AEMC

REVIEW

Australian Energy Market Commission

ISSUES AND APPROACH PAPER

REVIEW OF THE SYSTEM BLACK EVENT IN SOUTH AUSTRALIA

COAG Energy Council

18 APRIL 2019

INQUIRIES

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ABOUT THE AEMC

The AEMC reports to the Council of Australian Governments (COAG) through the COAG Energy Council. We have two functions. We make and amend the national electricity, gas and energy retail rules and conduct independent reviews for the COAG Energy Council.

EXECUTIVE SUMMARY

South Australia experienced a 'black system' event at 16:18 AEST on Wednesday 28 September 2016 (the event). Approximately 850,000 South Australian customers lost electricity supply including households, businesses, transport, community services, and major industries. Most electricity supply was restored in 8 hours, however the wholesale market in SA was suspended for a total period of 13 days.[1] The total cost of the black system event to South Australian business was estimated at $367 million.

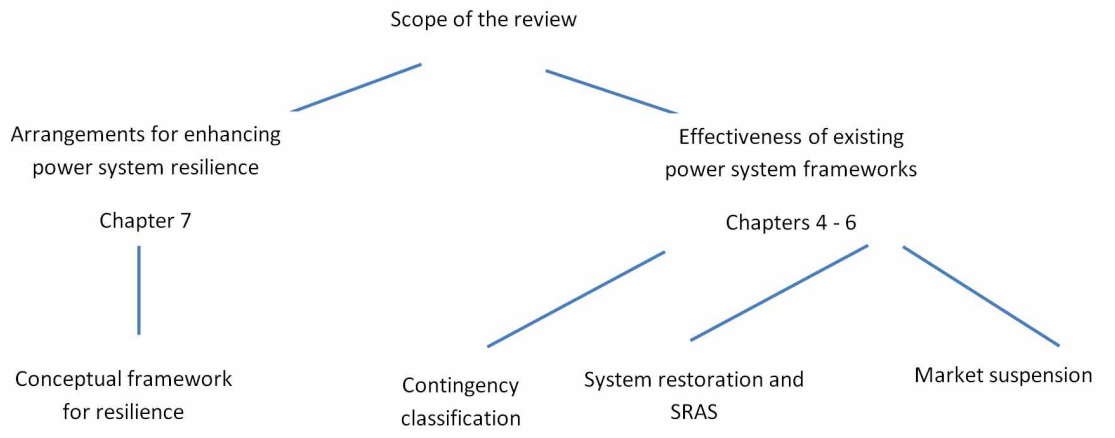
On 16 December 2016, COAG Energy Council provided terms of reference to the AEMC (Commission) to build on the work conducted by AEMO and the AER through identification of any systemic issues that contributed to the black system event in South Australia, or affected the response. The AEMC is required to commence this review when the work of both of AEMO and the AER is complete:

- AEMO published its final integrated incident report into the South Australian black system event in March 2017. As required under clause 4.8.15 and rule 3.14 of the NER, AEMO undertook a detailed examination of the technical issues that contributed to the black system event, including a thorough examination of how each component of the electricity system responded.
- On 14 December 2018, the AER published its assessment into pre- and post-black system event compliance. The AER's published assessment did not consider compliance associated with the circumstances leading to the black system itself, with the AER limiting its reporting to events prior to the loss of transmission lines in SA's mid-north and events following the commencement of system restoration.

With the publication of both the AEMO incident report and AER pre- and post-event compliance report, the Commission has commenced its review as required by COAG Energy Council. However, the AER has not yet published a compliance report or issued any findings related to the black system event period itself (taken to be the 87 seconds between the loss of transmission lines in the mid-north of South Australia and the black system). As a result, the review will focus its assessment on the pre- and post-stages of the event. The Commission will defer consideration of the black system event period itself, until such time as the AER has publically reported or otherwise issued findings on compliance during this period.

1 While most supply was restored within 8 hours, transmission line damage delayed final restoration to the whole state until 11 October 2016.

Figure 1: Scope of the review



Source: AEMC

Figure 1 illustrates the scope of this review and structure of this issues and approach paper. The scope of the review reflects the specific requirements set out in the review's terms of reference. Requirements in the terms of reference can be divided into the following two broad categories:

- whether existing system security frameworks and procedures operated effectively leading up to, during and following the event (addressed in Chapters 4 - 6 of this paper), and
- whether power system security frameworks are sufficient to manage high impact, low probability (HILP) events, and whether improvements in existing processes, tools available to the system operator or components of the electricity system in South Australia would assist in preventing future black system events (addressed in Chapter 7 of this paper).

COAG Energy Council's terms of reference are provided in full at the end of this executive summary and further information on the Commission's approach to addressing these terms of reference is provided in Chapter 1.

Systemic issues identified by the review will be considered in light of work completed by the Commission and AEMO since the black system event. The Commission has made a number of rule changes since 28 September 2016 which are relevant to the scope of this review. These include changes to address reductions in system fault level and inertia arising from generating mix changes (managing fault levels rule 2017, managing the rate of change of power system frequency rule 2017). In addition, the Commission has made changes to improve the observability, controllability, and operational flexibility of the power system in responding to extreme events (emergency frequency control schemes rule 2017, generating system model guidelines rule 2017). Standards for generator technical performance and power system frequency have also been revised to make the power system better able to withstand extreme disturbances (generator technical performance standards rule 2018, review of the frequency operating standard - stage 1, 2017).

AEMO has also made relevant changes since the black system event. In its incident report, AEMO made 19 recommendations for changes to its internal processes, systems and guidelines which have since been progressed. While AEMO and the Commission have made significant changes since 28 September 2016, areas for future development remain. The review will identify these areas and either make specific recommendations for change to NER frameworks or identify alternate future work streams in which specific recommendations will be made.

This issues and approach paper has been prepared to facilitate public comment on the systemic issues arising in respect of the South Australian black system event and Commission's approach to progressing the review. The following sections summarise the issues which are considered in detail in coming chapters of this paper.

Contingency classification

The COAG Energy Council's terms of reference required the Commission to consider AEMO and the AER's findings on whether existing power system security frameworks and procedures operated effectively leading up to the event. The following specific issues are considered:

- non-traditional system security risks and the contingency classification framework
- criteria and guidelines for re-classification, and
- interaction between the reclassification and protected event frameworks for managing non-credible contingency events.

Non-traditional system security risks and the contingency classification framework -The AER identified a number of issues related to the operational management of risks given high wind speeds during the pre-event period. Key amongst these was the extent to which the contingency classification framework, as set out in the NER, could be applied to manage non-traditional system security risks, such as those from rapid changes in wind farm output due to excessively high wind speeds.

In addition to these kinds of events (associated with changes in wind farm output), there may be other non-traditional generation events which could represent a risk to power system security, but not fall within a traditional view of what constitutes a contingency event eligible for management via re-classification. In this review, the Commission will therefore consider whether the framework for contingency classification is sufficiently flexible to address the system security risks associated with non-traditional events affecting power system security.

Reclassification criteria and guidelines - The NER requires AEMO to develop criteria for the reclassification of non-credible contingency events, given abnormal conditions, which the NER lists as including (without limitation) severe weather events, lightning, storms, and bush fires.

The AER identified a number of issues with AEMO's published reclassification criteria. In particular, the AER found that while AEMO had prepared detailed criteria for reclassifying the loss of transmission lines due to bushfires or lightning, there were no criteria provided for storms or severe weather conditions, as applied in South Australia on 28 September 2016.

The Commission notes that current rule arrangements do not mandate or provide guidance to AEMO as to which abnormal conditions should be covered by detailed criteria for re-classification. In light of the AER's findings, the review will consider whether current rule arrangements are appropriately detailed and specific in the guidance provided to AEMO in respect of the re-classification criteria.

Interaction between the reclassification and protected event frameworks - Protected events are a subcategory of non-credible contingency events. The concept of a protected event was introduced as part of the Commission's *Emergency frequency control schemes* rule made in 2017. Both contingency re-classification and protected events provide AEMO with mechanisms to manage some non-credible contingency events.

The Commission considers that these related power system security frameworks (such as contingency classification and protected events) should be consistent with each other and have clearly defined objectives in order to prevent confusion and regulatory uncertainty. As discussed above, the potential uncertainty associated with the kinds of events that can be addressed through reclassification, suggests that there would be benefit in holistic consideration of the interaction between the protected events and reclassification frameworks, to ensure clarity as to their respective roles in managing non-credible events.

System restart ancillary services

System Restart Ancillary Services (SRAS) are provided by generators with the ability to restart themselves independently of the electricity grid. Once they have restarted, they then provide enough energy to restart other generators and commence the processes of system restoration. This involves re-energising subsequent generators, with blocks of customer load brought on to stabilise the voltage and frequency of the electricity in the grid. The number of generators and blocks of customer load are gradually built up until the full electricity system is restored.

A number of issues arose during the re-start process after the black system event on 28 September 2016, most notably the failure of SRAS generators in South Australia to deliver services as contracted. The AER made a number of recommendations in respect of these issues. In this review, the Commission will therefore consider the following issues:

- roles and responsibilities of the NSP in SRAS testing and system restart services, and
- role and content of local black start procedures.

Roles and responsibilities of the network service provider in SRAS testing and system restart services - During restoration, Origin Energy's Quarantine Power Station (QPS) was not able to deliver SRAS due to the switching configuration used by ElectraNet (the South Australian transmission network service provider). The AER concluded that it was the lack of a clear understanding by each party as to their roles and responsibilities, which led to this failure.

The Commission considers the roles and responsibilities of the NSP in SRAS testing and system restart services to be a systemic issue justifying detailed consideration and the development of specific recommendations.

Role and content of local black start procedures - All generators and network service providers are required to develop Local Black System Procedures (LBSP). The AER identified the purpose and function of LBSP in the rules as being unclear and recommended that the review consider how the role of the LBSP could be clarified and enhanced. The AER considers this lack of clarity to create a risk that participants could understand the requirements of the LBSPs differently from AEMO, leading to a lack of consistency in application of the rules potentially impacting operations during system restoration.

Given the large number of new participants entering the market, often utilising smaller scale, newer technologies, the Commission considers it important to clarify the role and content of the LBSPs. The review will therefore consider this issue as an area for detailed consideration and the development of specific recommendations.

Market suspension

The market suspension period following the South Australian system black event was an unprecedented 13 days long. During this time, AEMO and market participants restored the power system, established the causes of the black system, and implemented new arrangements to maintain system security given the system security vulnerabilities identified in the South Australian power system.

The AER's post event compliance investigation identified a number of issues associated with the clarity of rules frameworks under market suspension. The following issues were identified by the AER in respect of the market suspension period in South Australia following the system black event:

- applicability of market rules during market suspension, and
- rules arrangements regarding the use of quick energy constraints for system security purposes.

Applicability of market rules during market suspension -There are relatively few obligations in the NER explicitly specifying how the market should operate during market suspension. Other areas of the rules do not explicitly reference the extent to which they do, or do not, apply during periods of market suspension. In its compliance report, the AER identified confusion and disagreement as to the applicability of these requirements, such as the requirement to issue market notices, which the rules do not explicitly require during a period of market suspension.

While existing rules provide some flexibility for AEMO during market suspension, an inference that the rules generally have limited application when the market is suspended would create significant regulatory uncertainty. The Commission considers it important to clarify which market rules should apply during periods of market suspension. As a result, the review will include the applicability of market rules during market suspension as an area for detailed consideration and the development of specific recommendations.

Quick energy constraints as system security interventions - The AER's compliance report identified AEMO's use of 'quick' energy constraints to achieve system security outcomes during the market suspension period, without issuing market notices, as raising

questions about the means by which AEMO manages emerging power system security issues without formally directing market participants

A core element of arrangements for market interventions, through directions or any other means, involves transparency. Notification requirements, which apply to directions, give market participants the opportunity to make informed decisions to respond to circumstances. The Commission therefore considers it relevant for the review to consider whether notification requirements should apply to the use of 'quick' energy constraints by AEMO in the absence of a direction.

Frameworks for enhancing power system resilience

The review terms of reference require the Commission to consider the effectiveness of the power system security framework established under the NER for managing high impact, low probability (HILP) events. In addition, the terms of reference require the review to consider any improvements in existing processes, tools available to the system operator or components of the electricity system in South Australia (for example, the availability of additional ancillary/system balancing services, additional interconnection with eastern states) that would assist in preventing a recurrence of the events experienced.

The review considers these requirements through the lens of 'power system resilience' in this issues and approach paper.[2] This paper provides a definition for the concept of resilience, outlines the existing frameworks that fall within it, including the actions taken by the AEMO and the Commission to enhance the resilience of the power system since 28 September 2016. The review will also consider:

- how power system resilience might be enhanced, and
- metrics for measuring power system resilience.

The concept of resilience - The ability of the power system to survive and recover from HILPs can be described as the resilience of the power system. The review will define power system resilience to aid a common understanding between market participants in planning for, and managing the risks associated with HILPs.

Rule changes made to enhance the resilience of the power system since 28 September 2016 – Existing NER frameworks include arrangements for power system resilience and the Commission has made a number of rule changes to enhance the resilience of the power system in response to the South Australian black system event on 28 September 2016. The review will map these existing arrangements and frameworks in terms of their contribution to the NEM's resilience and identify areas in which further framework development is required.

Options for enhancing power system resilience - The resilience of a power system may be enhanced through a range of measures including hardening via a more interconnected grid, and/or a stronger grid. In addition to hardening the power system, introducing smart processes such as intelligent control actions to pre-empt and respond to emergency events

2 Resilience is not defined NER term. It is a term that has only recently been applied to power systems.

as they occur can also enhance power system resilience. The review will consider approaches to assessing economic considerations of different options for enhancing the resilience of the power system.

Metrics - There are costs and benefits associated with enhancing power system resilience. In considering future improvements to existing frameworks, the review will consider the role of different metrics for assessing the costs and benefits of options for enhancing power system resilience.

Next steps

The Commission is intending to publish a draft review report in mid-September and a final review report in December. The Commission will review this publication timetable when further information becomes available from the AER in relation to its compliance review into the black system event itself.

The Commission invites comments from interested parties in response to this approach paper by **Friday 24 May 2019.** Detailed instructions on making a submission are contained in Chapter 1 section 1.4.

COAG
Energy Council
Chair

Mr John Pierce
Chair
Australian Energy Market Commission
PO Box A2449
SYDNEY SOUTH NSW 1235

Dear Mr Pierce John

As you are aware, at its meeting of 7 October 2016, the Council of Australian Governments (COAG) Energy Council (the Council) agreed to direct the Australian Energy Market Commission (AEMC) to review the factors which contributed to the 'black system' event experienced in South Australia (SA) on 28 September 2016. I am writing to request the AEMC undertake this review as per the attached Terms of Reference (TOR).

The review should build on work being conducted by the Australian Energy Regulator (AER) and the Australian Energy Market Operator (AEMO), focused on the compliance of market participants with requirements in the National Electricity Law and National Electricity Rules and technical issues contributing to the event respectively. The AEMC should consult with AEMO, the AER, ElectraNet, SA Power Networks and the SA Government in conducting the review, along with other stakeholders as appropriate. The AEMC is requested to advise the Council on how it proposes to conduct the review by 1 February 2017, with the final report provided within six months of the completion of both AEMO's investigation report and the AER's compliance report on the 'black system' event.

If you require further information, please contact Mr James O'Toole, Assistant Secretary, Electricity Branch, Department of the Environment and Energy at james.o'toole@environment.gov.au or on (02) 6275 9023.

Yours Sincerely

The Hon Josh Frydenberg MP
Chair
COAG Energy Council
December 16

Secretariat
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TERMS OF REFERENCE

REVIEW OF THE SYSTEM BLACK EVENT IN SOUTH AUSTRALIA ON 28 SEPTEMBER 2016

1. BACKGROUND

South Australia experienced a 'system black' event at 16:18 AEST on Wednesday 28 September 2016. The event occurred during a period of extreme weather.

The Australian Energy Market Operator's (AEMO) updated preliminary report indicates that, immediately prior to the event, a mix of South Australian wind (883 MW) and gas generation (330MW) and imports from Victoria (613MW) were meeting 1895MW of electricity demand from South Australian consumers.

AEMO's updated preliminary report indicates that the sequence of events resulting in system black included the loss of three major transmission lines, generation reductions at a number of wind farms coinciding with a voltage drop at each generator's connection point, a resulting overload and trip of the Heywood interconnector with Victoria leading to the islanding of South Australia from the rest of the National Electricity Market (NEM). This resulted in a rapid reduction in power system frequency, which was greater than the design of the under frequency load shedding scheme, and greater than performance standards required of generation. Accordingly, frequency ultimately fell to zero and generation tripped off to avoid damage.

As required under clause 4.8.15 of the National Electricity Rules, AEMO is currently undertaking a detailed examination of the technical issues that contributed to the event, including a thorough examination of how each component of the electricity system responded. AEMO is also required to report on the suspension of the spot market under clause 3.14 of the Rules. AEMO published a preliminary report on 5 October 2016, an update to the preliminary report on 19 October 2016, and is expected to publish further reports as more information and data is provided.

In addition, the Australian Energy Regulator (AER) is given powers under Section 15 of the National Electricity Law to investigate compliance with the Law and the Rules by market participants and AEMO.

The potential for system black events, such as that experienced by South Australia on 28 September 2016, has led to the initiation of several work streams focused on identifying, and developing solutions to address, vulnerabilities in the grid architecture and operational processes as an increasing proportion of renewable generation is integrated into the NEM.

The Australian Energy Market Commission (AEMC) is conducting the System Security Market Frameworks Review, in cooperation with AEMO. As part of this work the AEMC is considering a number of rule change requests focused on the procurement of and standards for ancillary services which can support power system security. The AEMO's Future Power System Security (FPSS) programme is examining operational challenges arising from the changing generation mix, and technical options to address these challenges. While these work streams are operating to separate timelines, they are interdependent and are expected to collectively inform advice to Ministers on potential system-wide reforms.

2. PURPOSE

The purpose of this review is to build on the work currently being conducted by the AEMC and AEMO through identification of any systemic issues that contributed to the system black event in South Australia, or affected the response, and provide a report to Ministers on:

- Any recommended actions or amendments to the regulatory frameworks, whether the NEL, NER or other jurisdictional instruments, that should be taken to address these broader systemic issues; and/or
- How the recommendations will be addressed in the AEMC's ongoing work programme, to the extent that there are suggested changes to the NER.

The Council of Australian Governments (COAG) Energy Council requests this report under section 6 of the *Australian Energy Market Commission Establishment Act (SA) 2004*.

3. SCOPE

In carrying out this review, the AEMC must have regard to the National Electricity Objective, in particular to have regulatory frameworks that support investment in and operation of infrastructure that provides for the long term interests of consumers.

The AEMC will need to consider the incident report prepared by AEMO under the rules noted above and any compliance reporting on these events by the AER.

In particular the AEMC should take into account any reporting by the AEMO and the AER on:

- the causes of the system black event, including the role of the transmission sector and the role of the generation sector in contributing to the event or the response;
- why a state-wide system black event occurred, rather than being contained within limited parts of the network;
- any conclusions as to whether the power system security frameworks and procedures specified in the National Electricity Rules operated effectively leading up to, during and following the event, in particular, the effectiveness of power system restart processes following the event; and
- any implications of vulnerabilities identified with respect to the South Australian electricity system for the stability and security of the grid as a whole.

The AEMC should take into account any other reports prepared and published concerning the SA events including the findings to date of any of its own current studies that may be relevant. The work of the review should be complementary to, and inform where appropriate, the broader Independent Review into the Reliability and Stability of the National Electricity Market underway.

In the light of any issues identified through the reports or otherwise, the AEMC must consider and report on:

- the needs of high energy users to maintain secure and reliable energy supplies so that they maintain international competitiveness, and how these needs may be met;
- the nature of the economic costs of disruption to the power system, similar to the system black event that occurred in South Australia on 28 September 2016;
- the effectiveness of the power system security framework established under the National Electricity Rules, and other relevant regulatory frameworks to manage high impact, non-credible events;
- any improvements in existing processes, tools available to the system operator or to components of the electricity system in South Australia (for example, the availability of additional ancillary/system balancing services, additional interconnection with eastern states) that would assist in preventing a recurrence of the events experienced; and
- whether additional synchronous generation (or any viable alternative technology with equivalent functionality) in the South Australian region would have helped in preventing the black system event on 28 September 2016 in SA.

4. CONSULTATION

In conducting the review, the AEMC must consult with AEMO, ElectraNet, SA Power Networks, the AER and the South Australian Government. The AEMC may consult with other stakeholders, including consumers and high energy users, as necessary to complete the review.

The AEMC will provide its report to the COAG Energy Council six months after the conclusion of both AEMO's investigation report and the AER's compliance report. The AEMC will provide to the COAG Energy Council an approach setting out how it proposes to carry out its work and including the provision of updates and status reports.

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TABLES

FIGURES

1 INTRODUCTION

South Australia experienced a 'black system' event at 16:18 AEST on Wednesday 28 September 2016. Approximately 850,000 South Australian customers lost electricity supply including households, businesses, transport, community services, and major industries. Most electricity supply was restored in 8 hours; however the wholesale market in SA was suspended for a total period of 13 days.[3] The total cost of the black system event to South Australian business was estimated at 367 million.[4]

The NEM is designed to avoid a black system from a range of events. Arrangements are in place for AEMO to manage the consequences of any credible event that may cause a risk to power system security. Emergency control schemes are in place to automatically reduce load given a serious non-credible event to maintain the core of the power system in an operational state.

A black system event occurs where existing power system security protections do not work effectively, or are insufficient, to prevent a major supply disruption. For these reasons, the black system event in South Australia on 28 September 2016 provides an opportunity to consider how the frameworks in the NER can be improved, particularly in the context of a power system which is changing rapidly.

On 14 December 2018, the AER published its compliance report investigating the black system event in South Australia. This triggered the terms of reference issued by COAG Energy Council to the Australian Energy Market Commission (AEMC or the Commission) to review the factors which contributed to the black system event. COAG specified the purpose of this review is to build on the AEMO incident and AER compliance investigations into the event by identifying any systemic issues that contributed to the black system event, or affected the response.[5] COAG tasked the AEMC to report on:

- any recommended actions or amendments to the regulatory frameworks, whether the NEL, NER or other jurisdictional instruments, that should be taken to address these broader systemic issues, and/or
- how the recommendations will be addressed in the Commission's ongoing work programme, to the extent that there are suggested changes to the NER.

This issues and approach paper has been prepared to facilitate public comment on the issues arising in respect of the South Australian black system event and Commission's approach to progressing the review.

This paper is structured as follows:

- Chapter 1 introduces the review including its terms of reference and scope

3 AEMO, Integrated final black system incident report, March 2017, p. 5.

4 Business SA, Blackout survey results – key findings. https://business-sa.com/getmedia/1b28b42b-0fc3-4ce4-ac24-de71d825c51a/J009159_blackout-Survey-results_v8

5 COAG Energy Council, Terms of Reference – Review of the black system event in South Australia on 28 September 2016, 16 December 2016.

- Chapter 2 introduces NER frameworks relevant to the black system event in South Australia
- Chapter 3 sets out the assessment framework for this review
- Chapter 4 discusses systemic issues arising from the management of risks to the power system during the pre-event period
- Chapter 5 discusses systemic issues arising from system restart process following the black system event
- Chapter 6 discusses systemic issues arising from the market suspension period following the black system event, and
- Chapter 7 discusses arrangements for the NEM's resilience.

1.1 Terms of Reference

The terms of reference issued by COAG Energy Council require the review to build on work conducted by the Australian Energy Regulator (AER) in its compliance report and the Australian Energy Market Operator (AEMO), in its technical incident report.[6]

In respect of findings from the AER compliance and AEMO incident reports, the terms of reference require the Commission to consider:

- the causes of the black system event, including the role of the transmission sector and the role of the generation sector in contributing to the event or the response
- why a state-wide black system event occurred, rather than being contained within limited parts of the network
- any conclusions whether the power system security frameworks and procedures specified in the National Electricity Rules (NER) operated effectively leading up to, during and following the event, in particular, the effectiveness of power system restart processes following the event, and
- any implications of vulnerabilities identified with respect to the South Australian electricity system for the stability and security of the grid as a whole.

In providing its report to the COAG Energy Council, the terms of reference also require the Commission to consider and report on:

- the needs of high energy users to maintain secure and reliable energy supplies so that they maintain international competitiveness, and how these needs may be met
- the nature of the economic costs of disruption to the power system, similar to the black system event that occurred in South Australia on 28 September 2016
- the effectiveness of the power system security framework established under the NER, and other relevant regulatory frameworks to manage high impact, non-credible events
- any improvements in existing processes, tools available to the system operator or to components of the electricity system in South Australia (for example, the availability of

6 Ibid.

additional ancillary/system balancing services, additional interconnection with eastern states) that would assist in preventing a recurrence of the events experienced, and

- whether additional synchronous generation (or any viable alternative technology with equivalent functionality) in the South Australian region would have helped in preventing the black system event on 28 September 2016.

This issues and approach paper presents and discusses the Commission's approach to addressing these terms of reference.

1.2 Related AEMO and AER reviews

The terms of reference require the review to build on findings in the AER's compliance report and AEMO's incident report. This section introduces these two related reviews and discusses their status and scope in the context of COAG Energy Council's terms of reference.

1.2.1 AEMO incident report

AEMO published its final integrated incident report into the South Australian black system event in March 2017. As required under clause 4.8.15 and rule 3.14 of the NER, AEMO undertook a detailed examination of the technical issues that contributed to the black system event, including a thorough examination of how each component of the electricity system responded.[7]

AEMO's final incident report considered events leading up to, during, and following the black system. The scope of their assessment was divided into the following sequence of stages:

- **pre-event –** investigated the status of the power system in SA prior to the black system on 28 September 2016 and provided a summary of NER provisions related to AEMO's decisions on pre-event system security
- **the events resulting in the black system –** investigated the sequence of events on the power system that occurred in the SA region of the NEM in the 87 seconds before system shut-down at 16:18:16
- **system restoration and system restart ancillary services –** investigated the sequence of steps taken to restore normal power supply to all SA electricity consumers, and
- **market suspension and subsequent operation –** investigated the sequence of events from the system shut-down to lifting of market suspension on 11 October 2016 at 2230 hrs.

The Commission's review intends to draw from AEMO's incident report primarily for facts regarding the events prior to, during and post the black system event. AEMO also made 19 recommendations for changes in its incident report. Most of these recommendations relate to AEMO's internal processes for managing risks to power system security, improving response to adverse events which may occur, enhancing system restoration, and improving operation

7 AEMO, Integrated final black system incident report, March 2017.

during periods of market suspension. The review will consider any recommendations made by AEMO to the extent that they relate to systemic issues for relevant NER frameworks.

1.2.2 AER compliance report

On 14 December 2018, the AER published its assessment into pre- and post-black system event compliance by AEMO and market participants.[8] The AER's published assessment did not consider compliance associated with the circumstances leading to the black system itself, with the AER limiting its reporting to events prior to the loss of transmission lines in SA's mid-north and events following the commencement of system restoration.

The AER's pre- and post-event compliance assessment addressed the following:

- **pre event compliance -** AEMO and ElectraNet's actions in the lead up to the storm event, and how they met their obligations under the NER given the abnormal weather conditions applying on 28 September 2016
- **system restoration compliance –** the actions of certain participants in relation to the provision and use of System Restart Ancillary Services (SRAS) to restore the network following the black system conditions, and
- **market suspension -** how participants operated during the 13-day period where the spot market in South Australia was suspended, including how AEMO managed power system security during this time.

In addition to the work done by the AER and AEMO, the Commission will also consider a range of other reports prepared and published concerning the SA black system event. These include the Independent Review into the Reliability and Stability of the National Electricity Market ('Finkel Review'), determinations made by the Commission since 28 September 2016 on matters relevant to the black system event, as well as statutory reports and reviews published by other jurisdictions such as the South Australian Government.

1.3 Scope of the review

This section sets out the Commission's approach to setting the scope of the review. In particular the:

- Commission's approach to determining the systemic issues arising from the AEMO incident and AER compliance reports,
- implication for the review given the ongoing AER compliance investigation, and
- review's approach to considering changes to existing frameworks and arrangements for future frameworks for enhancing power system resilience.

1.3.1 Approach to determining the scope

COAG Energy Council's terms of reference require the review to identify and report on any systemic issues that contributed to the black system event in South Australia, or affected the response. This review will therefore consider what changes to existing regulatory and market

8 AER, The black system event compliance report, December 2018.

frameworks are necessary to address the systemic issues identified in respect of the SA black system event.

The Oxford English Dictionary defines a systemic issue as one relating to a system, as opposed to a particular part of that system. A systemic issue in the NEM can therefore be taken as one which relates to the function of the NEM as a whole including the effective function of both the physical and regulatory elements of the industry necessary for the secure supply of electric energy services in line with the National Electricity Objective.

In this review, issues arising from the South Australian black system event are taken to be systemic to the extent that they relate to the broader set of frameworks for system security in the NER and are not solely limited to the circumstances which applied on 28 September 2016. A simple test is whether an issue arising from the South Australian black system event has material implications for other regions of the NEM or arrangements for the continued secure supply of electrical energy services in line with the NEO more generally.

The Commission does not anticipate making detailed recommendations to deal with each systemic issue identified. Priority will be allocated to those issues which most closely align with the terms of reference and which have not been substantively addressed through other Commission, or relevant AEMO work, conducted since 28 September 2016. In line with the terms of reference, a systemic issue will either be:

- subject to detailed investigation with detailed recommendations made for change to regulatory frameworks, or
- given high level consideration with reference to completed, ongoing, and future Commission work streams, or work being progressed by other market bodies. This approach is particularly intended for issues which have been partially addressed by work completed since 28 September 2016, or work which is currently under way by the Commission, AEMO, or the AER.

The Commission will use the following factors when determining the treatment of identified issues:

- the extent to which the issue aligns with the factors specified by the terms of reference for consideration and reporting
- the extent to which the issue is addressed by both the AEMO's incident report and AER's pre- and post-event compliance report
- whether work conducted since 28 September 2016 has addressed the identified systemic issue, and
- whether the issues can be reasonably and practicably addressed in the time-frames available to the review.

1.3.2 Scope of the review

COAG Energy Council's terms of reference require the Commission to build on the findings from the AER compliance and AEMO incident reports in considering whether the power system security frameworks and procedures specified in the NER operated effectively leading

up to, during and following the event. This element of the review's terms of reference speaks to systemic issues relevant to existing frameworks in the NEM.

With the publication of both the AEMO incident report and AER pre- and post-event compliance report, the AEMC has commenced its review as required by COAG Energy Council. While the AER has not yet published a compliance report or issued any findings related to the black system event period itself, the Commission intends to progress this review and will use the AER's assessment of the pre- and post-stages of the event. The AEMC will supplement the facts and assessment relevant to its work, as necessary, once the AER has publically reported or otherwise issued findings on compliance during the black system event itself.

In addition to considering the effectiveness of existing frameworks, COAG Energy Council's terms of reference also require the Commission to consider the following:

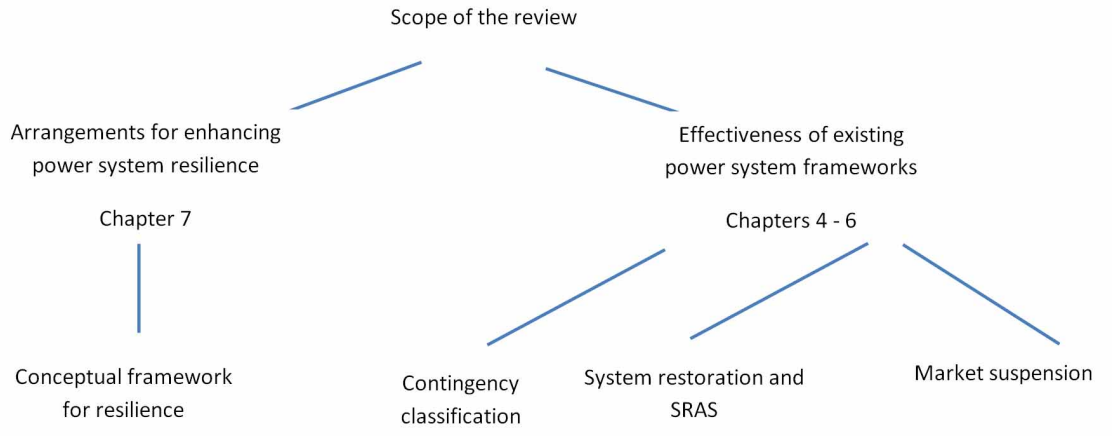
- the effectiveness of the power system security framework established under the NER, and other relevant regulatory frameworks to manage high impact, non-credible events, and
- any improvements in existing processes, tools available to the system operator or to components of the electricity system in South Australia (for example, the availability of additional ancillary/system balancing services, additional interconnection with eastern states) that would assist in preventing a recurrence of the events experienced, and whether additional synchronous generation (or any viable alternative technology with equivalent functionality) in the South Australian region would have helped in preventing the black system event on 28 September 2016 in SA.

The Commission interprets these terms as requiring the review to consider the evolution of NER frameworks beyond the current arrangements for managing system security in the NEM. In particular, these terms speak to the concept of power system resilience, which may involve a set of arrangements or systems or obligations, over and above those currently included in the NEM to manage system security, specifically for managing high impact low probability events such as the tornadoes and storm cells which bought down the transmission lines in South Australia leading to the black system.

The review will provide detailed consideration and make detailed recommendations addressing the systemic issues with the existing frameworks, and will also consider the terms of reference involving resilience to high impact, low probability events and the role of additional system services or interconnection that are part of, and could improve, power system resilience.

The Commission has structured the scope of this review to include specific issues related to the pre-event and post-event stages of the black system event and high level consideration of future frameworks addressing non-credible contingencies, or HILPs, more generally. Figure 1.1 illustrates the scope of the review including the consideration of existing and future frameworks for power system security.

Figure 1.1: Scope of the review



Source: AEMC

1.4 Review process and consultation

The terms of reference require the Commission to provide its report to the COAG Energy Council six months after the conclusion of both AEMO's investigation report and the AER's compliance report. As at the publication of this issues and approach paper, the AER has solely reported on the pre- and post-event stages of the black system event. Given the AER has not yet reported on the black system event itself, we do not consider that the six-month timeline specified in the terms of reference has yet been triggered.

As the Commission does not know when the AER will be publishing findings on the black system event itself, the review is being planned on a stand-alone basis. The Commission intends to review the time-lines for delivery of the review once further information is available from the AER. As at this time, anticipated review publication dates are presented in Table 1.1.

Table 1.1: Review deliverables

PUBLICATION	ANTICIPATED PUBLICATION DATE
Issues and approach paper	18 April 2019
Draft review report	mid September 2019
Final review report	December

COAG Energy Council's terms of reference require the Commission to consult with AEMO, ElectraNet, SA Power Networks, the AER and the South Australian Government. Terms of reference also allow the Commission to consult with other stakeholders, including consumers and high energy users, as necessary to complete the review.

The Commission plans a mix of public consultation and targeted consultation. The Commission proposes formal bi-lateral meetings with stakeholders specified in the terms of reference at each stage of the project and ongoing ad-hoc meetings as and when required. In addition to these stakeholders we also welcome meetings with other parties. Stakeholders wishing to meet with the AEMC should contact Graham Mills at 02 8296 7800 or graham.mills@aemc.gov.au.

The Commission invites comments from interested parties in response to this issues and approach paper by **Friday 24 May 2019.** All submissions will be published on the Commission's website, subject to any claims of confidentiality.

Electronic submissions must be lodged online via the Commission's website, www.aemc.gov.au, using the "lodge a submission" function and selecting project reference code " EPR0057".

The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated. Upon receipt of the electronic submission, the Commission will issue a confirmation email. If this confirmation email is not received within 3 business days, it is the submitter's responsibility to ensure the submission has been delivered successfully.

If choosing to make submissions by mail, the submission must be on letterhead (if submitted on behalf of an organisation), signed and dated. The submission should be sent by mail to:

Australian Energy Market Commission

PO Box A2449

Sydney South NSW 1235

2 AN INTRODUCTION TO NER FRAMEWORKS RELEVANT TO THE SA BLACK SYSTEM EVENT

This chapter provides an introduction to NER frameworks relevant to the review's scope. The following are introduced:

- system security in the NEM
- system restoration and system restart ancillary services for restoring electricity supply following a black system event, and
- suspension of the market following a system black event.

A number of changes have been made since 28 September 2016 which are relevant to maintaining system security in the NEM. These include rule changes to impose minimum requirements for inertia and fault current, increase technical standards for connecting generators, and implement a new category of contingency, the 'protected event'. These changes are introduced in Chapter 7 as part of the discussion of power system resilience. This chapter provides an overview of core concepts and arrangements which applied in South Australia on 28 September 2016. More detail is provided in each of the chapters discussing issues relevant to existing frameworks (Chapters 4 - 6).

2.1 System security in the NEM

System security relates to the arrangements for managing disturbances to the power system while still being able to balance generation and demand, maintain voltage, frequency, and equipment loading within acceptable technical limits.

The South Australian black system event was a system security incident arising from a set of electrical faults due to severe weather that damaged transmission assets in the mid-north of South Australia. These disturbances were followed by the sustained reduction of 456MW of wind generation, the overloading of the Heywood interconnector, separation of Victoria and South Australia, and an uncontrolled reduction in power system frequency which resulted in the loss of all electricity supply to South Australia.[9]

While these disturbances relate to the black system event itself and are therefore outside the scope of the Commission's review, an understanding of system security frameworks is also necessary for a discussion of issues arising from pre-event management of risks to the power system and post event system restoration.

This section therefore introduces the following:

- the concept of credible and non-credible contingencies
- processes for managing system security, and
- contingency re-classification for managing abnormal conditions.

9 AEMO, Integrated final black system incident report, March 2017, p. 32

2.1.1 Credible and non-credible contingencies

A contingency event is a disturbance that poses a risk to the stable and secure operation of the power system. Contingency events are defined in the NER as events affecting the power system which AEMO expects would likely involve the failure or removal from operational service of one or more generating units and/or transmission elements.[10]

Traditional events that represent power system contingencies include electrical faults or the unplanned loss of one or more transmission lines or generating units. Power system security frameworks describe the approach to, and means of, managing such disturbances.

Power system security arrangements are set out in Chapter 4 of the NER and divide the set of all possible contingencies into two categories, those that are considered reasonably possible and those that are not reasonably possible given prevailing conditions. Contingencies that AEMO considers reasonably possible are termed 'credible' contingencies.

Examples of credible contingency events include (but are not limited to) the loss of a single generating unit or major item of transmission plant, other than as a result of a three-phase fault.[11] System security arrangements require AEMO to operate the power system to prevent the loss of any load due to the occurrence of a credible contingency event.[12]

Non-credible contingency events are events which AEMO considers to not be reasonably possible given prevailing conditions. These can include (without limitation) three-phase network faults or the simultaneous failure of multiple generating units or double circuit transmission lines.[13] Non-credible contingencies may still occur but the probability of their occurrence is sufficiently low to make them not reasonably possible. While AEMO is not required to prevent the loss of load given a non-credible contingency, power system security frameworks require the implementation of emergency frequency control schemes as a last line of defence preventing a black system event due to the occurrence of a non-credible contingency.

2.1.2 Processes for managing system security

Power system security arrangements involve the procedures and processes in place to manage the consequences of both credible and non-credible contingency events. The NER defines power system security as the safe scheduling, operation and control of the power system on a continuous basis in accordance with the power system security principles.[14] The power system security principles include the following key elements:[15]

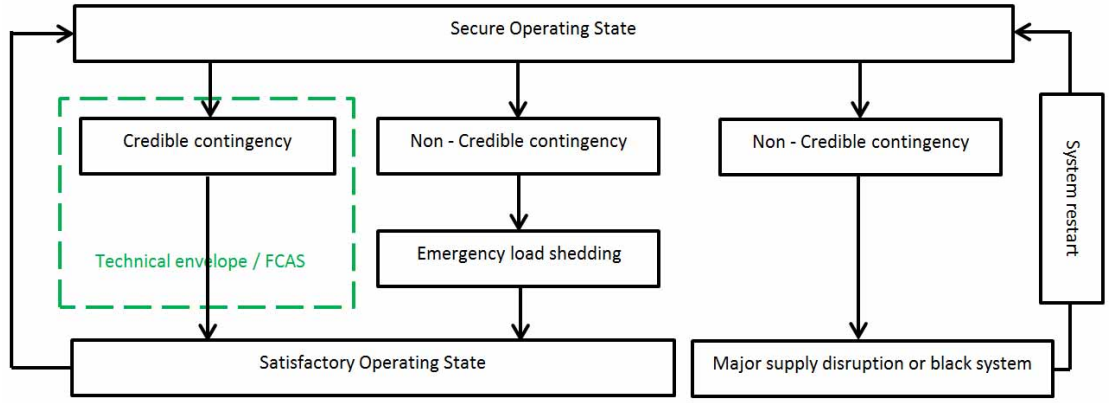
- to the extent practicable, the power system should be operated in a secure operating state

10 Clause 4.2.3(a) of the NER.
11 Clause 4.2.3(b) of the NER.
12 Clause 4.2.4(b) of the NER, with a clause 4.2.2(a) requiring a satisfactory operating state to exclude under frequency load shedding.
13 Clause 4.2.3(e) of the NER.
14 Chapter 10 of the NER, Glossary.
15 Clause 4.2.6 of the NER.

- following a contingency event (whether a credible or non-credible contingency) AEMO should take all reasonable steps to return the power system to a secure operating state as soon as practicable and in any case within 30 mins
- provision for emergency under frequency load shedding should a non-credible contingency occur, and
- sufficient system restart ancillary services should be available to re-energise the system following a major supply disruption such as a system black event.

System security arrangements for managing credible and non-credible contingency events are graphically illustrated as a block diagram in Figure 2.1.

Figure 2.1: Block diagram representation of NEM system security arrangements



Source: AEMC

This block diagram describes system security arrangements through the transition between a secure operating state, satisfactory operating state, or system black given a credible or non-credible contingency event. A satisfactory operating state is achieved when power system frequency, voltage, current, and plant operation is within appropriate ratings and other technical limits.[16] A power system which is in a satisfactory operating state may not however be in a secure operating state. A power system that is in a secure operating state is able to maintain a satisfactory operating state following the occurrence of a credible contingency event.[17] This is sometimes referred to as being N-1 secure to any credible contingency event.

AEMO is required to operate the power system, to the extent practicable, in a secure operating state.[18] In order to remain in a satisfactory operating state following a credible contingency, AEMO applies security arrangements by defining a technical envelope within which the power system is to be operated (the technical envelope represents operating limits applied to each element of the power system) and providing sufficient reactive power and frequency response to manage any credible contingency.[19] These arrangements are

16 Clause 4.2.2 of the NER.
17 Clause 4.2.4 of the NER.
18 Clause 4.3.1 of the NER.

represented by the left most path in Figure 2.1 which shows a credible contingency event surrounded by a dashed green box. This dashed green box represents the security arrangements which maintain the power system in a satisfactory operating state following any credible contingency event.

AEMO is not required to maintain the system in a satisfactory operating state following a non-credible contingency. AEMO is obliged to co-ordinate with Network Service Providers to implement emergency frequency control schemes which shed load or generation to reduce the risk of cascading outages and major supply disruption (such as a system black) should a non-credible contingency occur.[20] This situation is depicted by the middle path in Figure 2.1 which is made up of a non-credible contingency, such as the loss of multiple generating or network elements, followed by the action of emergency control schemes and load shedding in order for the power system to transition to a satisfactory operating state.

A severe non-credible contingency which overwhelms the emergency control schemes may result in a black system. A black system is defined in the NER as the absence of voltage on all or a significant part of the transmission system or within a region during a major supply disruption affecting a significant number of customers.[21] For a black system to occur, all system security arrangements must have been overwhelmed including emergency control schemes as the last line of defence. This was what occurred in South Australia on 28 September 2016. While the NEM is designed to avoid the occurrence of a black system, AEMO is still required to procure system restart ancillary services in the event that a black system occurs (system restart arrangements are discussed in Chapter 5). The path on the far right of Figure 2.1 illustrates the circumstances which applied in South Australia on 28 September 2016 by describing a severe non-credible contingency which leads to a black system event requiring system restoration.

2.1.3 Contingency re-classification for managing abnormal conditions

AEMO is required to form a view on whether a contingency is reasonably possible given the prevailing circumstances.[22] Events which are not reasonably possible, and therefore non-credible, under normal conditions may become reasonably possible, and therefore credible, under abnormal conditions. [23] The NER defines abnormal conditions as conditions posing added risks to the power system including, without limitation, severe weather conditions, lightning, storms, and bushfires.[24] AEMO is required to develop and publish criteria for deciding whether any non-credible contingency has become 'reasonably possible' given such conditions.[25]

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19 The technical envelope is reflected in the operational constraints applied to the operation of the power system. Constraints include inter-regional interconnector flows, intra regional transmission flows, and generator dispatch. These constraints are to reflect thermal, voltage, and transient stability limits in the power system.

20 Clauses 4.3.1(pa) and S5.1.10.1 of the NER.

21 Chapter 10 of the NER, Glossary.

22 Clause 4.2.3(b) of the NER.

23 Clause 4.2.3A(e) of the NER. Assessment of what is and is not reasonably possible is a decision for AEMO to make having regard to all relevant facts and circumstances.

24 Clause 4.2.3A(a) of the NER.

25 Clause 4.2.3B of the NER.

On identifying the existence of abnormal conditions, AEMO is required to identify any non-credible contingency event which has become 'more likely' and notify the market.[26] Should the identified event then proceed to becoming 'reasonably possible', AEMO is required to re-classify the non-credible contingency to become a credible contingency and notify the market.[27] A decision to reclassify allows AEMO to prepare for the identified contingency by taking ex-ante action including adjusting the technical envelope (such as by limiting interconnector flows) and procuring appropriate levels of ancillary services to maintain the system in a secure state, should the contingency eventuate.

Circumstances in South Australia on 28 September 2016 involved abnormal conditions. During the days preceding the 28th, weather services were forecasting a severe storm heading towards SA with severe weather warnings and forecasts of high wind speeds. AEMO identified the storm and high-wind conditions as abnormal conditions and considered re-classifying non-credible contingencies to manage the risks to power system security. AEMO's decisions regarding reclassification were considered by the AER in its compliance report. Implications for NER frameworks identified by the AER in the areas of pre-event risk management are considered further in Chapter 4.

2.2 System restoration and system restart ancillary services

The NER's general principles for maintaining power system security require sufficient system restart ancillary services (SRAS) to be available in accordance with the system restart standard following a major supply disruption.[28] SRAS are provided by generators with the ability to restart themselves independently of the electricity grid. Once they have restarted, they then provide enough energy to restart other generators and commence the processes of system restoration. This involves re-energising subsequent generators, with blocks of customer load brought on to stabilise the voltage and frequency of the electricity in the grid. The number of generators and blocks of customer load are gradually built up until the full electricity system is restored.

AEMO is responsible for procuring sufficient SRAS to achieve the system restart standard at the lowest possible cost.[29] As at 28 September 2016,[30] the system restart standard applying in South Australia required SRAS sufficient to:[31]

- re-supply and energise the auxiliaries of power stations within 1.5 hours such that there is sufficient capacity to supply 40 per cent of peak demand in the sub-network, and
- restore generation and transmission such that 40 per cent of peak demand in that sub-network could be supplied within four hours.

26 Clause 4.2.3A(b)(2) and (c) of the NER.
27 Clause 4.2.3A(g) of the NER.
28 Clause 4.2.6(e) of the NER.
29 Clauses 4.3.1(p) and 3.11.7(a1) of the NER.
30 The System Restart Standard was revised in December 2016 following the black system event.
31 AER, The black system event compliance report, December 2018. 106.

AEMO procures SRAS and enters into an ancillary service agreement with an SRAS provider.[32] This agreement requires contracting generators to provide restart services on instruction by AEMO and demonstrate their restart capability through regular testing. NSPs are not parties to SRAS agreements but have obligations under the rules to negotiate in good faith with a prospective SRAS provider and participate in, or facilitate, testing of a system restart ancillary service proposed to be provided by a prospective SRAS provider.[33]

The system restoration process following a black system event requires close co-ordination between AEMO, SRAS providers and TNSPs. Each party has defined responsibilities and successful restart depends on all parties understanding those responsibilities and acting accordingly. AEMO has primary responsibility under the rules to develop a system restart plan 'for the purpose of managing and coordinating system restoration activities during any major supply disruption' following a black system event.[34] A detailed system switching plan is then developed by each TNSP in order to operationalize the restart options identified by AEMO in its system restart plan.[35] Other generators and NSP's are required to develop Local Black System Procedures (LBSPs) and undertake preparatory steps prior to a major supply disruption.[36]

On 28 September 2016, following the black system event, AEMO and ElectraNet agreed on a restoration strategy. This strategy was to use the SRAS capable Quarantine Power Station (QPS) and to import electricity from Victoria through the Heywood interconnector.[37] As discussed further in Chapter 5, QPS was unable to deliver its contracted SRAS so AEMO and ElectraNet proceeded to re-energise South Australia through the Heywood interconnector. Despite the failure of QPS, AEMO and ElectraNet were able to commence load restoration at approximately 1900 hours and by 2030 hours (four hours after the Black System), approximately 40% of the load that was available for restoration was restored. By midnight on 28 September 2016 (7.5 hours after the black system event), approximately 1,000 MW or 80–90% of load that could be restored had been restored. AEMO gave clearance to restore all remaining load at 1829 hours on Thursday 29 September.[38]

2.3 Suspension of the market following a black system

Following the black system, AEMO suspended the spot market in SA with effect from the trading interval commencing at 16:00 hours on 28 September 2016.[39] On 3 of October 2016, AEMO was satisfied that the market could safely restart as re-energisation was largely complete and the causes of the black system were sufficiently understood. On 4 October 2016, AEMO notified the SA Minister that the market could re-start. However, the SA ministerial direction to suspend the market in SA remained in place. On 11 October 2016 the

32 Clause 3.11.9(a) of the NER.
33 Clause 3.11.9(2)-(3) of the NER.
34 Clause 4.8.12(a) of the NER.
35 AER, The black system event compliance report, December 2018, p. 106.
36 Clause 4.8.12(d) of the NER.
37 AEMO, Integrated final black system incident report, March 2017, p. 70.
38 AEMO, Integrated final black system incident report, March 2017, p. 73.
39 AEMO, Integrated final black system incident report, March 2017, p. 82

SA ministerial direction was revoked and AEMO re-started the market 13 days after the black system event.[40] The NER provides AEMO with the authority to suspend the operation of the spot market if any of the following occur:[41]

- the power system has collapsed to a 'black system'
- AEMO has been directed to suspend the market by a participating jurisdiction, or
- AEMO has determined it cannot operate the spot market in accordance with the NER.

Chapter 3 of the NER sets out arrangements applying to a market suspension period. If the market is suspended, then to the extent that AEMO, in its reasonable opinion, considers practicable, the procedures for operating central dispatch must be used supplemented with directions issued to registered participants as required to operate the power system.[42] AEMO therefore has some discretion, and it is open to manage the market suspension as it considers appropriate, subject to being in accordance with any applicable rules.

Prices are set according to one of a number of methods to provide price control during a market suspension period. At the time of the SA black system event, the NER specified a hierarchy of four possible pricing options including normal dispatch pricing where AEMO considers it practical and reasonably possible to do so. If normal dispatch pricing is not possible AEMO can use pricing based on a neighboring region, pre-dispatch pricing, or pricing according to the market suspension pricing schedule.[43] During the SA market suspension, spot prices were determined in accordance with a pre-published 'suspension pricing schedule' of average regional prices which were calculated as the average price in the region for each corresponding trading interval over the previous four billing weeks.[44]

AEMO's obligations to maintain power system security are unchanged during times of market suspension. This is particularly relevant to the market suspension period following the black system event as AEMO was subject to an SA government ministerial direction to maintain the expected Rate of Change of Frequency (RoCoF) of the South Australian power system to within +/- 3Hz/s. This requirement raised issues related to the interaction between the system security and market suspension frameworks which are discussed further in Chapter 6.

40 AER, The black system event compliance report, December 2018, p. 165
41 Clause 3.14.3(a) of the NER.
42 Clause 3.14.5(a) of the NER.
43 Clause 3.14.5(d)(g)(j) of the NER in force at the time of the SA black system event.
44 AEMO, Integrated final black system incident report, March 2017, p. 83.

3 ASSESSMENT FRAMEWORK

This chapter sets out the assessment framework for how the Commission will conduct this review, specifically:

- the objective guiding the Commission's approach to this review: the NEO
- the principles we will consider in identifying options and making recommendations
- our approach to considering economic costs and trade-offs in the review, and
- the Commission's approach to conducting the review.

3.1 Achieving the NEO

The overarching objective guiding the Commission's approach to this review is the National Electricity Objective (NEO). The Commission's assessment of any recommendations must consider whether the proposed recommendations promote the NEO. Similarly, with any related rule changes, the Commission must consider whether the proposed rules promote the NEO.[45] The NEO is set out in section 7 of the National Electricity Law (NEL), which states:

> To promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to -
>
> (a) price, quality, safety, reliability and security of supply of electricity; and
>
> (b) the reliability, safety and security of the national electricity system.

Based on a preliminary assessment of the issues raised, the Commission considers that the relevant aspects of the NEO for further consideration are the efficient operation of the electricity system with respect to the price and security of supply of electricity, as well as the safety and security of the national electricity system.

3.2 Assessment principles

In addition to the NEO, the Commission has set out a number of principles to guide the assessment of options on potential changes to market and regulatory frameworks relevant to the scope of the review. These principles are:

- **Efficient framework design -** When assessing new regulatory frameworks we consider whether these frameworks will be able to identify and balance all costs and benefits to determine the most efficient outcome.
- **Proportionality -** When considering the development of new regulatory frameworks, the materiality of current and potential issues must be assessed, including whether issues can be adequately managed under existing frameworks. In doing so, potential changes under-way in the NEM and the ability of current frameworks to adapt and address the consequences of those changes are considered.

45 Section 88 of the NEL.

- **Technology neutrality -** Regulatory arrangements should be designed to take into account the full range of potential solutions. They should not be targeted at a particular technology, or be designed with a particular set of technologies in mind. Technologies are changing rapidly and, to the extent possible, a change in technology should not require a change in regulatory arrangements. Equally, however, regulatory frameworks should not form a barrier to new technologies, to the extent that the use of those technologies is consistent with the physical safety and security requirements of the NEM.
- **Flexibility -** Regulatory arrangements must be flexible to changing conditions. They must be able to remain effective in achieving system security over the long term in a changing market and power system environment. Regulatory or policy changes should not be implemented to address issues that arise at a specific point in time. Further, NEM-wide solutions should not be put in place to address issues that have arisen in a specific jurisdiction only. Solutions should be flexible enough to accommodate different circumstances in different jurisdictions.
- **Risk allocation -** Regulatory arrangements should be designed to explicitly take into consideration the trade-off between the risks and costs of meeting system security requirements. Risk allocation and the accountability for decisions should rest with those parties best placed to manage them.
- **Effective governance:** When assessing new regulatory frameworks we will consider whether these new frameworks adhere to good governance principles, including:
  - Stability and transparency: Efficient investment and operational decisions are supported by confidence in the maintenance of a secure and safe power system. This confidence will be maintained where the regulatory frameworks for power system security are predictable and transparent.
  - Appropriate allocation of responsibilities: Roles and responsibilities should be allocated on the basis of experience of organisations. Allocation of responsibilities should also reflect the primary function of the organisation.
  - Clear and transparent objectives: Organisations should have clearly defined objectives and adequate operational scope to meet those objectives within the overarching governance framework.
  - Accountability: Organisations should be accountable for how they have met their objectives. This should be enabled through obligations to consult and regular reporting obligations.

3.3 Economic assessment and trade-offs

The COAG Energy Council's terms of reference require the review to consider and report on:

- the nature of the economic costs of disruption to the power system similar to the system black event that occurred in South Australia on 28 September 2016, and
- the needs of high energy users to maintain secure and reliable energy supplies so that they maintain international competitiveness, and how those needs may be met.

This section considers how the Commission will consider economic issues relevant to the terms of reference and issues identified as being in the scope of the review. In particular, the review will consider economic issues and trade-offs as part of:

- developing a conceptual framework for enhancing the resilience of the power system, and
- making specific recommendations for changes to NER frameworks to address the systemic issues arising from the pre- and post-event AER compliance and AEMO incident reports.

The Commission's consideration of economic costs of disruption to the power system, and competitiveness issues for large energy users, will be grounded in a comprehensive literature review. This literature review will cover the economic costs of black system events in general as well as studies investigating the costs associated with the South Australian black system event on 28 September 2016.

3.3.1 Conceptual framework for enhancing power system resilience

As part of its review of the black system event in South Australia, the Commission intends to develop a conceptual framework for enhancing power system resilience.

The Commission will explore how to describe and quantify the economic impact of high impact, low probability events that carry with them a material risk of causing a black system event. This will include how to quantify economic costs of a black system event, and consider whether existing approaches to estimating the costs of supply disruption, such as Value of Customer Reliability (VCR), are fit for purpose when applied to major system disruptions and system black events.

More of the proposed economic elements of this framework is presented Chapter 7.

3.3.2 Economic trade-offs in assessing changes to existing frameworks

In making recommendations for changes to existing frameworks (Chapters 4 - 6) the Commission will balance two key considerations:

- additional costs borne today to provide a higher level of protection against adverse circumstances that affect the power system (which could include additional costs from implementing a stronger, more interconnected, or smarter power system), and
- uncertain future benefits associated with a reduction in the consequences of adverse events.

As an example, the Commission will consider additional costs from possible changes to enhance the management of risks to power system security in response to issues arising from the pre-event period.

When AEMO re-classifies contingency events, it undertakes a range of ex-ante actions, including constraining interconnectors. Constraining interconnector flows can increase the overall costs of generating energy, as limits are placed on the extent to which lower cost generation in one region can be transmitted to serve load in another, higher cost, region.

This cost to consumers needs to be weighed against future benefits associated with a more secure power system which is also able to recover more effectively from a black system event. While there are significant levels of uncertainty associated with the specific benefits of a more secure power system, the consequences of an adverse power system security outcome can be very serious. The black system event in South Australia illustrates the potential severity of adverse system security events.

3.4 Assessment approach

On 31 January 2017, the Commission set out its approach to conducting the review in a letter to COAG Energy Council.[46] In its letter, the Commission proposed three phases of work to progress the review. Each of these phases is described below, along with our intended approach for this review.

Phase 1 - developing a fact base: The first task is to develop a fact base of the events of 28 September 2016. The Commission will draw upon the incident reports prepared by AEMO and the findings of the AER's investigation as the primary resources in developing a fact base. The Commission will also review and capture any other relevant information from other reports and work related to the event.

Acknowledging the amount of time that has passed since the black system event and the extensive amount of work conducted by a range of parties, the Commission will develop the fact base as a literature review of all relevant work conducted by AEMO, the AER and a range of other parties and jurisdictions. This literature review will compile key facts and findings relevant to the review scope and inform detailed consideration of options and recommendations for the development of NER frameworks.

The compiled fact base will include information from, but not limited to:

- AEMO power system incident reporting (as required by the NER)
  - Black System in South Australia - Final Integrated Report, 28 March 2017
  - Black System in South Australia - Third Report, 16 December 2016
  - Black System in South Australia - Update to Preliminary Report, 19 Oct 2016
  - Black System in South Australia - Preliminary Report, 05 Oct 2016
- Grattan Institute, Keeping the Lights on – Lessons from SA
- South Australian Legislative Council - State-wide Electricity Blackout and Subsequent Power Outages
- ESCOSA - 28 September 2016 state-wide power system outage
- The Burns Report - Independent review of the extreme weather event South Australia
- Manitoba HVDC Research Centre, Review of the Black System South Australia Report
- SACOSS submission to the Finkel Review
- Business SA, Blackout survey results

46 AEMC, letter to COAG – review of the system black event in South Australia on 28 September 2016, 31 January 2017.

Phase 2 - assessing issues: The starting point for the review's assessment will be to critically evaluate the findings of AEMO and the AER. However, the review's consideration of the issues will not necessarily be limited to those identified by AEMO and the AER. The terms of reference permit the Commission a wide scope in its considerations including the effectiveness of the power system security frameworks and procedures leading up to, during, and following the event.

The Commission does not intend for the review to focus on any findings by the AER involving non-compliance with requirements under the existing rules framework. The Commission intends to refer to and discuss any findings of non-compliance only to the extent they are relevant to the systemic issues identified as being in the review's scope. In general, the Commission will take a forward-looking view which focusses on delivering regulatory frameworks that are fit for the future in a power system which is undergoing rapid technological change.

The Commission will consider systemic issues initially in the context of the characteristics of the South Australian power system, particularly the continuing transition of that power system away from dispatchable synchronous to variable asynchronous generation. However, the challenges arising from this transition in South Australia will also be related to future challenges anticipated in other regions of the NEM.

Phase 3 - developing recommendations: The Commission will identify changes to market and regulatory frameworks that will be required to address the issues identified through the above process. The review will consider both modifications to existing, and potentially new, mechanisms.

The Commission will assess these options for change and develop recommendations by applying the NEO, the assessment principles, and the approach to economic trade-offs introduced in the above sections. These recommendations will either substantively address the systemic issues or identify alternate work streams in which those issues will be addressed. This approach will manage the breadth of the potential scope, leverage work completed since 28 September 2016 or currently under-way, while also creating a forward-looking agenda for regulatory frameworks which are fit for the power system of the future.

QUESTION 1: ASSESSMENT FRAMEWORK

Do stakeholders agree with the Commission's proposed approach regarding the:

- Assessment principles to be used by the review?
- Approach to considering economic costs and trade-offs?
- Assessment approach?
- Do stakeholders have any other comments or suggestions regarding the assessment framework to be used?

4 CONTINGENCY CLASSIFICATION

The COAG Energy Council's terms of reference require the Commission to consider AEMO and the AER's findings on whether existing power system security frameworks and procedures operated effectively leading up to the event. This chapter addresses this requirement by considering issues arising from the management of risks to power system security in the lead up to the black system event in South Australia.

The following specific issues are considered:

- non-traditional system security risks and the contingency classification framework
- criteria and guidelines for reclassification, and
- interaction between the reclassification and protected event frameworks for managing non-credible contingency events.

4.1 Non-traditional system security risks and the contingency classification framework

In its compliance report, the AER identified a number of issues related to the operational management of risks given high wind speeds during the pre-event period. Key amongst these was the extent to which the contingency classification framework as set out in the NER could be applied to manage non-traditional system security risks, such as those from wind farm feathering.

This section introduces the concept of wind farm feathering and steps through certain events that occurred in South Australia during the pre-event period of 28 September 2016. It then considers whether these kinds of events could be defined as contingency events and be captured by the contingency classification frameworks, and therefore be addressed by AEMO as a system security issue. Finally, it discusses the implications of this uncertainty from the perspective of the structural issues to be considered by the review.

4.1.1 Wind farm feathering and the conditions in South Australia on 28 September 2016

A key issue identified by the AER was that during the period leading up to the black system event itself, rapid variability ("feathering") of wind farm output in South Australia caused flows on the Heywood interconnector to exceed secure limits. For this reason, the AER found that they could not conclusively state that the power system was known to be in a secure operating state during the pre-event period.[47]

On 28 September 2016, and during the days leading up to it, weather services were forecasting a severe storm heading towards SA with forecasts of high wind speeds including gusts of up to 140 km/h.[48] The generation mix serving South Australia during the pre-event period on 28 September 2016 was characterized by high wind generation and high interconnector flows into South Australia from Victoria. With 613 MW served by Victoria via

47 AER, The black system event compliance report, December 2018, p. 60.
48 AEMO, Integrated final black system incident report, March 2017, p. 24.

the Heywood interconnector, only 330 MW (18%) of South Australian demand was being satisfied by South Australian synchronous generation. Wind generation as a proportion of total SA generation exceeded 50% most of the time.[49]

In the lead up to the black system event, AEMO was operating the South Australian power system with interconnector import limits into South Australia set to cover the loss of the largest credible contingency within South Australia, being the loss of the 260 MW Lake Bonney wind farm.[50]

However, during the pre-event period, the AER's analysis found that there were several extended periods during which the Heywood interconnector experienced flows significantly exceeding its import limits. In one case, the import limit exceedence reached 156 MW.[51] This occurred due to rapid reductions in wind farm output in South Australia, which are understood to be least partly due to feathering of multiple distributed wind turbines across the South Australian region (wind speeds at the time significantly exceeded the 90 km/h feathering threshold).[52]

BOX 1: WIND FARM FEATHERING DURING THE PRE-EVENT PERIOD

Feathering is an event which involves a wind turbine's control system detecting excessively high wind speed conditions and adjusting the angle at which the wind turbine blades meet the wind, to reduce the aerodynamic load on the machine. This is a known turbine safety mechanism that affects each turbine according to its local meteorological conditions. It is generally understood that feathering begins to occur for wind speeds of 90 km/hr which was significantly below the forecast maximum wind speed on 28 September 2016. When a wind farm undergoes feathering its active power output can drop significantly, and may remain low for as long as the high wind speed conditions remain.

Feathering is unlikely to uniformly or simultaneously affect all turbines in a wind farm as they are geographically dispersed, but the aggregate output from the wind farm will vary as individual machines enter feathering mode. Under conditions where the average wind speed is consistently high or there are high intensity gusts, numerous machines may stop operating and wind farm output may drop quite quickly and significantly. In regions with high penetrations of wind farms, the aggregate outcome of feathering distributed across multiple wind farms may result in reasonably rapid changes in active power flows within the region, and also across interconnectors with other regions.

In its compliance report, the AER considered that this situation may have represented a risk to power system security, as the actual metered flows on the Heywood interconnector were sufficiently high to raise the possibility of separation between South Australia and Victoria, had the 260 MW largest credible contingency been experienced. That is, the feathering of the

49 AEMO, Integrated final black system incident report, March 2017, p. 25.
50 AER, The black system event compliance report, December 2018, p. 58.
51 Ibid.
52 AER, The black system event compliance report, December 2018, p. 42.

multiple wind turbines pushed Heywood flows to a point where, had the identified credible contingency (loss of Lake Bonney WF) occurred, there was a real risk of excessive flows tripping the Heywood interconnector.[53]

4.1.2 Key considerations

This section considers whether non-traditional events, such as wind farm feathering, can be considered to be contingency events and therefore eligible for management through existing system security frameworks.

As defined in the NER, a contingency is an event affecting the power system which AEMO expects is likely to involve the failure, or removal from operational service, of one or more generating units and/or transmission elements.[54] The concept of what events can be considered 'contingency' events is a critical element in AEMO's ability to maintain power system security during both normal and abnormal conditions.

The concept and definition of exactly what AEMO considers to be a contingency event is directly relevant to the structural issues identified through the AER's assessment of the events of 28 September 2016. This is because the AER found that AEMO did not identify forecast wind feathering events as a contingency event.[55] This meant that AEMO did not then reclassify the loss of generation (due to feathering across multiple affected wind farms) from non-credible to credible contingency status, which in turn meant it did not take ex-ante action to manage the potential consequences of this event. While the AER did not find AEMO to be non-complaint, it considered that the overall security of the power system may have been reduced during the pre-event period due to wind feathering not being identified as a contingency event with action taken accordingly.[56]

Through its investigation of this matter, the AER uncovered a fundamental disagreement with AEMO as to what kinds of events on the power system can be identified by AEMO as a contingency event. This is important as AEMO's decision whether an event is a contingency event directly informs how the event is managed. Once it makes the initial decision to define an event as a contingency event, AEMO then has the ability to decide whether it is a credible or non-credible contingency event, which in turn informs what actions it takes to address the consequences of that event. Identification of an event as a contingency event therefore forms a crucial first step, before AEMO can take actions to address the risks due to the event, through the system security frameworks.

AEMO's view was that the NER contingency identification, classification and reclassification framework caters only for the loss of large generating units or transmission elements, which are sudden and unpredictable events. AEMO argued that dispersed and non-instantaneous

53 AER, The black system event compliance report, December 2018, p. 52 - It is important to note that the AER did not assert that this issue contributed to the actual black system event itself, but rather represented a separate risk that occurred in the pre-event period.

54 Clause 4.2.3(a) of the NER.

55 AER, The black system event compliance report, p. 32.

56 AER, The black system event compliance report, p. 61.

variations in supply or demand, such as caused by feathering of multiple wind farms, are instead addressed through the dispatch process and are not considered a security issue.[57]

In contrast, the AER considered AEMO to have broad, flexible discretion to decide what constitutes a contingency event. As currently defined in the NER, a contingency event is any event affecting the power system which AEMO expects would be likely to involve the failure or removal from operational service of one or more generating units and/or transmission elements.[58] The AER considered that high wind speeds can potentially cause a loss of output, or failure of wind farm generation units, and thus meets the contingency definition of removing from service one or more generating units. The AER therefore considered that the current contingency definition, and classification / reclassification framework allows AEMO sufficient flexibility to deal with system security risks caused by feathering.[59]

While the events of 28 September 2016 involved wind feathering, the Commission notes that similar issues have been identified in several other projects. The applicability of the contingency classification framework to non-traditional events impacting system security, such as sudden unexpected variations in solar and wind generation, have been considered in the following:

- **Lack of reserve declarations rule change request** - AEMO considered "the concept of credible contingency events, generally the loss of large conventional generating units" to be a "simple criterion … traditionally used for assessing short-term reliability, but is progressively becoming less relevant in the changing power system". AEMO then went on to note that "significant, rapid deteriorations in short-term power system conditions now frequently occur due to non-contingency based variations", including forecast errors affecting large scale wind and solar, or stressful ambient conditions reducing thermal plant availability.[60]
- **Reliability Panel's stage one review of the frequency operating standard (FOS) -** a new definition of "generation event" was introduced (a generation event being a specific type of contingency event as defined in the FOS). Previously, this definition had accounted only for instantaneous events, such as trips or unit synchronisation. The Panel amended this definition to also include the sudden, unexpected and significant change in output from one or more generating systems of 50 MW or more, within a 30 second period. This change was introduced to address events where multiple co-located renewable energy generators are commonly affected by a localised change in energy source availability (such as a cloud passing over the sun, or a localised drop in wind speed). It was intended to allow AEMO to manage these sudden changes through the use of contingency FCAS, rather than through regulating FCAS.[61]
- **AEMC reliability frameworks review interim report -** it was acknowledged that AEMO had identified that "the concept of credible contingency may no longer be

57 AER, The black system event compliance report, p. 52.

58 Clause 4.2.3(a) of the NER.

59 AER, The black system event compliance report, p. 32.

60 AEMO, Lack of reserve notices rule change request, 1 August 2017, p. 2 - The project team noted at that time that considerations of the contingency classification framework were out of scope of the rule change.

61 AEMC Reliability Panel, Review of the frequency operating standards – stage one final determination, November 2017, p. 38.

appropriate in the context of reliability and security outcomes in the current environment, where variances from demand and variable renewable generation may be greater than the loss of a largest generator".[62] In the interim report, the Commission noted the complexities associated with making changes to the contingency classification framework, and the issue was not progressed further in the directions paper or final report of that review.

The consideration of non-traditional events such as wind farm feathering in these work programs indicates that the types of events posing a risk to power system security may have changed, in line with the significant changes in the generation mix.

4.1.3 Systemic issues for consideration in the review

The Commission considers a key structural issue to be considered in this review is whether the existing rules frameworks for contingency classification are sufficient to capture the extent of system security risks associated with non-traditional events affecting power system security.

Historically, it may have been the case that a "contingency" could reasonably be held to include only instantaneous events, such as the trip of one or more large generating units, or transmission lines. Other more gradual changes on the power system that affected the supply demand balance occurred slowly and could therefore be reasonably accounted for in dispatch.

Whether this assumption remains reasonable is affected by the rapid change in the nature of the generation mix. In particular, as the generation mix changes to include more variable asynchronous generation, including a larger number of individual smaller capacity units, potentially distributed across a wider area than traditional generation centres. These changes mean that events leading to significant changes in the supply demand balance may increasingly occur over time-frames that span the gap between the instantaneous "security" time-frame and the longer, 5 minute "dispatch" time-frame. These events may also not match the "traditional" consideration of a contingency as specific, instantaneous events such as the loss of one or more generating units or transmission lines, but may rather be slower and distributed in nature.

While wind farm feathering was the particular event observed on 28 September 2016, the Commission considers that there may be other kinds of non-traditional events which may not be captured under some interpretations of the term contingency event. Noting these different interpretations of what can be considered to be contingency events, the Commission considers the applicability of the contingency classification framework to be a material and systemic issue for the review to consider. The Commission therefore proposes non-traditional system security risks and the contingency classification framework to be included in the review scope as an item for detailed consideration and the development of specific recommendations.

62 AEMC, Reliability Frameworks Review – Interim report, April 2018, p. 77.

QUESTION 2: NON-TRADITIONAL SYSTEM SECURITY RISKS AND THE CONTINGENCY CLASSIFICATION FRAMEWORK

The Commission seeks stakeholder views on the following:

- To what extent does wind turbine feathering represent a risk to power system security? Can feathering be adequately managed through the dispatch process?
- Are there any other types of events possible in the existing NEM power system, or in likely future configurations of the NEM power system, which may not be captured by an interpretation of contingency events as single, definable and instantaneous events?
- How are other jurisdictions managing such risks?

4.2 Reclassification criteria and guidelines

This section discusses the criteria for contingency reclassification in the context of events on 28 September 2016. It then considers existing arrangements and whether clarity and transparency in the process of reclassifying contingencies may be enhanced. Finally, it discusses the role of rule arrangements applying to reclassification guidelines from the perspective of the structural issues to be considered by the review.

AEMO did not reclassify any contingency events prior to the black system occurring. The AER found that it was a reasonable decision not to reclassify the loss of multiple transmission lines or the failure of multiple wind generator units during the pre-event period. This is because the super cells and tornadoes which led to transmission lines collapsing were not forecast events.[63] This meant that there was no information available to AEMO that would have allowed it to assess whether the loss of the transmission lines in the mid North of SA had become reasonably possible.

The AER however identified a number of other issues related to the guidelines and criteria used by AEMO to make decisions whether to reclassify contingencies due to the abnormal conditions applying in South Australia on 28 September 2016. While these particular issues were not material in causing the black system event, they are still relevant to whether contingency classification frameworks in the NER are fit for purpose.

4.2.1 Existing arrangements and the South Australian context on 28 September 2016

This section introduces existing NER requirements relating to reclassification criteria and guidelines before considering the relevant factors which applied in South Australia on 28 September 2016.

The NER requires AEMO to develop criteria for reclassification given abnormal conditions, where abnormal conditions include, without limitation, severe weather events, lightning, storms, and bush fires.[64] AEMO is also responsible for reviewing the criteria for

63 AER, The black system compliance report, p. 29.

64 Clauses 4.2.3B(a) and 4.2.3A(a)of the NER.

reclassification every 2 years and making changes accordingly.[65] In reviewing the criteria for re-classification, AEMO is required to consult with relevant stakeholders, ensure that the criteria has regard to the particulars of any risks to the power system arising from abnormal conditions, and publish the criteria on its website as soon as practicable.[66]

In addition, the rules also include obligations regarding the real time, operational process for deciding whether to re-classify a non-credible contingency as a credible contingency due to abnormal conditions. This process includes:[67]

- AEMO is required on a regular basis to make reasonable attempts to promptly obtain all information relating to how the abnormal conditions may affect a contingency event and identify any non- credible contingency event which has become more likely to occur because of the existence of abnormal conditions
- as soon as practicable after AEMO identifies a non-credible contingency event which has become 'more likely' to occur because of the existence of abnormal conditions AEMO must notify market participants, and
- if AEMO decides that the existence of abnormal conditions make the occurrence of a non-credible contingency event 'reasonably possible', it must re-classify the event to be a credible contingency event and notify market participants as soon as is practicable.

The process and criteria for re-classification are currently contained in AEMO's Power System Security Guidelines (PSSG). The PSSG is a power system operating procedure and applies to AEMO and all Registered Participants.[68] AEMO's main reclassification procedures are found in Part 11 of its PSSG, which sets out, among other things:

- AEMO's general approach to reclassifying contingency events
- AEMO's interpretation of its responsibilities with respect to reclassification, and
- AEMO's interpretation of the responsibilities of Registered Participants and System Operators.

The AER reported that early in the morning on 28 September 2016, AEMO staff discussed risks to the power system in South Australia given the approaching storm. The AER reported that, given the abnormal conditions, AEMO identified that the occurrence of a non-credible contingency event (the loss of multiple transmission circuits or generating units) were heightened. AEMO then considered whether there were non-credible contingencies which should be reclassified as credible.[69]

AEMO's focus in this early morning risk assessment was on whether the non-credible loss of the double circuit Heywood interconnector should be reclassified due to the risk of lightning strikes. During AEMO's early morning risk assessment, it was concluded that there was no

65 Clauses 4.2.3B(b) and (c) of the NER.
66 Clause 4.2.4B(d) of the NER.
67 Clause 4.2.3A of the NER.
68 Clause 4.10.1(a)(2) of the NER.
69 AER, The black system compliance report, December 2018, p. 44.

cause to reclassify the loss of the Heywood interconnector as it was not classified as vulnerable to lightning in accordance with the PSSG.[70]

Part 11 of the PSSG contains detailed criteria for reclassifying the loss of transmission lines due to bushfires or lightning. However, there are no detailed procedures on reclassification stemming from other abnormal conditions, such as the high wind speeds forecast for 28 September 2016. Due to the lack of detailed reclassification criteria for storms and high wind conditions, AEMO relies on the advice of the TNSP in order to make a re-classification decision in such conditions.[71] AEMO and ElectraNet discussed the general impacts of the storm during the morning. In this discussion, ElectraNet noted it would be managing outages differently because of the forecast storm however did not advise of any specific risks to its transmission line assets posed by forecast weather conditions.[72]

4.2.2 Key considerations

This section considers rule arrangements relating to the criteria for re-classification given the AER's findings in respect of the South Australian black system event on 28 September 2016.

The AER's compliance report identified a number of issues with the processes for re-classification outlined in the PSSG. These include:

- The criteria for reclassification did not cover the full range of abnormal conditions considered by the rules. The rule lists (without limitation) severe weather conditions, lightning, storms and bush fires as abnormal conditions which pose added risks to the power system that are manageable through reclassification.[73] AEMO's PSSG provided detailed criteria for reclassification for lightning and bushfires but not storms or severe weather conditions as applied in South Australia on 28 September 2016.
- The PSSG lacked a detailed risk assessment framework for assessing whether non-credible contingencies have become 'more likely' or 'reasonably possible'. The PSSG did not detail any process for notifying market participants when a non-credible contingency has become more likely.[74]
- The PSSG did not specify any process through which AEMO seeks advice from other market participants on the likelihood of a non-credible contingency occurring associated with equipment under their ownership or control.[75] This is particularly relevant to reclassification decisions for which the PSSG did not include detailed assessment criteria, such as storms, as AEMO relies on the advice of other market participants for decisions regarding reclassification. The PSSG placed the burden on other market participants to tell AEMO if there is a problem rather than on AEMO to actively ask for advice.[76]

70 AER, The black system compliance report, December 2018, p. 45.
71 AEMO, Power system security guideline, p. 35.
72 AER, The black system compliance report, December 2018, p. 46.
73 Clause 4.2.3A(a) of the NER.
74 AER, The black system compliance report, December 2018, p. 64.
75 AER, South Australian black system compliance report, p. 37.
76 AEMO, Power System Security Guideline, p.23.

AEMO is provided with the authority to make reclassification decisions as part of its management of power system security. This is appropriate as AEMO is the party with the skills and information required to make specific decisions as to power system security and operation of the power system. In providing AEMO with this authority however, the rules require AEMO to develop and consult on criteria which will guide their decision making and provide transparency to the market as to how these decisions are made.

The Commission notes that current rule arrangements do not mandate or provide guidance to AEMO as to which abnormal conditions should be covered by detailed criteria for re-classification. While current arrangements require AEMO to consult with relevant stakeholders every two years and have regards to the particulars of any risks to the power system associated with the various types of abnormal conditions that might arise, the requirement to consult is not subject to the rules consultation procedures. The rules do not provide for a specific guideline in which the re-classification criteria must be published nor provide guidance for what that guideline should specifically contain.

4.2.3 Systemic issues for consideration in the review

The Commission identifies existing rule arrangements relating to the criteria for reclassification and review as systemic and structural issues for consideration by the review.

In light of the AER's findings, there is a question whether current rule arrangements are appropriately detailed and specific. The Commission intends to consider whether additional principles and guidance are appropriate as to which abnormal conditions should be covered by detailed criteria for re-classification. This includes whether further guidance should be provided as to the re-classification criteria addressing risks associated with severe weather conditions and storms.

The Commission also intends to consider whether additional arrangements for the review of reclassification criteria are warranted. The Commission considers efficient operational decisions are supported by confidence in the maintenance of a secure and safe power system. This confidence will be maintained where the regulatory frameworks for power system security are predictable and transparent. Arrangements for the review of criteria used by AEMO for reclassification are a core mechanism for such transparency.

The Commission notes that the rules provide the Reliability Panel with a role to publish principles and guidelines that determine how AEMO should maintain power system security.[77] While the Reliability Panel has not exercised this role or determined guidelines in this area, the Commission intends to consider whether there is a role for the Reliability Panel in enhancing transparency in the review and development of re-classification criteria.

The Commission intends to consider whether additional flexibility is justified for AEMO to consider the consequences of a reclassification decision. If AEMO decides that the existence of abnormal conditions make the occurrence of a non-credible contingency event 'reasonably possible', the rules require that it must re-classify the event to be a credible contingency event. The only relevant factor for AEMO to consider is whether the occurrence of a non-

77 Clauses 4.2.6(b)(2) and 8.8.1(a)(2a) of the NER.

credible contingency event has become 'reasonably possible'. The rules do not provide AEMO any flexibility to take into account the potential consequences of a reclassification decision. A key aspect of the review's assessment criteria is to consider the appropriate allocation of risk, as well as governance issues related to what organisation should do what, based on their function and expertise. As there may be circumstances where the consequences of a reclassification make it an inappropriate decision in the circumstances, the Commission intends to consider whether additional flexibility is justified for AEMO to take into account consequences of a reclassification, alongside the probability of event occurring, in its development of criteria for re-classification.

The Commission therefore proposes to include arrangements applying to reclassification criteria and guidelines in the review scope as an area for detailed consideration and the development of specific recommendations.

QUESTION 3: RECLASSIFICATION CRITERIA AND GUIDELINES

The Commission seeks stakeholder views on:

- To what extent should AEMO rely on the advice of other market participants in order to make reclassification decisions?
- Are stakeholders aware of any other material issues regarding the criteria for, and process of, making reclassification decisions?
- What are stakeholder views as to a role for the reliability panel in the re-classification criteria review process?
- Is there scope for the provision of further guidance in the NER as to how AEMO should make reclassification decisions, particularly in regard to whether the consequences of a reclassification should be considered alongside the probability of an event when making a decision to reclassify?

4.3 Interaction between the reclassification and protected event frameworks

This section introduces the concept of a protected event and the rationale for its implementation given the events in South Australia on 28 September 2016. It then introduces the application made by AEMO for the declaration of a protected event covering high wind speed conditions in South Australia. Finally, it considers the interaction between the contingency reclassification and protected event frameworks from the perspective of the structural issues to be considered by the review.

Contingency re-classification was the sole mechanism available to AEMO to manage the increased risks associated with non-credible contingencies given abnormal conditions at the time of the SA black system event. On 30 March 2017, the Commission made the emergency frequency control schemes rule which introduced the protected event as an additional

mechanism for AEMO to manage power system security risks arising from certain non-credible contingencies.[78]

The protected event framework is relevant to considerations of how to mitigate the effects of high impact, low probability events. The Commission therefore intends to consider the interactions between the protected events mechanism and the contingency classification framework more generally.

4.3.1 Protected events and the South Australian context on 28 September 2016

The concept of a protected event was introduced as part of the Commission's emergency frequency control schemes rule made on 30 March 2017. This rule places an obligation on AEMO to undertake, in collaboration with Transmission Network Service Providers (TNSPs), an integrated, periodic review of power system frequency risks associated with non-credible contingency events. One of the objectives of this assessment is to determine whether it would be economic for AEMO to operate the power system in a way that limits the impact of certain high consequence non-credible contingency events, through the declaration of a 'protected event'.[79]

In its rule change request, the South Australian Government specifically noted that the high percentage of renewable energy generation in South Australia had increased the state's reliance on the Heywood interconnector for South Australia's power system security and reliability. Under normal operating conditions, the South Australian power system can continue to operate securely and reliably. However, this stable electricity supply does rely heavily on the transmission network connecting South Australia remaining in service and uninterrupted.[80] The South Australian Government's rule change request also noted that there is some uncertainty regarding what kind of multiple, non-credible contingencies can be managed through contingency re-classification.

To address these issues, the South Australian Government proposed that an independent body, such as the Reliability Panel, should be able to define specific non-credible system events for which AEMO must maintain system frequency, in addition to credible events. In effect, this would create a new subset category of specified non-credible contingencies that would sit between the two current categories of credible and non-credible contingency events.

By defining the nature of these specified events, AEMO would be able to procure FCAS and take some other limited ex-ante actions to protect against their impacts on power system frequency.[81]

The emergency frequency control schemes rule made by the Commission provides for AEMO to submit a request to the Reliability Panel to have one (or more) non-credible contingency events which it considers may be economically efficient to manage through a mix of ex-ante

78 AEMC, National Electricity Amendment (Emergency frequency control schemes) Rule 2017.
79 AEMC, Final Rule Determination, Emergency Frequency Control Schemes, p.ii.
80 South Australian Government, proposed rule change – system security, 12 July 2016, p. 4.
81 AEMC, Emergency frequency control schemes - consultation paper, p. 15.

and ex-post measures declared a 'protected event'. The rule makes a protected event a subcategory of non-credible contingency events which can be managed through a mix of operational actions, such as adjustment of the technical envelope,[82] as well as ex-post actions, such as automatic under frequency load shedding, or automatic over frequency generation shedding.[83]

4.3.2 Key considerations

The section introduces a key consideration for the Commission being the manner in which contingency re-classification and protected events, which are both mechanisms for AEMO to manage risks to power system security from some normally non-credible events, are complementary given the uncertainty associated with the scope and flexibility provided by the contingency classification framework.

In November 2018, AEMO submitted a request to the Reliability Panel for a new protected event to be declared to manage risks relating to transmission line failure causing generation disconnection and subsequent islanding during destructive wind conditions in South Australia.[84] AEMO considered that the risk of a large loss of generation in South Australia leading to the loss of the Heywood interconnector is increased during destructive wind conditions due to the heightened risk of occurrence and potentially greater magnitude of line failures and other transmission faults. In making its application, AEMO identified the South Australian black system event as justifying the need for a protected event to be declared. If approved by the Reliability Panel, this protected event will allow AEMO to take operational action to protect against an otherwise non-credible contingency, under specified circumstances. This will allow the implementation of constraint equations to mitigate the risk of the contingency.[85]

In making its application for a protected event to be declared, AEMO considered that the loss of multiple unspecified generating units due to forecast destructive wind conditions in South Australia cannot be reclassified from a non-credible contingency event to a credible contingency event under the contingency reclassification framework. AEMO considered reclassification to require the identification of specific power system equipment which is vulnerable to damage from the destructive winds. AEMO cited the difficulty in forecasting the potential impact on specific generating units or damage to transmission infrastructure over a large geographic area as a reason why potential impacts on the power system cannot be determined at a sufficiently localised level to enable reclassification.[86]

The Commission notes the relationship between AEMO's justification for a protected event and the issues considered in this chapter regarding whether non-traditional events which pose a risk to system security can be considered to be contingency events. In particular, AEMO's view that contingency reclassification caters only for the loss of large generating

82 Adjustment of the technical envelope is generally achieved through applying relevant constraints to power system operation.
83 Reliability Panel, AEMO request for a protected event declaration – consultation paper, p. 6.
84 Reliability Panel, AEMO request for a protected event declaration - consultation paper, p. 6.
85 Ibid.
86 Ibid.

units or transmission elements, and that dispersed and non-instantaneous variations in supply or demand do not qualify as contingencies. In contrast, the AER considered that AEMO has broad, flexible discretion to decide what constitutes a contingency event and that the contingency classification framework provided significant flexibility to manage non-traditional events effecting power system security.

Both contingency reclassification and protected event declaration provide mechanisms for AEMO to manage risks associated with certain non-credible contingency events, such as the high impact, low probability events to be discussed in Chapter 7. The extent to which the contingency classification framework provides flexibility for managing non-traditional events impacting power system security, including events of a distributed nature, is currently uncertain and will be considered in detail in this review. The Commission's view on the definition of contingency event and the flexibility provided by the contingency re-classification framework is therefore relevant to the role and function of the protected event framework.

4.3.3 Systemic issues for consideration in the review

The Commission considers that related power system security frameworks should be consistent with each other and have clearly defined objectives. The role and function of protected events and the contingency reclassification framework therefore need to be clear, and consistent to prevent confusion and regulatory uncertainty.

Given the issues identified, and the issues raised around the kinds of events that can be addressed through the reclassification framework, the Commission sees a need for holistic consideration of the interaction between the protected events and the reclassification frameworks, to ensure clarity as to their respective roles in managing non-credible events.

The Commission therefore intends for the review to provide detailed consideration and develop specific recommendations regarding the interaction between the reclassification and protected event frameworks.

QUESTION 4: INTERACTION BETWEEN THE RECLASSIFICATION AND PROTECTED EVENT FRAMEWORKS

The Commission seeks stakeholder views on:

- What are stakeholder views as to the respective roles of protected events and the contingency reclassification framework?
- Do the rules need to specify which type of events are appropriately considered in each mechanism?

5 SYSTEM RESTART ANCILLARY SERVICES (SRAS)

This chapter focusses on the specific issues identified by the AER in respect of restart following the South Australian black system event. The review's approach to considering issues related to the procurement and provision of SRAS in a future power system is included in the review's consideration of power system resilience (Chapter 7).

System Restart Ancillary Services (SRAS) are provided by generators with the ability to restart themselves independently of the electricity grid. Once they have restarted, they then provide enough energy to restart other generators and commence the processes of system restoration. This involves re-energising subsequent generators, with blocks of customer load brought on to stabilise the voltage and frequency of the electricity in the grid. The number of generators and the blocks of customer load are gradually built up until the full electricity system is restored.

COAG Energy Council's terms of reference specifically require the review to consider whether existing system security frameworks operated effectively following the black system event and in particular, the effectiveness of power system restart processes. A number of issues arose during the re-start process on 28 September 2016, most notably the failure of SRAS generators in South Australia to deliver services as contracted. The AER made a number of recommendations in respect of these issues. This chapter addresses the following areas:

- roles and responsibilities of the NSP in SRAS testing and system restart services, and
- role and content of local black start procedures.

5.1 Roles and responsibilities of the NSP in SRAS testing and system restart services

This section firstly introduces roles and responsibilities defined under existing frameworks for system restart in the context of events on 28 September 2016. Conceptual issues are then discussed. Finally, it describes what structural issues will be considered by the review.

System restoration following a black system event requires close co-ordination between AEMO, SRAS providers and TNSPs. Each party has defined responsibilities and successful restart depends on all parties understanding those responsibilities and acting accordingly. In its compliance report, the AER identified a range of misunderstandings and information asymmetries which led to the failure of contracted SRAS resources and produced a longer restart process than otherwise would have been the case.

5.1.1 The role of the NSP given events in South Australia on 28 September 2016

This section introduced the specific issues which arose in South Australia during system restoration followed by a summary of the AER's findings in respect of the clarity of rules arrangements specifying the role of the NSP in prior to, and during, system restart.

During restoration of the network on 28 September 2016, one SRAS generator (Synergen's Mintaro power station) had earlier been declared unavailable, most likely due to lightning

damage, and another SRAS Provider (Origin's Quarantine Power Station (QPS)) failed to deliver its contracted SRAS when called upon by AEMO.[87]

QPS was not able to deliver SRAS due to the switching configuration used by ElectraNet, which caused the protection settings at QPS unit 5 to trip. The AER found that that Origin's failure to provide SRAS as requested delayed auxiliary supply to Adelaide's main generators, requiring AEMO to rely solely on the Heywood interconnector for restart, delaying overall restoration of load for approximately one hour.[88]

The key technical issues identified as resulting in the failure of Origin's QPS were:[89]

1. ElectraNet had a different switching arrangement for QPS in its System Restart System Switching Program (SSP) (which utilised a hard start) to those it used in QPS's SRAS tests (which involved a soft start).[90]
2. Origin and AEMO did not know that the System Restart SSP had a different switching arrangement for Quarantine to that set out in the SRAS test system switching plan.

While the AER found ElectraNet, AEMO, and the South Australian SRAS providers had complied with their obligations under the rules, the AER identified a range of issues relating to the role of the NSP and the sharing of information between parties that undermined the system restoration on 28 September 2016. These included:[91]

- ElectraNet stated '[a]t no time before 28 September 2016 was ElectraNet aware that Origin were not expecting 'hard starting' their generator during actual system restart as per the system restart procedure'.
- Origin had provided some information during the procurement and testing processes regarding its soft start requirements but it was unclear whether the full implications were understood by AEMO at the time.
- AEMO stated that neither AEMO staff nor Origin staff involved in the SRAS testing were aware that the system restart switching procedures developed by ElectraNet were different from those of the SRAS May 2016 test for QPS.

The AER concluded that there was a lack of a clear understanding of roles and responsibilities, and who was responsible for communication and the sharing of information between parties. This included confusion over who was responsible for sharing the system restart System Switching Plan (SSP), the lack of an established practice for ensuring that the System Restart SSP was checked, and there was no established practice for identifying and exploring any difference between the System Restart SSP and the SRAS test SSP.[92]

The AER also identified a need for improved communication and information flows between parties both prior to and during the event. As an example, the AER considered the

87 AER, The black system compliance report, December 2018, p. 102.
88 Ibid.
89 AER, The black system compliance report, December 2018, p. 103.
90 When switching in a soft start manner the larger unit's transformers experience a gradual in-rush of current (as opposed to an instantaneous surge in a hard start).
91 AER, The black system compliance report, December 2018, p. 139.
92 AER, South Australian black system compliance report, p. 140.

procurement process as an opportunity to identify the need for a soft start requirement of QPS5 and for this to be communicated to all relevant parties. The failure of clear communication protocols for technical parameters was therefore a factor in ElectraNet not being aware of QPS's soft start requirements.[93]

5.1.2 Key considerations

Given the circumstances applying in South Australia during the system restoration period, and the AER's findings, the Commission identifies clarity in roles and responsibilities, and effective communication protocols to be key considerations for the review.

The SRAS framework established in the NER defines a bi-lateral relationship between an SRAS provider and AEMO for the provision of system restart ancillary services. In this regard, the Commission notes the AER's view that there is a need to strengthen the applicability of the SRAS process (including procurement, testing and provision) to include NSPs, particularly as NSPs are not parties to SRAS Agreements.[94] The TNSP is required to develop a detailed system switching plan, which is consistent with AEMO's restart plan, but is only required to participate in, or facilitate, testing of an SRAS service provided by a 'prospective' SRAS provider where it is reasonable and practicable to do so.[95] The AER raised concern about the term 'prospective' which appears to limit an NSP's ongoing obligations.

Even though the NSP is not a party to SRAS agreements under existing frameworks, the NSP is central to the procurement, testing and delivery of SRAS (alongside AEMO and the SRAS provider). In this regard, uncertainty in the role of the NSP post the procurement phase is an area the Commission considers relevant for the review to consider, particularly given the failure of QPS due to the system switching sequence used by ElectraNet.

Effective communication between parties is essential for effective system restoration. The Commission notes the AER's recommendation that communication protocols should be extended to cover any preparations for major supply disruption, not just those protocols that apply during a major supply disruption. In the AER's view, the communication protocols that were in place to facilitate the exchange of all information in the implementation of the system restart plan were not sufficiently clear or comprehensive enough.[96] AEMO also considers that the protocols could be improved by including more detailed guidance and facilitating the exchange of information as part of any planning for a system restart, not only at the time of a system restart. [97]

The Commission notes that there have been AEMC and AEMO rule and guideline changes related to these issues during the period since 28 September 2016. These include:

93 AER, The black system compliance report, December 2018, p. 153.
94 AER, The black system compliance report, December 2018, p. 151.
95 Clause 3.11.9(i) of the NER.
96 AER, The black system compliance report, December 2018, p. 193.
97 AER, South Australian black system compliance report, p. 153.

- AEMO making significant revisions to its SRAS guideline to clarify AEMO's expectations of NSPs. These changes address the specific circumstances arising from the events of 28 September by:[98]
  - making it clear NSPs/third party equipment owners are to provide approvals for test procedures and AEMO approval is conditional on this. AEMO included additional guidance in the SRAS Guideline on the matters to be approved, and
  - explicitly reflect AEMO's expectation that the test procedure for SRAS should replicate that used following a major supply disruption and where different, the difference must be justified and documented.
- The Commission made the System restart plan release provisions rule on 20 February 2018 to allow AEMO to disclose the system restart plan to certain parties for the purposes of preparing for, and participating in, system restoration during a major supply disruption.[99]

The Commission considers AEMO's guideline changes to materially clarify the role and responsibility of the NSP. However, as noted by the AER, the SRAS guideline does not currently bind an NSP and the rules require a clearly enforceable obligation for the NSPs to be involved in testing, endorsement, and delivery of SRAS before and after the SRAS provider and AEMO enter into a formal SRAS Agreement. In this regard, the Commission understands that the AER is proposing a rule change to provide clarity as to the NSP's involvement in SRAS process beyond procurement.[100]

In addition, the Commission understands that the AER is proposing an additional rule change to require AEMO and NSPs for each region to jointly prepare written communication protocols which set out the timing of and manner in which information will be exchanged and between which parties, both in preparation for and during a major supply disruption specifically, and the nature of that information.[101]

5.1.3 Systemic issues for review by the Commission

The Commission considers the principles for effective governance (contained in the assessment framework) to be particularly applicable to the role of the NSP specified in the rules in respect of system restoration. Of these principles, the following are considered especially relevant:

- **Appropriate allocation of responsibilities**: Roles and responsibilities should be allocated on the basis of experience of organisations. Allocation of responsibilities should also reflect the primary function of the organisation,
- **Clear and transparent objectives**: Organisations should have clearly defined objectives and adequate operational scope to meet those objectives within the overarching governance framework, and

98 AER, The black system compliance report, december 2018, p. 147.
99 AEMC, National Electricity Amendment (System restart plan release provisions) Rule 2018, 20 February 2018.
100 AER, The black system compliance report, December 2018, p. 151.
101 AER, The black system compliance report, December 2018, p. 151.

- **Accountability**: Organisations should be accountable for how they have met their objectives. This should be enabled through obligations to consult and regular reporting obligations.

The Commission considers the roles and responsibilities of the NSP in SRAS testing and system restart services to be a systemic issue justifying detailed consideration and the development of specific recommendations. The Commission however notes that significant work has been done since 28 September 2016 to address the issues identified in respect of system restoration following the SA black system event. The Commission also notes the AER's two rule changes which are proposed to address remaining gaps in the framework. The Commission will therefore consider the extent to which existing and proposed guideline and rule changes have, or will, address the material issues arising from the AER's findings prior to making any detailed recommendations for change to rules frameworks in this area.

QUESTION 5: ROLES AND RESPONSIBILITIES OF THE NSP IN SRAS TESTING AND SYSTEM RESTART SERVICES

The Commission seeks stakeholder views on:

- Are existing and proposed rule and guideline changes sufficient address the material issues identified by the AER relating to the role of the NSP in SRAS?
- Are there additional facts or matters relevant to the role and responsibilities of the NSP in SRAS testing and system restart which the Commission should consider in the review?

5.2 Role and content of the local black start procedures

This section firstly introduces the role of Local Black Start Procedures (LBSP) under existing frameworks. The AER's concerns are then described in the context of events of 28 September 2016. Finally, it considers the issues from the perspective of the structural issues to be considered by the review.

All generators and network service providers are required to develop LBSP.[102] The AER identified the purpose and function of LBSP in the rules as being unclear and recommend the review consider how the role of the LBSP could be clarified and enhanced.

5.2.1 Role and function of the LBSP given events of 28 September 2016

Complementing AEMO's obligation to prepare a system restart plan is the requirement for each Generator and NSP to develop Local Black Start Procedures (LBSPs). LBSPs are an important set of documents used by AEMO to develop its regional restoration options. The rules require LBSP's to:[103]

- provide sufficient information to enable AEMO to understand the likely condition and capabilities of plant following any major supply disruption, such as a black system event,

102 Clause 4.8.12(d) of the NER.
103 Clause 4.8.12(f) of the NER.

such that AEMO is able to effectively co-ordinate the safe implementation of the system restart plan, and

- appropriately incorporate any energy support arrangements to which a generator or NSP may be a party.

AEMO has an obligation to develop and publish guidelines for the preparations of LBSP's and is responsible for approving LBSP's submitted by generators and NSPs.[104] The LBSP Guidelines set out the information to be provided to AEMO covering the technical requirements and limitations in a restart environment regarding generation and network plant.[105]

Despite the requirement for the LBSP's to be consistent with SRAS agreements and provide information regarding the plant's technical requirements and limitations in a restart environment, Origin did not include the soft start requirement in the LBSP for QPS. While the AER did not find Origin non-compliant, as its LBSP was developed in accordance with AEMO's guideline and had been approved by AEMO, the AER however considered a range of issues to be relevant to the review's consideration, including:[106]

- The need for improved guidance on what is required in an LBSP to provide AEMO with more complete information from Generators and NSPs
- The need for greater consistency with technical parameters relevant to any SRAS agreement
- Improved arrangements for the dissemination of information contained in LBSPs, and
- The need for greater clarity on the overall function and role of the LBSP.

5.2.2 Key considerations

In addition to questions on the level of technical detail required from a generator in an LBSP, there is a disagreement between the AER and AEMO regarding the role and function of the LBSP itself.

Under the rules, there is an obligation for LBSPs to be consistent with SRAS agreements and there is an obligation for NSPs and generators to comply with their LBSP as quickly as practicable.[107] The AER consider this provision indicates that LBSPs were intended to encompass procedures such as the actions Generators (including SRAS Providers) and NSPs will undertake when a major supply disruption is declared at their local level.[108]

AEMO however consider the LBSP Guidelines focus on eliciting information to identify the conditions and capabilities of power system assets after a total loss of supply and are not, in fact, procedures. The purpose of the LBSP is to inform AEMO of the likely capability of the asset in re- energising and maintaining a stable operating state on a potential restart path.[109]

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104 Clause 4.8.12(g) of the NER.

105 *Guidelines for the Preparation of Local Black System Procedures* (the LBSP Guidelines) which were in effect as at 28 September 2016.

106 AER, The black system compliance report, December 2018, p. 152.

107 Clauses 4.8.14(b) and 4.8.12(d) of the NER.

108 AER, The black system compliance report, December 2018, p. 192.

109 Ibid.

This disagreement demonstrates that a potential ambiguity in the rules as to the role and function of the LBSP. The AER therefore sees a risk that participants could understand the requirements of the LBSPs differently to AEMO leading to a lack of consistency in application of the rule. This risk is heightened by the large number of new, smaller participants entering the market with various technologies.

5.2.3 Systemic issues for review by the Commission

Consistent with the principles for efficient governance, the Commission considers that arrangements should have clearly defined objectives and provide adequate operational scope to meet those objectives within the overarching governance framework. Arrangements should also include accountability mechanisms such that participants are kept accountable for how they have met their objectives.

The Commission agrees with the AER that the role and function of the LBSP is currently unclear in the regulatory framework and there are valid concerns as to the integrity, consistency, and completeness of the information being provided by generators and NSPs in their LBSPs. LBSPs are only as useful as the information they contain. This situation has the potential to undermine the integrity of the system restoration process.

Given the large number of new, smaller participants entering the market with various technologies currently entering the power system, the Commission considers this to be a particularly important issue and intends to include it in the scope of the review as an area for detailed consideration and the development of specific recommendations.

QUESTION 6: ROLE AND CONTENT OF THE LOCAL BLACK START PROCEDURES

The Commission seeks stakeholder views on:

- Was there a historic use of the LBSP as a procedural document?
- Are current arrangements regarding the completeness and accuracy of the information contained in the LBSP's sufficient?
- Is the current approach to LBSPs suitable for a future power system with large numbers of smaller generators?

6 MARKET SUSPENSION

The market suspension period following the South Australian system black event was an unprecedented 13 days long. During this time AEMO and market participants restored the power system, established the causes of the black system, and implemented new arrangements to maintain system security given the system security vulnerabilities identified in the South Australian power system.

The AER noted in its compliance report that AEMO had to navigate operating the power system under unprecedented circumstances and that AEMO and SA Market Participants were committed to, and achieved, the safe restoration of power.[110] The AER's post event compliance investigation however identified a number of issues associated with the clarity of rules frameworks under market suspension. This chapter addresses the following issues identified by the AER in respect of the market suspension period in South Australia following the system black event:

- applicability of market rules during market suspension
- rules arrangements regarding the use of quick energy constraints for system security purposes, and
- arrangements for suspension pricing.

6.1 Applicability of market rules during market suspension

This section considers issues related to the applicability of market rules during market suspension. It firstly introduces the circumstances which applied following 28 September 2016 followed by a discussion of the disagreement between AEMO and the AER on the requirement to issue market notices when AEMO is considering intervention. Finally, it considers this uncertainty from the perspective of the structural issues to be considered by the review.

Market suspension is rare, having only occurred once before in the history of the NEM, and involves specific rules and procedures that had limited precedents.[111] AEMO and market participants were therefore operating with very high levels of uncertainty during the market suspension period following the South Australian system black. Given this uncertainty, effective communication, transparency, and clarity regarding the applicability of market rules will be particularly important.

In its compliance report, the AER identified several occasions on which AEMO had not issued market notices when there were foreseeable circumstances that may have required it to intervene in the market through clause 4.8.9 directions.[112] In coming to its view, the AER identified a deeper issue involving confusion and disagreement as to the applicability of these

110 AER, The black system compliance report, December 2018, p. 158.

111 The first market suspension occurred on 8 April 2001 for a period of two hours affecting all regions of the NEM following a market systems (IT system) failure.

112 AER, The black system compliance report, December 2018, p. 158.

requirements, such the requirement to issue market notices, which the rules do not explicitly require during a period of market suspension.

6.1.1 Market suspension and the requirement to issue market notices

This section introduces rules requirements for market suspension followed by the AER's findings relevant to consideration by the review.

There are relatively few obligations in Chapter 3 of the NER explicitly specifying how the market should operate during market suspension. The NER, as it was at the time of the South Australian black system event, set out three requirements as follows:[113]

- the circumstances in which AEMO can suspend the spot market and requirements for AEMO to review and report on the market suspension
- the high-level process for declaring a market suspension and AEMO's ability to issue clause 4.8.9 directions. It also reiterates the requirement for AEMO to report on the market suspension, and
- how AEMO is to determine spot market prices during market suspension, including high-level requirements for AEMO to follow the procedures in the rules for PASA and dispatch requirements of rules 3.8 and 3.9 where practically and reasonably possible (which are the provisions detailing how the spot market is to be dispatched and prices determined when the market is not suspended).

Other areas of the rules do not explicitly reference the extent to which they do, or do not, apply during periods of market suspension.

During the market suspension period AEMO was subject to an SA government ministerial direction to provide sufficient power system inertia to maintain the expected Rate of Change of Frequency (RoCoF) of the South Australian power system to within +/- 3Hz/s.[114] AEMO implemented this direction by maintaining a minimum of three thermal synchronous generator units, (each of not less than 100 MW installed capacity), in-service at all times. AEMO partly used clause 4.8.9 directions to implement this requirement during the market suspension period.[115]

A 4.8.9 direction involves AEMO requiring a Registered Participant to do any act or thing if AEMO is satisfied that it is necessary to maintain or re-establish the power system to a secure operating state, a satisfactory operating state, or a reliable operating state.[116] When AEMO is considering intervening in the market by issuing a direction, the rules require it to immediately publish a notice of any foreseeable circumstances that may require it to intervene.[117]

In its compliance report, the AER identified several occasions on which AEMO had not issued market notices when there were foreseeable circumstances that may have required it to

113 Clauses 3.14.3, 3.14.4, and 3.14.5 of the NER.
114 AER, The black system compliance report, December 2018, p. 169.
115 AER, The black system compliance report, December 2018, p. 171.
116 Clause 4.8.9(a) of the NER.
117 Clause 4.8.5A(a) of the NER.

intervene in the market through clause 4.8.9 directions.[118] In coming to its view, the AER identified a deeper issue involving confusion and disagreement as to the applicability of these requirements, such the requirement to issue market notices, which the rules do not explicitly require during a period of market suspension.

6.1.2 Key considerations

A key consideration for the Commission is the extent to which the rules are unclear as to the applicability of arrangements which are not explicitly specified as applying during periods of market suspension.

The Commission notes the disagreement between the AER and AEMO as to the extent to which rules requirements apply during a period of market suspension, unless explicitly required. The AER considered that NER Chapter 4 obligations which require market notices to be published when AEMO is considering or directing a market participant, continue to operate even when the market is suspended. AEMO however, does not consider the suspension provisions to specifically mandate compliance with any market operation rules other than those which are explicitly specified as applying during a period of market suspension. The AER reported that AEMO consider the regulatory framework for market suspension afforded them the flexibility to apply the NER where it was practical and reasonable to do so when the market is suspended.[119]

A period of market suspension is likely to involve a significant level of uncertainty in underlying power system operations. Given this, it is important for AEMO to have flexibility to apply certain rules arrangements to the extent it is practical and reasonable to do so. Existing rule arrangements provide flexibility to AEMO, particularly in respect of central dispatch, spot market operation, and price determination during a period of market suspension.

While existing rules provide some flexibility for AEMO during market suspension, the implication of the rules generally having limited application when the market is suspended may create significant regulatory uncertainty. In particular, the Commission notes the AER's observation that AEMO's interpretation, when taken to extremes, imply that compliance with dispatch instructions may not be required during a market suspension period unless they are a clause 4.8.9 direction.[120]

The Commission notes the AER's findings that the rules may lack specificity as to which requirements do and do not apply during market suspension. The AER's findings show that current arrangements led to significant levels of confusion during the market suspension period following the system black event. Given the potentially adverse circumstances and high levels of uncertainty which apply during a period of market suspension, the Commission does not consider it desirable for there to be additional confusion and disagreement as to the extent to which rules requirements do or do not apply.

118 AER, The black system compliance report, December 2018, p. 158.
119 AER, The black system compliance report, December 2018, p. 160.
120 AER, The black system compliance report, December 2018, p. 193.

6.1.3 Systemic issues for review consideration

The Commission considers that efficient operational decisions are supported by confidence in the maintenance of a secure and safe power system. This confidence will be maintained where the regulatory frameworks for power system security are predictable and transparent. The Commission considers uncertainty as to which, and whether, market rules apply during a period of market suspension to be a situation not supporting appropriate levels of confidence in regulatory frameworks.

The Commission considers the difference of opinion between AEMO and the AER to indicate that there is merit in exploring whether the NER should be clarified as to the applicability of market rules during a period of market suspension. The Commission therefore considers the value of regulatory certainty to justify detailed consideration of which market rules should apply during periods of market suspension as a material and systemic issue for inclusion in the scope of the review.

> QUESTION 7: APPLICABILITY OF MARKET RULES DURING MARKET SUSPENSION
>
> The Commission seeks stakeholder views on:
>
> - does AEMO require more flexibility than that already available under the rules during a period of market suspension?
> - is it necessary to explicitly specify each rule's application during a period of market suspension? If so, which elements of the rules need to explicitly provide for their application during a period of market suspension?

6.2 Quick energy constraints as system security interventions

This section introduces the concept of a 'quick' energy constraint in the context of how it was used during the market suspension period. It then discusses the uncertainty in the rules regarding the extent to which arrangements for interventions apply to their use. Finally, it discusses arrangements applying to the use of quick energy constraints as system security intervention as a systemic issue for consideration in the review.

The AER's compliance report identified an issue with AEMO's use of 'quick' energy constraints during the market suspension period. The AER identified rule arrangements governing the use of such constraints in the absence of a direction to be unclear and raised questions about the means by which AEMO manages emerging power system security issues without formally directing market participants.[121]

121 AER, South Australian black system compliance report, p. 158.

6.2.1 Quick energy constraints and system security interventions during market suspension

This section introduces quick energy constraints in the context of their use in South Australian on 28 September 2016 along with the questions raised by the AER about the means by which AEMO manages emerging power system security issues without formally directing Market Participants.

Following system restoration and prior to 4 October 2016, AEMO manually dispatched generators by telephone instead of its usual electronic NEMDE system. On 5 October 2016, AEMO was sufficiently confident in to restart NEMDE and provide dispatch instructions issued by the standard methods. This means that, following 5 October, generators were making bids, NEMDE was automatically determining a merit order and issuing dispatch instructions to Market Participants. However, AEMO was still also telephoning generators about dispatch at the same time to manage power system security and stability. Prices at this stage were still being set by the Market Suspension Pricing Schedule.[122]

Following the restart of NEMDE, it became more difficult for AEMO to maintain three synchronous generators on-line to manage power system security as required by the SA ministerial direction to maintain RoCoF of the South Australian power system to within +/- 3Hz/s.[123] By 7 October 2016 the market had been suspended for 9 days. The AER reported that several generators made a commercial decision at this time that they would not operate plant contrary to their bids unless they were formally directed by AEMO. This was attributed to the financial losses they were incurring due to market suspension prices below their cost of operation.[124] It was at this time that AEMO used quick energy constraints to make certain synchronous generators ran to achieve the system security requirement to maintain RoCoF of the South Australian power system to within +/- 3Hz/s.

Quick energy constraints are used by AEMO to set a specific generator's dispatch level. Under normal circumstances, these constraints are generally used when a generator fails to respond to a dispatch instruction and is deemed to be non-conforming. Otherwise, a quick energy constraint will be used when a generator is issued a formal clause 4.8.9 direction to ensure that the generator is dispatched consistent with the direction.

It was AEMO's use of quick energy constraints on an individual generator, out of merit order (where the generator was constrained on at an output level above the output level it had offered to be dispatched at, a particular price), towards the end of the market suspension period, and without formally directing the participant, which represents the issue identified by the AER.[125]

The AER considered that the rules are not clear whether the use of quick energy constraints on an individual generator constitutes a clause 4.8.9 direction or a dispatch instruction. While the AER did not make any compliance finding on this matter, it did raise questions about the means by which AEMO manages emerging power system security issues without formally

122 AER, The black system compliance report, December 2018, p. 170.
123 AER, The black system compliance report, December 2018, p. 171.
124 Ibid.
125 AER, The black system compliance report, December 2018, p. 163.

directing Market Participants and the suitability of the directions/interventions framework for managing future system security risks.[126]

6.2.2 Key considerations

The Commission considers the clarity of rules frameworks for directing market participants to be a key consideration for the review. The Commission notes the AER's finding, that the different rule clauses which could inform whether the use of quick energy constraints constituted a 4.8.9 direction, were inconclusive.[127]

A direction involves AEMO requiring a registered participant to do any act or thing if AEMO is satisfied that it is necessary to do so to maintain or re-establish the power system to a secure operating state, a satisfactory operating state, or a reliable operating state.[128] While a quick energy constraint may force a generator to operate at a certain level, that generator does have the option of bidding itself un-available. Therefore, AEMO's use of quick energy constraints during the market suspension period may have some, but not all, of the characteristics of a direction.

While the use of quick energy constraints may have some characteristics of a direction, current arrangements are unclear as to whether any of AEMO's obligations related to interventions apply when quick energy constraints are used as a standalone measure. A core element of arrangements for interventions, through directions or any other means, involves transparency. Notification requirements, which apply to directions, give market participants the opportunity to make informed decisions to respond to circumstances. It is therefore likely to be relevant for the review to consider whether notification requirements apply to the use of quick energy constraints in the absence of a direction.

6.2.3 Systemic issues for review consideration

The Commission identifies the rules arrangements regarding the use of constraints and directions for system security purposes to be a systemic issue, particularly given the potential for an increasing frequency of use of both. The Commission is however considering frameworks for interventions through other work streams such as the following interventions investigation and pending rule changes:[129]

- investigation into intervention mechanisms and system strength in the NEM
- thresholds for participant compensation following market intervention rule change
- alignment of intervention compensation and settlement timetables rule change
- deadlines for additional compensation claims following market intervention rule change, and

126 AER, The black system compliance report, December 2018, p. 158.

127 The AER investigated two clauses - clauses 3.8.21(i) and 4.8.7(b) of the NER.

128 Clause 4.8.9(a)(1) of the NER.

129 The three pending interventions rule changes have been consolidated under the investigation of intervention mechanisms and system strength. AEMC, Investigation into intervention mechanisms and system strength in the NEM, consultation paper, 4 April 2019.

- enhancement to the Reliability and Emergency Reserve Trader.[130]

While these processes may not consider the specific issue identified by AEMO with respect to the use of quick energy constraints, the Commission will consider whether there is overlap between the issue identified here and the scope of the above investigation and rule changes. To the extent that they do not address this issue, the Commission intends to provide detailed consideration and make specific recommendations for change in this review.

> QUESTION 8: QUICK ENERGY CONSTRAINTS AS SYSTEM SECURITY INTERVENTIONS
>
> The Commission seeks stakeholder views on:
>
> - whether the rules should permit the use of quick energy constraints as a standalone intervention measure?
> - which aspects of the arrangements for directions should apply to the use of quick energy constraints, independent of AEMO actually issuing a direction?

6.3 Suspension pricing

During periods of market suspension, AEMO must determine the spot price and ancillary service prices in a suspended region, according to clause 3.14.5 of the NER. Under clause 3.14.5 and associated procedures, AEMO determines a weekly suspension pricing schedule for each region on a rolling basis, published where possible 14 days before the first day to which the schedule relates. These schedules include a price for each 30-minute trading interval in the billing week, calculated as the average price in the region for each corresponding trading interval over the previous four billing weeks.[131]

The AER found that in administering market suspension pricing including the spot price impacts on other NEM regions and FCAS during the market suspension period, AEMO fulfilled its obligations. AEMO however identified a number of issues with the NER market suspension pricing framework.[132] AEMO's Final Report recommended that AEMO review market processes and systems, in collaboration with Registered Participants, to identify improvements and any associated NER or procedure changes necessary to implement those improvements.[133]

Following discussions with AEMO's Market Suspension Working Group, AEMO submitted two rule changes to the AEMC regarding different aspects of the market suspension pricing regime. In response to AEMO's proposed rule changes:

130 AEMC, Enhancement to the reliability and emergency reserve trader - draft determination, 7 February 2019.
131 AEMO, integrated final incident report, p. 83.
132 AER, South Australian black system compliance report, p. 158
133 AEMO integrated final incident report, p. 105.

- In October 2017 the AEMC made a final ruling that simplifies the process for setting prices if the spot market is suspended, and establishes a simpler, more workable market suspension pricing framework.[134]
- On 15 November 2018 the AEMC made a final rule establishing a new compensation framework so that certain Market Participants who incur losses during a market suspension event can be compensated.[135]

Given the AER's findings, AEMO's work program, and the rule changes made such 28 September 2016, the project team does not identify any systemic issues associated with market suspension pricing and therefore does not recommend that it be included in the review's scope.

QUESTION 9: SUSPENSION PRICING

The Commission seeks stakeholder views on:

- whether there are outstanding issues with suspension pricing arrangements in the NER which should be considered by the review?

134 AEMC, National Electricity Amendment (Pricing during market suspension) Rule 2017.

135 AEMC, National Electricity Amendment (Participant compensation following market suspension) Rule 2018.

7 FRAMEWORKS FOR ENHANCING POWER SYSTEM RESILIENCE

As noted in the introduction (Chapter 1), COAG Energy Council's terms of reference require the Commission to consider:

- the effectiveness of the power system security framework established under the National Electricity Rules (NER), and other relevant regulatory frameworks to manage high impact, non-credible events, and
- any improvements in existing processes, tools available to the system operator or components of the electricity system in South Australia (for example, the availability of additional ancillary/system balancing services, additional interconnection with eastern states) that would assist in preventing a recurrence of the events experienced, and
- whether additional synchronous generation (or any viable alternative technology with equivalent functionality) in the South Australian region would have helped in preventing the black system event on 28 September 2016.

These issues speak to the resilience of the power system in the presence of high impact-low probability disturbances (HILPs). HILPs can be thought of as a subset of non-credible contingencies. Given its terms of reference, the Commission intends to consider the framework for managing such high impact-low probability events, as part this review. This chapter introduces the concept of resilience. It also outlines how it is to be defined, identifies sources of resilience, introduces relevant Commission work since 28 September 2016, and outlines issues relevant to the economic assessment of costs and benefits of measures to enhance resilience.

7.1 Relationship between power system reliability, power system security and resilience

The NEM is currently operated on the basis of maintaining a reliable and secure supply of energy for consumers. While the concepts of reliability and security are inter-related, they are currently managed through different measures and are therefore considered separately.

A reliable power system has enough generation, demand response and network capacity to supply customers with the energy that they demand, with a very high degree of confidence. A reliable power system therefore requires adequate investment and disinvestment as well as appropriate operational decisions, so that supply and demand are in balance at any particular point in time.

Reliability is distinct from system security. A secure system is one that is able to operate within defined technical limits, even if there is a credible contingency event, such as the loss of a major transmission line or large generator.

Security events are mostly caused by sudden disturbances, such as equipment failure caused by a lightning strike or severe weather, that results in the system operating outside of defined technical limits, such as voltage and frequency. The ability of the power system to avoid,

survive and recover from high impact low probability (HILP) events is increasingly being referred to as power system resilience.

For the purposes of this review, the Commission will focus on the concept of resilience only as it applies to system security; that is, the ability of the power system to avoid, survive and be restored from disturbance events.

Changes to operational frameworks to improve resilience could conceivably have flow on consequences that improve reliability outcomes. For example, procuring additional system services like fault current or inertia, may primarily improve resilience, but could potentially also increase available generation supply and therefore improve reliability outcomes.[136]

While these potential interactions between resilience and reliability may occur, they are not the Commission's focus for this review. Separate work programs are being progressed by the Energy Security Board and the AEMC related to the reliability of the NEM.

7.2 Power system resilience

Large, distributed power systems like the NEM are routinely subject to a number of disturbances, of varying severity and frequency. As introduced in Chapter 2, the power system is planned and operated on the basis of the frequency and severity of these disturbances, in terms of the impact that the disturbance has on the operation of the power system.

The majority of the disturbances that affect the operation of a power system are classed as credible contingencies.[137] These are disturbances that occur reasonably frequently, with small to moderate impacts that can easily be modelled.

The NER requires that the power system be operated on the basis of these credible contingencies occurring; the power system must be maintained in a secure operating state, which means that the power system must return to a satisfactory operating state following a credible contingency.

However, power systems can also experience more severe disturbances which occur much less frequently than credible contingency events. These are HILP events that occur much less often and are often difficult to model. As such, their severity is much less predictable and their probability of occurrence much less known.

Power systems can be affected by a range of these more severe disturbances, which can have consequences including the loss of large portions of consumer load, up to and including a black system event. The basis of these disturbances are varied and may include natural events such as floods, cyclones, tornadoes, earthquakes, tsunamis or space weather events.

136 The impact of high impact-low probability events within large distribution networks is also a major concern in some power systems. An example of such an event would be hurricane Sandy in 2012 that resulted in power outages to over 8 million people across 21 states, for days and even weeks. The Commission does not intent to consider the resilience of distribution networks to storms and other high impact-low probability events in its review of the South Australian black system event on 28 September 2016.

137 There are many events that occur and which have no material impact on the power system. These events may occur more or less frequently, however, as their impact on the power system is immaterial, they are not relevant for consideration.

Cyber attacks or physical attacks on power system infrastructure may also severely impact the operation of the power system.[138]

In a general sense, the ability of the power system to survive and recover from HILPs can be described as the "resilience" of the power system. Power system resilience is a relatively new concept and there is not a commonly accepted understanding of what it denotes and how it can be modelled.[139] However, as discussed in further detail below, in this review, we will generally consider power system resilience in the NEM in the context of the following ways in which it responds to high impact, low probability events:

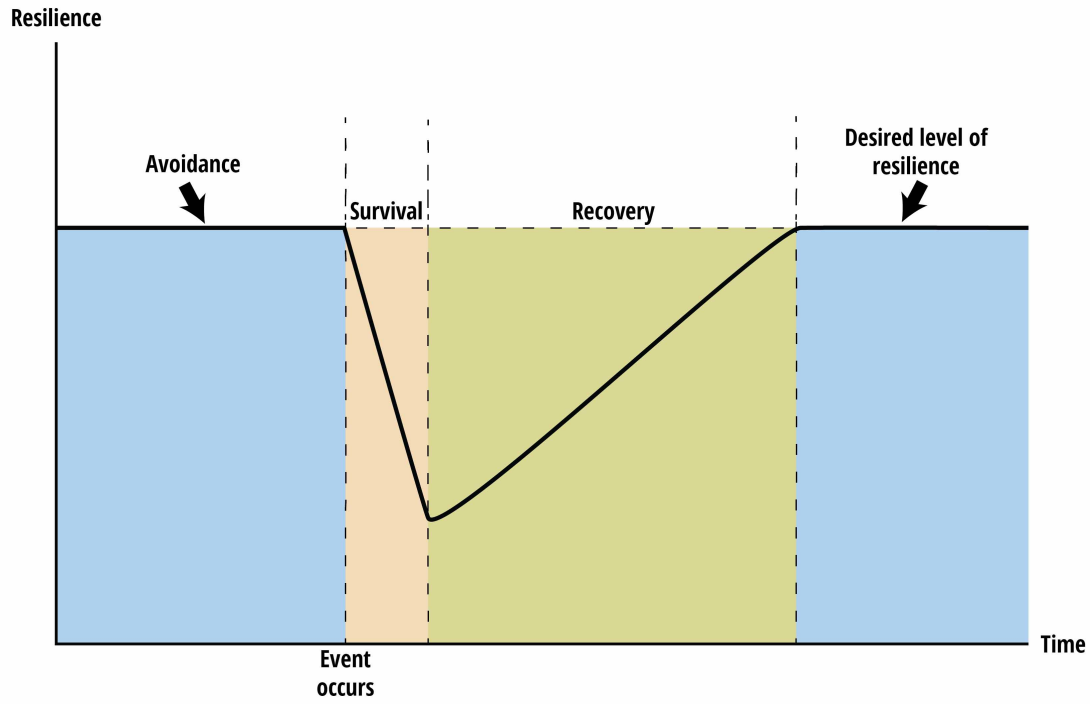
- **avoidance:** the ex-ante prevention, or limitation, of the extent to which the disturbance has an impact on the operation of the power system
- **survival:** the extent to which the power system is able to withstand the disturbance, typically assessed in terms of the system's ability to avoid load shedding, recover to a satisfactory state, and ultimately avoiding a cascading failure that could lead to a black system
- **recovery:** the ex-post ability of the system to be restored to a secure operating state following the disturbance, and
- **learning:** incorporating learning from power system incidents to enhance resilience to future events.

Figure 7.1 illustrates each of these stages (avoidance, survival, and recovery) in response to a high impact - low probability event affecting the power system.

138 While it is also possible that factors endogenous to the power system, such as interactions from distributed energy resources or mal-operation of protection equipment, can have severe impacts on the power system, these are generally not considered as high impact low probability events which are relevant to arrangements enhancing power system resilience.

139 *Power systems resilience assessment: hardening and smart operational enhancement strategies*, M. Panteli, D. Trakas, P. Mancarella and N. Hatziargyriou, Proceedings of the IEEE, Vol. 105, No. 7, July 2017.

Figure 7.1: Power system resilience and avoidance, survival, and recovery



Source: Figure Source

The avoidance phase involves preparing the power system for one of these high impact, low probability events. This can include:

- developing new special protection and emergency control schemes that would limit the severity of a severe event (for example automatic under-frequency load shedding schemes)
- changing generator technical performance standards to enhance the ability of connected generators to withstand disturbance conditions
- reclassification of a non-credible contingency as credible, where there is sufficient cause to do this. This allows for changes to be made to the operating state of the power system, such as reductions in network flows on vulnerable transmission lines, and increasing the quantities of inertia, system strength and other services available, and
- changes to the operating state of the power system such as reductions in network flows on vulnerable transmission lines, and increasing the quantities of inertia, system strength and other services available

The survival of the power system is a measure of the extent to which the functionality of the power system is degraded as a consequence of the high impact low probability event. The ability of the power system to survive the event will depend on:

- the technical performance of generating systems and network being maintained at a sufficiently high standard
- having sufficient inertia, system strength and other services within the power system to be able to ride through frequency and voltage disturbances, and
- the effective operation of special protection schemes and emergency frequency management schemes designed to shed load, generation or trip network elements in order to arrest the progress of a cascading outage.

Following a HILP event, it will be desirable to restore the functionality of the power system to the pre-contingency level. This phase will include:

- a period of time following the disturbance where the status of the power system is assessed and an action plan developed to return the power system to its pre-disturbance level of functionality
- the operation of system restart services, where there has been a major supply disruption or black system event
- restarting of any additional generation necessary to meet demand
- reconnection of supply to affected customers, and
- the repair of damaged equipment, which may take several weeks and be necessary to restore supply to some customers.

Many of these aspects of resilience are already present, to differing degrees, in the existing NER frameworks. For example, as discussed in Chapter 2, the existing system security frameworks set out in Chapter 4 of the NER. Chapter 4 allows for the reclassification of non-credible contingencies to credible, which is a key part of the avoidance stage of resilience. Similarly, the technical capabilities required of generators, as set out in the generator access standards of S5.2.5 of the NER, are relevant to the survival aspects of resilience.

7.3 Enhancing power system resilience

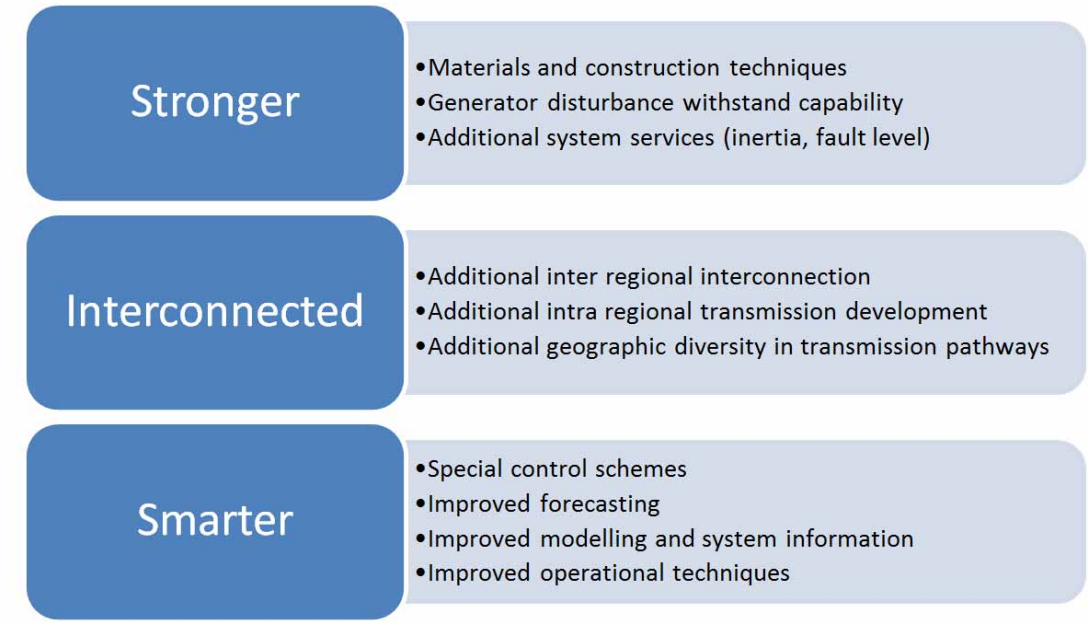
The resilience of a power system may be enhanced through a range of measures. These measures can include a combination of power system hardening and operational measures.[140] Hardening measures can involve a more interconnected grid, and/or a stronger grid. In addition to hardening the power system, introducing smart processes such as intelligent control actions to pre-empt and respond to emergency events as they occur can also enhance power system resilience.

A more interconnected grid involves physical changes to network configuration to make the network less vulnerable to severe events. This can include additional geographic diversity in transmission line siting, re-routing transmission lines to areas less affected by extreme weather, and introducing additional interconnection between regions. Arrangements in the NEM for increasing interconnection are particularly contemplated by the review's terms of reference which require the Commission to consider whether additional interconnection with

140 The Grid: Stronger, Bigger, Smarter?: Presenting a Conceptual Framework of Power System Resilience, M. Panteli, P. Mancarella, IEEE Power and Energy Magazine, June 2015.

the eastern states would assist in preventing a recurrence of the South Australian black system event.

Figure 7.2: Options for enhancing power system resilience



Source: Adapted from - The Grid: Stronger, Bigger, Smarter?: Presenting a Conceptual Framework of Power System Resilience, M. Panteli, P. Mancarella, IEEE Power and Energy Magazine, June 2015

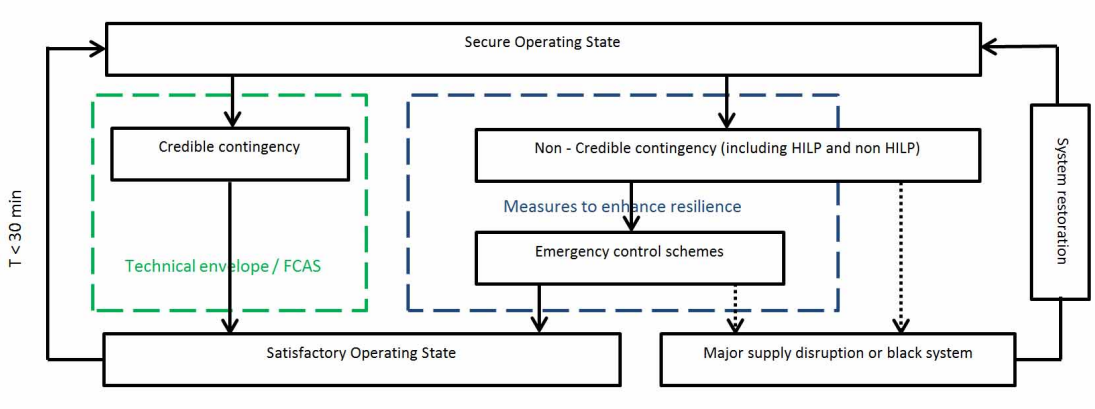
A stronger grid can be achieved by increasing the level of certain power system services (notably inertia and fault level) as well as increasing the ability of generating systems to withstand voltage and frequency disturbances. In South Australia, the retirement of the Northern Power Station in March 2016 reduced the amount of synchronous generation in the SA region and contributed to the loss of physical attributes that have traditionally been provided as an inherent characteristic of energy generated by synchronous generators. The loss of physical inertia was particularly important in the events leading to the South Australian black system event. The review's terms of reference particularly contemplate arrangements for a stronger grid by requiring consideration of whether availability of additional ancillary/system balancing services would assist in preventing another black system event.

A smarter grid can involve a broad set of actions that improve the observability, controllability, and operational flexibility of the power system in responding to high impact low probability events. In addition to decision-making regarding re-classification of certain disturbances, the implementation of special protection schemes which pre-emptively shed load on observation of a high impact low probability event, and improvements in modelling and forecasting of such events, are also examples of smart measures to improve the resilience of the power system. Smart measures may be thought of as additional 'tools' for the system operator as specified by the review's terms of reference.

While the concept of power system resilience is focused on the ability to avoid, survive, and recover from HILPs, enhancing power system resilience may also assist in keeping the power system stable and secure in the presence of credible contingency events. A more interconnected, stronger, and smarter grid may also reduce the operational, and other, measures required to maintain the power system in a secure state under existing frameworks. The benefits of actions to enhance power system resilience will therefore not only include a reduction in the costs associated with high impact low probability events, but may also reduce the ongoing costs associated with the actions AEMO takes to manage power system security.

Figure 7.3 adapts the system security block diagram presented in Chapter 2 to include the concept of resilience. Measures to enhance resilience increase the probability of the power system ultimately returning to a satisfactory operating state following a non-credible contingency (HILP or non HILP) rather than ending in a major supply disruption or black system event. These measures are represented by the dashed blue box.

Figure 7.3: Enhancing system security through a more resilient power system



Source: AEMC

7.4 Power system resilience and relevant work completed since 28 September 2016

The Commission has made a number of relevant rule changes since the SA black system event in 2016. Both the Commission and AEMO's work programs have been undertaken in the context of recommendations made by Chief Scientist Alan Finkel in the Independent Review into the Future Security of the National Electricity Market (the Finkel Review).[141] This section introduces relevant work that has been completed since the SA black system event, divided into changes which make the power system stronger, smarter, and more interconnected.

141 Commonwealth of Australia, Independent Review into the Future Security of the National Electricity Market - Blueprint for the Future, June 2017.

7.4.1 A stronger power system

Synchronous generators provide a set of inherent system services associated with the inertia and fault current produced by the rotating masses of synchronous generator turbines. Inertia and fault level act to stabilise power system frequency and voltage in the event of a disturbance event. As system strength and inertia have declined in parts of the NEM such as South Australia, the power system in these areas will experience voltage and frequency disturbances that are deeper, more widespread and longer lasting, undermining the stability, security, and resilience of the power system.

Historically, these critical system services were inherently provided as a bi-product of synchronous generation. They were in plentiful supply as the power system was dominated by synchronous generating systems. However, a changing generating mix is seeing these inherent services decline as aysnchronous, inverter connected, generation (such as wind and solar PV) do not provide inertia or system strength at comparable levels. The South Australian region is a case in point. The black system event exposed a set of vulnerabilities which had emerged in South Australia due to low fault levels and very low levels of synchronous inertia due to the retirement of synchronous generating systems.

The Commission's system security work program has taken a first step towards defining the 'missing services' identified due to declining levels of synchronous generation in the power system. Relevant rule changes include the:

- **Managing fault levels rule -** specified a process and allocated roles and responsibilities for maintaining power system fault currents above the minimum level required for system security. [142]
- **Managing the rate of change of power system frequency rule -** provided a mechanism and specified roles and responsibilities for maintaining inertia at sufficient levels to prevent rates of change of frequency exceeding critical levels following a contingency.[143]

The other element of a stronger power system is its ability to withstand disturbances without causing a cascading generator outage. Following the South Australian black system event, the Commission has enhanced requirements for generating systems to maintain continuous uninterrupted operation given multiple disturbances. Relevant rule changes include:

- **the Generator technical performance standards rule -** amended technical requirements for connecting generators to require higher capabilities to maintain continuous uninterrupted operation given multiple disturbances as well as providing critical power system voltage support during disturbance conditions.[144]

7.4.2 A smarter power system

A smarter grid can involve a broad set of actions that can improve the observability, controllability, and operational flexibility of the power system in responding to extreme

142 AEMC, National Electricity Amendment (Managing power system fault levels) Rule 2017.
143 National Electricity Amendment (Managing the rate of change of power system frequency) Rule 2017.
144 National Electricity Amendment (Generator Technical Performance Standards) rule 2018.

events. Following the South Australian black system event, which involved the failure of the existing emergency under frequency load shedding system, the Commission made a rule change which included an enhanced regime for planning for and managing high impact non-credible events. The Emergency frequency control schemes rule includes arrangements for the implementation of special protection schemes which pre-emptively shed load on observation of a high impact event. Relevant rule changes include the:

- **Emergency frequency control scheme rule -** implemented a framework to regularly review current and emerging power system frequency risks, an enhanced process to develop emergency frequency control schemes, and implemented a new classification of contingency event, the protected event, giving AEMO new tools to manage non-credible contingencies.[145]
- **Generating system model guidelines rule -** clarified the scope and level of detail of model data that registered participants and connection applicants are required to submit to the Australian Energy Market Operator (AEMO) and network service providers. The Generating system model guidelines rule enhances AEMO's ability to accurately model power system behaviour under low system strength conditions as apply in South Australia.[146]
- **Review of the frequency operating standard - stage one determination** - revised of the definition of 'generation event' to include the sudden, unexpected and significant change in output from one or more generating systems of 50MW or more within a 30-second period. This revision is being made it clear that AEMO is able to use contingency FCAS to manage sudden variations of generation output from the increasing quantity of larger variable renewable generation power stations.[147]

7.4.3 A more interconnected power system

AEMO, in its Integrated System Plan, has identified a need for additional interconnection between South Australia and NSW. The security and resilience of South Australia's power system is challenged by its reliance on the Heywood interconnector, following the retirement of Northern Power Station.[148] The ability to securely operate the power system in SA relies on the transmission network connecting South Australia to Victoria remaining in service and uninterrupted. Risks associated with this reliance on the Heywood interconnector are most acute when there are high flows from Victoria to South Australia, as was the case during the pre-event period on 28 September 2016. The Commission is currently considering a rule change which will speed up the regulatory processes associated with the development of this additional interconnector.

- **Early implementation of Integrated System Plan priority projects –** the Commission is currently considering a proposed rule change to streamline regulatory processes for three projects (including an additional interconnector between South

145 National Electricity Amendment (Emergency frequency control schemes) Rule 2017.
146 National Electricity Amendment (Generating System Model Guidelines) Rule 2017.
147 Reliability Panel, Stage one draft determination, review of the frequency operating standard, 12 September 2017, p. ii.
148 AEMO, Power System Frequency Risk Review Report, September 2017

Australia and New South Wales 'Project EnergyConnect') which have been identified by AEMO as priority projects in its inaugural Integrated System Plan (ISP).[149]

7.4.4 Potential areas for future framework development

While the Commission has made a number of rule changes which will assist the resilience of the South Australian power system, and the NEM, there are also areas for further framework development. These areas may include:

Voltage control services - An AC power system (such as the NEM power system) relies on the availability of reactive power to sustain flows in the network and stay in a secure operating state. Just as frequency reflects the dynamic balance between active power production and consumption, voltage reflects the dynamic balance between injection and absorption of reactive power. Failure to provide sufficient reactive power can lead to voltage instability and collapse. By controlling the injection and absorption of reactive power at all levels in the system, the network's voltage profile can be maintained within acceptable limits necessary for the management of power system security and minimisation of transmission losses.

Responsibility for the provision of reactive power has been traditionally shared between generators, networks, and loads. The NEM's framework for reactive power voltage control will need to be robust to the needs of a transitioning power system. As the power system transitions to lower levels of synchronous and higher levels of asynchronous generation, a number of issues will need to be accounted for when considering future arrangements for reactive power and voltage control. The Commission's System Security Market Frameworks' review identified a need to continue to scope further power system security issues likely to arise from the ongoing transformation of the market, such as the adequacy of current voltage control arrangements.

SRAS in a future power system - The retirement of existing synchronous generating systems will also introduce an additional system security vulnerability given a reduction in the number generators capable of system restart. Only synchronous generating systems have been used to date for large scale power system restoration. Standard asynchronous generating systems are not capable of re-energising a black system as they have 'grid following' inverters. In a black system there is no grid for them to synchronise to. South Australia is one of the most vulnerable regions of the NEM from an SRAS point of view following the retirement of SRAS capable Northern Power Station.

In addition to the presence of SRAS capable generating systems, successful restoration relies on the availability of stable load. Sufficient stable load is needed to support voltage, frequency, and the restart of generating systems during restoration. The presence of a large amount of distributed solar PV introduces high levels of uncertainty into size and nature of the load blocks used for restoration. Such a situation may compromise the integrity of system restart process.

149 AEMC, early implementation of ISP priority projects rule change, consultation paper, 24 January 2019.

While NEM arrangements exist for the procurement, testing, and utilisation of SRAS, these arrangements may not be suitable in a future power system with lower levels of synchronous generation and higher levels of distributed DER.

7.5 Economic considerations in enhancing power system resilience

The benefits of a greater level of resilience in the power system are derived from the power system being: better prepared to avoid the severe consequences of a high impact-low probability event, a greater ability to survive such an event, and greater resources being available to recover following the event (i.e. a faster recovery from the event).

However, there are costs of including greater levels of resilience, including both the capital costs of additional power system plant as well as additional operating costs associated with changing the operational profile of the power system, and procuring additional system security services.

Determining the appropriate level of resilience of a power system is, therefore, both a technical and an economic assessment. This assessment is not easy due to a number of factors including:

- the difficulty in determining the likelihood of different high impact-low probability events occurring
- the difficulty of modelling the outcomes of these events, including the likelihood of a cascading outage significantly increasing severity of a given event, and
- whether stakeholders in the market are risk adverse, that is, whether additional services and facilities are acquired over and above what a pure economic assessment may justify.

A key economic challenge is to assess the benefits of actions to improve power system resilience. An outcome of a higher level of resilience could be a reduction in the frequency and/or duration of supply outages (including outages resulting from a black system). The value of customer reliability (VCR) is one measure of the value electricity customers place on an uninterrupted supply of electricity, and illustrates a customer's willingness to pay to avoid outages or load shedding.[150] VCR is however most commonly applied to short duration outages. Major supply disruptions, such as system black events, can be many hours in length and involve extreme consumer impacts associated with the loss of critical infrastructure systems reliant on electricity such as internet, transport, and payment systems. A new metric, or evolved VCR, may be required to accurately assess the customer damage arising from long duration, major supply outages, such as system black events.

The cost of achieving a given level of system resilience is also non-trivial, as it depends on the mechanisms that are used to deliver that resilience. The costs and effectiveness of different measures to enhance system resilience was considered by Panteli and Mancarella who considered that hardening measures (stronger, more interconnected) may be more effective at enhancing resilience but come at a higher cost. In contrast, smart/operational

150 Deloitte Access Economics, Assessment of System Restart Ancillary Services, 2016, p. 2

measures are cheaper to implement but less effective at enhancing resilience.[151] This suggests a portfolio approach may be appropriate when considering different options with differing levels of cost and effectiveness.

7.6 Commission's proposed approach

As part of this review, the Commission will develop a framework for considering power system resilience. In particular, the Commission will develop a conceptual framework which will:

- outline existing frameworks and NER arrangements that provide for power system resilience
- define what falls within the concept of resilience, and
- outline metrics for assessing the benefits of increasing power system resilience to reduce the consequences of adverse events.

This conceptual framework and gap analysis will support any future work undertaken by the Commission to make specific changes to NER frameworks to enhance resilience.

The rules made by the Commission to date, referred to in section 7.5 above, represent significant first steps in addressing the system resilience issues arising from a transitioning power system. The Commission however appreciates the need for further framework development that may include defining new system services and/or improving those made since the South Australian black system event. Accordingly, the Commission intends to collaborate with AEMO in developing a work package looking at system services, including voltage control, frequency control and addressing the consequences of increased DER penetration.

QUESTION 10: ARRANGEMENTS FOR ENHANCING POWER SYSTEM RESILIENCE

The Commission seeks stakeholder views on:

- What other parts of the existing frameworks do stakeholders consider provide power system resilience?
- Are stakeholders aware of metrics other than Value of Customer Reliability that may be used to assess customer impacts from black system events?
- Do stakeholders consider there are other areas for future framework development in addition to those suggested in this chapter?

151 The Grid: Stronger, Bigger, Smarter?: Presenting a Conceptual Framework of Power System Resilience, M. Panteli, P. Mancarella, IEEE Power and Energy Magazine, June 2015.

8 LODGING A SUBMISSION

Written submissions on the rule change request must be lodged with Commission by Friday 24 May 2019 online via the Commission's website, www.aemc.gov.au, using the "lodge a submission" function and selecting the project reference code EPR0057.

The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated.

Where practicable, submissions should be prepared in accordance with the Commission's guidelines for making written submissions on rule change requests.[152] The Commission publishes all submissions on its website, subject to a claim of confidentiality.

All enquiries on this project should be addressed to Graham Mills on (02) 8296 7800 or graham.mills@aemc.gov.au.

152 This guideline is available on the Commission's website www.aemc.gov.au.

ABBREVIATIONS

Delete and add abbreviations as appropriate.

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
Commission	See AEMC
MCE	Ministerial Council on Energy
NEL	National Electricity Law
NEO	National electricity objective
NERL	National Energy Retail Law
NERO	National energy retail objective
NGL	National Gas Law
NGO	National gas objective