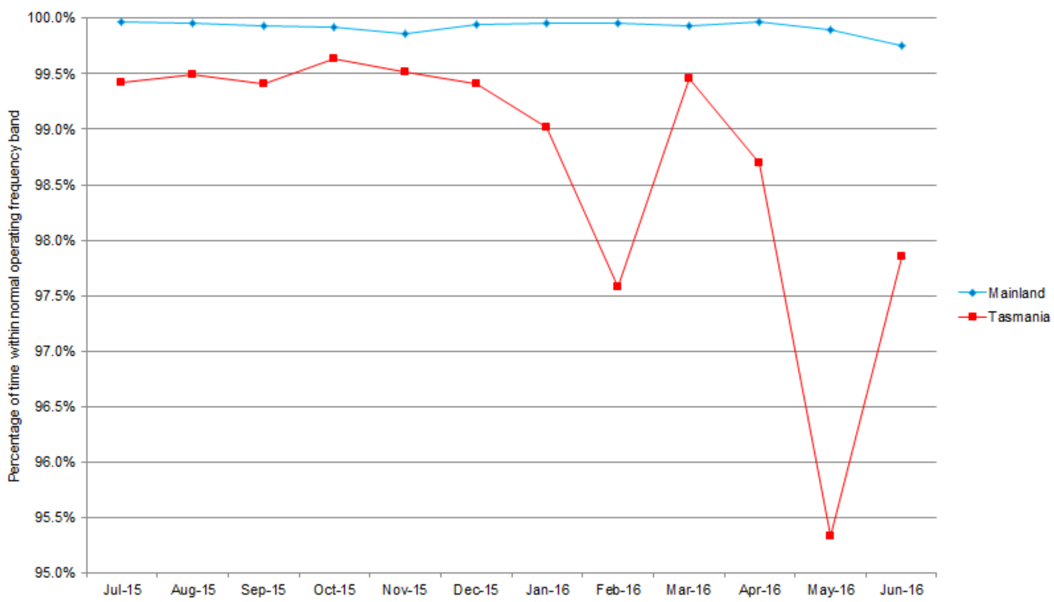
For these reasons, the Panel has developed different frequency operating standards for Tasmania to the mainland. If Tasmania was required to have the same frequency operating standards as the mainland, it would likely result in a shortage of FCAS resources, or substantially high FCAS costs.

Figure 5.1 shows that during 2015/16, the mainland frequency remained within the NOFB more than 99.5 per cent of the time. This indicates that the mainland power system was operating in a condition where load was balanced with generation and frequency was kept within the bands required under the frequency operating standards.

Tasmania was outside the normal operating frequency band for over 1% of the time for February, April May and June 2016. This coincides with the outage on Basslink. This indicates that there was difficulty in balancing generation and demand during this period, which was exacerbated by shortages in hydro reserves.

More detail on the frequency operating standard is provided in appendix G.

Figure 5.1 Percentage of time within normal operating frequency band



Source: AEMO.

The percentage of time the system was operated outside of the normal operating frequency band for greater in 2015/16 than in previous years, for both the mainland and Tasmania. These results are explained below.

Mainland

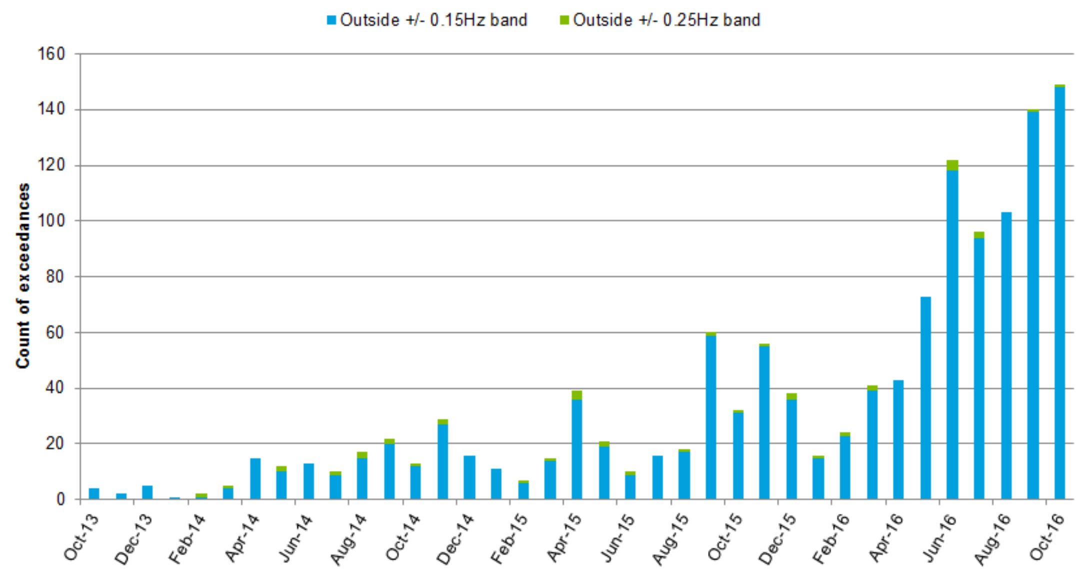
In 2015/16, the system operated outside the NOFB for 25,592 seconds as compared with 6,640 seconds in 2014/15 and 2,656 seconds in 2013/14. Despite an increased amount of

150 Reliability Panel, *Tasmanian Frequency Operating Standard Review*, December 2008.

time operating outside the NOFB, the percentage of time inside NOFB met the required standard of 99% over each 30 day period in 2015-16.[151]

Figure 5.2 shows that over the past three years, the number of times the NOFB has been exceeded on the mainland has increased. This may indicate that the frequency on the mainland has become increasingly variable, and potentially more difficult to contain to within the NOFB.

Figure 5.2 Number of frequency band exceedances - mainland



Source: Data for this graph was taken from AEMO, *Frequency monitoring - three year historical trends*, December 2016, p. 4.

Tasmania

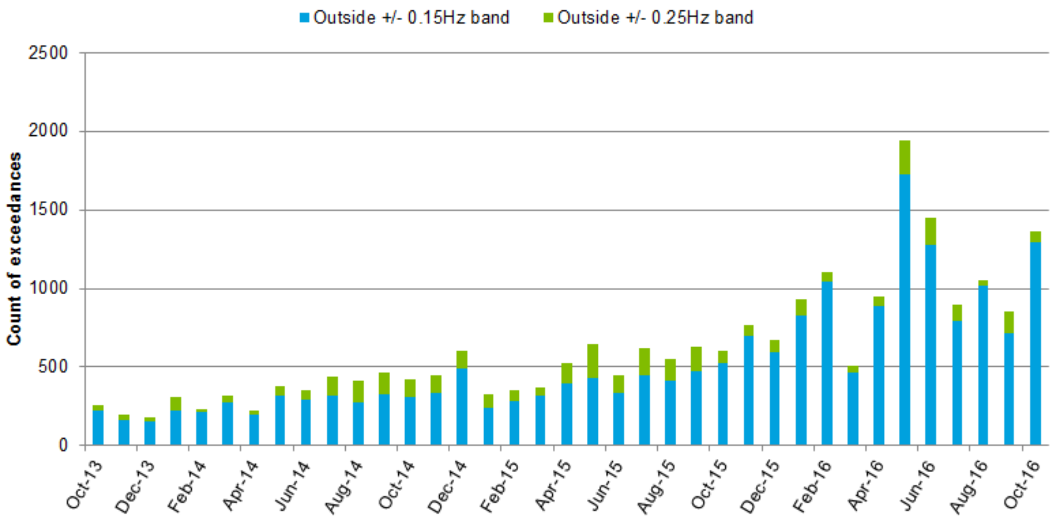
In 2015/16, Tasmania operated outside the normal operating frequency band for 398,544 seconds as compared with 165,040 seconds in 2014/15. In addition, the percentage of time inside NOFB did not meet the required standard of 99% over a 30 day period[152] for the months February, April, May and June 2016. The periods where Tasmania did not meet the standard coincided with an outage of Basslink and a shortage of water impacting upon hydro generation. Tasmania met the standards with Basslink in service as this provided a source of additional generation and controllability to the region. More detail on the Basslink outage is provided in chapter 6.

Figure 5.3 shows that over the past three years, the number of times the NOFB has been exceeded in Tasmania has increased. The Panel also notes that the number of frequency band exceedances in Tasmania is much greater than on the mainland. Additionally, there is a relatively larger number of frequency band exceedances in Tasmania that go outside the +/-0.25Hz band as compared to the mainland.

151 Reliability Panel, Application of Frequency Operating Standards During Periods of Supply Scarcity, April 2009, p.16.

152 Reliability Panel, *Tasmanian Frequency Operating Standard Review*, December 2008, p. 37.

Figure 5.3 Number of frequency band exceedances - Tasmania



Source: Data for this graph was taken from AEMO, *Frequency monitoring - three year historical trends*, December 2016, p. 5.

5.1.2 Under frequency load shedding

If a frequency deviation results in the frequency moving significantly outside of the normal ranges, automatic protection systems operate to trip load (for an under-frequency excursion) or generation (for an over-frequency excursion) to bring the frequency back to within the normal operating standards.[153]

Currently, these protection systems include under-frequency load shedding schemes (UFLS).[154] UFLS are designed to arrest the fall in frequency that can occur following a non-credible contingency, such as the simultaneous trip of several generators or transmission lines. UFLS does this by disconnecting blocks of consumer load in a controlled manner, until the fall in frequency stops or there is no more load to be shed.[155]

In 2015/16, there were two occasions where UFLS schemes were triggered.[156] These events are detailed in Table 5.1.

153 Typically, automatic under frequency load shedding mechanisms are triggered when the frequency moves outside of the operational frequency tolerance band of 49Hz to 51Hz..

154 AEMO, *Fact sheet: frequency control*, p. 3.

155 The Panel notes that the AEMC's Emergency frequency control scheme rule change is considering the introduction of over frequency generator shedding scheme, to address sudden increases in power system frequency.

156 These events are covered in greater detail in chapter 6.

Table 5.1 UFLS events in the NEM for 2015/16

Date	Region	Incident	Amount of load turned off	Time load turned off	Time load turned on	Supply interrupted[157]
2 August 2015	Tasmania	Loss of both FA-RE lines in Tasmania	225MW	10:29	11:04	132MWh
1 November 2015	South Australia	South Australia separation event	105MW	21:51	22:30	68MWh

Source: AEMO.

The current UFLS schemes are being reviewed to reflect changing market conditions. The AEMC's Emergency frequency control schemes rule change is considering the development of new frameworks to support more efficient schemes to manage extreme over and under frequency events.[158] This is discussed in greater detail in section 2.5.

The future risk of load shedding is projected to be greatest between 2.00 pm and 8.00 pm, if high demand coincides with low wind and rooftop PV generation, unplanned generation outages, and/or low levels of imports from neighbouring regions.[159]

5.1.3 Voltage limits

Satisfactory voltage limits represent the minimum or maximum safe operating level of a network asset set by the asset owner and which should not normally be exceeded. A secure voltage limit is the normal minimum or maximum operating limit of a network asset such that, post contingency, voltage levels will not exceed the satisfactory limits.

It is possible for secure limits to be exceeded for short durations. In accordance with clause 4.8.15(a)(1)(iv) of the NER, AEMO must correct any breaches as soon as possible but within a maximum of 30 minutes. During 2015/16, there was one instance of the power system being operated outside its secure limits for greater than 30 minutes.

The power system in Victoria was not in a secure operating state for over 30 minutes on 15 June 2016 due to post contingency voltage violations Moorabool substation. For 174 minutes, the post contingent voltage[160] at Moorabool substation would have exceeded the maximum allowable voltage. Figure 5.4 shows the post contingent voltage and the voltage rating at the Moorabool substation throughout the event

157 Neither of these events met the Rules definition of USE.

158 For more information see http://www.aemc.gov.au/Rule-Changes/Emergency-frequency-control-schemes-for-excess-gen

159 AEMO, *Electricity statement of opportunities*, August 2016, pp. 3-4.

160 This refers to the voltage that would have occurred following a credible contingency. The credible contingency that would have caused this voltage excursion was the potential trip of line between Moorabool substation and Ballarat substation.

Figure 5.4 Post contingent voltages at Moorabool substation

Source: AEMO, *Power system not in a secure operating state in Victoria on 15 June 2016*, November 2016.

In AEMO post event assessment, AEMO concluded:[161]

- the cause of the incident was a combination of an unusual transmission configuration and difficulties in managing the reactive power output of Mt Mercer wind farm
- the delay in restoring the power system to a secure operating state was related to difficulties in reducing the reactive power output from Mt Mercer wind farm.

More information on power system stability is provided in appendix H.

5.1.4 Constraints

AEMO uses constraint equations to model power system congestion in the NEMDE. Constraint equations can have an impact on pricing and dispatch in the electricity market.

The key findings of the NEM constraint report 2015 were:[162]

- 2015 had the largest number of constraint equation changes since the start of the NEM: this was mostly due to generation changes.
- The market impact due to binding constraints was the highest since the data became available in 2009. This was primarily driven by FCAS costs in South Australia and network support agreements in Queensland.

More information on constraints is provided in appendix G.

5.1.5 System restart standard

The Panel determines the system restart standard that applies to the NEM.

The SRS sets out several key parameters for power system restoration, including the timeframe for restoration and how much supply is to be restored. The standard provides AEMO with a target against which it procures SRAS from contracted SRAS providers.

Prior to September 2016, AEMO had never called on procured SRAS, including during the financial year period 2015/16. However, in September 2016, AEMO drew on SRAS

161 AEMO. *Power system not in a secure operating state in Victoria on 15 June 2016, November 2016*, p. 7.

162 AEMO, *The NEM constraint report*, May 2016.

to restore supply in South Australia following a system black event. A short description of this system black event is provided in chapter 6.[163]

On 25 August 2016, the Reliability Panel released a draft system restart standard for public consultation. The final system restart standard was published on 15 December 2016. More information on the final SRS is available in chapter 2.

The Panel also notes that, since 1 July 2015, AEMO is required to report annually on matters related to system restart services. This requirement was placed on AEMO as part of the AEMC's final rule determination for the system restart ancillary services rule change.[164]

5.2 Emerging system security issues

In the context of falling levels of synchronous generation, a number of system security issues have arisen. These issues include, but are not limited to:

- decreases in available system inertia, resulting in increased challenges to maintain system frequency following disturbances
- declining system strength.

5.2.1 Inertia and challenges in maintaining system frequency

Traditional large spinning generators are synchronised to the AC power system. This means that they rotate at the same speed as the frequency of the system. It also means that there is an electro-mechanical "link" between the mechanical energy of the generator and the electrical frequency of the power system. As the electrical frequency of the AC system increases, the generator will tend to spin faster, and as the frequency falls, the generator will slow down. This is referred to as the physical inertia provided by the generating unit.

This link means that a degree of physical inertia can be provided by some of the larger, heavier synchronous generators. This in turn means that in a system with lots of these heavy spinning units, any fall in the frequency caused by a disturbance will be slowed by the heavy spinning mass of the generator. In effect, the inertia of these synchronous units slows down the rate at which the frequency will change following a sudden disturbance to the power system, such as the sudden loss of a generator or load.

As demonstrated in chapter 3, a key trend in the NEM is that these synchronous units are being replaced with non-synchronous units. These non-synchronous units often do not provide the same kind of inertial response. It follows that as synchronous generation is withdrawn from the power system, the level of inertia decreases, potentially resulting in faster rates of change of frequency following a disturbance to the power system.[165]

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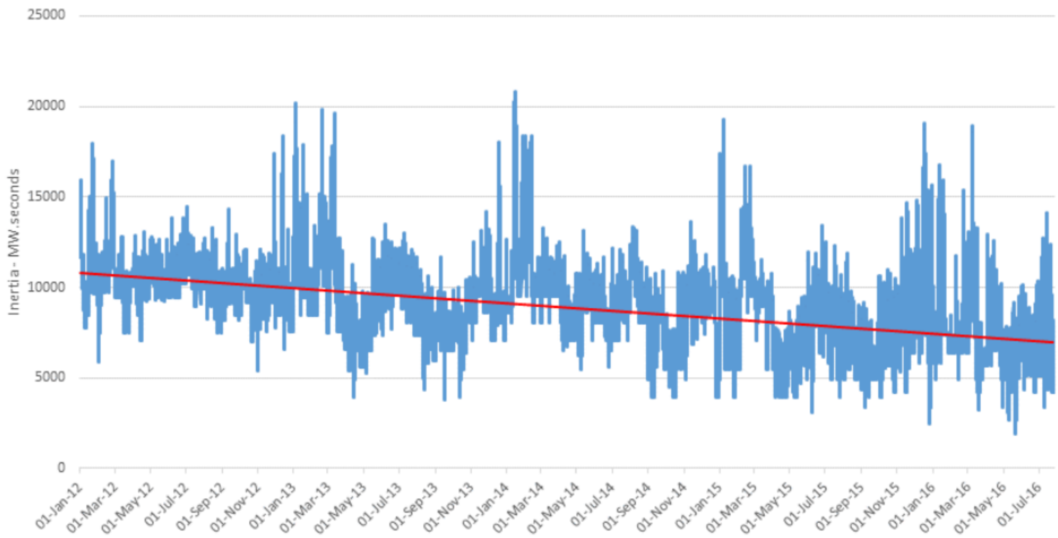
163 As the system black in South Australia occurred outside the reporting period for AMPR 2016, it will be covered in greater detail in AMPR 2017.

164 For more information, see: http://www.aemc.gov.au/Rule-Changes/System-Restart-Ancillary-Services

165 The rate of change of the frequency following a major disturbance is a product of both the level of inertia in the system, as well as the size of the disturbance.

As discussed in chapter 3, in recent years the South Australian region of the NEM has seen significant withdrawal of synchronous generation and increased penetration of non-synchronous generation. This has contributed to a decreasing level of system inertia. This is shown in Figure 5.5.

Figure 5.5 Inertia in South Australia



Source: AEMO, *Future power system security program progress report*, August 2016, p. 21.

A certain level of inertia is necessary to maintain the rate of change of frequency to manageable levels.[166] If the rate of change of frequency is sufficiently large, it can result in the load or generation "tripping" off the system. There is a risk that this may lead to a further worsening of the frequency disturbance. Furthermore, if the rate of change of frequency is large enough, emergency frequency control schemes may not be able to prevent a broader system disruption.

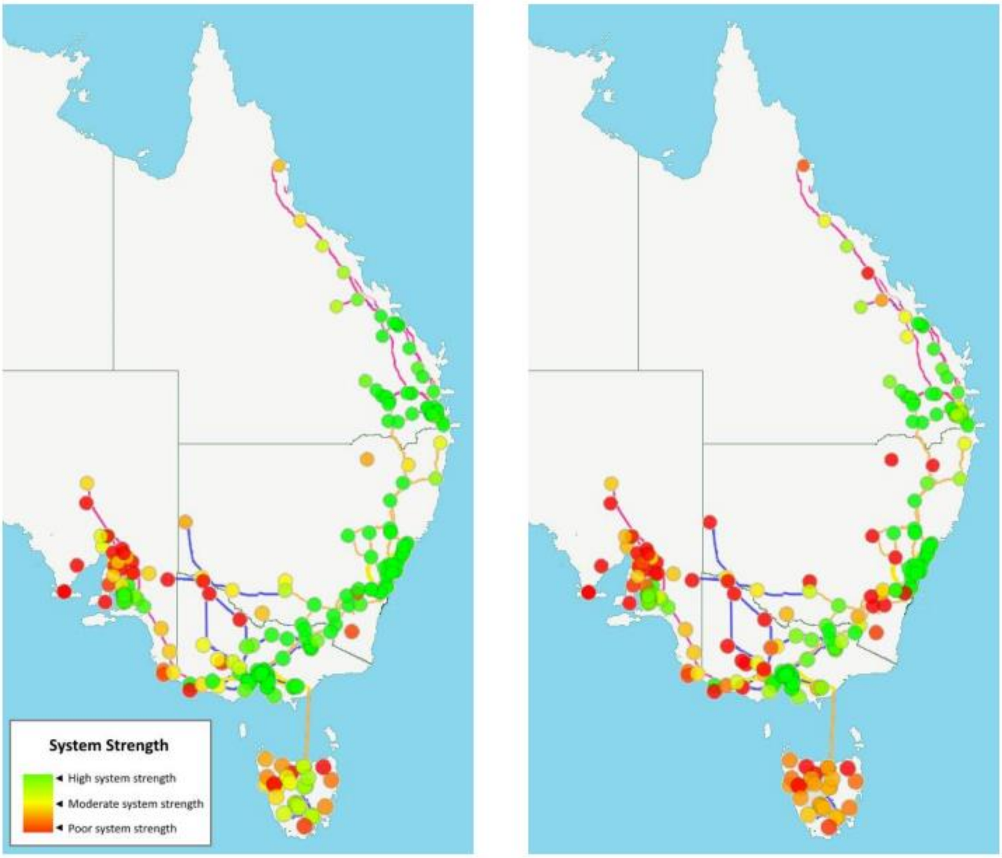
5.2.2 System strength

System strength is a quantity inherent to any power system and is typically provided by synchronous generation. The supportive characteristics of synchronous generation are not typically provided by power electronic converter-connected, non-synchronous generation technologies. As the quantity of connected synchronous generation declines and the penetration of power electronic converter-connected non-synchronous generation increases, levels of system strength may decline. [167]A projection of estimated future levels of system strength is shown in Figure 5.6.

166 This is the case in the NEM currently. Future technologies may be able to substitute for inertia.

167 AEMO, *Future power system security program progress report, August 2016, p. 45*.

Figure 5.6 Projected system strength in 2016/17 (left) and 2035/36 (right)



AEMO, *National transmission network development plan*, December 2016, p. 67.

This projection predicts that there may be reduced system strength in Tasmania, South Australia and west Victoria by 2035/36. Additionally, system strength is also projected to decline throughout NSW and Queensland as increasing levels of non-synchronous generation look to connect there. [168]

Declining system strength can lead to localised issues and can also have broader power system impacts. Three potential challenges for power system security are:[169]

- the possible reduced effectiveness of some types of network and generating systems' protection functions
- power electronic converter-interfaced devices such as wind turbines and solar inverters require a minimum fault level to operate in a stable and reliable condition.[170] Reduced system strength could therefore impact on their ability to ride through faults on the system
- voltage control in response to small and large system disturbances is also affected by system strength, with weaker systems more susceptible to voltage instability or collapse.

168 AEMO, *National transmission network development plan,* December 2016, p. 67.

169 AEMO, *Future power system security program progress report*, August 2016, p. 45.

170 Fault levels are directly related to power system strength. A low strength system will have low fault levels.

Maintaining the security of the NEM will be highly contingent of addressing these issues among others.

As discussed in section 2.5 above, both the AEMC and AEMO are progressing a number of work streams to address these issues. The AEMC's System Security Market Frameworks review is considering a number of changes to the power system to address the consequences of the reduction in inertia levels, including the introduction of new mechanisms for the provision of inertia and fast frequency response. The AEMC is also progressing the Emergency frequency control schemes rule change, which is developing more effective approaches to limit the consequences of severe power system disturbances.

In addition to this, the AEMC has received a rule change request from AEMO that is intended to improve AEMO's ability to model power systems with lower levels of system strength. The generating systems model guidelines rule change proposes that generators be required to provide more detailed models to AEMO. It is proposed that this will allow AEMO to undertake more effective modelling and gain a better understanding of how the power system will function under low power system conditions. [171]

5.3 Power system directions

Under clause 4.8.9 of the NER, AEMO has the power to either issue directions as a last resort measure, or to contract for the provision of reserves through the reliability and emergency reserve trader mechanism, in order to maintain power system security and reliability.

5.3.1 Power system directions issued by AEMO in 2015/16

During 2015/16, AEMO issued power system directions on one occasion. On 13 October 2015, AEMO issued directions to some north Queensland generating units to restore power system security. The incident involved:

- multiple unplanned outages of the Ross - Strathmore 879 275 kV line (Line 879)
- simultaneous outage of the Line 879 and Ross - Strathmore 8858 275 kV line 275kV (Line 8858) transmission lines was reclassified as a single credible contingency event
- directions were given to some north Queensland generating units to restore power system security.

AEMO issued four directions to generating units to synchronise and follow dispatch targets in north Queensland. Several unexpected delays occurred during the direction process due to:

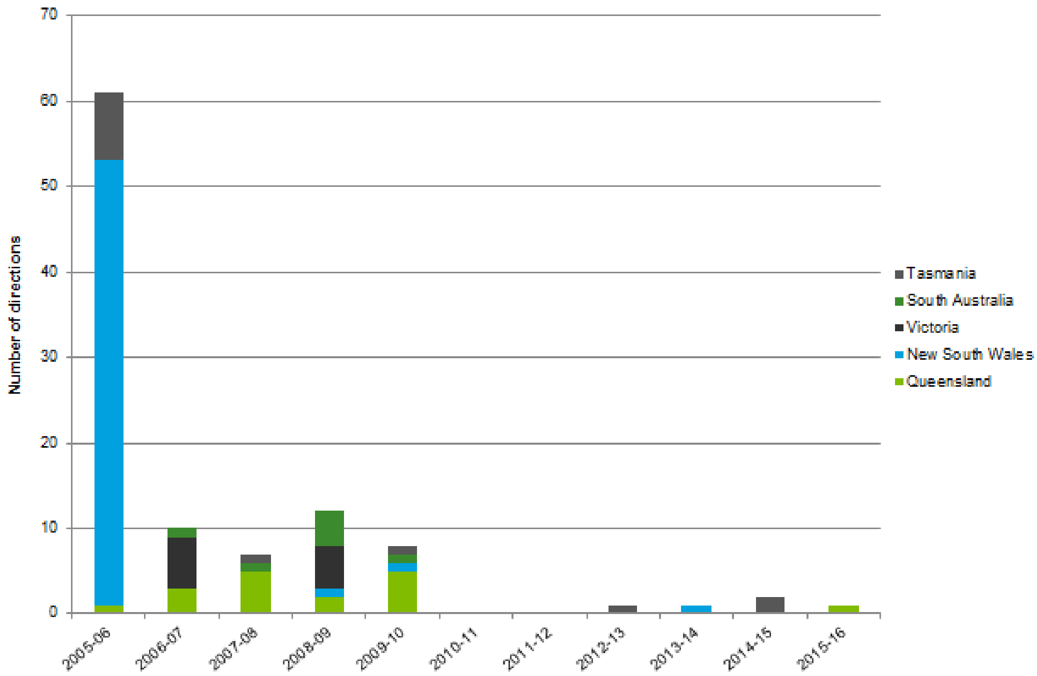
- two generating units being unable to synchronise and follow dispatch targets
- approximately 20 minutes extra delay to the normal fast start profile for one generating unit to synchronise and follow targets.

171 More information is available at: http://www.aemc.gov.au/Rule-Changes/Generating-System-Model-Guidelines

5.3.2 Historical summary of AEMO issued power system directions

Figure 5.7 sets out the number of power system directions issued by AEMO in the last ten years. The number of directions issued by AEMO has also been declining over this period.

Figure 5.7 Numbers of directions issued



Source: AEMO

5.3.3 Use of reliability emergency reserve trader mechanism

The RERT is a mechanism that allows AEMO to contract for reserves up to 10 weeks ahead of a period where AEMO projects there to be inadequate electricity generation capacity, such as during periods of high demand. [172] AEMO is also able to, where practicable, dispatch these additional reserves should an actual shortfall occur. The RERT acts as a safety net, typically used in rare events where ordinary market mechanisms are unlikely to deliver adequate electricity supply to meet market demand.

No reserve contracts were entered into during 2015/16.

172 This period was nine months prior to a rule change by the AEMC. More information on the rule change is available in appendix J.

6 Power system incidents

This chapter assesses the reviewable operating incidents that occurred during 2015/16 and provides a more detailed consideration of three major events that had reliability and security implications for the NEM.

AEMO is required to conduct a review of every reviewable operating incident. A reviewable operating incident is defined in the NER as:[173]

- a non-credible contingency event or multiple contingency events on the transmission system
- a black system condition
- an event where the frequency of the power system is outside limits specified in the power system security standard
- an event where the power system is not in a secure operating state for more than 30 minutes
- an event where AEMO issues an instruction for load shedding
- an incident where AEMO has been responsible for the disconnection of a Registered Participant or
- any other operating incident identified to be of significance to the operation of the power system or a significant deviation from normal operating conditions.

The Panel is required to assess the number and types of reviewable operating incidents in the NEM. The Panel also assesses how AEMO manages the process of identifying and reviewing these incidents to determine whether AEMO's processes can be improved.[174]

This section provides a summary of the operating incidents that were reviewed by AEMO during 2015/16.

It also provides a more detailed description of the most significant of these incidents that occurred in the NEM in 2015/16. While some of these may have been also classified as AEMO reviewable operating incidents, others are not and have been included for review by the Panel due to the extent of their impact on consumers.

6.1 Reviewable operating incidents during 2015/16

During 2015/16, there were 20 incidents that were reviewed in accordance with the operating incident guidelines as set out in Table 6.1. Of these events, AEMO classified 10 as multiple contingency events.

173 NER clause 4.8.15.

174 The guidelines for identifying reviewable operating incidents can found on the AEMC Reliability Panel website: www.aemc.gov.au.

Table 6.1 Reviewable operating incidents during 2014/15 and 2015/16

Incident	Number of incidents (2014/15)	Number of incidents (2015/16)
Transmission related incidents (excluding busbar trips)	16	8
Generation related incidents	1	0
Combined transmission and generation incidents	2	1
Busbar related reviewable incidents	5	7
Power system security related incidents	4	4

Source: AEMO.

The number of events in 2015/16 was lower than the previous financial year which experienced 28 reviewable operating incidents (with 16 of these being classified as multiple contingencies). However, the total number of incidents can fluctuate significantly each year and there is no evidence of any trend regarding the annual number of incidents.

6.2 Major incidents

This section provides some further consideration of major incidents that occurred in 2015/16 that impacted upon the security and reliability of the NEM. These major incidents are:

- November 2015 trip of the Heywood interconnector
- December 2015 outage of Basslink
- August 2015 load shedding in Tasmania.

These particular events have been selected by the Panel as they illustrate the extent of the potential supply and price impacts for consumers following major reliability or security events in the power system.

While a number of other significant events have occurred, such as the South Australian black system event of 28 September 2016, these fall outside the reporting period of the 2016 AMPR. As such, a brief overview of those events is provided here and a more detailed review will be provided in the 2017 AMPR.

6.2.1 Heywood planned outage and subsequent trip - October and November 2015

During October and November 2015, high FCAS prices and load shedding were experienced in South Australia. This coincided with a series of planned outages on the Heywood interconnector between Victoria and South Australia.

Background

The Heywood interconnector is an alternating current (AC) link connecting South Australia to south-west Victoria. It is comprised of two 275kV lines and is the only synchronous AC link between South Australia and Victoria.[175]

Planned outage request and changed FCAS requirements

In June 2015, ElectraNet submitted requests for a series of planned outages on Heywood commencing 11 October 2015. During these outages, the synchronous separation of South Australia from the rest of the NEM (i.e. no AC interconnection with the rest of the NEM) was considered a credible contingency. AEMO considered that during the outages, power system security would be impacted if the available regulation FCAS was insufficient. Noting that 35MW of both raise and lower regulating FCAS would be required if South Australia was islanded, AEMO determined to procure this volume of regulation FCAS on a pre-contingent basis.

AEMO made this determination on 8 October 2015, three days before the first outage. AEMO considered that the FCAS constraint sets were necessary for ensuring the power system was secure pre-contingent given the credible risk of separation.[176]

High FCAS prices during planned outage - 11, 12 and 25 October 2016

The price for both lower and raise frequency control regulation services exceeded $5000/MW for 92 consecutive 5 minute dispatch intervals on 11 and 12 October and for 38 consecutive dispatch intervals on 25 October. The total cost for both services was around $7.4 million on 11 and 12 October and around $4 million on 25 October.[177]

The AER found two main causes for the high FCAS prices:[178]

- **Late notice of changed FCAS requirements**. AEMO listed changed FCAS requirements in the Network Outage Scheduler three days before the planned outages were due to begin. This limited the ability of market participants to pursue options to register to provide these services. The AER considers that AEMO's lack of communication of the change in FCAS requirements did not allow market participants’ the ability to pursue options to either register to provide these services or take steps to avoid potential adverse financial impacts. AEMO has indicated it will take steps to inform the market to changes of its protocol for procuring FCAS.[179]
- **Generator rebidding** . On 11 and 12 October 2015, the Torrens Island power station was responsible for satisfying the SA FCAS requirements and was also able to set the price. AGL (the owner of Torrens Island) rebid 60MW of both lower and raise services to $13,000/MW. The price was immediately reset to that price

175 Murraylink connects South Australia to Victoria but it is a direct current (DC) interconnection.

176 AEMO, *NEM - Market event report - High FCAS prices in South Australia*, December 2015, p. 18.

177 Australian Energy Regulator, *Report into Market ancillary service prices above $5000: South Australia, 11, 12 and 25 October 2015*, December 2015, p.1.

178 Ibid, p. 15.

179 AEMO, *NEM - Market event report - High FCAS prices in South Australia*, December 2015, p. 18.

until it reached the cumulative price threshold at 4.05pm on 12 October, at which point the administered price cap was applied. On October 25, Alinta was able to set the price through services offered by Northern Power Station. Again, the cumulative price threshold was breached and the administered price cap was applied.

High FCAS prices and load shedding - 1 November 2015

On 1 November 2015 load shedding occurred in South Australia. The incident involved:

- the trip of Heywood Line 1 that resulted in South Australia being islanded from the rest of the NEM
- the loss of 160MW of customer load and 11MW of generation
- problems controlling the frequency in the islanded South Australian power system.

Following separation, the SA power system operated as an island for 35 minutes. As a result of the separation of SA from the rest of the NEM, 160MW of SA customer load was disconnected and 11MW of SA generation was tripped.[180] This event occurred as follows:

1. **Trip of Heywood Line 1**: On 1 November, Heywood Line 2 was still out of service. At 9.51pm, a relay at the South East sub-station misinterpreted a signal and tripped the Line 1. The resulted in South Australia separating and losing synchronisation with the rest of the NEM.
2. **Tripped generation**: Immediately following the trip of line No.1, Cathedral Rock wind farm tripped offline. This was due to Cathedral Rocks wind farm's frequency protection systems operating. AEMO has determined that the rate of change of frequency in SA as a result of this incident was around 0.36 Hz/second. Generating units are normally expected to stay connected for rates of change of frequency below 1 Hz/second. AEMO and Energy Australia have subsequently investigated whether the trip was in accordance with the Cathedral Rocks Performance Standards.[181]
3. **Under frequency load shedding**: Following the trip of Heywood Line 1, SA frequency fell to a minimum of 48.96 Hz at 21:51:08 hrs and recovered to near 50 Hz within 12 seconds. This recovery was due to the operation of the South Australian UFLS scheme. Consequently, the Frequency Operating Standards were not breached immediately following the islanding of South Australia. AEMO reviewed the operation of the South Australian UFLS scheme, and confirmed that it performed as designed. Approximately 105 MW of load was disconnected by the automatic UFLS scheme to assist frequency recovery. The rest of the 160 MW load disconnected during this event was not via UFLS, but tripped due to the frequency and voltage disturbances.

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180 AEMO, *Load shedding in South Australia on Sunday 1 November 2015*, February 2016, p. 5.

181 AEMO, Load shedding in South Australia on Sunday 1 November 2015, February 2016, p. 7.

4. **Frequency control issues in islanded South Australian power system**: Over 20 minutes after the islanding of South Australia, the frequency exceeded the normal operating frequency bands for 92 seconds. The frequency excursion, which was an over-frequency event, was the result of the combination of an increase in non-scheduled and semi-scheduled generation, and an incorrect FCAS response for Torrens Island B. Torrens Island B was sent signals to reduce output but units 2 and 4 continued to increase output. As a result, AEMO directed Torrens Island B units to manually follow dispatch targets. Following the event, AEMO and AGL have worked to resolve issues relating to Torrens Island B governor response.

   Due to the high frequency in South Australia, it was not possible to resynchronise South Australia with the rest of the NEM until 10.26pm. AEMO estimates that the incorrect FCAS response from Torrens Island B delayed the resynchronisation of South Australia with the rest of the NEM by 26 minutes.

5. **FCAS prices**: Following the separation, FCAS prices in South Australian were elevated to above $9000/MW for each service. The AER does not consider rebidding contributed to the high FCAS prices.[182]

6.2.2 Basslink outage – December 2015 to June 2016

On 20 December 2015 a fault occurred on Basslink, the interconnector running between Tasmania and the mainland. This fault took Basslink out of service and separated Tasmania from the mainland. At the time of the fault occurring, approximately 250MW of industrial load was disconnected under the Frequency Control Special Protection Scheme.[183] This load was restored within 30 minutes.[184]

The outage of Basslink coincided with record lows in dam storage levels due partially to El Nino weather conditions. Average dam levels were at 26% on 22 December 2015, and fell as low as 12.8% in March 2016.

In response to the Basslink outage and low hydro levels, a number of actions were taken to maintain adequate supply of electricity:[185]

- the Tamar Valley Combined Cycle Gas Turbine (208MW) was returned to service in January 2016
- HydroTasmania, TasNetworks and other government bodies installed approximately 200MW of temporary diesel generation
- HydroTasmania negotiated voluntary commercial load reductions in cooperation with major industrial users, such as Bell Bay Aluminium and TEMCO.

During the Basslink outage, the average wholesale price increased and the average demand decreased. This is shown in Figure 6.1.

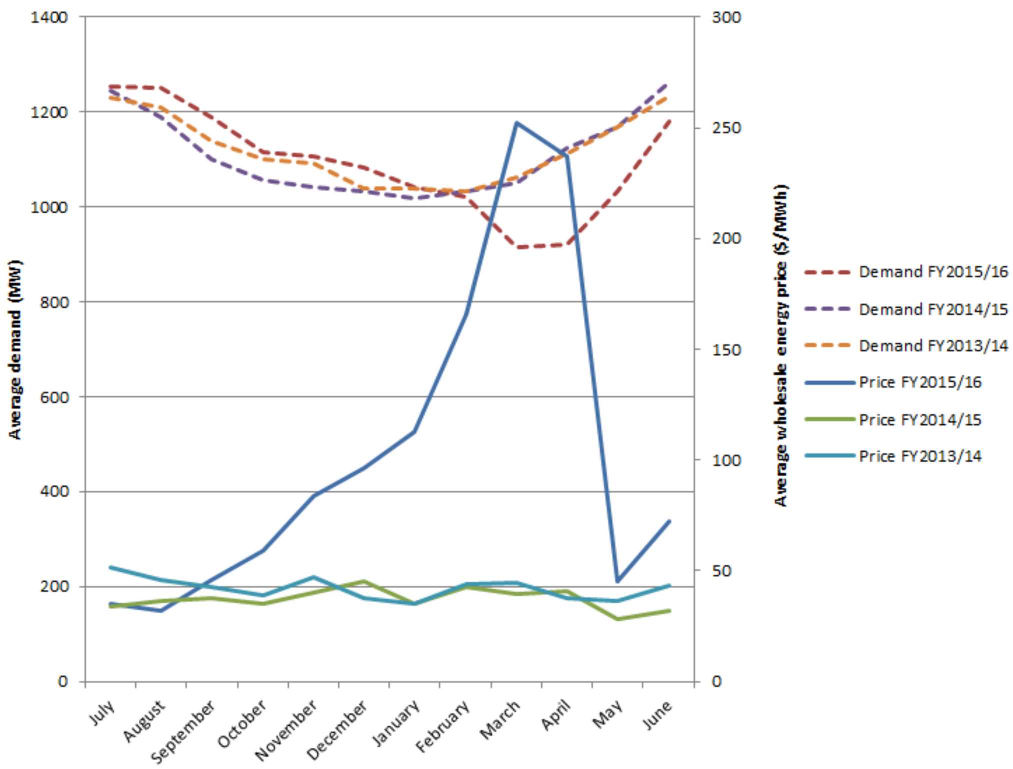
182 Australian Energy Regulator, Report into Market ancillary service prices above $5000: South Australia, 1 November 2015, February 2016, p. 6.

183 The Tasmanian special protection schemes are market based schemes where loads are paid a fee in return for being shed following certain contingency events. This kind of commercially negotiated load shedding is not counted towards USE or measures of load shedding.

184 AEMO, *Media Statement*, December 2015.

185 AEMO, *Energy adequacy assessment projection*, March 2016.

Figure 6.1 Prices and demand in Tasmania during Basslink outage



Above average rainfall was observed in Tasmania in May 2016 which resulted in the storage levels for hydro dams reaching 28%. Increased availability of hydro generation allowed Bell Bay Aluminium and TEMCO to return normal production levels. The combined cycle gas turbine at Tamar Valley Power Station was taken offline on 11 May 2016.[186]

Basslink was returned to service on 10 June 2016. Despite Tasmania being separated from the mainland for almost six months and dam levels reaching record lows, Tasmania did not experience any unserved energy.[187] This was due to additional generation capacity being made available as well as reductions in load.[188]

An investigation into the cause of the Basslink fault, undertaken by Cable Consulting International, concluded that it was not possible to determine the cause of the fault.[189]

6.2.3 Load shedding in Tasmania - August 2015

On 2 August 2015, a lightning strike tripped the two Farrell-Reece transmission lines (the FA-RE lines) in Tasmania. As a result of the line trip, two generating units at Reece Power Station were disconnected resulting in the loss of 228MW of generation in

186 AEMO, *Energy adequacy assessment projection*, June 2016.

187 There were reductions in load to assist the Tasmanian power system; however, this does not meet the NER definition of USE.

188 Ibid.

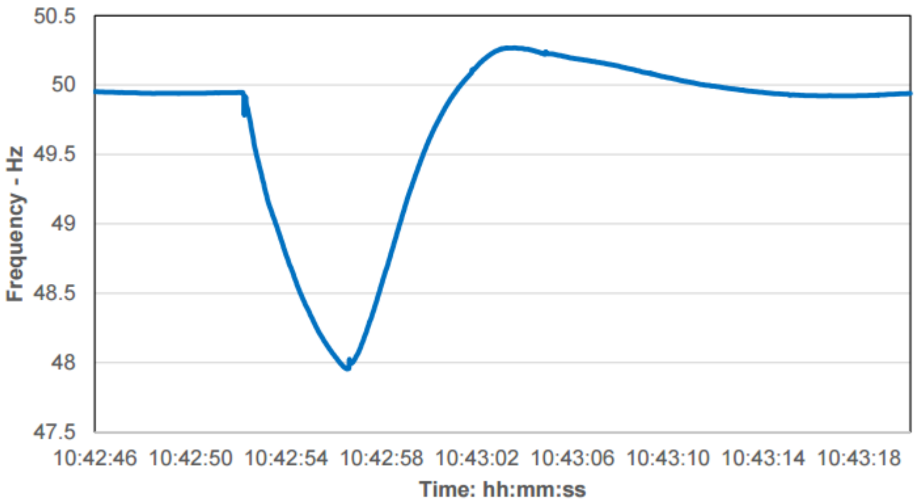
189 Basslink, *Media statement: Basslink fault cause investigation completed*, December 2016.

Tasmania. Both lines and the generating units at Reece Power Station were restored after 12 minutes.[190]

Due to the proximity of lightning to the FA-RE lines prior to the lightning strike, AEMO had reclassified the loss of both lines as a credible contingency.

For a network event, the frequency standard for Tasmania requires the frequency to be contained to a minimum of 48.0Hz. The frequency following the trip, show in Figure 6.2 fell below 48.0Hz.

Figure 6.2 Frequency in Tasmania following trip



Source: AEMO, *Under frequency load shedding in Tasmania on Sunday 2 August 2015*, October 2015.

The arrest in frequency was mostly due to load shedding. 225MW of load was shed:

- 101MW at Bell Bay Aluminium
- 124MW at Nyrstar.

At the time of the event, Basslink was flowing from Tasmania to Victoria. In response to the event, Basslink reduced exports by about 85MW. Additionally, 50MW of six second raise contingency FCAS was procured in Tasmania.

In response to reclassification of the FA-RE lines as a credible contingency, AEMO sourced sufficient FCAS to cover the credible contingency loss of the FA-RE lines. AEMO subsequently identified an error in sourcing the FCAS that resulted in insufficient contingency FCAS being enabled. As a result of this issue there was a deficiency of about 70MW in the amount of six second raise FCAS enabled for the loss of both FA-RE lines. AEMO considers it unclear whether additional six second raise FCAS would have resulted in load shedding not being required.[191]

During this incident the Musselroe and Bluff Point wind farms experienced units tripping:

- two turbines at Mussleroe wind farm tripped in response to the fault.

190 AEMO, *Under frequency load shedding in Tasmania on Sunday 2 August 2015*, October 2015, pp. 4-5.

191 AEMO, *Under frequency load shedding in Tasmania on Sunday 2 August 2015*, October 2015, p. 9.

- six turbines at Bluff Point wind farm 'stopped'[192] in response to the fault.

While not considered as the primary cause of the under frequency load shedding, analysis by TasNetworks indicates a high probability that UFLS would not have occurred if this additional generation loss had not occurred.[193]

6.2.4 Black system event in South Australia - 28 September 2016

On 28 September 2016, there was a system black event in South Australia in which the entire supply to the SA region was lost.

Due to damage caused by extreme weather, including tornados in a few areas, there were a number of faults on the South Australian transmission network. Due to these faults, a number of wind farms tripped off resulting in a reduction in wind farm output of 456MW. The reduction in wind farm output resulted in a significant increase in flow through the Heywood interconnector. The flow on the interconnector reached excessive levels and subsequently tripped off.

As a result of the Heywood interconnector tripping off, the South Australian power system was separated from the rest of the NEM, and the entire supply to the region was lost resulting in a system black.[194]

Immediately following the loss of supply to the region, an assessment of the transmission network was undertaken by AEMO and ElectraNet and the restart process was commenced. A generator contracted to provide SRAS was successfully started but unable to provide enough power to restart a major generating unit. The restoration process then proceeded through power supplied via the Heywood interconnector.

Approximately four hours after the system black occurred, 40% of load in SA that was capable of being restored had been restored. After around eight hours, 80-90% of the load in SA that was capable of being restored has been restored.[195]

Following the black system event in SA, AEMO, the AER and AEMC are undertaking reviews of the event.

AEMO has published a number of preliminary reports as part of its ongoing review of the black system event and is due to publish its final report in March 2017.[196]

The AER is undertaking a review of the black system event to assessing the compliance of participants with power system security obligations and market operation requirements under Chapters 3 and 4 of the NER.[197]

The AEMC has been tasked with undertaking a review of systemic issues that caused the system black or affected the response. The AEMC will look at possible changes to

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192 This was distinct from tripping as the turbines remained connected to the power system but reduced output to zero.

193 AEMO, *Under frequency load shedding in Tasmania on Sunday 2 August 2015*, October 2015, p. 10.

194 AEMO, *Black system South Australia 28 September 2016: Third preliminary report*, December 2016.

195 Ibid.

196 AEMO, *Media release: AEMO publishes preliminary recommendations following the South Australian state-wide power outage*, December 2016.

197 AER, *Quarterly compliance report, 1 October - 31 December 2016*, December 2016.

market rules and legislation flowing from analysis of those systemic issues. The review is likely to start in mid-2017.[198]

As discussed above, the 28 September 2016 South Australian system black event falls outside of the reporting period of the 2016 AMPR. The Panel intends to give further consideration to this event, as well as the findings of various market bodies' assessments of the event, in the 2017 AMPR.

198 For more information see http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-System-Black-Event-in-South-Australi

7 Safety review

This chapter presents the Panel's review of the power system from a safety perspective for 2015/16.

As outlined in chapter 2, the scope of the Panel's consideration of performance for this review primarily relates to generation and the bulk transmission system of the NEM. The Panel's assessment of the safety of the NEM is therefore limited to consideration of the links between security of the power system and maintaining the system within relevant standards and technical limits.

Generally, jurisdictions have specific provisions that explicitly refer to safety duties of transmission and distribution systems. The Panel has included a summary of safety outcomes in each NEM jurisdiction by reference to jurisdictional safety requirements. This summary is included in appendix H.

As part of the Panel's assessment of the safety of the power system, this section analyses the responses to operating incidents which have occurred within the NEM during 2015/16. As operating incidents have implications for the overall safety of the system, the response to these incidents is a key indicator of safety performance.

For 2015/16 the Panel reviewed the power system incident reports issued by AEMO and the security performance of the system more generally. Based on publicly available information, the Panel is not aware of any incidents where AEMO's management of power system security has resulted in a safety issue with respect to maintaining the system within relevant standards and technical limits.

There may be instances where AEMO issues a direction (discussed in chapter 6), the directed participant may choose not to comply on the grounds that complying with the direction would affect the safety of its equipment or personnel. The Panel notes that there were no instances in 2015/16 where this occurred.

A Generation capacity changes

This appendix summarises changes in generation capacity in the NEM during 2015/16. Generally, the changes included:

- an increase in renewable sources of generation, namely more wind farms and large-scale solar
- large withdrawals of synchronous generation from South Australia, and announced withdrawals of synchronous generation from Queensland, New South Wales and Victoria
- the ability for some of the recently withdrawn generation to be recalled within three months.

A.1 Increases in NEM capacity

Table A.1 provides a granular analysis of the generation capacity committed and commissioned during 2015/16.[199] All of the generation commissioned or committed in 2015/16 comes from renewable sources. 109MW of large-scale solar was commissioned in New South Wales and an additional 537.2MW of wind generation is committed between New South Wales, South Australia and Victoria.

Table A.1 New generation commissioned and committed in 2015/16

Region	Status (at the end of 2015/16)	Power Station	Capacity (MW)	Fuel source
New South Wales	Commissioned	Broken Hill	53	Solar
	Commissioned	Moree	56	Solar
	Committed	White Rock	175	Wind
South Australia[200]	Committed	Hornsdale Stage 1	102.4	Wind
	Committed	Waterloo Stage 2	19.8	Wind
Victoria	Committed	Ararat	240	Wind
Total commissioned			**109**	
Total committed			**537.2**	

199 Since the end of the 2015/16 reporting period, new generation projects have become committed. These include: Hornsdale Stage 2 Wind Farm (102MW, SA); Mt Gellibrand Wind Farm (66MW, Vic); Coonooer Bridge Wind Farm (19.8MW, Vic); Williamsdale Solar Farm (10MW, NSW); Mugga Lane Solar Park (13MW, NSW); Cook Shire Solar Storage Project (28MW, QLD).

200 At the time of publication, both Hornsdale Stage 1 and Waterloo Stage 2 have been completed and are undergoing commissioning tests.

Of the generation withdrawn in 2015/16, all was withdrawn from South Australia and all was synchronous generation. Additionally, all of the generation withdrawals announced are synchronous generation. Table A.2 contains the withdrawn generation and generation that has announced the intention to withdraw.

Table A.2 Generation withdrawals during 2015/16

Region	Status (at the end of 2015/16)	Power station	Capacity (MW)	Fuel source
Queensland[201]	To be withdrawn	Mackay GT Power Station	34	Diesel
New South Wales	To be withdrawn	Smithfield Power Station	170.9	Gas
		Liddel A Power Station	2,000	Black coal
Australian Capital Territory	No generation withdrawals			
Victoria	To be withdrawn	Hazelwood Power Station[202]	1600	Brown coal
South Australia	Withdrawn	Northern Power Station	546	Brown coal
		Playford B Power Station	240	Brown coal
		Pelican Point Power Station[203]	239 (short-term withdrawal)	Gas
Tasmania	No generation withdrawals			
Total withdrawn			1025	
Total to be withdrawn			3804.9	
Total			4829.9	

Table A.3 shows whether recently withdrawn generation is able to be recalled and if so, the timeframe within which the withdrawn generation would be able to come back online. AEMO has been advised that Wallerawang, Smithfield and Liddel are not able to be recalled, whereas Swanbank E, Pelican Point and Tamar Valley CCGT have

201 Swanbank E was placed in cold storage in December 2014. Stanwell had originally advised that Swanbank E would be returned to service in July 2017 but Stanwell has subsequently delayed the expected return until the summer period on 2018.

202 The withdrawal of Hazelwood Power Station was announced outside the 2015/16 reporting period.

203 The capacity of Pelican Point has been halved. The power station remains in operation with a capacity of 239MW.

advised AEMO that while they are currently withdrawn, they would be able to come back online within three months.

Table A.3 Ability for withdrawn generation to be recalled

Region	Participant	Plant	Ability to be recalled within three months	Ability to be recalled within six months	Ability to be recalled within 12 months
New South Wales	EnergyAustralia	Wallerawang	No	No	No
	Marubeni	Smithfield	No	No	No
	AGL	Liddel	No	No	No
Queensland	Stanwell	Swanbank E	Yes	-	-
South Australia	ENGIE	Pelican Point	Yes	-	-
Tasmania	Hydro Tasmania	Tamar Valley CCGT	Yes	-	-

B Network performance

This appendix provides a summary of transmission network and distribution network performance in 2015/16.

Network performance is can result in load not being served without causing to USE. This is because USE is demand not met due to insufficient generation and bulk transfer.

In contrast, demand cannot be met as the result of an intra-regional outage on the transmission network or on the distribution network.

Outages on the transmission network are measured in system unsupplied minutes which is the amount of energy not supplied, divided by maximum demand, multiplied by 60.

Outages on the distribution network are typically measured by both the aggregate time in which an outage occurred, SAIDI, and the frequency of outages, SAIFI.

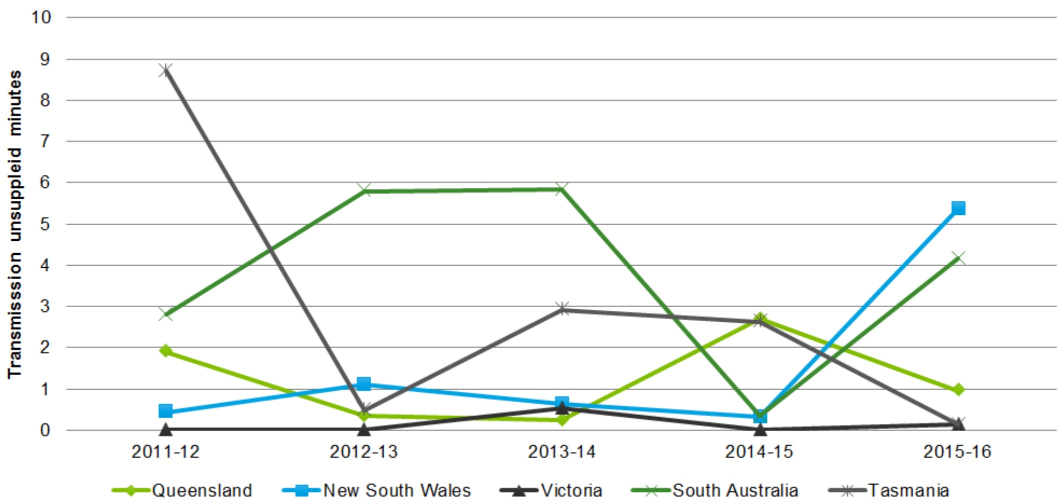
B.1 Transmission network

The number of system minutes not supplied due to transmission outages provides an aggregate indicator of the performance of transmission networks.

B.1.1 National

Figure B.1 shows the performance of the transmission networks as experienced by consumers in each region

Figure B.1 Transmission unsupplied minutes



Note: The calculated value of unsupplied minutes is the amount of energy not supplied, divided by maximum demand, multiplied by 60.

Source: Queensland: Powerlink; NSW (inc. ACT): TransGrid; Victoria: AusNet Services; South Australia: ElectraNet; Tasmania: TasNetworks.

In 2015/16, both Queensland and Tasmania experienced decreased levels of transmission unsupplied minutes. New South Wales and South Australia experienced a significant increase in transmission unsupplied minutes from 2014/15 levels. Victoria experienced a typically low level of transmission unsupplied minutes. AMPR 2015 indicated that there was a NEM wide trend of increasing transmission system reliability; however, this trend has not continued in 2015/16.

There are some national requirements that impact upon the reliability of the transmission network. Part B of Chapter 5 of the NER includes planning requirements for transmission networks. TNSPs are required to carry out an annual planning review which must be reported in an annual market performance report. In addition, they must undertake a regulatory investment test for transmission where the estimated capital cost of the most expensive potential credible option to address an identified need is more than $6 million.

Schedule 5.1 of the NER describes the planning, design and operating criteria that must be applied by TNSPs. It also describes the requirements on TNSPs to institute consistent processes to determine the appropriate technical requirements to apply for each connection enquiry or application to connect processed by the TNSP. The objective is that all connections satisfy the requirements of this schedule.

In addition, TNSPs are subject to the AER's service target performance incentive scheme which provides financial incentives to maintain and improve performance, including reliability.[204]

B.1.2 Queensland

For Queensland, in addition to the requirements in the rules above, mandated reliability obligations and standards are contained in the *Electricity Act 1994 (Queensland).* As the TNSP in Queensland, Powerlink must adhere to these obligations and its connection agreements with other parties.

Powerlink plans future network augmentations in accordance with these requirements (among other things). It does this based on satisfying the following obligations:

- to ensure as far as technically and economically practicable that the transmission grid is operated with enough capacity (and if necessary, augmented or extended to provide enough capacity) to provide network services to persons authorised to connect to the grid or take electricity from the grid[205]
- planning and developing its transmission network in accordance with good electricity industry practice such that the power transfer available through the power system will be such that the forecast of electricity that is not able to be supplied during the most critical single network element outage will not exceed either 50 MW at any one time; or 600 MWh in aggregate.[206]

B.1.3 New South Wales

In accordance with the Transmission Operator's Licence issued by the NSW Government on 7 December 2015, TransGrid must plan and develop its transmission

204 The service target performance incentive scheme is developed and published by the AER in accordance with clause 6A.7.4 of the NER.

205 Section 34(2) of the *Electricity Act 1994 (Queensland)*.

206 Transmission Authority No. T01/98.

network to meet the NSW Transmission Network Design and Reliability Standard dated December 2010.

In general terms the standard requires TransGrid to plan and develop its transmission network on an "N–1" basis. This may be varied to accommodate AEMO's operating practices, distributor licence conditions or by agreement with distributors or other customers.

The standard requires that TransGrid's planning process be interlinked with licence obligations placed on distributors in NSW. In particular, TransGrid must ensure that their transmission network is adequately planned to enable distributor licence requirements to be met. TransGrid outlines its plans to meet its obligations with the standard in the transmission annual planning report (TAPR) that it publishes by 30 June each year.

B.1.4 Victoria

AEMO is responsible for planning and directing augmentations of the Victorian electricity declared shared network in accordance with its obligations under the rules. AEMO identifies the benefits of various network and non-network investment options. These benefits may, amongst other things, result from:

- a reduction in unserved energy
- a reduction in generation fuel costs
- transmission loss reductions
- capital plant deferrals.

B.1.5 Tasmania

TasNetworks is the TNSP in Tasmania. It is obliged to meet the requirements of its transmission licence, Electricity Supply Industry (Network Performance Requirements) Regulations 2007 (Tas), and the terms of its connection agreements.

The objective of the Electricity Supply Industry (Network Performance Requirements) Regulations 2007 (Tas) is to specify the minimum network performance requirements that a planned power system of a TNSP must meet in order to satisfy the NER. TasNetworks is required by the terms of its licence to plan and procure all transmission augmentations to meet these network performance requirements. TasNetworks publishes an Annual Planning Report, which includes discussion of any forecast supply shortfalls against the Electricity Supply Industry (Network Performance Requirements) Regulations 2007 (Tas), and proposed remedial actions.

The Electricity Supply Industry (Network Performance Requirements) Regulations 2007 (Tas) sets out:

- minimum network performance requirements in respect of electricity transmission services in Tasmania
- the process for exemptions in respect of such requirements
- provisions in respect of Ministerial approval of certain augmentation in respect of such services.

B.1.6 South Australia

The objective of the Electricity Supply Industry (Network Performance Requirements) Regulations 2007 (Tas) is to specify the minimum network performance requirements that a planned power system of a TNSP must meet in order to satisfy the NER. TasNetworks is required by the terms of its licence to plan and procure all transmission augmentations to meet these network performance requirements. TasNetworks publishes an Annual Planning Report, which includes discussion of any forecast supply shortfalls against the Electricity Supply Industry (Network Performance Requirements) Regulations 2007 (Tas), and proposed remedial actions.

As the TNSP in South Australia, ElectraNet is subject to the Electricity Transmission Code administered by the Essential Services Commission of South Australia (ESCOSA). The Code sets specific reliability standards which are determined economically and expressed on a deterministic basis (for example, N, N–1, and N–2) for each transmission exit point.

ESCOSA has commenced a review of the specific reliability standards set out in clause 2 of the Electricity Transmission Code. The final determination, which was published in September 2016, resulted in no material changes to reliability standards and will be reflected in ElectraNet's revenue proposal for the 2018/2023 regulatory control period.[207]

B.2 Distribution network

All jurisdictions have their own monitoring and reporting frameworks for reliability of distribution network service providers (DNSPs). There are two main indicators of distribution network reliability:

- system average interruption frequency index (SAIFI)
- system average interruption duration index (SAIDI).

B.2.1 National

The performance of distribution networks, and the reliability standards that must be met, fall within the responsibility of jurisdictions.

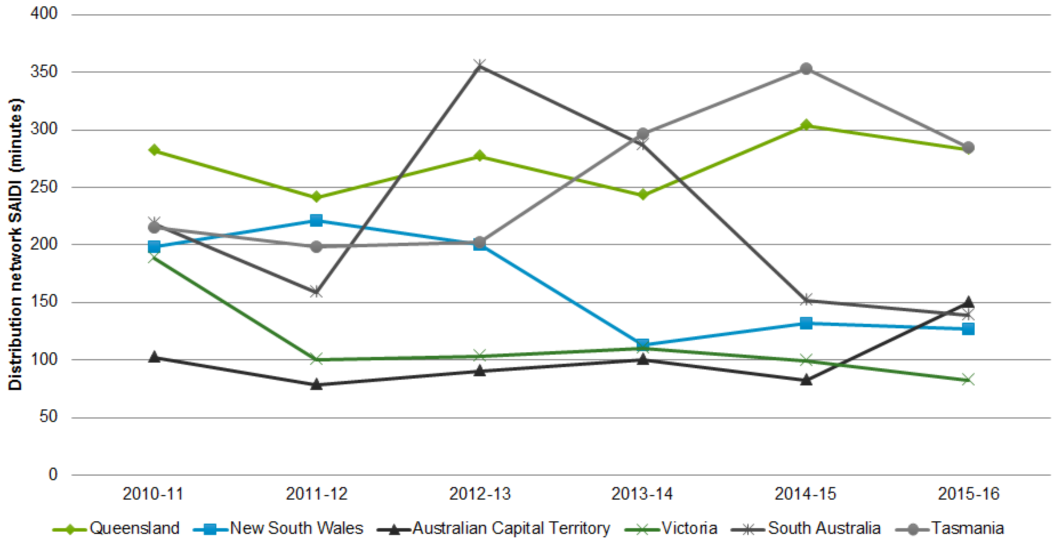
These reliability standards are often measured in terms of the SAIDI. SAIDI is defined as the sum of the duration of each sustained customer interruption, divided by the number of customers. It is calculated for different parts of each distribution network service provider's (DNSP) network. Unplanned SAIDI relates to unplanned outages. These unplanned outages are typically caused by operational error or damage caused by extreme weather and damage by trees. The average SAIDI figure for each NEM jurisdiction over the past five years is shown in Figure B.2.

The Panel notes different exclusion methodologies, variances in customer numbers by feeder and different geographical conditions may apply in each jurisdiction. These averages are therefore to represent a summary only. Additionally, the average SAIDI

207 ESCOSA, *Electricity Transmission Code review: Final decision*, September 2016.

provided is calculated on a different basis and therefore, averages should not be directly compared between jurisdictions.

Figure B.2 Distribution network SAIDIs



Source: Queensland: Queensland Department of Energy and Water Supply; NSW: Independent Pricing and Regulatory Tribunal; ACT: Independent Competition and Regulatory Commission; Victoria: Australian Energy Regulator; South Australia: Essential Services Commission of South Australia; Tasmania: Office of the Tasmanian Economic Regulator.

In 2015/16, with the exception of the ACT, all jurisdictions experienced flat or declining levels of distribution outages. Each jurisdiction's performance is explored in more detail below.

B.2.2 Queensland

The Queensland Electricity Act 1994 and the Electricity Regulation 2006 define the arrangements for the Queensland DNSPs.

Performance standards for Queensland DNSPs were introduced in September 2007. The Queensland Electricity Industry Code requires that the Queensland Competition Authority to review the minimum service standards and guaranteed service level requirements to apply at the beginning of each regulatory period. These service levels were set following a review in early 2009. They have been applied to Ergon Energy and Energex since 1 July 2010.

The DNSPs report quarterly to the Queensland Competition Authority on their performance relative to their targets and on guaranteed service levels. The Queensland Competition Authority then reports this information to the Queensland Department of Energy and Water Supply.

In December 2015, the Queensland Government announced its intention to merge government-owned electricity companies, Ergon Energy and Energex. On 1 July 2016, the parent company Energy Queensland was created. This will affect the reporting of reliability for Queensland distribution networks in financial year 2016/17.

Table B.1 details the performance of Energex and Ergon Energy against the minimum service standards set for 2015/16. It shows that Energex and Ergon met most of their SAIDI and SAIFI targets for the different feeder categories during 2015/16.

Table B.1 Performance of Queensland DNSPs in 2015/16

DNSP	Feeder level	SAIDI		SAIFI	
		Target	Average	Target	Average
Energex	CBD	15	4.68	0.15	0.032
	Urban	106	76.67	1.26	0.74
	Short-rural	218	180.89	2.46	1.56
Ergon	CBD	149	127.70	1.98	1.27
	Short-rural	424	349.59	3.95	3.02
	Long-rural	964	954.72	7.40	6.77
Average	-	-	282	-	-

Source: Queensland Department of Energy and Water Supply.

B.2.3 New South Wales

The Electricity Supply Act 1995 requires the NSW DNSPs to be licenced. Network performance standards for the NSW DNSPs have been set by the Minister for Energy through licencing conditions.[208]

The performance of the NSW DNSPs against the performance standards is monitored by IPART by various means including:

- periodic self-exception reporting
- compliance audits
- Energy and Water Ombudsman complaints
- industry complaints
- media reporting.

DNSPs in NSW are required by the Electricity Supply (Safety and Network Management) Regulation 2008 to publish annual reports on network performance against their Network Management Plans. IPART also produces a licence compliance report, which from 2007 includes compliance with the reliability standards.

Table B.2 shows a summary of the performance of the NSW DNSPs overall and by feeder classification. All NSW DNSPs met their respective SAIDI and SAIFI targets in 2015/16.[209]

208 These conditions were set in 2007 and are published on the Independent Pricing and Regulatory Tribunal's (IPART's) website, https://www.ipart.nsw.gov.au/Home/Industries/Energy/Energy-Networks-Safety-Reliability-and-Compliance/Electricity-networks

209 More detailed performance information is available from network performance reports published on each of the DNSPs websites

Table B.2 Performance of New South Wales DNSPs in 2015/16

DNSP	Feeder level	SAIDI		SAIFI	
		Target	Actual	Target	Actual
Essential Energy	Urban	125	66	1.8	0.75
	Short-rural	300	204	3	1.83
	Long-rural	700	458	4.5	2.91
	All	-	214	-	1.77
Ausgrid	CBD	45	9.4	0.3	0.02
	Urban	80	65.4	1.2	0.62
	Short-rural	300	131.7	3.2	1.15
	Long-rural	700	590.4	6	3.19
	All	-	76.0	-	0.7
Endeavour Energy	Urban	80	67.6	1.2	0.75
	Short-rural	300	211.7	2.8	1.67
	Long-rural	n/a	167.4	n/a	2.32
	All	-	90.9	-	0.98
Average	-	-	127.0	-	

Source: Independent Pricing and Regulatory Tribunal.

B.2.4 Australian Capital Territory

The Utilities Act (2000) underpins all codes and performance and compliance requirements for DNSPs operating in the ACT.

The Independent Competition and Regulatory Commission sets the performance standards for DNSPs operating in the ACT. These standards are available in the Electricity Distribution Supply Standards Code and in the Consumer Protection Code, which also has minimum service standards.

Table B.3 shows a summary of the performance of ActewAGL Distribution, the DNSP in the ACT, against the performance targets pertaining to each feeder classification for 2015/16.

It shows that while ActewAGL met its SAIFI target, it exceeded its SAIDI and customer average interruption duration index (CAIDI) targets.[210]

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210 More detailed performance information is available from network performance reports published on ActewAGL's website, http://www.actewagl.com.au/Networks.aspx

Table B.3 Performance of ActewAGL for 2015/16

Feeder level		SAIDI		SAIFI		CAIDI	
		Target	Actual	Target	Actual	Target	Actual
Urban	Overall	n/a	62.3	n/a	0.65	n/a	95.3
	Distribution network – planned	n/a	34.3	n/a	0.18	n/a	194.5
	Distribution network – unplanned	n/a	28.0	n/a	0.48	n/a	58.6
Rural-short	Overall	n/a	311	n/a	0.58	n/a	537.7
	Distribution network – planned	n/a	276.7	n/a	0.40	n/a	688.2
	Distribution network – unplanned	n/a	43.3	n/a	0.18	n/a	194.5
Network	Overall	91	149.8	1.2	0.86	74.6	174.8
	Distribution network – planned	n/a	133.8	n/a	0.25	n/a	454.6
	Distribution network – unplanned	n/a	36.0	n/a	0.61	n/a	59.4

B.2.5 Victoria

The Electricity Industry Act 2000 and the Essential Services Commission Act 2001 contain the network performance requirements for the Victorian DNSPs.

From 1 January 2009, responsibility for the compliance monitoring and enforcement of the DNSPs' distribution licence conditions was transferred to the AER from the Essential Services Commission of Victoria.

As part of its 2010 distribution regulatory determination, the AER sets SAIDI and SAIFI targets for the Victorian DNSPs for the 2011–15 regulatory period.[211] These targets are developed for the purpose of applying the AER's service target performance incentive scheme to the DNSPs. Under the service target performance incentive scheme, the AER annually reviews the service performance outcomes and determines the resulting financial penalty or reward based on a DNSPs performance against the targets established at the time of a distribution determination.

Table B.4 shows a summary of the performance of the Victorian DNSPs including an overall target for each DNSP and the actual performance by feeder classification. AusNet Services, Jemena and Powercor met most of their performance targets, whereas CitiPower and United Energy did not meet most of their targets for 2015/16.

Table B.4 Performance of Victorian DNSPs for 2015/16

DNSP	Feeder level	SAIDI		SAIFI	
		Target	Actual	Target	Actual
Jemena	Urban	55.94	46.10	0.96	0.763
	Short-rural	93.52	63.88	1.28	0.97
	Whole network	-	46.95	-	0.77
CitiPower	CBD	11.27	14.43	0.186	0.286
	Urban	22.36	29.02	0.45	0.413
	Whole network	-	26.38	-	0.3904
Powercor	Urban	82.47	60.58	1.263	0.79
	Short-rural	114.81	99.49	1.565	1.15
	Long-rural	233.76	285.31	2.54	2.47
	Whole network	-	134.4	-	1.38
AusNet Services	Urban	101.80	62.5	1.448	0.94
	Short-rural	208.54	165.13	2.632	2.14
	Long-rural	256.58	231.8	3.378	2.45

211 The AER released its distribution revenue and service determination for the 2016-20 period in May 2016.

DNSP	Feeder level	SAIDI		SAIFI	
		Target	Actual	Target	Actual
	Whole network	-	13.76	-	1.73
United Energy	Urban	55.09	60.07	0.899	0.846
	Short-rural	99.15	126.49	1.742	1.503
	Whole network	-	66.3	-	0.91
Average			82.16		1.04

B.2.6 Tasmania

The network performance requirements for electricity distribution in Tasmania are prescribed in the Tasmanian Electricity Code (TEC).

On 1 January 2008, the Office of the Tasmanian Economic Regulator amended the TEC to incorporate new distribution network supply reliability standards, which were developed jointly by the Office of the Tasmanian Energy Regulator, the Tasmanian Office of Energy Planning and Conservation, and TasNetworks (previously Aurora Energy). These are designed to align the reliability standards more closely to the needs of the communities served by the network.

The distribution network supply reliability standards have two parts:

- minimum network performance requirements specified in the TEC for each of five community categories: Critical Infrastructure, High Density Commercial, Urban and Regional Centres, Higher Density Rural and Lower Density Rural
- a guaranteed service level supported by the TEC and relevant guidelines.

Table B.5 shows a summary of the performance of TasNetworks' distribution network for 2015/16, against the performance targets pertaining to each community category. In 2015/16, the high density commercial category was the only category where performance was within both the frequency and duration limits. All other outage duration limits were exceeded. All of the outage frequency limits were met with the exception of the critical infrastructure target.

Table B.5 Performance of TasNetworks (distribution) for 2015/16

Community category	SAIDI		SAIFI	
	Target[212]	Actual	Target	Actual
Critical infrastructure	30	33.9	0.2	0.25

212 These targets are set as 12 month limits in the Tasmanian Electricity Code.

Community category	SAIDI		SAIFI	
	Target[212]	Actual	Target	Actual
High density commercial	60	23.1	1	0.26
Urban	120	140.9	2	1.24
High density rural	480	501.7	4	3.12
Low density rural	600	722.3	6	3.87

B.2.7 South Australia

The Essential Services Commission of South Australia (ESCOSA) continues to be responsible for setting elements of the service standard framework. For example, ESCOSA remains responsible for setting the South Australian jurisdictional service standards applying to SA Power Networks and guaranteed service levels.

ESCOSA has established annual standards for frequency and duration interruptions for seven geographic regions within SA Power Network's distribution network. These are specified by ESCOSA as 'best endeavour' annual targets in the Electricity Distribution Code. SA Power Networks must comply with the service standards set out in Chapter 1 of the Code.

In October 2014, ESCOSA released its final decision on the jurisdictional service standards and Guaranteed Service Level scheme to apply to SA Power Networks for the 2015-2020 regulatory period. The final decision consisted of:

- Network reliability and service standards: to be set for the frequency and duration of unplanned interruptions to reflect the average historical reliability levels at four levels of distribution feeders. These reliability targets had traditionally been set for geographical regions.
- Guaranteed Service Level scheme:[213] the state-based scheme will continue and will include an additional tier for outages greater than 48 hours. The payment levels were adjusted to reflect the change in consumer price index since they were first set.

Table B.6 shows a summary of the performance of SA Power Networks Distribution for 2015/16 against the performance targets pertaining to each feeder classifications. SA Power Networks met all of its performance targets in 2015/16.

213 The Guaranteed Service Level scheme relates to the experience of individual customers. Payments are automatically made to customers who receive service that does not meet threshold levels. The relevant services include timeliness of appointments and frequency and duration of supply interruption. More information on the current scheme is available at http://www.escosa.sa.gov.au/projects-and-publications/projects/electricity/sa-power-networks-service

Table B.6 Performance of SA Power Networks for 2015/16

Feeder level	SAIDI		SAIFI	
	Target	Actual	Target	Actual
CBD	15	2.3	0.15	0.02
Urban	120	97.9	1.3	1.04
Short-rural	220	174.8	1.85	1.48
Long-rural	300	289.4	1.95	1.7
Total	165	1139	1.5	1.2

C Reliability assessment

This appendix provides details on the information sources used to assess reliability in the NEM.

C.1 Reserve projections and demand forecasts

Market information is provided in a number of formats and time frames ranging from long-term projections (more than 10 years) that are published annually, through to the detailed five and thirty minute pre-dispatch price and demand projections. The information provided over a shorter timeframe is discussed in appendix D. The long-term information is published across a range of tailored reports, including:

- the national electricity forecasting report (NEFR)
- the electricity statement of opportunities (ESOO)
- the national transmission network development plan (NTNDP)
- the energy adequacy assessment projection (EAAP)
- ongoing market notices.

These documents together inform market participants on the state of the market and its potential evolution over the short and longer terms. This information can assist both existing and intending participants when identifying opportunities in the market. The following sections describe these information sources in more detail.

C.2 Planning information

C.2.1 National electricity forecasting report

AEMO publishes the NEFR each June which provides AEMO's independent electricity consumption, maximum/minimum demand, and probability of exceedance (POE) forecasts for each of the five NEM regions (the ACT is included within NSW). The report presents twenty year forecasts at an annual resolution and across high, medium, and low growth scenarios.

AEMO also publishes updates to the NEFR forecasts where new information becomes available that may significantly alter forecasts, such as the withdrawal of a large generator. AEMO uses the NEFR forecasts as inputs into its other electricity planning publications identified in this section of this report.

In addition to the NEFR, AEMO also publishes:

- NEFR Action Plan Implementation Plans, which outline how the activities proposed in the previous NEFR Action Plan Implementation report were implemented in the most recent NEFR. It also identifies actions requiring further investigation for the following NEFR.
- Forecast Accuracy Reports, aimed to report on the accuracy of the consumption and maximum demand forecasts disclosed in the relevant year's NEFR. In each Forecast Accuracy Report, the accuracy of the forecasts is determined by comparing actual values which those forecasted in the previous NEFR and/or

previous NEFR Update. Based on the forecast accuracy results, AEMO then identifies focus areas and improvements which can be made for the following year's NEFR.

C.2.2 Electricity statement of opportunities

The ESOO provides technical and market data and information, to the market. It assesses the adequacy of supply to meet demand over a ten year outlook period, highlighting changes to NEM-wide generation and demand side investment opportunities by analysing the factors which influence these types of investment. The 2016 ESOO is reliant on the forecasts disclosed in the 2016 NEFR.

C.2.3 National transmission network development plan

The NTNDP provides industry stakeholders such as the NSPs, AER, AEMC, and other policy makers with an independent strategic view for the efficient development of the national transmission network over a 20-year planning horizon.

In preparing the NTNDP, AEMO explores a range of scenarios to assess the impact of demand, fuel price, and policy settings on the optimal evolution of the transmission network. To achieve this, AEMO undertakes an annual consultation with stakeholders to establish the scope of the NTNDP, identify material issues for investigation, and seek feedback on the proposed methodology and modelling inputs.

C.3 Energy adequacy assessment projection

AEMO is required to publish the EAAP each quarter. The EAAP provides information and analysis that quantifies the impact of energy constraints on energy availability (including water availability and other fuel supply limitations) over a 24 month period and under a range of scenarios. The energy constraints are based on information provided by scheduled generators and include information regarding planned outages, power transfer capability of the NEM, and demand forecasts that are provided by jurisdictional planning bodies for the purposes of the ESOO.

D Market forecasts

This appendix considers market information on demand and reserve forecasts as published by AEMO in 2015/16 in various reports. The outlook periods for the forecasts range from the next trading day to ten years.

The Panel has previously noted the essential role played by energy and demand forecasts in the market and that these are used by key operational and investment decision makers. Electricity demand and usage forecasts are also important for transparency and to improve awareness in the energy markets. It is therefore critical that demand forecasts are as accurate as possible.

AEMO is required to produce electricity demand and energy forecasts for each NEM region as well as for the NEM as a whole

D.1 National Electricity Forecasting Report

AEMO publishes the NEFR each June which provides AEMO's electricity consumption, maximum/minimum demand, and probability of exceedance (POE) forecasts for each of the five NEM regions (the ACT is included within NSW). The report presents twenty year forecasts at an annual resolution and across high, medium, and low growth scenarios.

AEMO also publishes updates to the NEFR forecasts where new information becomes available that may significantly alter forecasts, such as the withdrawal of a large generator. AEMO uses the NEFR forecasts as inputs into its other electricity planning publications identified in this section of this report.

Complimentary to the NEFR, AEMO also publishes:

- NEFR Action Plan Implementation Plans, which outline how the activities proposed in the previous NEFR Action Plan Implementation report were implemented in the most recent NEFR. It also identifies actions requiring further investigation for the following NEFR.
- Forecast Accuracy Reports, aimed to report on the accuracy of the consumption and maximum demand forecasts disclosed in the relevant year's NEFR. In each Forecast Accuracy Report, the accuracy of the forecasts is determined by comparing actual values which those forecasted in the previous NEFR and/or previous NEFR Update. Based on the forecast accuracy results, AEMO then identifies focus areas and improvements which can be made for the following year's NEFR.

D.1.1 National electricity forecasting report 2016

The 2016 NEFR was published in June 2016 providing AEMO's 20 year electricity forecasts for the five NEM regions under high, medium, and low consumption growth scenarios.[214]

214 AEMO, *National Electricity Forecasting Report for the National Electricity Market*, June 2016.

For the first time, the 2016 NEFR reviews trends in and forecasts of overall electricity usage by electricity consumers, as well as operational consumption and maximum and minimum demand from the grid.

A summary of the main findings of the 2016 NEFR are presented below:

- **Households are using more electrical appliances**: Household electric appliance use, and the capacity and functionality (or "benefits") of these appliances, has increased since 2009. This trend is expected to continue in the next 20 years.[215]
- **Consumption of electricity from the gird is expected to remain flat**: Despite increasing reliance on electricity, the amount of electricity consumed from the grid, has declined across the NEM since 2009 as rooftop photovoltaics (PV), energy efficiency, and a range of other factors have offset increased electrical appliance use.[216]
- **New technologies are forecast to reduce energy use**: Mobile and web-connected device use is growing, while use of PCs and stationary home entertainment devices is forecast to decline. Battery storage technology may further offset increases in electricity consumption, by enabling households to use lower cost energy from the sun during the time of evening peak use.[217]
- **The Australian economy has reducing levels of energy-intensive manufacturing**: The main growth sectors for electricity use are forecast to be the services/commercial sector and food and beverage manufacturing, which are expected to grow with population and income. Energy-intensive manufacturing is expected to continue its relative decline. Growth drivers for Australian energy-intensive manufacturing are currently projected to be minimal.[218]

Regional maximum and minimum demand forecasts

Forecasts of maximum annual demand are strongly driven by weather, and occur on different days for each region of the NEM. For this reason, a total maximum demand forecast is not estimated for the NEM – forecasts are shown on a region-by-region level.[219]

Maximum demand is shown for summer and winter. The distinction is made as there are different drivers of the seasonal peaks. Summer maximum demand is influenced strongly by residential air conditioning loads, whereas the winter maximum demand is being driven by an increasing switch of heating sources from gas-fuelled to electric appliances. Figure D.1 shows the forecast 10% POE maximum summer demands.

215 AEMO, *National Electricity Forecasting Report for the National Electricity Market*, June 2016, p.3.

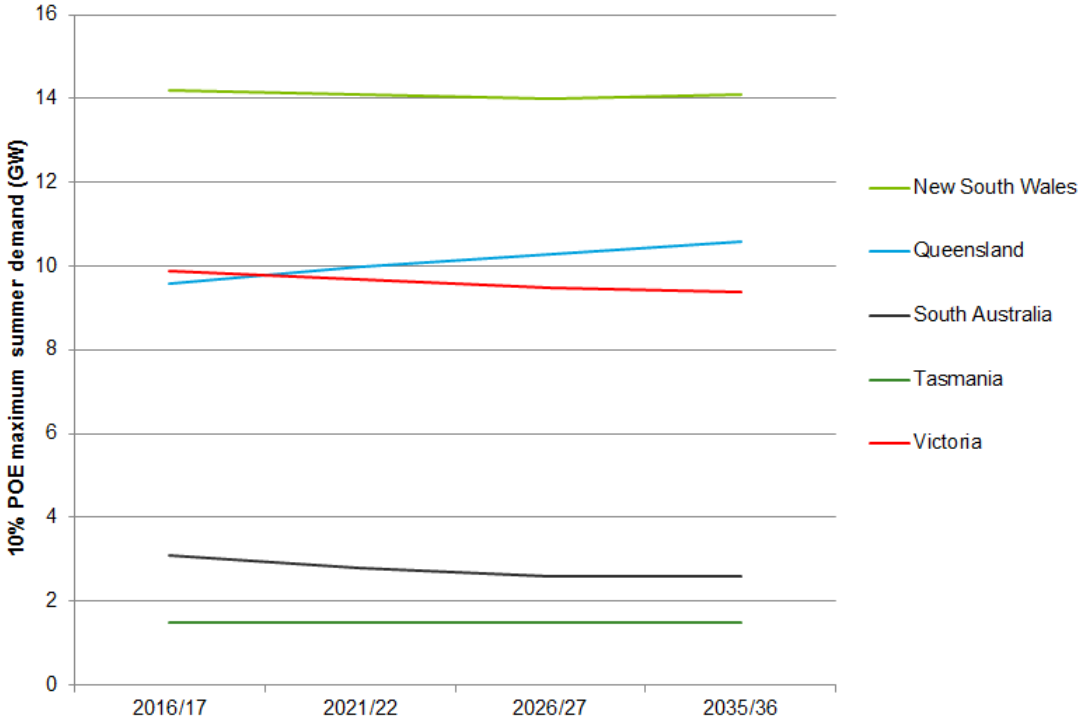
216 Ibid, p.4.

217 Ibid, p.5.

218 Ibid.

219 Ibid, p. 24.

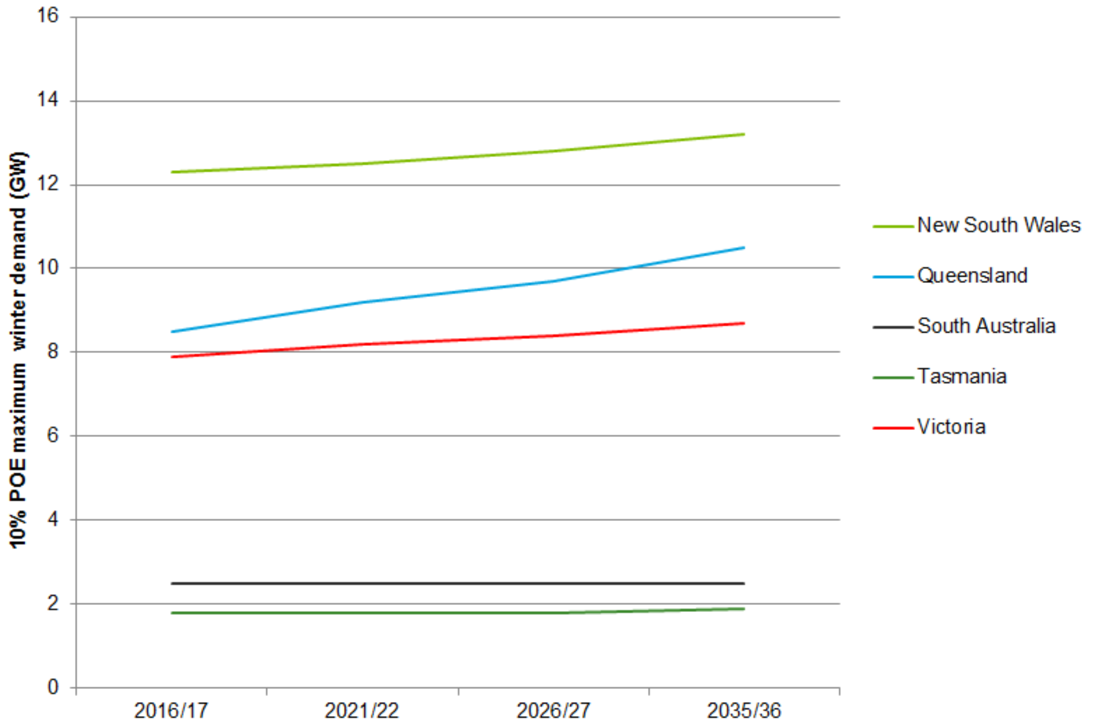
Figure D.1 Forecast maximum summer demand



Source: AEMO, *National Electricity Forecasting Report*, June 2016

Figure D.2 shows the forecast 10% POE maximum summer demands.

Figure D.2 Forecast maximum winter demand



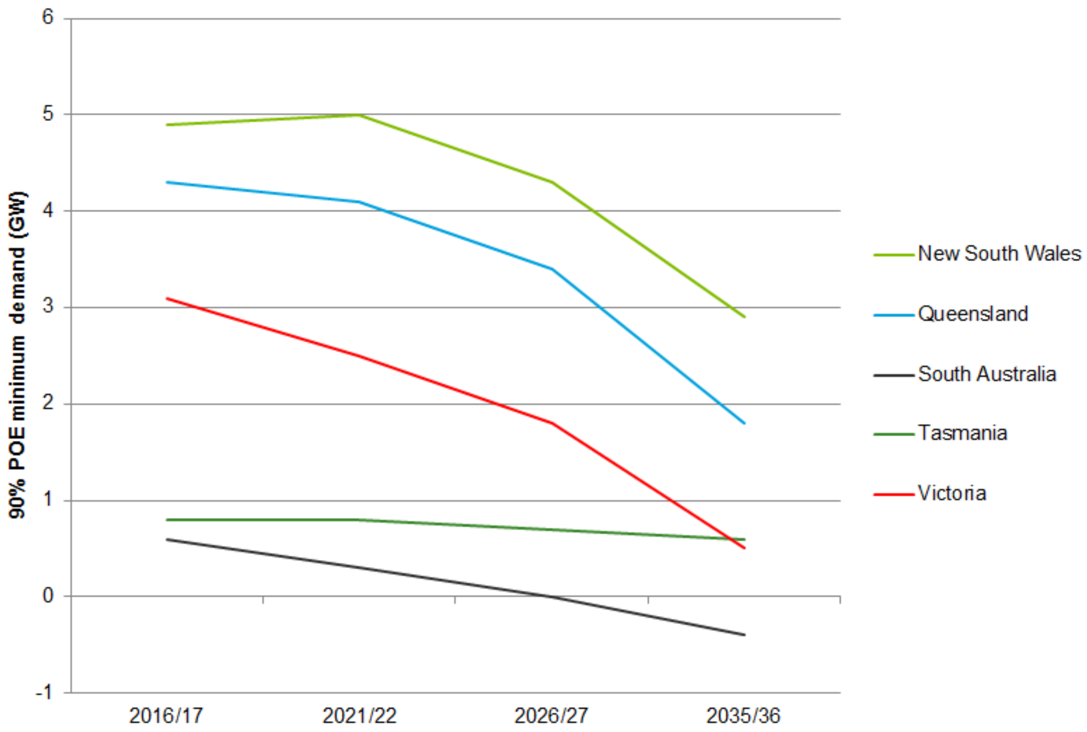
Source: AEMO, *National Electricity Forecasting Report*, June 2016.

With the exception of Queensland (forecast to grow 10% over the 20 year outlook) and South Australia (forecast to decrease by 15% over the 20 year outlook), maximum demand forecasts are generally flat. The key points for forecasts for 10% POE maximum demand are:

- winter maximum is forecast to grow faster than summer demand and by 2030 is expected to reach similar levels. This is being driven by the electrification of heating devices.
- continued growth in PV is forecast to offset some drivers of peak demand. It will continue to push the time of the summer peak demand to later in the day.
- Queensland's maximum demand will continue to grow due to increased LNG operations.
- South Australia's maximum demand is forecast to decline due to continued high levels of growth in rooftop PV. The lower forecast is also due to decreased consumption from the business sector.

Figure D.3 shows the forecast 90% POE minimum demands. A 90% POE forecast is expected to be exceeded in nine out of 10 years.

Figure D.3 Forecast minimum demand



Source: AEMO, *National Electricity Forecasting Report*, June 2016.

Minimum demand is becoming increasingly important for managing the security of the power system. Reducing minimum demand presents challenges to secure operation of the power system.[220] These challenges include frequency control and the impact on generator of negative minimum demand and the associated ramping rates as PV generation falls away.

220 Ibid, p. 26.

Minimum demand in all NEM regions except South Australia currently occurs at night. However, minimum demand in these regions is forecast to follow trends already evident in South Australia:

- minimum demand is projected to shift from overnight to midday
- this minimum demand will then reduce in the middle of the day as PV capacity increases.

The key points for each region are:[221]

- Queensland: despite increases in demand from LNG facilities, increased PV uptake will reduce minimum demand to less than 2GW by 2035/36.
- South Australia: minimum demand is projected to fall below zero by 2026/27. This means that South Australia is projected to exceed all demand with generation from distributed energy resources.
- Victoria: by 2017/18 it is expected that the time of minimum demand will switch from overnight to around midday, when the sun is most overhead. At this point minimum demand is expected to decrease driven by the increasing rooftop PV.
- Tasmania and New South Wales: there are similar drivers of minimum demand in these regions, where a larger fraction of the demand is insensitive to weather. As such, these regions experience lesser declines in minimum demand.

D.1.2 Forecast accuracy report 2016

The purpose of this report is to assess the accuracy of the operational consumption[222] and maximum demand forecasts in the 2015 NEFR. This is achieved by comparing 2015/16 forecasts in the 2015 NEFR with actual results for 2015/16. The 2016 Forecast Accuracy report also discussed changes made to the forecasting methodology which was used in the 2016 NEFR. In particular, the changes made to the econometric model in order to capture recent consumption patterns and to become more sensitive to region-specific trends.

The accuracy of AEMO's forecasts of operational consumption and maximum demand is a function of AEMO's forecast models, which in turn rely on forecast input data, including economic forecasts.

Regional forecast accuracy - operational consumption and maximum demand

The forecast accuracy provides a regional breakdown of various forecasts. The key points for each region are:

- **Queensland**: In Queensland the forecasts of residential and commercial consumption were with 0.2% of actual consumption. However, forecast consumption of the LNG projects was higher than the actual consumption due to a slower ramp-up of LNG project.

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221 Ibid, p. 27.

222 Operational consumption is the electrical energy supplied by scheduled, semi-scheduled, and significant non-scheduled generating units, less the electrical energy supplied by small non-scheduled generation

- **New South Wales**: Large industrial consumption was higher than forecast, due to increased consumption by some major industrial consumers.
- **South Australia**: Large industrial consumption was slightly lower than forecast, due to a fall in consumption by some major industrial consumers. Additionally auxiliary loads were lower than forecast, reflecting a downward trend in auxiliary loads in South Australia as more renewable energy is introduced.
- **Victoria**: Residential and commercial consumption was under forecast by 1%, due to higher than expected heating degree days in winter and cooling degree days in summer. Large industrial consumption was lower than expected, due to lower consumption by some major industrial consumers.
- **Tasmania**: Industry consumption was lower than forecast, due to a fall in consumption by some major industrial consumers. Auxiliary load and transmission losses were significantly over-forecast in Tasmania, most likely due to the Basslink cable being down, as Tasmania is a net exporter of electricity.

The regional variances between forecast operational consumption and actual operation consumption ranged from -1.0% to 4.7%. The forecast and actual operational consumption values are presented in Table D.1

Table D.1 Variance between forecast and actual operational consumption

Region	Forecasted operational consumption (GWh)	Actual operational consumption (GWh)	Variance (GWh)	Variance (%)
New South Wales	70,284	70,999	-715	-1.0%
Queensland	55,731	54,261	1,470	2.7%
South Australia	13,309	13,411	-102	-0.8%
Tasmania	10,547	10,071	476	4.7%
Victoria	47,580	47,104	476	1.0%
NEM	197,451	195,846	1,605	0.82%

Source: AEMO, *Forecasting accuracy report 2016*, November 2016.

The regional variances between forecast 50% POE maximum demand and actual maximum demand ranged from -6.4% to 5.7%. The forecast 50% POE maximum demand and actual maximum demand values are presented in Table D.2.

Table D.2 Variance between forecast 50% POE maximum demand and actual maximum demand

Region	Forecasted 50% POE maximum demand (MW)	Actual maximum demand (MW)	Variance (%)	Actual POE
New South Wales	12,531	13,047	4.0%	0.30
Queensland	9,231	8,672	-6.4%	0.96
South Australia	2,926	2,895	-1.1%	0.55
Victoria	8,517	9,029	5.7%	0.30
Tasmania	1,685	1,660	-1.5%	0.68

Source: AEMO, *Forecasting accuracy report 2016*, November 2016.

D.2 Electricity statement of opportunities

The Electricity Statement of Opportunities (ESOO) provides technical and market data that informs the decision-making processes of market participants, new investors, and jurisdictional bodies as they assess opportunities in the National Electricity Market (NEM) over a 10-year outlook period.[223]

The 2016 NEM ESOO provides a projected outlook to 2025/26 of supply adequacy under a number of scenarios, and this year has modelled further generation withdrawals in response to Australia's 2015 Paris 21st Conference of Parties emission abatement commitment (COP21 commitment).

The key points from the 2016 ESOO include:[224]

- Under a neutral economic and consumer outlook – and in the absence of new generation, network or non-network development – coal-fired generation withdrawals at the levels assumed may lead to USE
- The future risk of load shedding is projected to be greatest between 2.00 pm and 8.00 pm, if high demand coincides with low wind and rooftop PV generation, unplanned generation outages, and/or low levels of imports from neighbouring regions
- The withdrawal of synchronous generation (such as coal and gas-fired generation) is leading to the scarcity of support services in the NEM. These support services include Frequency Control Ancillary Services and System Restart Ancillary Services.

Changes in generation detailed in the ESOO are covered in appendix A.

223 AEMO, *Electricity statement of opportunities*, August 2016.

224 Ibid, pp. 3-4.

D.3 National transmission network development plan

AEMO published the 2016 National Transmission Network Development Plan (NTNDP) in December 2016. The purpose of the NTNDP is to facilitate the efficient development of the national transmission grid. It does this by providing a strategic view of the efficient development of the grid over a 20-year planning horizon. The 2016 NTNDP provides an assessment of balancing reliability, security, and cost considerations while meeting emissions reduction targets.

The key points from the 2016 NTNDP are:[225]

- the NEM is moving into a new era for transmission planning:
  - transmission networks designed for transporting energy from coal generation centres will need to transform to support large-scale generation development in new areas.
  - transmission networks will increasingly be needed for system support services, such as frequency and voltage support, to maintain a reliable and secure supply.
- high level modelling suggests positive net benefits for potential interconnection developments, if they are competitively priced. These interconnection developments include:
  - a new interconnector linking South Australia with either New South Wales or Victoria from 2021
  - augmenting existing interconnection linking New South Wales with both Queensland and Victoria in the mid to late 2020s
  - a second Bass Strait interconnector from 2025, when combined with augmented interconnector capacity linking New South Wales identified above, although the benefits are only marginally greater than the costs.
- co-ordination and contestability can maximise the benefits of transmission investments across the NEM:
  - modelling shows greater total net benefits when these developments are combined, creating a more interconnected NEM. These benefits are projected to increase as the energy transformation accelerates
  - geographic and technological diversity smooths the impact of intermittency and reduces reliance on gas-powered generation. Greater interconnection facilitates this diversity and delivers fuel cost savings to consumers
  - contestability in transmission should make development more competitively priced, reducing costs for consumers
- interconnection does not necessarily solve all challenges – local network and non-network options are also needed to maintain a reliable and secure supply:
  - synchronous condensers, or similar technologies, will be required to provide local system strength and resilience to frequency changes

225 AEMO, *National transmission network development plan*, December 2016.

— AEMO modelling suggests benefits from augmenting transmission in western Victoria to accommodate over 4 GW of projected new renewable generation capacity.

D.4 Energy adequacy assessment projection

AEMO is required to publish the energy adequacy assessment projection (EAAP) each quarter.[226] The EAAP provides information and analysis that quantifies the impact of energy constraints on energy availability (including water availability and other fuel supply limitations) over a 24 month period and under a range of scenarios. The energy constraints are based on information provided by scheduled generators and include information regarding planned outages, power transfer capability of the NEM, and demand forecasts that are provided by jurisdictional planning bodies for the purposes of the ESOO.

D.5 MTPASA

Medium-term projected assessment of system adequacy (MT-PASA) assesses the adequacy of supply to meet demand at the time of anticipated daily maximum demand, based on a 10-year POE for each day over the next two years. AEMO publishes the MT-PASA for each NEM region weekly.

D.6 STPASA and pre-dispatch load forecasting

In addition to MT-PASA reports, AEMO also publishes short-term projected assessment of system adequacy (ST-PASA) reports. As compared to the MT-PASA, which makes projections over a two-year period, the ST-PASA makes projections for the following seven-day period on a half-hourly basis.

Pre-dispatch provides an aggregate supply and demand balance comparison for each half-hour of the next trading day. This information is provided to the relevant participants to assist with their operations management.

Both ST-PASA and pre-dispatch use the same load forecasting model. With this model, AEMO produces 10%, 50% and 90% POE forecasts for all timeframes. The 50% POE forecast is used to set generation targets in pre-dispatch. The 50% and 10% POE forecasts are used in the ST-PASA process to calculate reserve levels.[227]

The key inputs into the demand forecasting system include:[228]

1. historical actual metered loads (actual load data from January 2010)
2. real-time actual metered loads (supervisory control and data acquisition (SCADA) data from immediately preceding intervals)
3. historical and forecast weather data (temperature and humidity)

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226 The EAAP reports are available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Energy-Adequacy-Assessment-Projection

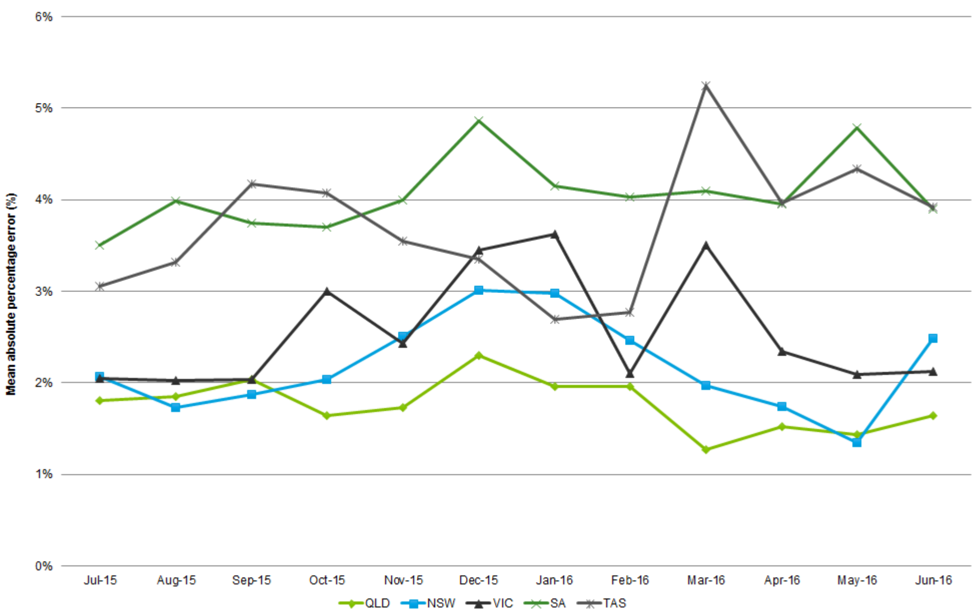
227 AEMO, *Power system operating procedure - load forecasting*, June 2014.

228 Ibid, p. 8.

4. non-scheduled wind generation forecasts
5. non-scheduled solar generation forecasts
6. type of day, school holidays, public holidays and daylight savings information
7. mandatory restrictions (MR)/RERT schedules.

Figure D.4 shows the mean absolute percentage error for load forecasting 12 hours ahead.

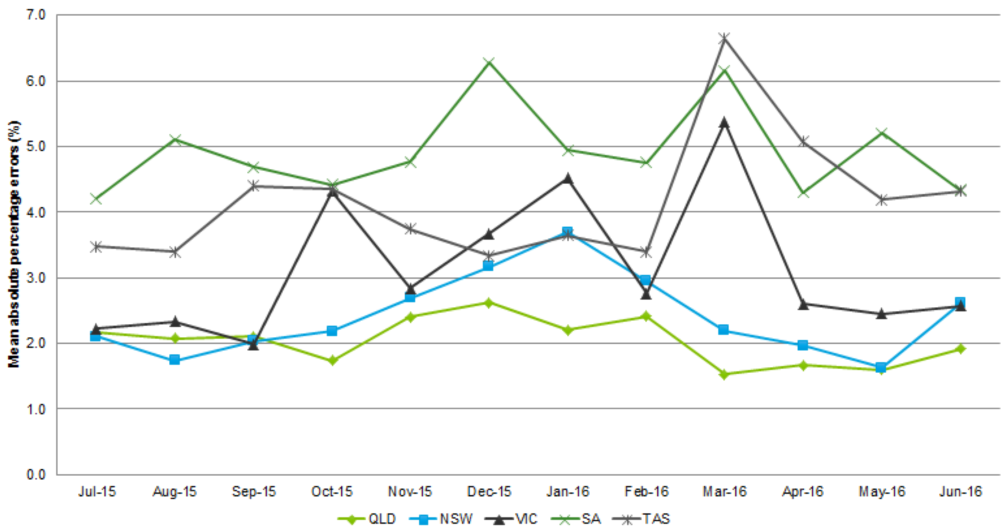
Figure D.4 Load forecasting error - 12 hours ahead



Source: AEMO

Figure D.5 shows the mean absolute percentage error for load forecasting 12 hours ahead.

Figure D.5 Load forecasting error - two day ahead



Source: AEMO

In regards to load forecasting in 2015/16, the Panel notes that:

- Load forecasts were generally more accurate in winter months.
- Tasmania experienced an increase in load forecasting error without Basslink in service.
- South Australian load was typically forecast with the least accuracy, whereas New South Wales load was the most predictable.
- As expected, the 12 hour ahead load forecasts were generally more accurate than the two day ahead forecasts.

D.7 Trading intervals affected by price variation

The Panel has considered the number of trading intervals affected by significant variations between pre-dispatch and actual prices during 2015/16 as well as likely reasons for the variations.[229] The data that the Panel has considered is disclosed in Table D.3.

Table D.3 Number of trading intervals affected by price variation

Price variation reason	Queensland		New South Wales		Victoria		South Australia		Tasmania	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Demand	3,517	51.8	2,848	52.0	3,909	55.0	4,750	51.6	1,089	11.9
Availability	1,955	28.8	1,505	27.5	2,072	29.2	3,009	32.7	8,040	88.0
Combination[230]	1,319	19.4	1,127	20.6	1,118	15.7	1,429	15.5	0	0.0
Network	0	0.0	2	0.0	6	0.1	16	0.2	3	0.0
Total	6,791	100	5,482	100	7,105	100	9,204	100	9,132	100
Trading intervals affected	5,264	30.0	4,265	24.3	5,805	33.0	7,268	41.4	8,788	50.0

Source: AER.

229 Significant price variations are defined in clause 3.13.7(a) of the NER. Under this clause, the AER must determine whether there is a significant variation between the spot price forecast and actual spot price. The AER must then review the reasons for the variation. The AER does this in each of its electricity weekly reports.

230 This could be the combination of changes in plant availability and changes in demand.

A comparison of the regions shows that Tasmania reported the highest number of significant price variations in 2015/16 with most of these variations caused by plant availability. Contrarily, in all other regions changes in demand was the cause of the majority of price variations.

The Panel notes that the number of trading intervals affected has significantly increased in all regions from 2013/14.

D.8 Reliability safety net

AEMO has the power to contract for the provision of reserves through the reliability and emergency reserve trader (RERT) to maintain power system security and reliability.

The RERT allows AEMO to contract for reserves up to 10 weeks[231] ahead of a period where reserves are projected to be insufficient to meet the reliability standard. During 2015/16, AEMO did not exercise the RERT or contract for any reserves.

231 This period was nine months prior to a rule change by the AEMC. More information on the rule change is available in appendix J.

E Intermittent generation forecast assessment

This appendix summarises the forecasting of intermittent generation, both through the performance of AEMO to forecast wind energy and the projections of levels of uptake of rooftop PV and integrated PV and storage systems.

E.1 Wind forecasts

The Australian wind energy forecasting system was implemented by AEMO in a two stage process. 'Phase 1' of the project was implemented internally in 2008 and then 'Phase 2' was completed in June 2010. The development of the system was funded by the then Commonwealth Department of Resources, Energy and Tourism involving a 'world first 'integrated system designed specifically for the NEM by a European consortium.[232]

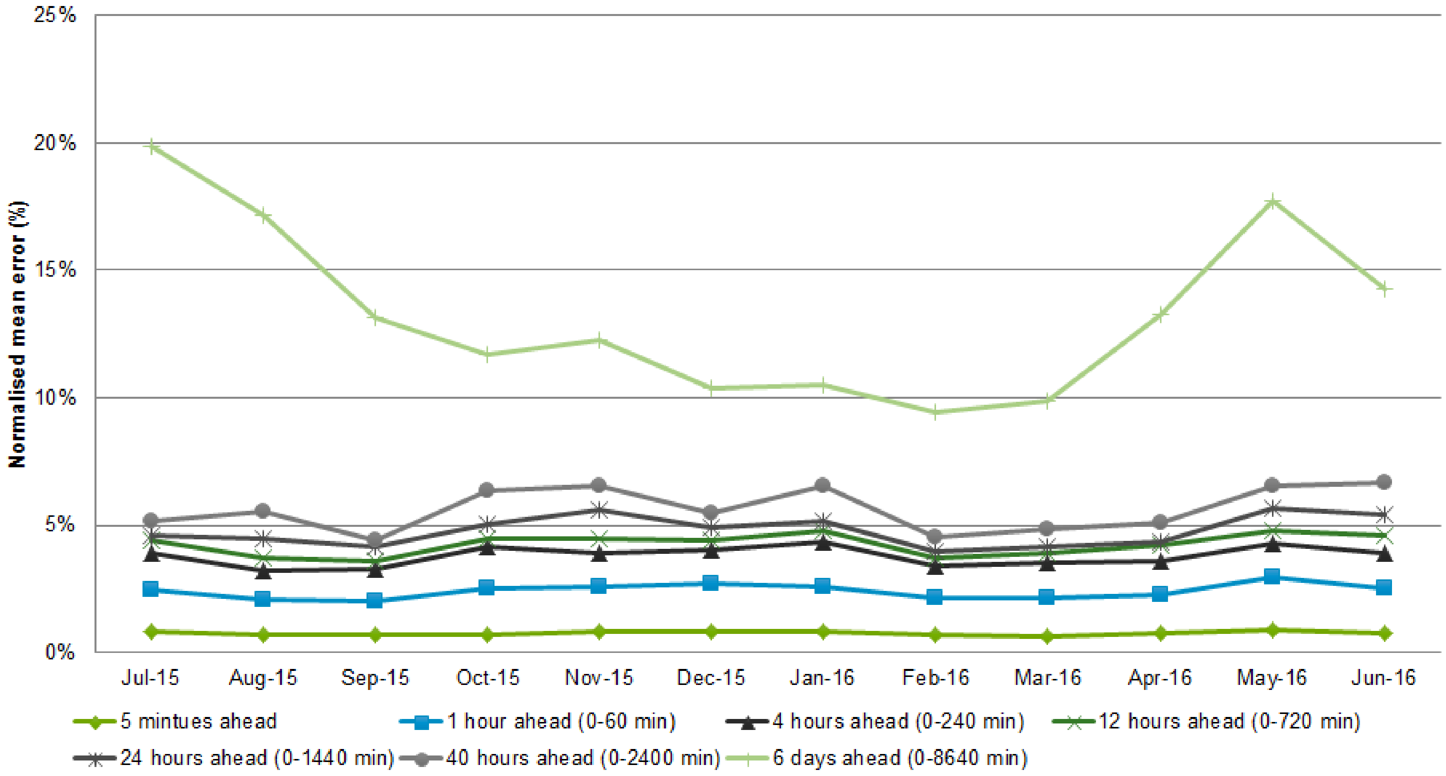
The Australian wind energy forecasting system was developed by AEMO to fulfil its obligation under clause 3.7B of the NER, to prepare forecasts of the available capacity of semi-scheduled generators. It involves statistical, physical and combination models to provide wind generation forecasts using a range of inputs including historical information, standing data (wind farm details), weather forecasts, real time measurements and turbine availability information.

As set out in previous sections, the Panel recognises that wind generation capacity in the NEM is expected to continue to grow under Australia's LRET. On this basis, the Australian wind energy forecasting system will continue to be an important tool for promoting efficiencies in NEM dispatch, pricing, network stability and security management.

The Panel has considered the performance of Australian wind energy forecasting system based on the average percentage error across all regions in the NEM. The performance for 2015/16 is depicted in Figure E.1. As could be expected, the accuracy of the forecasts deteriorates as the forecast horizon increases. The highest normalised absolute error values correspond to situations when forecasting is difficult, for example, when there is high or low wind speed.

232 AEMO, Australian Energy Forecasting System (AWEFS), September 2014.

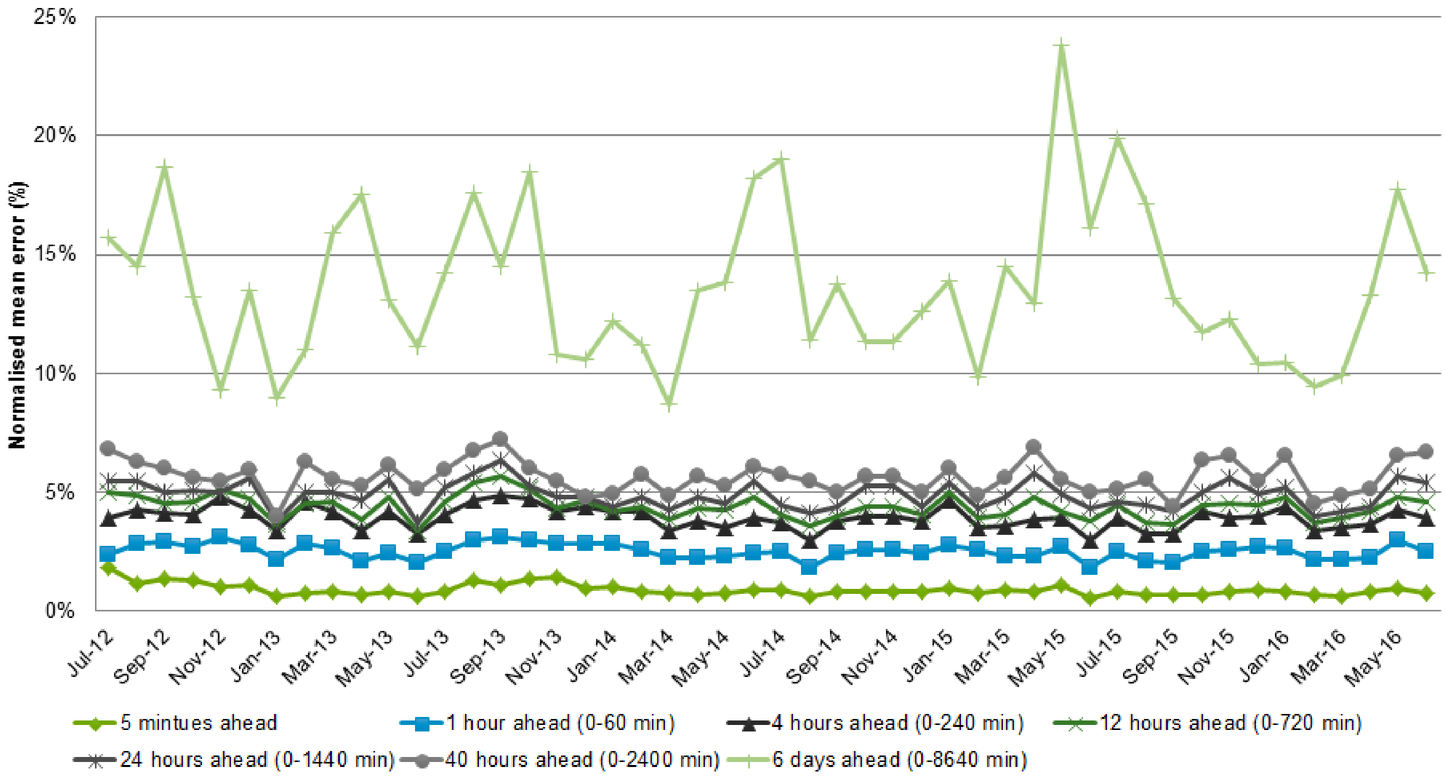
Figure E.1 Australian wind energy forecasts for 2015/16



Source: AEMO

Figure E.2 shows the performance of the system from 2012/13 to 2015/16. It shows that the forecast error of Australian wind energy forecasting system has been relatively steady and increases in the amount of wind generation appears to have not significantly affect forecast performance.

Figure E.2 Australian wind energy forecasts from 2012 to 2016



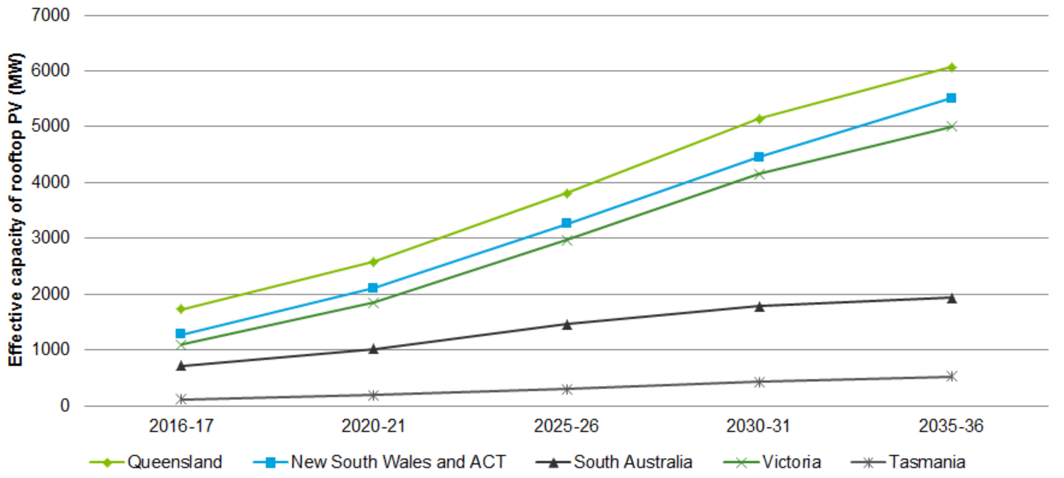
Source: AEMO

E.2 Rooftop PV and integrated system uptake forecasts

In response to the rapid expansion of solar generating capacity in the NEM, AEMO has produced forecasts of residential and commercial solar PV capacity. Additionally, AEMO has forecast the uptake of integrated systems consisting of rooftop PV and storage systems.

Figure E.3 shows the AEMO forecasts of projected uptake of rooftop PV. AEMO is forecasting consistent uptake in all NEM regions and the total installed capacity of rooftop PV in 2035/36 is projected to be over 19GW.

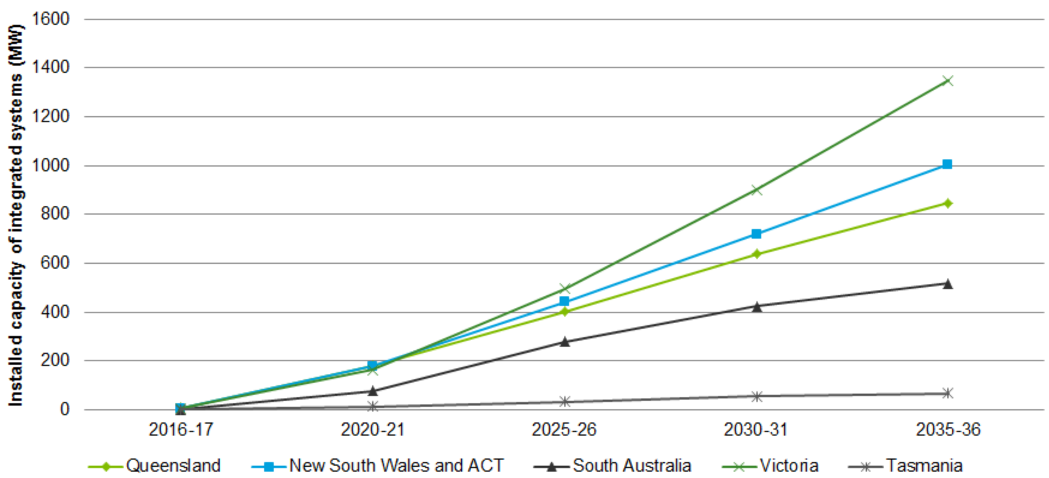
Figure E.3 Installed rooftop PV capacity forecasts



Source: AEMO, *National Electricity Forecasting Report*, June 2016.

Figure E.4 shows the AEMO forecasts of projected uptake of integrated PV and storage systems (IPSS). AEMO is forecasting the rates of uptake to vary between NEM regions, with Victoria forecast to experience the fastest rates of uptake.[233] The total installed capacity of IPSS in 2035/36 is projected to be 3.8GW.

Figure E.4 Integrated PV and storage systems capacity forecast



Source: AEMO, *National Electricity Forecasting Report*, June 2016.

E.2.1 Drivers of forecast rooftop PV and IPSS capacity changes by region

The following summarises the drivers for uptake of PV and IPSS in each region:[234]

233 The model used by AEMO for forecast the uptake of IPSS does not consider the retrofitting of storage to existing PV systems. As a result, regions with current higher penetrations of PV systems experience decreased uptake of IPSS as the number of potential sites is diminished.

234 AEMO, *National Electricity Forecasting Report*, June 2016.

- **Queensland** - The strong growth of rooftop PV and IPSS uptake in the commercial sector is projected to offset a forecast decline of residential installations. Queensland is projected to have the highest total projected capacity of systems at the end of the forecast period.
- **New South Wales and ACT** - steady adoption of rooftop PV systems is forecast in both residential and commercial segments, with IPSS representing almost 25% of annual rooftop PV installations after 2020.
- **South Australia** - The uptake of residential rooftop PV systems in is forecast to decline as saturation is reached in some regions, with the commercial sector forecast to have steady growth.
- **Victoria** - Steady adoption of rooftop PV systems is forecast to continue until 2033, when saturation is expected to be reached in some regions. The assumed faster transition to a time-of-use tariff structure in Victoria contributes to forecast rapid penetration of PV systems with battery storage.
- **Tasmania** - growth of rooftop PV installations in both the residential and commercial segments is forecast to be slowest among NEM regions, due to lower levels of sunshine reducing the financial attractiveness of the systems.

F Weather summary

F.1 Seasonal weather summary

F.1.1 Winter 2015

Winter in 2015 was a relatively warm winter for the majority of Australia, with the exception being the southeast where it was colder than average. The rainfall for winter 2015 was 16% below the long term average for the country as a whole.

F.1.2 Spring 2015

Spring of 2015 was an exceptionally warm spring. National mean temperatures were the second warmest on record and both the maximum and minimum temperatures recorded were substantially above average.

It was also a relatively dry spring with rainfall 29% below the long-term mean for Australia as a whole.

F.1.3 Summer 2015/16

Summer of 2015/16 had the sixth warmest national mean temperature and maximum temperatures were substantially above average for southeast Australia and much of the tropical coast.

There were periods of extended hot weather in southeast Australia in December. From 16 to 19 December, the temperature in Adelaide exceeded 40°C. The heatwave peaked on 19 December where Port Augusta reached 47.2°C.

Rainfall was close to average for the majority of the country; however, exceptional rainfall was witnessed in Tasmania in January. Launceston received 86mm of rain in the 24 hours to 9am on 29 January.

F.1.4 Autumn 2016

Autumn 2016 was Australia's warmest Autumn on record. Temperatures for much of eastern and northern Australia were the highest on record. Rainfall across the country was close to average but there was significant regional variation.

F.2 Notable periods during 2015/16

Table F.1 shows the highest and lowest temperatures recorded in the capital of each state in the NEM.

Table F.1 Extreme temperatures (°C)

	Lowest temperature		Highest temperature	
City	**Temperature**	**Date**	**Temperature**	**Date**
Brisbane (CBD)	5.4	15 July 2015	36.2	2 February 2016
Sydney	5.0	5 August 2015	40.9	20 November

	Lowest temperature		Highest temperature	
City	Temperature	Date	Temperature	Date
(Observatory Hill)				2015
Canberra (airport)	-7.0	3 July 2015	39.3	13 January 2016
Adelaide (Kent Town)	1.8	20 July 2015	43.2	19 December 2016
Melbourne (Olympic Park)	0.6	19 July 2015	42.4	13 January 2016
Hobart (Elleslie Road)	0.3	8 July 2015	36.0	25 December 2015

G Security performance

This appendix provides a detailed analysis of the power system's security management, and the measurement of the power system's security performance. The complete review of the power system's security performance is discussed in chapter 5.

G.1 Security management

Maintaining the security of the power system is one of AEMO's key obligations. The power system is deemed to be in a secure operating state when it is in a satisfactory operating state and will return to a satisfactory operating state following the occurrence of any single credible contingency event.

A satisfactory operating state is achieved when:

- the frequency is within the normal operating frequency band
- voltages at all energised busbars at any switchyard or substation are within relevant limits
- the current flows on all transmission lines of the power system are within the ratings
- all other plant forming part of or impacting on the power system is operating within its rating
- the configuration is such that the severity of any potential fault is within the capability of circuit breakers to disconnect the faulted circuit or equipment.

A secure or satisfactory operating state depends on the combined effect of controllable plant, ancillary services, and the underlying technical characteristics of the power system plant and equipment.

AEMO determines the total technical requirements for all services needed to meet the different aspects of security from:

- the Panel's power system security and reliability standards
- market rules obligations and knowledge of equipment performance as supplied by the TNSPs
- design characteristics and modelling of the dynamic behaviour of the power system.

This allows AEMO to determine the safe operating limits of the power system and associated ancillary service requirements.

AEMO uses constraints provided by TNSPs in the NEM dispatch process to ensure that plant remains within rating and power transfers remain within stability limits so that the power system is in a secure operating state.[235] In the event that AEMO is not able to manage the secure and satisfactory limits, AEMO can exercise a number of options. These options are listed in AEMO's suggested priority order and may not all be available under all circumstances:

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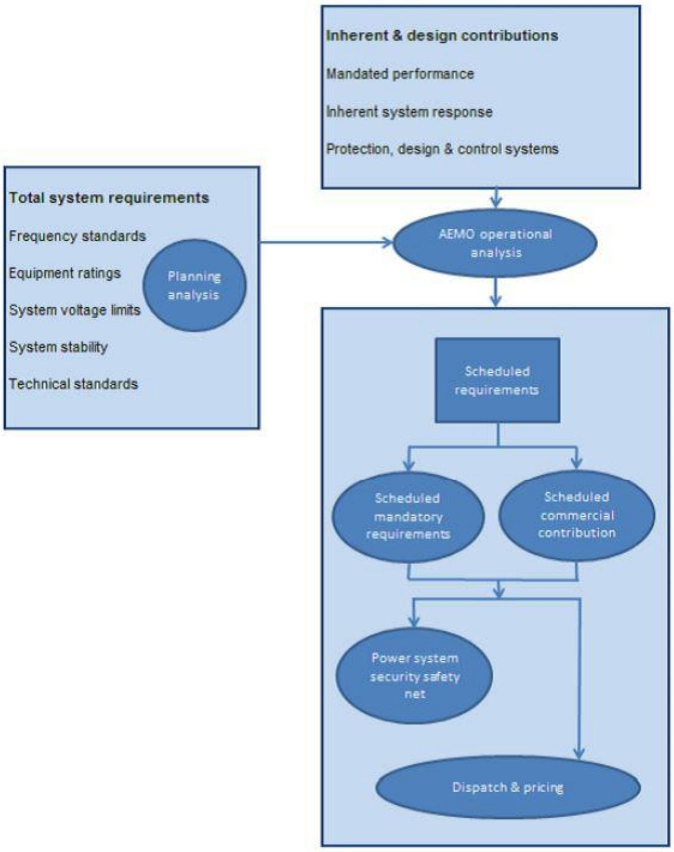
235 AEMO, *Power system security guidelines*, February 2017.

- revising plant thermal limits
- revising power system limits
- implement a plan such as a contingency plan or network support agreement
- reconfigure the network
- dispatch or activation of reserve contracts to address a power system security event
- if insufficient FCAS is available, issue a direction or instruction for a reduction in the size of the generation or load at risk
- instruct involuntary load shedding

Figure G.1 illustrates the overall arrangements for system security.

Figure G.1 System security model



Source: AEMO.

G.1.1 Power system stability

Transferring large amounts of electricity between generators and consumers over long distances can potentially compromise the stability of the power system. As system operator of the NEM, one of AEMO's obligations is to ensure that stability of the power system is adequately maintained. The primary means of achieving this is to carry out technical analysis of any threats to stability.

Generators and TNSPs are required to monitor indicators of system instability, such as responses to small disturbances, and report their findings to AEMO. AEMO is then responsible for analysing the data and determining whether the performance standards have been met. AEMO also uses this data to confirm and report on the correct operation of protection and control systems.

AEMO has a number of real-time monitoring tools, which help it meet its security obligations. These tools use actual system conditions and network configuration accessed in real-time from AEMO’s electricity market management system. These tools include:

- Contingency analysis: an online tool used to ensure that all power system equipment remains within its designed capability and ratings.
- Phasor point and oscillatory stability monitor: Phasor point is an online tool, which utilises phasor monitoring equipment installed at five locations across the NEM to detect underdamped oscillatory phenomena in the power system that could lead to a security threat.[236] The Oscillatory Stability Monitor uses the same measurements and produces parameter estimates of the three global oscillatory modes in the NEM based on a modal-identification algorithm. Data from both systems is stored to facilitate historical analysis of power system damping performances.
- Dynamic Security Assessment and Voltage Security Assessment Tool: this online security analysis tool simulates the behaviour of the power system for a variety of critical network, load and generator faults. The Dynamic Security Assessment undertakes transient stability analysis while the Voltage Security Assessment Tool is used for voltage stability analysis. Historical results are also stored for examination of power system performances as required.
- NEM-wide high-speed monitoring system that is installed and maintained by the TNSPs. This high-speed monitoring system provides visibility of the behaviour of the power system during stability disturbances, which is particularly useful for post-event analysis.

AEMO's review of significant events in recent times shows that system damping and fault ride-through performances are generally within stipulated requirements. However, AEMO has highlighted the need to maintain adequate monitoring so that possible causes of instability can be located and addressed in a timely manner.

There have been a number of occasions, including in 2015/16, where these real-time monitoring tools have identified the need to reduce transfer capability.

On these occasions, the power system conditions at the time were used to review the transfer limits. This is because when the transfer limits were originally determined, these combinations of dispatch scenarios, power system configurations and faults may not have been considered due to their low likelihood of occurrence. In time, this

236 Underdamped oscillatory phenomena refers to oscillatory stability or the ability of the power system to maintain synchronism after being subjected to a small perturbation without application of a contingency event.

analysis may lead to transfer limit functions being developed that could accurately deal with a broader range of more unusual power system configurations.

G.2 System technical requirements

To meet the power system security standards, a number of technical requirements must be satisfied. They include the technical standards, frequency operating standards, equipment ratings, system voltage limits, system stability criteria, and generator performance standards. These requirements are addressed by AEMO as part of its planning and operational activities.

G.3 System restart standard

The system restart standard sets out several key parameters for power system restoration, including the timeframe for restoring a specified amount of generation capacity as a basis for AEMO and TNSPs to restore the entire power system. The standard provides AEMO with a target against which it procures system restart ancillary services from contracted SRAS providers, such as generators with SRAS black start capability.

In the event of a major supply disruption, SRAS may be called on by AEMO to supply sufficient energy to restart power stations in order to begin the process of restoring the power system. AEMO's development of the System Restart Plan must be consistent with the Standard. The purpose of SRAS is to restore supply following an event that has a widespread impact on a large area – such as an entire jurisdiction.

The SRS does not relate to the process of restoring supply to consumers directly following blackouts within a distribution network or on localised areas of the transmission networks. In addition there is a separate process, developed with input of jurisdictional governments to manage any disruption that involves the operator on a network having to undertake controlled shedding of customers. Restoration of load from these localised or controlled events is not covered by the Standard.

During 2014/15, AEMO undertook a tender process for procuring system restart services for the period 1 July 2015 to 30 June 2018. In June 2015, AEMO announced the outcome of its procurement of SRAS for that period. As a result of this tender, the total amount AEMO expects to spend on the acquisition of SRAS dropped from $55 million a year in 2014/15 to $21 million a year in 2015/16, representing a reduction of 62 per cent. This is still higher than the cost of SRAS in the period before 2007/08, which were approximately $15 million.[237]

G.4 Technical standards framework

The technical standards framework is designed to maintain the security and integrity of the power system by establishing clearly defined standards for the performance of the system overall.

The framework comprises a hierarchy of standards:

237 AEMO, *System restart ancillary services 2015, Tender process report*, 2 July 2015.

- System standards define the performance of the power system, the nature of the electrical network and the quality of power supplied.
- Access standards specify the quantified performance levels that plant (consumer, network or generator) must have in order to connect to the power system.

These system standards establish the target performance of the power system overall.

The access standards define the range within which power system operators may negotiate with network service providers, in consultation with AEMO, for access to the network. AEMO and the relevant network service provider need to be satisfied that the outcome of these negotiations is consistent with their achieving the overall system standards. The access standards also include minimum standards below which access to the network will not be allowed.

The system and access standards are tightly linked. For example, the access standard is designed to meet the frequency operating standards, which is a system standard. In defining the frequency operating standards, consideration would need to be given to the cost of plant in meeting the required access standards.

G.5 Registered performance standards

The performance of all generating plant must be registered with AEMO as a performance standard. Registered performance standards represent binding obligations. To ensure a plant meets its registered performance standards on an ongoing basis, participants are also required to set up compliance monitoring programs. These programs must be lodged with AEMO. It is considered a breach of the rules if plant does not continue to meet its registered performance standards and compliance program obligations.

The technical standards regime, which came into effect in late 2003, "grandfathered" the performance of existing plant. This established a process to specify the registered standard of existing plant as the capability defined through any existing derogation, or connection agreement or the designed plant performance.[238]

Once set, a plant's performance standard does not vary unless an upgrade is required. Where that occurs, a variation in the connection agreement would be needed.

G.6 Frequency operating standards

Control of power system frequency is crucial to security. The Panel is responsible for determining the frequency operating standards that cover normal conditions, as well as the period following critical events when frequency may be disturbed. The frequency operating standards also specify the maximum allowable deviations between Australian Standard Time and electrical time (based on the frequency of the power system). The frequency operating standards are the basis for determining the level of quick acting response capabilities, or ancillary service requirements necessary to

238 While the changes to the rules were introduced in March 2003, the period between November 2003 and November 2004 allowed for all existing generators to register their existing performance with National Electricity Market Management Company Limited (now AEMO).

manage frequency. Tasmania has separate frequency operating standards to the mainland NEM.

Control of power system frequency is crucial to security. The Panel is responsible for determining the frequency operating standards that cover normal conditions, as well as the period following critical events when frequency may be disturbed. The frequency operating standards also specify the maximum allowable deviations between Australian Standard Time and electrical time (based on the frequency of the power system). The frequency operating standards are the basis for determining the level of quick acting response capabilities, or ancillary service requirements necessary to manage frequency. Tasmania has separate frequency operating standards to the mainland NEM.

G.6.1 NEM mainland frequency operating standards

The frequency operating standards that apply on the NEM mainland to any part of the power system other than an island[239] are shown in Table G.1.

Table G.1 NEM Mainland Frequency Operating Standards – interconnected system

Condition	Containment	Stabilisation	Recovery
Accumulated time error	5 seconds	n/a	n/a
No contingency event or load event	49.75 to 50.25 Hz, 49.85 to 50.15 Hz - 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Generation event or load event	49.5 to 50.5 Hz	49.85 to 50.15 Hz within 5 minutes	
Network event	49 to 51 Hz	49.5 to 50.5 Hz within 1 minute	49.85 to 50.15 Hz within 5 minutes
Separation event	49 to 51 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple contingency event	47 to 52 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes

Source: Reliability Panel, *Application of frequency operating standards during periods of supply scarcity*, April 2009.

The frequency operating standards that apply to an islanded system on the NEM mainland are shown in Table G.2.

239 If a part of the network on the mainland is islanded, the remaining majority of the network is required to meet the interconnected system frequency operating standards.

Table G.2 NEM Mainland Frequency Operating Standards – island system

Condition	Containment	Stabilisation	Recovery
No contingency event, or load event	49.5 to 50.5 Hz		
Generation event, load event or network event	49 to 51 Hz	49.5 to 50.5 Hz within 5 minutes	
The separation event that formed the island	49 to 51 Hz or a wider band notified to AEMO by a relevant Jurisdictional Coordinator	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes
Multiple contingency event including a further separation event	47 to 52 Hz	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes

Source: Reliability Panel, *Application of frequency operating standards during periods of supply scarcity*, April 2009.

The frequency operating standards that apply to the NEM mainland during supply scarcity are shown in Table G.3.

Table G.3 NEM Mainland Frequency Operating Standards – during supply scarcity

Condition	Containment	Stabilisation	Recovery
No contingency event or load event	49.5 to 50.5 Hz		
Generation event, load event or network event	48 to 52 Hz (Queensland and South Australia) 48.5 to 52 Hz (New South Wales and Victoria)	49 to 51 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes
Multiple contingency event or separation event	47 to 52 Hz	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes

Source: Reliability Panel, *Application of frequency operating standards during periods of supply scarcity*, April 2009.

G.6.2 Tasmanian frequency operating standards (except "islands")

The frequency operating standards that apply in Tasmania to any part of the power system other than an island are shown in Table G.4.

Table G.4 Tasmanian frequency operating standards (except "islands")

Condition	Containment	Stabilisation	Recovery
Accumulated time error	15 seconds		
No contingency event or load event	49.75 to 50.25 Hz 49.85 to 50.15 Hz, 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Load event	49.0 to 51.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Generation event	47.5 to 51.0 Hz	49.85 to 50.15 Hz within 5 minutes	
Network event	47.5 to 53.0 Hz	49.0 to 51.0 Hz within 1 minute	49.85 to 50.15 Hz within 5 minutes
Separation event	46 to 55 Hz	47.5 to 51.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple contingency event	46 to 55 Hz	47.5 to 51.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes

Source: Reliability Panel, *Tasmanian frequency operating standard review*, December 2008.

The frequency operating standards that apply to an islanded system within Tasmania are shown in Table G.5.

Table G.5 Tasmania frequency operating standards for "island" conditions

Condition	Containment	Stabilisation	Recovery
No contingency event or load event	49.0 to 51.0 Hz		
Generation event or network event	47.5 to 53.0 Hz	49.0 to 51.0 Hz within 5 minutes	
Load event	47.5 to 53.0 Hz	49.0 to 51.0 Hz within 10 minutes	
The separation event that formed the island	46 to 60 Hz	47.5 to 53.0 Hz within 2 minutes	49.0 to 51.0 Hz within 10 minutes
Multiple contingency event including a further separation event	46 to 60 Hz	47.5 to 53.0 Hz within 2 minutes	49.0 to 51.0 Hz within 10 minutes

Source: Reliability Panel, *Tasmanian frequency operating standard review*, December 2008.

In Tasmania, where it is not feasible to schedule sufficient frequency control ancillary service to limit frequency excursions to within this containment range for generation, network or load events, operation of the UFLS scheme or OFGSS is acceptable on the occurrence of a further contingency event.

G.7 Network constraints

The ability to transfer power across the system is limited by a number of factors including the capacity of the network.[240] Secure operation of the power system requires AEMO to maintain power flows within the capability of the network after allowing for credible contingencies.

NEMDE maximises the value of spot market trading in energy and ancillary services, subject to constraints designed to manage system security. Market participants make bids and offers to consume or produce electricity at various prices in each five minute dispatch interval in a day. Each generator's offers are combined into a merit order, and then dispatched by AEMO based on these bids, offers, constraints and other market conditions.

Where network constraints bind, generators may need to be dispatched from higher in the merit order, potentially resulting in increased wholesale prices. Constraints also represent the physical realities of the network, including network outages, which may affect customer's supply of electricity. Congestion is measured by the frequency and extent to which network constraints bind.

Increased congestion can result from a range of activities and does not necessarily indicate a reduction in network transfer capability. For instance, new generation located a significant distance away from a load centre may increase competition for existing transmission capacity, and so lead to increased congestion on the network.

G.7.1 Network constraint changes

A main driver for new or updated constraint equations is power system changes. These changes are likely to be the addition of, or removal of, either generation or transmission assets.

Table G.6 displays the yearly constraint changes since 2010 in NEMDE.

Table G.6 Number of constraint changes in the NEMDE

Calendar year	Constraint changes
2010	6250
2011	4776
2012	4130
2013	5817
2014	8121
2015	11967

240 The capability of the network to transfer power depends on a number of factors including; the capacity of network elements as indicated by their thermal, and fault ratings, the availability of spare capacity to accommodate sudden load increases following contingencies, the availability and location of generation, reactive plant that define voltage and stability related power transfer limits.

The changes in 2015 were the result of the number of different factors including:[241]

- the deregistration of Wallerawang
- the new Broken Hill solar farm caused changes to constraint equations in both NSW and Victoria
- the disaggregation of Laverton North and Valley Power resulted in a substantial number of changes to constraint equations in Victoria.

The changes to constraint equations due to transmission changes were dwarfed by the number of constraint equation changes due to generation changes.

G.7.2 Top binding constraints

Binding network constraints have an impact on market participants by constraining generation to ensure system security is maintained. Increasing levels of binding network constraints are an indicator that network augmentation may need to be assessed through the RIT-T to relieve those constraints. Binding constraints may also lead to customer load shedding in order for the network to remain in a secure state.

Table G.7 outlines the top five binding constraints impacting the NEM during 2015/16.[242]

Table G.7 Top five binding constraints impacting the NEM during 2015/16

Constraint	Hours binding	Description
Q>NIL_BI_FB	1,441	This is a system normal thermal constraint that limits generation from Gladstone Power Station, predominantly from the units connected at 132 kV.
V>>V_NIL_2A_R V>>V_NIL_2B_R V>>V_NIL_2_P	842.4	These constraints maintain flow on the South Morang F2 transformer within its continuous rating. When these constraints bind, they can affect flows between NSW-Victoria, Victoria-SA and Victoria-Tasmania.
V::N_NIL_xxx	788	This is a system normal transient stability constraint. It avoids transient instability for the fault and trip of a Hazelwood to South Morang 500kV line.
N_X_MBTE2_A	756	This constraint arose when two of the Directlink cables

241 AEMO, *NEM Constraint report 2015*, May 2016, pp. 6-8.

242 Note that section G.7.1 reports changes to constraint equations on a calendar year basis whereas this section reports on top binding constraints on a financial year basis.

Constraint	Hours binding	Description
N_X_MBTE2_B		were out.
VT_ZERO	626	This constraint reflects when Basslink was out of service.

G.8 Market notices

Market notices are notifications of events that impact the market, such as advance notice of lack of reserve conditions, status of market systems or price adjustments. They are electronically issued by AEMO to market participants to allow a more informed market response.[243]

AEMO issued 4,937 market notices during 2015/16, compared to 3,268 in 2014/15 and 3,148 in 2013/14. The number and type of market notices issued by AEMO are summarised in Table G.8. During 2015/16, AEMO issued significantly more market notices for prices being subject to review or prices being unchanged relative to the previous two years.

Table G.8 Market notices issued by AEMO

	Number of notices		
Type of notice	2013/14	2014/15	2015/16
Administered price cap	0	0	32
General notice	239	123	81
Inter-regional transfer	150	249	354
Market intervention	7	9	2
Market systems	117	86	161
Manual priced dispatch interval	0	0	0
NEM systems	0	1	3
Non-conformance	724	617	506
Power system event	85	87	72
Price adjustments	6	0	0

243 In accordance with clause 4.8 of the NER.

	Number of notices		
Type of notice	**2013/14**	**2014/15**	**2015/16**
Prices subject to review	210	213	781
Prices unchanged	202	210	776
Process review	0	0	0
Reclassify contingency	1040	1440	1686
Reserve notice	339	194	400
Settlements residue	29	20	56
Total	3148	3268	4937

Source: AEMO, Market Notices: http://www.aemo.com.au/Electricity/Data/Market-Notices.

H Safety framework

As noted in Chapter 5, NSPs and other market participants have specific responsibilities to provide for the safety of personnel and the public. The electrical system is designed with extensive safety systems to provide for the protection of the system itself, workers and the public. Each NEM region is subject to different safety requirements as set out in the relevant jurisdictional legislation. State and territory legislation governs the safe supply of electricity by network service providers and the broader safety requirements associated with electricity use in households and businesses.

Examples of the different jurisdictional safety arrangements are provided below. The Panel considers it is of benefit to provide an overview of some of the jurisdictional arrangements to provide context to issues that may be relevant to stakeholders. The Panel notes this is not an exhaustive summary of safety requirements in each region.

H.1 Queensland

In Queensland, the Electrical Safety Office is the electrical safety regulator that undertakes a range of activities to support electrical safety with the key objective of reducing the rate of electrical fatalities in Queensland. The *Electrical Safety Act 2002 (Qld)* places obligations on people who may affect the electrical safety of others. This stand-alone legislation fundamentally changed Queensland's approach to electrical safety, establishing a Commissioner for Electrical Safety, an Electrical Safety Board and three Board committees to advise the Minister on electrical safety issues. Additionally, an independent state-wide electrical safety inspectorate was established to administer and enforce the new legislative requirements.

One of the responsibilities of the Electrical Safety Board is the development of a five year strategic plan for improving electrical safety in Queensland. The Electrical Safety Plan for Queensland 2014–2019 was published in 2013 and sets out strategies designed to achieve the Board's goal of eliminating all preventable electrical deaths in Queensland by 2019.

H.2 NSW

In NSW, IPART is the safety and reliability regulator for electricity networks under the *Electricity Supply Act 1995 (NSW)* and the Electricity Supply (Safety and Network Management) Regulation 2014 (NSW). IPART strives to ensure safe and reliable supply of electricity for the benefit of the NSW community (including employees of the network operators) and the environment.

IPART has been granted new compliance and enforcement powers with an overall objective to:

- maintain safety standards within electricity networks
- meet relevant reliability standards set by government.

Electricity networks continue to have the ultimate responsibility for network safety and reliability. IPART holds these utilities accountable by developing an effective risk based compliance and enforcement framework.

The NSW Fair Trading monitors the safety of customer electrical installations under the *Electricity (Consumer Safety) Act 2004 (NSW)* and Electricity (Consumer Safety) Regulation 2015 (NSW). SafeWork NSW monitors the safety of work places under the *Work Health and Safety Act 2011 (NSW)* and Work Health and Safety Regulation 2011 (NSW). The NSW Department of Industry authorises accredited service providers under the *Electricity Supply Act 1995* (NSW) and the Electricity Supply (General) Regulation 2014 (NSW).

H.3 ACT

The ACT Planning and Land Authority administers the Electricity Safety Act 1971 (ACT) and Electricity Safety Regulation 1971 (ACT) in the ACT. This legislation ensures electrical safety, particularly in relation to:

- the installation, testing, reporting and rectification of electrical wiring work for an electrical installation and its connection to the electricity distribution network (the Wiring Rules are the relevant standard)
- the regulation and dealings associated with the sale of prescribed and non-prescribed articles of electrical equipment
- the reporting, investigation and recording of serious electrical accidents by responsible entities
- enforcement by the ACT Planning and Land Authority and its electrical inspectors (including inspectors' identification, entry powers, seizing evidence, disconnection of unsafe installations and articles, powers to collect verbal and physical evidence and respondents' rights)
- the appeals system
- miscellaneous matters such as certification of evidence.

H.4 Victoria

Electricity safety in Victoria is regulated by Energy Safe Victoria. The role of Energy Safe Victoria involves overseeing the design, construction and maintenance of electricity networks across the state and ensuring every electrical appliance in Victoria meets safety and energy efficiency standards before it is sold. Energy Safe Victoria oversees a statutory regime that requires major electricity companies to submit and comply with their Electricity Safety Management Scheme, submit bush fire mitigation plans annually for acceptance and electric line clearance management plans annually for approval, and to actively participate in Energy Safe Victoria audits to test compliance of their safety systems.

H.5 South Australia

In South Australia, the Office of the Technical Regulator is responsible for the administration of the *Electricity Act 1996 (SA)* and *Energy Products (Safety and Efficiency) Act 2000 (SA)*. The primary objective of these Acts is to ensure the safety of workers, consumers and property as well as compliance with legislation, technical standards and codes in the electricity industries.

The principal functions of the Office of the Technical Regulator under the *Electricity Act 1996 (SA)* are:

- monitoring and regulation of safety and technical standards in the electricity supply industry
- monitoring and regulation of safety and technical standards relating to electrical installations
- administration of the provisions of the Act relating to clearance of vegetation from power lines
- fulfilling any other function assigned to the Technical Regulator under the Act.

H.6 Tasmania

Until 1 June 2010, several safety functions were vested with the Office of the Tasmanian Economic Regulator under the *Electricity Industry Safety and Administration Act 1997 (Tas)* and the *Electricity Supply Industry Act 1995 (Tas). The Electricity Industry Safety and Administration Act 1997 (Tas)*:

- provides for electrical contractors and workers to be appropriately qualified and regulated
- establishes safety standards for electrical equipment and appliances
- provides for the investigation of electrical safety accidents in the electricity industry.

Safety-related responsibilities were transferred to Workplace Standards Tasmania via an amendment to the *Electricity Industry Safety and Administration Act 1997 (Tas)* in 2009.

I Pricing review

This chapter summarises the major pricing events during 2015/16.

AEMO publishes reports on significant price events in order to promote market transparency.[244] The reports explain:

- the factors contributing to unusual pricing outcomes
- whether outcomes were consistent with dispatch offers and power system conditions
- the performance of pre-dispatch in forecasting the unusual outcomes.

The reports are produced when:

- the maximum daily spot price (trading interval price) in any region is more than $2,000/MWh[245]
- the minimum daily spot price for any region is less than -$100/MWh
- the maximum daily sum of Frequency Control Ancillary Services (FCAS) half hourly averaged prices exceeds:
  - $3,000/MWh in Tasmania
  - $150/MWh in all other regions of the NEM.

During 2015/16, there were 108 pricing events in the spot market. Eight of these prices events were negative and in 35 of these price events the price exceeded $2000/MWh. The majority of the pricing events recorded occurred in South Australia. 27 of the pricing events occurred outside of peak hours, i.e. before 7.30am and after 10.00pm. Over the same period there were 32 pricing events in the FCAS markets, for 15 of which the sum of all services exceeded $2000/MWh.

Table I.1 displays the top five and bottom two spot price events, and the top five FCAS price events. The highest spot price for a trading interval was recorded in New South Wales on 23 September and attributed to planned/short notice outages of major transmission lines in New South Wales and Queensland.[246] Three of the top five spot price events occurred on 13 January 2016, with the high prices occurring during the evening peak period and when flows from the northern regions were limited due to the reclassification of critical transmission lines in response to lightning storms.[247]

244 The reports, and more information regarding the reports, are available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Pricing-event-reports

245 AEMO may also publish a brief report if the maximum daily spot price in any region is between $500/MWh and $2,000/MWh

246 More information is available on the highest spot prices for a trading interval at http://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Pricing-Event-Reports/2015/23-September-2015---High-Energy-price-NSW-High-FCAS-price-QLD.pdf

247 More information on the events of 13 January 2016 is available at http://www.aemo.com.au/-/media/Files/PDF/13_January_2016_-_High_Energy_Price_VIC_SA.pdf

Table I.1 Notable pricing events in the NEM during 2015/16

Date	Region	Trading interval (ending)	Price per MWh[248]
Top five spot pricing events			
23-Sep-15	New South Wales	18:30	$13,246
13-Jan-16	Victoria	15:30	$9,137
13-Jan-16	Victoria	16:00	$7,477
23-Sep-15	New South Wales	19:00	$6,717
13-Jan-16	South Australia	16:00	$5,173
Bottom two spot pricing events			
1-May-16	Tasmania	8:00	-$404
5-Apr-16	South Australia	16:00	-$175
Top five FCAS pricing events			
1-Nov-15	South Australia	22:30	$106,400
11-Oct-15	South Australia	23:00	$26,650
25-Oct-15	South Australia	16:00	$26,276
26-Mar-16	South Australia	3:00	$18,108

248 For FCAS pricing events, the price refers to the sum of all FCAS prices over a trading interval.

Date	Region	Trading interval (ending)	Price per MWh[248]
23-Sep-15	Queensland	18:30	$13,246

Source: AEMO, *Pricing Event Reports*, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Pricing-event-reports.

Table I.2 summarises the spot price events in the NEM during 2015/16.

Table I.2 Spot price events for July 2015 to June 2016

Period	Date	Region	Trading interval (ending)	Price per MWh
July 2015	3-Jul-15	South Australia	8:30	$2,296
	7-Jul-15	South Australia	19:00	$1,221
	13-Jul-15	Queensland	7:00	$2,325
	16-Jul-15	Queensland	7:00	$2,400
	17-Jul-15	Queensland	7:00	$2,351
	18-Jul-15	South Australia	0:00	$2,256
		Queensland	22:30	$2,459
	19-Jul-15	South Australia	18:30	$2,372
	20-Jul-15	Queensland	7:00	$2,336
	22-Jul-15	South Australia	18:30	$2,296
	27-Jul-15	South Australia	8:00	$4,449
	28-Jul-15	South Australia	8:00	$2,390
	29-Jul-15	South Australia	18:30	$1,968
		Queensland	7:00	$2,352
August 2015	1-Aug-15	South Australia	14:00	$4,542
	5-Aug-15	Queensland	19:00	$4,847
	7-Aug-15	South Australia	0:00	$2,310
		South Australia	22:00	$2,315
	16-Aug-15	South Australia	19:30	$2,351
	17-Aug-15	South Australia	20:30	$2,289
	20-Aug-15	Queensland	7:00	$2,334
	27-Aug-15	South Australia	8:00	$2,337
		South Australia	8:30	$1,835
	30-Aug-15	South Australia	19:00	$2,288
		South Australia	19:30	$1,846

Period	Date	Region	Trading interval (ending)	Price per MWh
September 2015	17-Sep-15	South Australia	15:30	$2,080
	22-Sep-15	South Australia	19:00	$2,036
		Victoria	19:00	$2,329
		Tasmania	19:00	$2,329
	23-Sep-15	New South Wales	18:30	$13,246
		New South Wales	19:00	$6,621
October 2015	No spot price event reports			
November 2015	1-Nov-15	South Australia	22:30	$1,821
	3-Nov-15	South Australia	10:00	$2,262
	4-Nov-15	Queensland	6:00	-$164.75
	4-Nov-15	South Australia	15:00	$1,992
	11-Nov-15	South Australia	13:30	$2,389
	12-Nov-15	South Australia	9:00	$2,291
	19-Nov-15	New South Wales	16:30	$2,504
		Queensland	16:30	$2,334
		New South Wales	17:00	$763.44
	20-Nov-15	New South Wales	15:30	$2,552
		Queensland	15:30	$2,432
		New South Wales	16:00	$2,485
		Queensland	16:00	$2,387
December 2015	17-Dec-15	South Australia	15:00	$864
		South Australia	15:30	$2,310
		South Australia	16:30	$1,682
		Victoria	16:30	$1,626

Period	Date	Region	Trading interval (ending)	Price per MWh
		Tasmania	16:30	$410
	20-Dec-15	Tasmania	14:30	$1,994
	25-Dec-15	South Australia	10:00	$901
	30-Dec-15	South Australia	15:30	$517
		South Australia	17:30	$1,014
	31-Dec-15	South Australia	15:00	$578
January 2016	9-Jan-16	South Australia	16:30	$587
	12-Jan-16	Tasmania	7:00	$1,132
	13-Jan-16	South Australia	0:30	$503
		Victoria	15:30	$9,137
		Victoria	16:00	$7,477
		South Australia	16:00	$5,173
	14-Jan-16	New South Wales	13:30	$642
		New South Wales	14:00	$5,023
	29-Jan-16	Queensland	13:30	$2,126
		Queensland	14:30	$2,474
February 2016	1-Feb-16	Queensland	18:30	$2,264
	2-Feb-15	Queensland	11:00	$1,845
		Queensland	17:00	$3,983
	15-Feb-15	Queensland	17:30	$2,538
	16-Feb-15	Queensland	14:00 - 19:30	$598 to $4095
	17-Feb-15	Queensland	14:30 - 20:00	$2177 to $2397
	18-Feb-15	Queensland	16:00 - 20:30	$1449 to $2251
	19-Feb-15	Queensland	14:00 - 19:00	$1794 to $2227
	21-Feb-15	Queensland	3:00	-$151.29
	26-Feb-15	Queensland	13:00	$2,310

Period	Date	Region	Trading interval (ending)	Price per MWh
		Queensland	16:30	$2,164
	27-Feb-15	Queensland	23:00	$2,323
	28-Feb-15	Queensland	22:30	$2,155
	29-Feb-15	Queensland	7:00	$2,342
		Queensland	19:00	$2,122
March 2016	1-Mar-16	South Australia	15:00	$2,126
		Victoria	15:00	$1,905
	2-Mar-16	Queensland	19:30	$2,135
	8-Mar-16	South Australia	16:30	$1,216
		Victoria	16:30	$2,031
		South Australia	17:00	$1,868
		Victoria	17:00	$2,109
		South Australia	18:30	$1,506
		Victoria	18:30	$1,974
	13-Mar-16	Queensland	19:00	$2,336
	15-Mar-16	Queensland	6:30	$1,974
	16-Mar-16	Queensland	7:00	$2,336
	17-Mar-16	Tasmania	11:00	$797
	18-Mar-16	Queensland	17:00 - 18:30	$2115 to $4648
	19-Mar-16	Queensland	16:30	$2,248
	21-Mar-16	Queensland	9:00	$727
	22-Mar-16	Queensland	22:30	$2,360
	23-Mar-16	Queensland	10:00	$2,344
	24-Mar-16	Queensland	7:00	$2,356
	28-Mar-16	Queensland	19:00	$2,386
	30-Mar-16	South Australia	7:30	$2,263
	31-Mar-16	Victoria	0:30	-$149

Period	Date	Region	Trading interval (ending)	Price per MWh
April 2016	5-Apr-16	South Australia	3:00-4:00	-$182 to -$203
		South Australia	16:00	-$174
		Victoria	16:00	-$163
	11-Apr-16 to 17-Apr-16	Tasmania	57 consecutive trading intervals between 9:30 on 11 April 2016 and 20:30 on 17 April 2016	>$500
	18-Apr-16 to 24-Apr-16	Tasmania	71 consecutive trading intervals between 04:00 on 18 April 2016 and 13:00 on 24 April 2016	>$500
	28-Apr-16	South Australia	14:30	-$126
	25 -Apr-16 to 30-Apr-16	Tasmania	43 consecutive trading intervals between 07:00 on 25 April 2016 and 04:00 on 30 April 2016	>$500
May 2016	1-May-16	Tasmania	8:00	-$404
	4-May-16	South Australia	0:00	$1,084
	5-May-16	Queensland	8:00	$2,337
	17-May-16	South Australia	8:30	$1,126
		South Australia	18:30	$2,062
		South Australia	19:30	$1,949
	18-May-16	South Australia	0:00	$1,860
	19-May-16	South Australia	0:00	$1,175
		Victoria	0:00	-$142
June 2016	27-Jun-16	South Australia	9:00	$1,252
		South Australia	9:30	$1,619
		South Australia	10:00	$1,241
	28-Jun-16	South Australia	10:00	$1,862

Period	Date	Region	Trading interval (ending)	Price per MWh
		South Australia	18:30	$2,054
		South Australia	19:00	$3,102

Source: AEMO, *Pricing Event Reports*, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Pricing-event-reports.

Table I.3 summarises the FCAS price events in the NEM during 2015/16.

Table I.3 FCAS price events for July 2015 to June 2016

Period	Date	Region	FCAS service	Trading interval (ending)	Price per MWh
July 2015	14-Jul-15	South Australia	Sum of all services	7:00	$193
August 2015	2-Aug-15	Tasmania	Sum of all services	23:00	$8,789
	29-Aug-15	Tasmania	Sum of all services	2:00	$3,043
September 2015	23-Sep-15	Queensland	Sum of all services	18:30	$13,246
		Queensland	Sum of all services	19:00	$6,620
October 2015	11-Oct-15	South Australia	Maximum sum of all services	23:00	$26,650
	11-Oct-15 to 13-Oct-15	South Australia	Sum of all services	91 consecutive trading intervals between 12:00 on 11 October 2015 and 18:00 on 13 October 2015	>$300
	25-Oct-15	South Australia	Maximum sum of all services	16:00	$26,276
	29-Oct-15 to 10-Nov-15	South Australia	Sum of all services	387 consecutive trading intervals between 8:00	>$150

Period	Date	Region	FCAS service	Trading interval (ending)	Price per MWh
				on 15 October 2015 and 11:00 on 26 October 2015	
November 2015	1-Nov-15	South Australia	Maximum sum of all services	22:30	$106,400
	29-Oct-15 to 10-Nov-15	South Australia	Sum of all services	549 consecutive trading intervals between 7:30 on 29 October 2015 and 18:00 on 10 November 2015	>$150
December 2015	No FCAS price reports				
January 2016	11-Jan-16	Queensland, New South Wales, Victoria and South Australia	Sum of all services	4 consecutive trading intervals between 14:00 and 16:00 on 11-Jan-16	>$74
	12-Jan-16	Tasmania	Sum of all services	7:00	$3,362
	14-Jan-16	Queensland, New South Wales, Victoria and South Australia	Sum of all services	14:00	$295
February 2016	No FCAS price reports				
March 2016	17-Mar-16	Tasmania	Sum of all services	11:00	$3,287
	23-Mar-16	Queensland	Fast raise	10:00	$2,027
		Queensland	Slow raise	10:00	$205
	24-Mar-16	South Australia	Fast raise	7:00	$2,201

Period	Date	Region	FCAS service	Trading interval (ending)	Price per MWh
	26-Mar-16	South Australia	Lower regulation	2:30	$6,904
		South Australia	Raise regulation	2:30	$6,901
		South Australia	Lower regulation	3:00	$9,141
		South Australia	Raise regulation	3:00	$8,967
April 2016	9-Apr-16	Queensland, New South Wales, Victoria and South Australia	Fast raise	18:00	$135
		Queensland, New South Wales, Victoria and South Australia	Fast raise	18:30	$78
May 2016	9-May-16	Queensland, New South Wales, Victoria and South Australia	Raise regulation	9 consecutive trading intervals between 8:00 and 13:00 on 09-May-16	>$79
		Queensland, New South Wales, Victoria and South Australia	Fast raise	9 consecutive trading intervals between 8:00 and 13:00 on 09-May-16	>$61
	22-May-16	Queensland, New South Wales, Victoria and South Australia	Delayed raise and raise regulation	18:00	$83
		Queensland, New South Wales, Victoria and South Australia	Delayed raise and raise regulation	18:30	$79

Period	Date	Region	FCAS service	Trading interval (ending)	Price per MWh
	24-May-16	Queensland, New South Wales, Victoria and South Australia	Delayed raise	8:30	$59
		Queensland, New South Wales, Victoria and South Australia	Raise regulation	8:30	$70
	9-May-16	Queensland, New South Wales, Victoria and South Australia	Delayed raise and raise regulation	3 consecutive trading intervals between 17:30 and 18:30 on 30-May-16	>$86
June 2016	3-Jun-16	Queensland, New South Wales, Victoria and South Australia	Raise regulation	12 consecutive trading intervals between 8:00 and 13:00 on 09-May-16	>$86

Source: AEMO, *Pricing Event Reports*, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Pricing-event-reports.

J Other NEM market reviews, AEMC rule changes and environmental policies

This appendix is additional to the information provided in section 2.5 in the main body of the report which summarises the current reviews most relevant to security and reliability. This appendix provides an overview of reviews commenced and/or completed by the Reliability Panel, the AEMC and other market bodies during 2015/16 as well as an overview of relevant rule changes made by the AEMC during 2015/16 that are relevant to the reliability and security of the NEM.

J.1 NEM market reviews

This section provides a high level summary of the relevant electricity market reviews that were completed during 2015/16 by the AEMC and other market bodies.

J.1.1 COAG Energy Council review of governance arrangements for Australian energy markets

On 11 December 2014, the COAG Energy Council agreed to the terms of reference for a Review of Governance Arrangements for Australian Energy Markets. The review was initiated in response to a COAG commitment to review the governance arrangements in the Australian energy market five years after the establishment of the AEMO in 2009. The review panel comprised Dr Michael Vertigan AC as Chair, Professor George Yarrow and Mr Euan Morton.

The final report was published in October 2015. The report concluded that the division of functions established by the current governance arrangements for Australian energy markets is fundamentally sound and that Australian energy market governance is amongst best practice internationally. Australia's energy market governance relies on clearly specified and stable policy and appropriate regulatory objectives, delegation of some roles to specialist institutions and importantly, institutional separation. In this overall structure, scope for improvement exists to adapt to the challenges foreshadowed by two themes that consistently emerged during consultations during the review:

- the pace of change in the energy sector is arguably unprecedented
- a 'strategic policy deficit' exists which has led to diminished clarity and focus in roles, fragmentation and a diminished sense of common purpose.

The review made multiple recommendations regarding improvements to governance arrangements in the NEM. These recommendations can be found in the final report.[249]

J.1.2 Independent Review into the Future Security of the National Electricity Market

At an extraordinary meeting on 7 October 2016, COAG Energy Ministers agreed to an independent review of the national electricity market to take stock of its current security

249 The final report is available at http://www.scer.gov.au/publications/review-governance-arrangements-australian-energy-markets-final-report

and reliability and to provide advice to governments on a coordinated, national reform blueprint.

A preliminary report from the review was released in December 2016. The preliminary report set out observations with the intention of guiding a process of extensive consultation.

The final report is due to be released in the first half of 2017.[250]

J.1.3 Integration of energy and emissions reduction

On 9 December 2016, the AEMC published its final report[251] analysing the characteristics and impacts on the energy market of three emissions reduction policy mechanisms. The Report also includes analysis, undertaken by AEMO, of the power system security implications of these three emissions reduction policy mechanisms.

At the December 2015 COAG Energy Council meeting, Energy Ministers tasked officials with preparing advice to allow the Energy Council to better understand the potential impacts of climate change policies on the NEM. The AEMC, along with AEMO, were asked to assist officials with this work. The following emissions reduction mechanisms were investigated in response to the request from officials to meet a target of 28 per cent emissions reduction on 2005 levels by 2030. The three emissions reduction mechanisms were:

- **Market-based**: The establishment of a declining emissions intensity target for the electricity sector, where generators with an emissions intensity above the target would need to buy credits and those with an emissions intensity below the target create and sell credits.
- **Technology subsidy**: Extension of the existing large-scale renewable energy target (LRET). Based on 2015 forecasts of demand, the current LRET would need to increase from 33,000 GWh in 2020 to 86,000 GWh in 2030 to meet the 28 per cent emissions reduction target.
- **Government regulation**: Based on current forecasts of demand, a regulatory policy mechanism is implemented by government to close the number of fossil-fuelled generators required to meet the emissions reduction target.

The report found that an emissions intensity target would have the lowest impact on prices relative the business-as-usual scenario. An emissions intensity target is also technologically-neutral and would therefore encourages the least-cost form of abatement to be adopted by market participants. An extended LRET would result in the highest cost of abatement as it only allows a limited number of technologies to meet the emissions constraint. Regulatory closure results in the largest increase in prices paid by

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250 More information on the Independent Review into the Future Security of the National Electricity Market is available at: http://www.environment.gov.au/energy/national-electricity-market-review

251 More information on the final report on the integration of energy and emissions reduction policies is available at http://www.aemc.gov.au/Markets-Reviews-Advice/Integration-of-energy-and-emissions-reducti on-poli

consumers, with the cost to the economy being higher than the emissions intensity target, but less that an the cost of an extended LRET.

J.1.4 Last resort planning power 2016

The last resort planning power (LRPP) is provided for in the NER. It allows the AEMC to require one or more network service providers to apply the regulatory investment test for transmission to augmentation projects that are likely to relieve a forecast constraint on a national transmission flow path.

In the 2016 LRPP, the AEMC found that TNSPs in the NEM are adequately considering inter-regional transmission constraints in their planning of investment in the network. The AEMC therefore decided not to exercise the last resort planning power in 2016.[252]

J.1.5 Optional Firm Access: Design and Testing

The AEMC was requested by the COAG Energy Council to design, test and assess the costs and benefits of the optional firm access model to address issues related to coordination between transmission and generation investment in the NEM under circumstances of changing energy demand and supply.

Upon publishing the final report on 9 July 2015, the AEMC concluded that in the current environment the implementation of optional firm access would not contribute to the achievement of the NEO. However, the model could be beneficial in a future environment where there is significant investment, but the patterns of this investment are uncertain.[253]

J.1.6 Electricity network transformation roadmap

The Electricity network transformation roadmap has been developed to provide guidance for an efficient and timely transformation of networks in Australia over the 2017-27 decade. Developed by CSIRO and the Energy Networks Australia, the roadmap is informed by numerous reports that summarise various analyses, scenario analyses and quantitative modelling to 2050. A set of actions are identified to with the intention of enabling balanced, long term outcomes for customers, enabling the maximum value of customer distributed energy resources and positioning Australia’s networks for resilience in uncertain and divergent futures.[254]

J.2 AEMC rule changes

This section provides a high level summary of the significant electricity rules changes that were completed during 2015/16 by the AEMC.

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252 More information on LRPP 2016 is available at http://www.aemc.gov.au/Markets-Reviews-Advice/Last-resort-planning-power-2016-review

253 More information on optional firm access is available at http://www.aemc.gov.au/Markets-Reviews-Advice/Optional-Firm-Access,-Design-and-Testing

254 More information on the Electricity network transformation roadmap is available at http://www.energynetworks.com.au/electricity-network-transformation-roadmap

J.2.1 Extension of the Reliability and Emergency Reserve Trader

In its management of power system reliability, AEMO can use any one of three reliability intervention mechanisms, of which the Reliability and Emergency Reserve Trader (RERT) is one.

The RERT allows AEMO to contract for reserves ahead of a period where reserves are projected to be insufficient to meet the reliability standard. AEMO is able to dispatch these reserves to manage power system reliability and, where practicable, security. The RERT, or some form of power for the market operator to contract for reserves, has been a feature of the NEM since its commencement in December 1998.

On 23 June 2016, the AEMC made a rule[255] which:

- omitted the sunset clause which continues the RERT arrangements unless and until a rule change amends or omits them
- shortened the period for AEMO to contract the reserves ahead of a projected reserve to allow greater opportunity for a market response to address the shortfall
- requires the Reliability Panel to amend the RERT guidelines and AEMO to amend the RERT procedures to reflect the changes to the RERT arrangements.

J.2.2 Energy Adequacy Assessment Projection timeframes

The EAAP is an information mechanism that provides the market with a two-year outlook on the effect of energy constraints in the NEM. Energy constraints refer to fuel shortages or constraints that limit the ability to use a generator, such as access to water for cooling or for hydro generation. The EAAP is part of a broader suite of tools that AEMO uses in assessing whether the electricity market will deliver enough capacity to meet consumer demand for electricity.

On 19 May 2016, the AEMC made a rule[256] that reduced the frequency of EAAP reporting while maintaining the ability to issue an EAAP when it is necessary. The rule also reduced EAAP fixed reporting frequency from quarterly to annually but requires AEMO to produce an additional EAAP if it becomes aware of new information that may materially alter the most recent EAAP. The rule improves the balance between the benefits of reporting on energy constraints and the costs of producing an EAAP report.

J.3 Environmental and renewable energy policies

This section provides a high level summary of changes to, and introduction of significant environmental policies relevant to the reliability, security and safety of the NEM during 2015/16.

255 More information on the extension of the RERT rule change is available at http://www.aemc.gov.au/Rule-Changes/Extension-of-the-Reliability-and-Emergency-Reserve

256 More information on the EAAP timeframes rule change is available at http://www.aemc.gov.au/Rule-Changes/Energy-Adequacy-Assessment-Projection-timeframes

J.3.1 Emissions reduction fund

Following the repeal of the carbon tax in July 2014, the Federal government introduced the Emissions Reduction Fund (ERF).[257] The ERF comprises three parts:

- **Crediting** - businesses identify emissions reductions and would earn credits for effecting these emissions reductions.
- **Purchasing** - businesses with a registered project have an opportunity to sell their Australian carbon credit units to the Australian Government, represented by the Clean Energy Regulator (CER). The CER runs auctions to select the lowest cost abatement. If a business' bid is successful at auction, they automatically enter into a contract with the CER to deliver Australia carbon credit units.
- **Safeguarding** - the safeguard mechanism makes sure that emissions reductions paid for by the ERF are not displaced by a significant rise in emissions above business-as-usual levels elsewhere in the economy. The safeguard mechanism commenced on 1 July 2016.

J.3.2 Meeting 2030 emissions reduction commitments

Australia has committed to emissions reductions of 26-28 per cent on 2005 levels by 2030. The ERF, discussed above, is a major component of Australia's commitment to meeting the emissions reductions target. This is complemented by the Renewable Energy Target, energy efficiency improvements, phasing out very potent synthetic greenhouse gases, and direct support for investment in low emissions technologies and practices.[258]

The Australian Government is also commencing a review in early 2017 which is intended to take stock of Australia's progress in reducing emissions.[259] The review will consider:

- the opportunities and challenges of reducing emissions on a sector-by-sector basis
- the impact of policies on jobs, investment, trade competitiveness, households and regional Australia
- the integration of climate change and energy policy, including the impact of state-based policies on achieving an effective national approach
- the role and operation of the ERF and its safeguard mechanism
- complementary policies, including the National Energy Productivity Plan;
- the role of research and development and innovation

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257 More information on the ERF is available at https://www.environment.gov.au/climate-change/emissions-reduction-fund

258 Department of Environment and Energy 2015, Department of Environment and Energy Australian Government, viewed 13 December 2016, http://www.environment.gov.au/climate-change/publications/factsheet-australias-2030-climate-change-target.

259 More information is available on the Government's review of climate policies at http://www.environment.gov.au/climate-change/review-climate-change-policies

- the potential role of credible international units in meeting Australia's emissions targets
- a potential long-term emissions reduction goal post-2030.

J.3.3 Renewable energy target

Since January 2011 the Renewable Energy Target (RET) scheme has operated in two parts—the Small-scale Renewable Energy Scheme (SRES) and the Large-scale Renewable Energy Target (LRET).

The LRET creates a financial incentive for the establishment or expansion of renewable energy power stations, such as wind and solar farms or hydro-electric power stations. It does this by legislating demand for Large-scale Generation Certificates (LGCs). One LGC can be created for each megawatt-hour of eligible renewable electricity produced by an accredited renewable power station. LGCs can be sold to entities (mainly electricity retailers) who surrender them annually to the Clean Energy Regulator to demonstrate their compliance with the RET scheme's annual targets. The revenue earned by the power station for the sale of LGCs is additional to that received for the sale of the electricity generated.

The LRET includes legislated annual targets which will require significant investment in new renewable energy generation capacity in coming years. Amending legislation to implement the Government's reforms to the RET was agreed to by the Australian Parliament on 23 June 2015. Due to these amendments, the large-scale targets ramp up until 2020 when the target will be 33,000 GWh of renewable electricity generation. Prior to the amendments the target was 41,000 GWh of renewable energy by 2020.

J.3.4 Jurisdiction-based renewable energy targets

Some proposed jurisdictional schemes include:

- ACT: 100% of generation provided to the ACT to come from renewable sources by 2020. This is given effect by a reverse auction of two-way contracts for difference.[260]
- Queensland: 50% of generation provided to Queensland to come from renewable sources by 2030. It is not yet clear how this generation will be procured and what the location of this generation will be.[261]
- Victoria: 25% of generation provided to Victoria to come from renewable sources by 2020, and 40% by 2025. This is also given effect through a reverse auction of two-way contracts for difference, and the generation will be located within Victoria.[262]

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260 ACT Government, *Canberra 100% renewable*, n.d.

261 For more information, see: https://www.dews.qld.gov.au/electricity/solar/solar-future

262 For more information, see: http://www.delwp.vic.gov.au/energy/renewable-energy/victorias-renewable-energy-targets

K Market price cap and cumulative price threshold

The AEMC is responsible for calculating the MPC and the CPT each year to apply from 1 July each year as part of the NEM's reliability settings.

Since 1 July 2012, the NER have required the AEMC to annually update the values for the MPC and CPT by applying consumer price index information published by the Australian Bureau of Statistics.

The AEMC is required to publish these values by 28 February each year. For 2014/15, the values for MPC and CPT are tabulated in Table K.1.

Table K.1 2015/16 market price cap and cumulative price threshold values

	From 1 July 2014 to 30 June 2015	From 1 July 2015 to 30 June 2016
Market price cap	$13,500/MWh	$13,800/MWh
Cumulative price threshold	$201,900	$207,000

Market price cap

During 2015/16, the market price cap was reached 12 times in total. Two of the times the market price cap was reached were in FCAS markets. The main reasons for the market price cap being reached were generator rebidding, periods of high demand and interconnector constraints.

Cumulative price threshold

During 2015/16, the cumulative price threshold was reached three times. All three times occurred in South Australia during October and November 2015. This was a result of the Heywood No.2 275kV transmission line planned outage. This is discussed in detail in chapter 6.

L Glossary

Available capacity	The total MW capacity available for dispatch by a scheduled generating unit or scheduled load (i.e. maximum plant availability) or, in relation to a specified price band, the MW capacity within that price band available for dispatch (i.e. availability at each price band).
Busbar	A busbar is an electrical conductor in the transmission system that is maintained at a specific voltage. It is capable of carrying a high current and is normally used to make a common connection between several circuits within the transmission system. The NER define busbar as 'a common connection point in a power station switchyard or a transmission network substation'.
Cascading outage	The occurrence of a succession of outages, each of which is initiated by conditions (e.g. instability or overloading) arising or made worse as a result of the event preceding it.
Contingency events	These are events that affect the power system's operation, such as the failure or removal from operational service of a generating unit or transmission element. There are several categories of contingency event, as described below: • credible contingency event is a contingency event whose occurrence is considered “reasonably possible” in the circumstances. For example: the unexpected disconnection or unplanned reduction in capacity of one operating generating unit; or the unexpected disconnection of one major item of transmission plant • non-credible contingency event is a contingency event whose occurrence is not considered “reasonably possible” in the circumstances. Typically a non-credible contingency event involves simultaneous multiple disruptions, such as the failure of several generating units at the same time.
Customer Average Interruption Duration Index (CAIDI)	The sum of the duration of each sustained customer interruption (in minutes) divided by the total number of sustained customer interruptions (SAIDI divided by SAIFI). CAIDI excludes momentary interruptions (one minute or less duration).
Directions	These are instructions AEMO issues to participants under clause 4.8.9 of the NER to take action to maintain or re-establish the

	power system to a secure operating state, a satisfactory operating state, or a reliable operating state.
Dispatch	The act of initiating or enabling all or part of the response specified in a dispatch bid, dispatch offer or market ancillary service offer in respect of a scheduled generating unit, a scheduled load, a scheduled network service, an ancillary service generating unit or an ancillary service load in accordance with clause 3.8 (NER), or a direction or operation of capacity the subject of a reserve contract as appropriate.
Distribution network	The apparatus, equipment, plant and buildings (including the connection assets) used to convey and control the conveyance of electricity to consumers from the network and which is not a transmission network.
Distribution Network Service Provider (DNSP)	A person who engages in the activity of owning, controlling, or operating a distribution network.
Frequency Control Ancillary Services (FCAS)	Those ancillary services concerned with balancing, over short intervals, the power supplied by generators with the power consumed by loads (throughout the power system). Imbalances cause the frequency to deviate from 50 Hz.
Interconnector	A transmission line or group of transmission lines that connect the transmission networks in adjacent regions.
Jurisdictional planning body	The transmission network service provider responsible for planning a NEM jurisdiction's transmission network.
Lack of reserve	This is when reserves are below specified reporting levels.
Load	A connection point (or defined set of connection points) at which electrical power is delivered, or the amount of electrical power delivered at a defined instant at a connection point (or aggregated over a defined set of connection points).
Load event	In the context of frequency control ancillary services, a load event: involves a disconnection or a sudden reduction in the amount of power consumed at a connection point and results in an overall excess of supply.
Load shedding	Reducing or disconnecting load from the power system either by automatic control systems or under instructions from AEMO. Load shedding will cause interruptions to

	some energy consumers' supplies.
Low Reserve Condition (LRC)	This is when reserves are below the minimum reserve level.
Momentary Average Interruption Frequency Index (MAIFI)	The total number of customer interruptions of one minute or less duration, divided by the total number of distribution customers.
Medium Term Projected Assessment of System (MT PASA) (also see ST PASA)	A comprehensive programme of information collection, analysis and disclosure of medium-term power system reliability prospects. This assessment covers a period of 24 months and enables market participants to make decisions concerning supply, demand and outages. It must be issued weekly by AEMO
Minimum Reserve Level (MRL)	The minimum reserve margin calculated by AEMO to meet the Reliability Standard.
Ministerial Council on Energy (MCE)	The MCE is the national policy and governance body for the Australian energy market, including for electricity and gas, as outlined in the COAG Australian Energy Market Agreement of 30 June 2004.
National Electricity Code	The National Electricity Code was replaced by the National Electricity Rules on 1 July 2005.
National Electricity Market (NEM)	The NEM is a wholesale exchange for the supply of electricity to retailers and consumers. It commenced on 13 December 1998, and now includes Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia, and Tasmania.
National Electricity Law (NEL)	The NEL is contained in a Schedule to the National Electricity (South Australia) Act 1996. The NEL is applied as law in each participating jurisdiction of the NEM by the application statutes.
National Electricity Rules (NER)	The NER came into effect on 1 July 2005, replacing the National Electricity Code.
National electricity system	The generating systems, transmission and distribution networks and other facilities owned, controlled or operated in the states and territories participating in the National Electricity Market.
Network	The apparatus, equipment and buildings used to convey and control the conveyance of electricity. This applies to both transmission networks and distribution networks.
Network capability	The capability of a network or part of a network to transfer electricity from one location to another.

Network Control Ancillary Services (NCAS)	Ancillary services concerned with maintaining and extending the operational efficiency and capability of the network within secure operating limits.
Network event	In the context of frequency control ancillary services, the tripping of a network resulting in a generation event or load event.
Network Service Providers	An entity that operates as either a Transmission Network Service Provider (TNSP) or a Distribution Network Service Provider (DNSP).
Network services	The services (provided by a TNSP or DNSP) associated with conveying electricity and which also include entry, exit, and use-of-system services.
Operating state	The operating state of the power system is defined as satisfactory, secure or reliable, as described below. satisfactory operating state The power system is in a satisfactory operating state when: • it is operating within its technical limits (i.e. frequency, voltage, current etc. are within the relevant standards and ratings); and • the severity of any potential fault is within the capability of circuit breakers to disconnect the faulted circuit or equipment.
Secure operating state	The power system is in a secure operating state when: • it is in a satisfactory operating state; and • it will return to a satisfactory operating state following a single credible contingency event.
Reliable operating state	The power system is in a reliable operating state when: • AEMO has not disconnected, and does not expect to disconnect, any points of load connection under clause 4.8.9 (NER); • no load shedding is occurring or expected to occur anywhere on the power system under clause 4.8.9 (NER); and • in AEMO's reasonable opinion the levels of short term and medium term capacity reserves available to the power system are at least equal to the required levels determined in accordance with the power system security and reliability standards.
Participant	An entity that participates in the National Electricity Market.

Plant capability	The maximum MW output which an item of electrical equipment is capable of achieving for a given period.
Power system reliability	The measure of the power system's ability to supply adequate power to satisfy demand, allowing for unplanned losses of generation capacity.
Power system security	The safe scheduling, operation and control of the power system on a continuous basis.
Probability of exceedance (POE)	POE relates to the weather/temperature dependence of the maximum demand in a region. A detailed description is given in the AEMO ESOO.
Reliable operating state	Under clause 4.2.7 of the NER, the power system is assessed to be in a reliable operating state when: • AEMO has not disconnected, and does not expect to disconnect, any points of load connection under clause 4.8.9 of the NER; • no load shedding is occurring or expected to occur anywhere on the power system under clause 4.8.9 of the NER; and • in AEMO's reasonable opinion the levels of short term and medium term capacity reserves available to the power system are at least equal to the required levels determined in accordance with the power system security and reliability standards.
Reliability of supply	The likelihood of having sufficient capacity (generation or demand-side response) to meet demand (the consumer load).
Reliability Standard	The Panel's current standard for reliability is that there should be sufficient generation and bulk transmission capacity so that so that the maximum expected USE is 0.002 per cent.
Reserve	The amount of supply (including available generation capability, demand side participation and interconnector capability) in excess of the demand forecast for a particular period.
Reserve margin	The difference between reserve and the projected demand for electricity, where: • Reserve margin = (generation capability + interconnection reserve sharing) – peak demand + demand-side participation.
System Average Interruption Duration Index (SAIDI)	The sum of the duration of each sustained customer interruption (in minutes), divided by the total number of distribution customers. SAIDI excludes momentary interruptions (one

	minute or less duration).
System Average Interruption Frequency Index (SAIFI)	The total number of sustained customer interruptions, divided by the total number of distribution customers. SAIFI excludes momentary interruptions (one minute or less duration).
Satisfactory operating state	Explanation: • excursions outside the normal operating frequency band but within normal operating frequency excursion band; • the voltage magnitudes at all energised busbars at any switchyard or substation of the power system are within the relevant limits set by the relevant network service providers in accordance with clause S5.1.4 of Schedule 5.1 (of the NER); • the current flows on all transmission lines of the power system are within the ratings (accounting for time dependency in the case of emergency ratings) as defined by the relevant network service providers in accordance with Schedule 5.1 (of the NER); • all other plant forming part of or impacting on the power system is being operated within the relevant operating ratings (account for time dependency in the case of emergency ratings) as defined by the relevant network service providers in accordance with Schedule 5.1 (of the NER); • the configuration of the power system is such that the severity of any potential fault is within the capability of circuit breakers to disconnect the faulted circuit or equipment; and • the conditions of the power system are stable in accordance with requirements designated in or under clause S5.1.8 of Schedule 5.1 (of the NER).
Scheduled load	A market load which has been classified by AEMO as a scheduled load at the market customer's request. A market customer may submit dispatch bids in relation to scheduled loads.
Secure operating state	Under clause 4.2.4 of the rules, the power system is defined to be in a secure operating state if, in AEMO's reasonable opinion, taking into consideration the appropriate power system principles (described in clause 4.2.6 of the NER): • the power system is in a satisfactory operating state; and

	• the power system will return to a satisfactory operating state following the occurrence of any credible contingency event in accordance with the power system security and reliability standards.
Separation event	In the context of frequency control ancillary services, this describes the electrical separation of one or more NEM regions from the others, thereby preventing frequency control ancillary services being transferred from one region to another.
Short Term Projected Assessment of System Adequacy (ST PASA) (also see MT PASA)	The PASA in respect of the period from two days after the current trading day to the end of the seventh day after the current trading day inclusive in respect of each trading interval in that period.
Spot market	Wholesale trading in electricity is conducted as a spot market. The spot market allows instantaneous matching of supply against demand. The spot market trades from an electricity pool, and is effectively a set of rules and procedures (not a physical location) managed by AEMO (in conjunction with market participants and regulatory agencies) that are set out in the NER.
Spot price	The price for electricity in a trading interval at a regional reference node or a connection point.
Supply-demand balance	A calculation of the reserve margin for a given set of demand conditions, which is used to minimise reserve deficits by making use of available interconnector capabilities.
Technical envelope	The power system's technical boundary limits for achieving and maintaining a secure operating state for a given demand and power system scenario.
Transmission network	The high-voltage transmission assets that transport electricity between generators and distribution networks. Transmission networks do not include connection assets, which form part of a transmission system.
Transmission Network Service Provider (TNSP)	An entity that owns operates and/or controls a transmission network.
Unserved energy (USE)	The amount of energy that cannot be supplied because there are insufficient supplies (generation) to meet demand.