RELIABILITY
PANEL AEMC

DETERMINATION

Reliability Panel AEMC

CONSULTATION PAPER

AEMO REQUEST FOR PROTECTED EVENT DECLARATION

13 DECEMBER 2018

INQUIRIES

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ABOUT THE RELIABILITY PANEL

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

RELIABILITY PANEL MEMBERS

SUMMARY

1 On 5 November 2018, the Australian Energy Market Operator (AEMO) submitted a request to the Reliability Panel (Panel) seeking the declaration of a protected event to assist AEMO in maintaining power system security in South Australia.[1] AEMO's request is included at Appendix A.

2 A "protected event" is a high-consequence non-credible contingency event. The category of protected event was introduced to give AEMO additional tools to manage the risks associated with such events, including the purchase of frequency control ancillary services (FCAS), constraining generation dispatch and the use of Emergency Frequency Control Schemes (EFCS). Protected events may be declared by the Panel following a request from AEMO.[2]

3 AEMO's request is an outcome of its *2018 Power System Frequency Risk Review* (PSFRR).[3] In the PSFRR, AEMO concluded that the risk of transmission faults in South Australia causing significant loss of generation which may lead to the loss of the Heywood interconnector is heightened during periods where "destructive wind conditions" (i.e. wind speeds above 140km/h) are forecast in the region.[4]

4 AEMO considers that the declaration of a protected event would provide AEMO with a transparent and fit-for-purpose mechanism for the ongoing management of this risk.

5 AEMO's request proposes that the protected event be defined as "***the loss of multiple transmission elements causing generation disconnection in the South Australia region during forecast destructive wind conditions***".[5]

6 AEMO has identified five options for managing the proposed protected event:[6]

1. Rely solely on the existing System Integrity Protection Scheme (SIPS), which is an EFCS that is designed to identify and counteract conditions that could result in a loss of synchronism between Victoria and South Australia
2. Incorporate more load and/or batteries into the existing SIPS
3. Implement a high-speed post-separation tripping scheme
4. Upgrade the SIPS
5. Upgrade the SIPS and limit total import capacity over the Heywood interconnector to 250 MW during destructive wind conditions (AEMO's recommended option).

7 AEMO has assessed that its recommended option for managing the proposed protected event will result in an annual net economic benefit of between $1.5 million and $10 million.[7] This assessment takes into account the costs of upgrading the SIPS and constraining the

1 AEMO, *AEMO Request for Protected Event Declaration*, November 2018.
2 NER clause 8.8.4.
3 AEMO, *Power System Frequency Risk Review Report*, June 2018, available from: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/PSFRR/2018_Power_System_Frequency_Risk_Review-Final_Report.pdf.
4 Ibid, p. 36.
5 AEMO, *AEMO Request for Protected Event Declaration*, November 2018, p. 17.
6 Ibid, p. 9.
7 Ibid, p. 16.

Heywood interconnector during forecast destructive wind conditions in South Australia, as well as the benefits of avoiding a black system in the region.

8 This consultation paper has been prepared to facilitate public consultation on AEMO's request. In particular, the Panel is seeking stakeholder feedback on:

- the technical feasibility of the options identified by AEMO for managing the protected event
- AEMO's assessment of the costs and benefits of its recommended option for managing the protected event.

9 This will inform the Panel's determination of whether the AEMO's recommended option for managing the protected event is the most appropriate and cost-effective approach.

10 The Panel invites written submissions on this consultation paper by **Friday 8 February 2019**.

CONTENTS

1	INTRODUCTION	1
1.1	Request for declaration of protected event	1
1.2	Purpose of consultation paper	1
1.3	Structure of consultation paper	2
2	BACKGROUND	3
2.1	What is a protected event?	3
2.2	What is the context for AEMO's request?	4
3	DETAILS OF AEMO'S REQUEST	6
3.1	Issues identified by AEMO	6
3.2	Options for managing the protected event	8
3.3	Assessment of costs and benefits of managing the event as a protected event	12
4	ASSESSMENT FRAMEWORK	15
4.1	Process for the declaration of a protected event	15
4.2	Assessment of options for managing the protected event	15
5	LODGING A SUBMISSION	18
Abbreviations		19
Glossary		20

APPENDICES

A	AEMO Request for Protected Event Declaration	23
B	AEMO's cost benefit assessment for recommended option for managing the protected event	24

TABLES

Table 3.1:	Summary of AEMO's assessment of the options for managing the proposed protected event	8
Table 3.2:	Summary of AEMO's cost benefit assessment	13

1 INTRODUCTION

1.1 Request for declaration of protected event

The Reliability Panel has received a request from AEMO for the declaration of a protected event under clause 5.20A.4 of the National Electricity Rules (NER). AEMO has proposed that the protected event to be declared by the Panel be defined as "***the loss of multiple transmission elements causing generation disconnection in the South Australia region during forecast destructive wind conditions***".[8] AEMO considers that this will address the risks associated with the potential loss of generation due to transmission element failure during destructive wind conditions in South Australia leading to the disconnection of the Heywood Interconnector.

The Commission's final determination on the *National Electricity Amendment* (*Emergency frequency control schemes) Rule* in March 2017 introduced protected events as a category of non-credible contingency event for which there are net economic benefits from AEMO taking some pre-emptive action to manage.[9] Protected events may be declared by the Panel in response to a request from AEMO. This is the first request for the declaration of a protected event which has been received by the Panel.

1.2 Purpose of consultation paper

This consultation paper has been prepared to facilitate public consultation on AEMO's request that the Panel declare a protected event. This includes inviting stakeholders to make written submissions to the Panel in response to this consultation paper in accordance with the Rules consultation procedures.[10] The Panel will consider stakeholders' submissions when making a draft determination with respect to AEMO's request.

This paper:

- explains the purpose and effect of a protected event declaration by the Panel
- sets out a summary of, and background to, AEMO's request
- identifies a number of issues and questions relating to AEMO's request to facilitate stakeholder consultation
- sets out the Panel's proposed approach to assessing AEMO's request
- outlines the process for making submissions.

The Panel welcomes submissions on this consultation paper. The Panel also welcomes interested stakeholders to contact us if they would like to meet with us to discuss this consultation paper or related issues.

All enquiries on this project should be addressed to Mitchell Shannon on (02) 8296 1639 or mitchell.shannon@aemc.gov.au.

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8 AEMO, *AEMO Request for Protected Event Declaration*, November 2018, p. 17.

9 AEMC, *Emergency frequency control schemes - final determination*, March 2017, available at: https://www.aemc.gov.au/rulechanges/emergency-frequency-control-schemes-for-excess-gen.

10 NER clause 8.8.4(b).

1.3 Structure of consultation paper

The remainder of this consultation paper is structured as follows:

- Chapter 2 sets out background information relevant to AEMO's request
- Chapter 3 summarises AEMO's request and identifies key issues for stakeholder comment
- Chapter 4 sets out the Panel's proposed assessment framework
- Chapter 5 sets out how stakeholders can respond to this consultation paper.

2 BACKGROUND

2.1 What is a protected event?

In March 2017, the Commission published its final determination on the *National Electricity Amendment* (*Emergency frequency control schemes) Rule* (the EFCS Rule). The EFCS Rule change introduced "protected events" as a new category of non-credible contingency event in the NER. A protected event is a non-credible contingency event the Panel has declared to be a protected event. The category of protected event was introduced to give AEMO additional tools to manage certain high consequence non-credible contingency events. AEMO must maintain the power system in a secure operating state in relation to protected events, including by managing power system frequency within the frequency operating standard following the occurrence of the event.[11]

The EFCS Rule introduced a requirement 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 – the PSFRR.

Under the PSFRR, AEMO is required to identify non-credible contingency events that could involve uncontrolled increases or decreases in frequency leading to cascading outages or major supply disruptions.[12] The outcomes of the PSFRR may include a proposal for the declaration of a protected event by the Panel.

Where the PSFRR identifies one (or more) non-credible contingency events which AEMO considers it may be economically efficient to manage using ex-ante operational measures in addition to some limited load or generation shedding, AEMO may submit a request to the Panel to have the event declared to be a protected event. Upon receipt of a request, the NER require the Panel to undertake an economic assessment of the request by weighing the costs of the options for managing the event (including the costs to the market of any load shedding) against the avoided cost of the consequences of the non-credible contingency event should it occur and not be managed. Where the economic benefits of managing the event outweigh the costs of doing so, the Panel may declare the event a protected event. The Panel does not have the discretion to declare a different protected event to that which is requested by AEMO.

AEMO may use a mixture of ex-ante actions to manage a protected event declared by the Panel. These actions include the purchase of FCAS, constraining generation dispatch, and the use of an EFCS in order to maintain the frequency operating standards applicable to protected events. As part of the declaration of a protected event, the Panel determines the range of ex-ante actions to be used by AEMO in managing the event.

Where the efficient management option for a protected event includes a new or modified EFCS, the Panel also sets a "protected event EFCS standard", which defines the target capabilities for the scheme. Network service providers (NSPs) are then required to design, implement and monitor the scheme in accordance with the standard. NSPs are exempt from

11 NER clause 4.2.4(a)(2).

12 NER clause 5.20A.1(a)(1).

a requirement to undertake the regulatory investment test for transmission (RIT-T) or the regulatory investment test for distribution (RIT-D) for a protected event EFCS. However, the protected event framework in the NER permits the Panel to undertake its own cost-benefit assessment of the EFCS when determining the target capabilities. This allows for the efficient assessment of costs and benefits by the Panel and is consistent with the Panel's broader role in setting various power system standards which often require a consideration of the trade-off between costs and security or reliability benefits.

The protected event framework in the NER was introduced to establish an integrated, transparent framework for the consideration and management of power system frequency risks arising from non-credible contingency events. As part of this process, AEMO is required to review the adequacy and necessity of the arrangements for managing existing protected events on an ongoing basis through the PSFRR. The outcomes of this review may include a request by AEMO that an existing protected event declaration be revoked by the Panel. This is the only circumstance in which the Panel can revoke a protected event declaration.

This is the first request for the declaration of a protected event which has been submitted by AEMO to the Panel. The request stems from a recommendation in AEMO's first PSFRR for the NEM, which was published in June 2018.

2.2 What is the context for AEMO's request?

Inertia is provided by synchronous generators and acts to resist frequency changes in the power system. Recent changes in the generation mix have reduced levels of inertia, thereby leading to potentially higher rates of change of frequency (RoCoF) following power system disturbances. The higher RoCoF leaves less time before the power system frequency moves outside of the bounds of the Frequency Operating Standard (FOS) and may mean that equipment which facilitates load shedding may no longer be able to act fast enough to arrest the consequent rapid fall in frequency. As such, there is an increased risk that such an event could more easily trigger a major blackout (a black system event).

In June 2018, AEMO released its 2018 PSFRR, in which it identified a number of scenarios that could result in the loss of multiple generators in South Australia, which could lead to a sudden and rapid increase in the power imported over the Heywood Interconnector.[13] Under some circumstances, the increase in power flow may result in an unstable power swing and consequent disconnection of the interconnector, thereby leading to a sudden separation and black system in the South Australian region. The existing SIPS in South Australia was designed to mitigate the risk of the Heywood Interconnector tripping and leading to a black system event under this scenario. The SIPS rapidly identifies conditions that could result in a loss of synchronism between South Australia and Victoria and corrects these conditions by injecting power from batteries or shedding some load to assist in re-balancing supply and demand in South Australia, in order to prevent unstable power swings on the Heywood Interconnector.

13 AEMO, Power System Frequency Risk Review Report, June 2018, p. 35.

However, AEMO identified in the PSFRR that the existing SIPS may be unable to prevent a loss of the Heywood Interconnector under all circumstances.[14] Further, AEMO's analysis suggests that the likelihood of these circumstances occurring is heightened during "destructive wind conditions" (i.e. wind speeds above 140km/h) in South Australia.[15] Wind speeds below 140km/h only pose a risk to some specific transmission lines, which can be managed by reclassifying the loss of those lines as a credible contingency.

In order to manage this risk, AEMO is currently constraining imports to South Australia on the Heywood Interconnector to 250 MW when weather forecasts for destructive winds are issued. This action is currently being performed under clause 4.3.1(v) of the NER, which allows AEMO to initiate an action plan to manage any abnormal situations or significant deficiencies which could reasonably threaten power system security following a major power system incident (in this case, the 28 September 2016 South Australian black system event).[16] AEMO does not consider this to be a preferable approach moving forward, as it involves manual processes which may not be sufficiently timely or efficient in all circumstances.

AEMO recommended in its PSFRR that:

- the risk of transmission line failure during destructive wind conditions in South Australia be managed through the declaration of a protected event, as this would provide greater certainty and transparency regarding AEMO's management of the risks associated with such an event
- an upgrade to the existing SIPS be progressed as a protected event EFCS to mitigate the risk of a black system event following a loss of multiple generators in South Australia.

AEMO's request to the Panel is consistent with its recommendation in the PSFRR.

14 This included instances where the Tailem Bend loss of synchronism relay failed to detect unstable power swings. AEMO also identified a risk that the current fixed load shed blocks may cause under or over-tripping and over-voltages, leading to trip of additional generation under some conditions.

15 See AEMO, Power System Frequency Risk Review Report, June 2018, p. 36. This is based on advice from ElectraNet that the likelihood of damage to transmission elements is increased during periods where wind speeds exceed 140km/h [advice TBC].

16 AEMO, *AEMO Request for Protected Event Declaration*, November 2018, p. 8.

3 DETAILS OF AEMO'S REQUEST

3.1 Issues identified by AEMO

AEMO's request identifies a number of characteristics of the South Australian power system which can create challenges from a power system management perspective.[17] These include:

- the region's high reliance on gas powered generation for system strength and inertia response
- a high penetration of rooftop solar PV and wind generation
- the radial design of the transmission network, with load centres being serviced by transmission elements connecting generation in remote parts of the network with low system strength
- the transmission network's susceptibility to severe storms and destructive winds.

AEMO noted that these characteristics contribute to the South Australian power system being vulnerable to the loss of a large amount of generation. In particular, if the region is importing a significant amount of power from Victoria over the Heywood Interconnector, a sudden increase in power flow and unstable power swings on the interconnector following the loss of generation in South Australia could lead to the disconnection of the interconnector and a potential black system event.

AEMO considers 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.

AEMO has identified historical power system security events in South Australia which have resulted from high flows over the Heywood Interconnector to emphasise the risk to frequency stability in the region.[18] However, AEMO also noted that only one of these events was caused by destructive wind conditions in the region. This was the black system event on 28 September 2016.[19]

AEMO also noted the following factors which it considers support the declaration of a protected event:[20]

- **Reclassification of the relevant non-credible contingency events is not feasible:** 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 current regulatory framework. Reclassification requires AEMO to determine that the occurrence of the event is "reasonably possible" due to the weather conditions. This would require the identification of specific power system equipment which is vulnerable to damage from the destructive winds. However, the geographically widespread nature of destructive wind conditions

17 AEMO, *AEMO Request for Protected Event Declaration*, November 2018, p. 6.
18 AEMO, AEMO Request for Protected Event Declaration, November 2018, p. 7.
19 AEMO, AEMO Request for Protected Event Declaration, November 2018, p. 8.
20 AEMO, AEMO Request for Protected Event Declaration, November 2018, p. 8.

means the potential impacts on the power system cannot be determined at a sufficiently localised level to enable reclassification. For example, it would be difficult to forecast the potential impact on specific generating units of damage to transmission infrastructure over a large geographic area.

- **The current approach to managing the risks is an interim solution:** As noted in section 2.2, AEMO is currently managing the risk of loss of large amounts of generation during destructive wind conditions by constraining imports into South Australia over the Heywood Interconnector to 250 MW when such conditions are forecast. This action is being taken under clause 4.3.1(v) of the NER. An interim EFCS was also implemented following the black system event in South Australia in September 2016 to reduce the impact of a similar event occurring in the region. However, AEMO considers that the protected event framework provides a more transparent and fit-for-purpose mechanism for the ongoing management of this risk, as it allows for the regular review of the need for, and level of management of, the protected event by AEMO and the Reliability Panel based on stakeholder consultation.

On that basis, AEMO has requested that the Reliability Panel declare a protected event to allow AEMO to manage the risk of loss of transmission elements leading to the loss of the Heywood Interconnector when destructive wind conditions are forecast in South Australia.

AEMO has proposed that the protected event declared by the Panel be defined as "***the loss of multiple transmission elements causing generation disconnection in the South Australia region during forecast destructive wind conditions***".[21]

AEMO will determine whether destructive wind conditions are present in South Australia in accordance with its existing internal procedures, which are based on weather forecasts issued by the Bureau of Meteorology.[22]

As noted above, the Panel does not have the discretion to declare a different protected event to that which is requested by AEMO. In its final determination on the EFCS Rule the Commission stated that AEMO, as the power system operator and the body responsible for maintaining power system security, is the appropriate body to identify non-credible contingency events which it may be beneficial for the Panel to declare a protected event. On the other hand, the Panel is considered to be the appropriate body to determine whether it is economically efficient for the event to be managed as a protected event.

Should the Panel declare a protected event in accordance with AEMO's request, this declaration would be in effect continuously unless it is revoked by the Panel at a later date (at which time the non-credible contingency event would cease to be a protected event).[23] However, the actions taken by AEMO such as constraints to interconnector flows would only need to be taken when the condition of forecast destructive winds occurs.

21 AEMO, AEMO Request for Protected Event Declaration, November 2018, p. 17.

22 These procedures are contained in Temporary Operating Advice documents provided to AEMO's control room.

23 The Panel may only revoke a protected event declaration if requested by AEMO under clause 5.20A.5 of the NER.

3.2 Options for managing the protected event

This section sets out issues for consultation in relation to:

- the options identified by AEMO for managing the protected event
- the upgrades to the SIPS proposed by AEMO as part of its recommended option for managing the protected event.

Each issue raised for consultation is accompanied by questions to guide stakeholder submissions.

3.2.1 Overview of options identified by AEMO

The NER require a request for the declaration of a protected event to identify the options for managing the relevant non-credible contingency event as a protected event, as well as AEMO's recommended option and the rationale for this recommendation.[24] This is relevant to the Panel's determination of the request, which may include a determination on the availability and operation of an EFCS and other matters relating to AEMO's operation of the power system for the protected event.[25]

AEMO has identified five options for managing the proposed protected event:

1. Rely solely on the existing SIPS
2. Incorporate more load and/or batteries into the existing SIPS
3. Implement a high-speed post-separation tripping scheme
4. Upgrade the SIPS
5. Upgrade the SIPS and limit total import capacity over the Heywood interconnector during destructive wind conditions (AEMO's recommended option).

AEMO's analysis of these options is summarised in Table 3.1.

Table 3.1: Summary of AEMO's assessment of the options for managing the proposed protected event

OPTION	CAN THIS OPTION ADEQUATELY MANAGE THE EVENT?	REASONING
Rely solely on the existing SIPS	No	Studies by AEMO and ElectraNet have shown that there are known conditions for which the existing SIPS fails to detect unstable power oscillations, even under system normal conditions.[1] The existing SIPS may be ineffective in managing the risk of separation when there is a loss of generation, which includes

24 NER clause 5.20A.4(b)(2).

25 NER clause 8.8.4(f)

OPTION	CAN THIS OPTION ADEQUATELY MANAGE THE EVENT?	REASONING
		synchronous units, while at the same time there are high power flows on the Heywood Interconnector into South Australia.
Incorporate more load and/or batteries into the existing SIPS	No	Approximately 200 MW to 300 MW of load is currently available to the SIPS for tripping if unstable power swings are detected or the power imported across the Heywood Interconnector exceeds a specified level. Increasing the level of load which is tripped would create additional system security risks due to excessively high voltage within the South Australian region, which may lead to tripping of other load, generation or network elements. There are currently no additional utility scale batteries available in the South Australian region for inclusion in the SIPS.
Implement a high-speed post-separation tripping scheme	No	If load tripping and/or battery injection were to be triggered after the loss of generation and subsequent tripping of the Heywood Interconnector had already occurred, the RoCoF would likely be too high for the scheme to be capable of returning the South Australia region to a satisfactory operating state.[2]
Upgrade the SIPS	No	AEMO recommended a number of upgrades to the SIPS in the PSFRR to improve the scheme's ability to respond more effectively to the loss of generation in the region. However, AEMO considers that the upgraded SIPS would not, on its own, adequately address factors such as transmission lines being out of service, higher levels of generation loss and reduced control action available to AEMO which may eventuate during destructive wind conditions.
Upgrade the SIPS and limit total import capacity over the Heywood Interconnector	Yes	AEMO considers that combining constraints on Heywood Interconnector flows into South Australia with the proposed SIPS upgrade will deliver a robust and cost-efficient approach to managing power system risks associated with destructive wind

OPTION	CAN THIS OPTION ADEQUATELY MANAGE THE EVENT?	REASONING
during destructive wind conditions		conditions. AEMO therefore proposes that the SIPS upgrade be progressed as a protected event EFCS. This would mean that the proposed expenditure relating to the EFCS investment would be exempt from the RIT-T.[3] Section 3.2.2 provides further information on AEMO's proposed upgrades to the SIPS. AEMO noted in its request that it considered implementing a second EFCS specifically for destructive wind conditions, but found the solution to be unnecessarily complex and costly.

Note: 1. See AEMO, *2018 Power System Frequency Risk Review*, June 2018, section 5.2.3.

Note: 2. See AEMO, *Black System South Australia 28 September 2016,* March 2017, sections 3.1.3 and 3.3.3, available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf.

Note: 3. See NER clause 5.16.3(a)(8)

QUESTION 1: OPTIONS FOR MANAGING THE PROTECTED EVENT

1. Do stakeholders agree with AEMO's evaluation of its proposed options for managing the protected event?
2. Do stakeholders consider there to be any options for managing the protected event which were not identified by AEMO?
3. Do stakeholders consider that more detailed information is required to properly evaluate the options for managing the protected event? If so, what specific information would be useful to stakeholders?

3.2.2 AEMO's recommended option for managing the protected event

The Panel has identified a number of issues for initial consultation in relation to AEMO's recommended option for managing the protected event.

Target capabilities for SIPS upgrade

The existing SIPS consists of three progressive stages which are intended to operate in an escalating manner:

1. Stage 1: Fast response trigger to inject energy from battery storage systems
2. Stage 2: Load shedding trigger to shed approximately 200 MW to 300 MW of South Australian load

3. Stage 3: Out-of-step trip scheme (i.e. disconnection of the interconnector and islanding of the South Australia region).

AEMO has recommended a number of technological upgrades to the SIPS as part of its recommended option for managing the protected event. Where a request for the declaration of a protected event recommends a new or modified EFCS to manage the event, the request must include the target capabilities for that EFCS.[26] AEMO's request identifies a number of proposed target capabilities for the modifications to the SIPS.[27] One of the target capabilities for the upgraded SIPS proposed by AEMO is that the SIPS should be capable of compensating for the loss of 500 MW of generation in the South Australia region. AEMO has indicated that a number of factors were considered in determining that the loss of 500 MW of generation was an appropriate design standard for the SIPS, including:

- Currently, there are large credible contingencies in the South Australia region that are capable of tripping large wind farms, such as Lake Bonney wind farm, which has a nameplate capacity of 279 MW. The SIPS needs to be capable of responding to potentially larger non-credible contingency events.
- Historical non-credible contingency events involving loss of generation have been in the range of 450 MW to 520 MW. However, the loss of 520 MW of generation related to events involving Northern power station, which is no longer in operation. Pelican Point, which has a nameplate capacity of 478 MW, was identified as an example of a current potential non-credible contingency event in South Australia.
- Stage two of the SIPS involves the triggering of load shedding if power imported across the Heywood Interconnector exceeds a defined threshold. AEMO has advised that the amount of load which is available for shedding under the SIPS is expected to be limited to 200 MW to 300 MW, as load shedding in excess of this level would likely cause voltage disturbances in the power system which may lead to further load or generation tripping. The combination of this amount of load shedding and the injection of energy from battery storage systems in stage one of the SIPS is considered to represent an upper limit on the amount of generation loss that can be compensated for by the SIPS.
- Extensive studies undertaken under a range of system conditions indicate that a 500 MW target capability will be challenging to meet under all conditions.[28] There are also inherent uncertainties associated with such studies which make it difficult to identify a precise amount of generation loss as the appropriate standard, including:
    - how South Australian load would respond during such an event
    - how embedded generation such as rooftop solar PV would respond during the event
    - actual system conditions prior to the event (including demand, synchronous plant dispatch, interconnector flow and additional line outages)
    - the sequence of tripping events during the event.

26 NER clause 5.20A.4(b)(4)(i)

27 AEMO, *AEMO Request for Protected Event Declaration*, November 2018, p. 13.

28 The 500 MW target capability is based on internal work being undertaken by AEMO and ElectraNet. Further information on these studies will be forthcoming at a future date.

- Targeting a level of generation loss below 500 MW may result in marginally lower costs, but this would not effectively mitigate the risks associated with the protected event. Conversely, a level of generation loss above 500 MW is less likely to occur and would be very difficult to reliably mitigate against from a technical perspective.

AEMO considers that a target capability for the SIPS which accounts for the loss of 500 MW of generation in the South Australia region to be reasonable, having regard to the above factors.

Constraint on the Heywood interconnector

AEMO is currently managing the risks associated with the proposed protected event by limiting the maximum flow into South Australia on the Heywood Interconnector to 250 MW during destructive wind conditions. AEMO considers a 250 MW import limit to be necessary, having regard to the limitations on the available load shedding and injection of energy from battery storage systems discussed above, as this allows for a 600 MW head-room up to the 850 MW satisfactory limit of the Heywood Interconnector. AEMO considers that this amount of head-room accounts for the size of historic generation contingency events of between 450 MW and 520 MW, as well as potential increases in interconnector flow due to increased system losses and additional tripping of embedded generation such as rooftop PV.

The import limit of 250 MW was only reached for one per cent of the time the limit was invoked in 2017-18, as South Australia is generally exporting power during periods of high wind speeds.

AEMO has also noted in its request that it will review the 250 MW import limit regularly through the PSFRR (which occurs every two years) or in the event of any power system conditions changing.

QUESTION 2: AEMO'S RECOMMENDED OPTION FOR MANAGING THE PROTECTED EVENT

1. Do stakeholders agree that AEMO's recommended option is the most appropriate option for managing the protected event? Alternatively, do stakeholders consider that other options would be more appropriate for managing the protected event?
2. Do stakeholders agree that the ability to compensate for the loss of 500 MW of generation in the South Australia region is an appropriate target capability for the SIPS?

3.3 Assessment of costs and benefits of managing the event as a protected event

AEMO's request includes an assessment of the costs and benefits of managing the relevant non-credible contingency event as a protected event, as required by the NER.[29]

In particular, AEMO considered:

29 NER clause 5.20A.4(b)(3)

- the costs of the proposed upgrades to the SIPS and constraining the import capacity of the Heywood interconnector during destructive wind conditions
- the benefits of increasing the likelihood of avoiding a black system event in South Australia during destructive wind conditions.

Based on this assessment, AEMO estimates that implementing its recommended option for managing the protected event will result in an estimated annual net benefit of between $1.5 million and $10 million.

AEMO's calculations, including the relevant assumptions and methodology used, are summarised in Table 3.2. AEMO's full cost benefit assessment is available at Appendix B.

Table 3.2: **Summary of AEMO's cost benefit assessment**

	DESCRIPTION	ASSUMPTIONS AND METHODOLOGY	AMOUNT
Costs	Limiting import capacity of Heywood interconnector into South Australia to 250 MW during destructive wind conditions	This action results in the displacement of Victorian brown coal generation (which has a short run marginal cost (SRMC) ~$10.5/MWh) with gas generation within South Australia (which has a SRMC ~$120/MWh). This displacement of generation is assumed to occur for volumes of between 50-400 MW for 13.8-27.6 hours per annum.	$75,000 to $1.2 million per annum
	Proposed SIPS upgrade	Capital costs for the SIPS upgrade are estimated at $4-5 million. Maintenance costs for the SIPS upgrade are estimated at 1% of capital costs.	Total annualised costs[1] ≈ $0.58 million to $0.73 million per annum
Benefits	Increased probability of avoiding a system black in South Australia due to the SIPS upgrade	Value of customer reliability (VCR) calculated as two times the estimated VCR for the black system event in 2016 for total unserved energy of 5,200-7,800 MWh (on the basis that average VCR underestimates the cost of widespread outages).[2] Probability of Heywood separation occurring during destructive winds estimated at between 2-4%. SIPS upgrade estimated to increase	$3.4 million to $10.5 million per annum

	DESCRIPTION	ASSUMPTIONS AND METHODOLOGY	AMOUNT
		the probability of avoiding a system black by 20% compared to the existing SIPS.3	
Net cost/ benefit	**Estimated annual net benefit between $1.5 million to $10 million**		

Note: 1. Total annualised costs are based on a 10-year lifetime and weighted average cost of capital of 6%.

Note: 2. The Australian Energy Regulator (AER) published a consultation paper on VCR in October 2018, in which the AER sought stakeholder feedback on whether the AER should determine a VCR for prolonged and extensive outages such as a system black event (See AER, *Values of Customer Reliability - Consultation Paper*, October 2018, p. 17, available at: https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/values-of-customer-reliability-vcr).

Note: 3. Operation of SIPS assumes 250 MW of unserved load for a period of one hour before restoration.

QUESTION 3: COST BENEFIT ASSESSMENT

1. Do stakeholders agree with AEMO's assessment of the costs and benefits of its recommended option for managing the protected event?
2. Do stakeholders consider VCR to be an appropriate metric for use in assessing the costs and benefits of the options for managing the protected event?

4 ASSESSMENT FRAMEWORK

This section sets out the Panel's proposed approach to assessing AEMO's request, having regard to the process set out in the NER.

4.1 Process for the declaration of a protected event

The Panel will make a determination with respect to AEMO's request in accordance with the process set out in chapter 8 of the NER. In doing so, the Panel must have regard to the National Electricity Objective (NEO).

The process for making a determination on AEMO's request includes the following requirements:

- **Consultation on AEMO's request**: The Panel will consult with all registered participants and interested parties on AEMO's request. This is the purpose of this consultation paper. Stakeholder views received in response to this paper will inform the Panel's determination with respect to AEMO's request.
- **Assessment of options for managing the event**: The Panel will undertake an assessment of the potential options for managing the event as a protected event. Section 4.3 contains further information on the Panel's proposed approach to this process. This may include:
  - a cost benefit assessment of AEMO's recommended option for managing the event
  - a cost benefit assessment of other options for managing the event as a protected event.
- **Draft determination:** Following stakeholder consultation on AEMO's request and the completion of an assessment of the options for managing the event as a protected event, the Panel will publish a draft determination. The draft determination will set out the Panel's draft decision in relation to:
  - the event to be declared as a protected event, including the terms of the declaration and any applicable conditions, the rationale for the determination, any other options considered and the corresponding expected power system security outcomes and costs and benefits
  - the standards that set out the target capabilities of any protected event EFCS.
- **Final determination:** Following stakeholder consultation on the Panel's draft determination, the Panel will publish a final determination. It is estimated that the Panel's final determination will be published in mid-2019, subject to the outcomes of the consultation process and the Panel's assessment process.

4.2 Assessment of options for managing the protected event

The options identified by AEMO for managing the proposed protected event are set out in section 3.2. The purpose of this section is to set out the Panel's proposed approach to assessing these options, as well as any alternative options which were not identified by AEMO.

The Panel proposes to undertake a two-stage approach to assessing the options presented by AEMO for managing the proposed protected event.

Stage 1: Evaluation of options identified by AEMO for managing the event

AEMO has identified five options which may be implemented to manage the protected event, including its recommended option to upgrade the SIPS and constrain the Heywood Interconnector during forecast destructive wind conditions.

The Panel will evaluate the options presented by AEMO having regard to:

- whether AEMO's recommended option is the most appropriate option for managing the protected event from a technical perspective
- whether AEMO's assessment of the costs and benefits of managing the protected event in accordance with its recommended option is sufficiently accurate and comprehensive.

The Panel's assessment of the options identified by AEMO for managing the protected event will be informed by the analysis provided by AEMO as part of its request, stakeholder feedback and external advice being sought by the Panel. In particular, the Panel intends to seek external technical advice to evaluate the practical feasibility of each of the options identified by AEMO, as well as the costs of AEMO's recommended option from a power system engineering perspective.

The outcomes of this process will determine whether the Panel proceeds with stage 2 of assessing the costs and benefits of the options for managing the protected event.

Stage 2: Assessment of the costs and benefits of options for managing the event

Having regard to stakeholder feedback and external advice sought by the Panel during stage 1, the Panel may undertake further analysis of the potential options for managing the protected event if stage 1 identifies that:

- AEMO's recommended option for managing the protected event is not the most appropriate option from a technical perspective; or
- AEMO's recommended option for managing the protected event is the most appropriate option from a technical perspective, but AEMO's assessment of the costs and benefits of its recommended option is not sufficiently accurate or comprehensive, or the potential costs of the option are substantially more material than was identified in AEMO's request.

If the Panel considers that this further analysis is required, it may undertake a comprehensive independent assessment of the potential options for managing the protected event, including the technical feasibility and the costs and benefits of AEMO's recommended option and any alternative options identified in stage 1. This assessment may include market modelling to determine the nature and magnitude of the benefits of managing the event as a protected event.

If this analysis identifies that an alternative option would be more appropriate for managing the protected event from a technical perspective or would be more cost-effective than AEMO's recommended option, this may be taken into account in the Panel's draft determination.

The NER allow the Panel to issue guidelines in relation to requests for a protected event declaration by AEMO or the Panel's determination of such requests.[30] The Panel has not issued any such guidelines to date, but may consider doing so in the future.

QUESTION 4: ASSESSMENT FRAMEWORK

Do stakeholders agree with the proposed assessment framework? Alternatively, are there additional principles that stakeholders consider the Panel should be taking into account?

30 NER clause 8.8.1(a)(2d)

5 LODGING A SUBMISSION

Written submissions on this request must be lodged with the Reliability Panel by **Friday 8 February 2019** via the Commission's website, www.aemc.gov.au, using the "lodge a submission" function and selecting the project reference code REL0069.

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

The Commission publishes all submissions on its website, subject to a claim of confidentiality.

All enquiries on this project should be addressed to Mitchell Shannon on (02) 8296 1639 or mitchell.shannon@aemc.gov.au.

ABBREVIATIONS

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
Commission	See AEMC
EFCS	Emergency Frequency Control Scheme
FCAS	Frequency Control Ancillary Services
FOS	Frequency Operating Standard
NEL	National Electricity Law
NEO	National electricity objective
PSFRR	Power System Frequency Risk Review
RIT-D	Regulatory investment test for distribution
RIT-T	Regulatory investment test for transmission
RoCoF	Rate of change of frequency
SIPS	System Integrity Protection Scheme
TNSP	Transmission Network Service Provider

GLOSSARY

Cascading outage	The occurrence of a succession of outages, each of which is initiated by conditions (e.g. instability or overloading) arising or made worse as a result of the event preceding it.
Contingency events	These are events that affect the power system's operation, such as the failure or removal from operational service of a generating unit or transmission element. There are several categories of contingency event, as described below: • credible contingency event is a contingency event whose occurrence is considered "reasonably possible" in the circumstances. For example: the unexpected disconnection or unplanned reduction in capacity of one operating generating unit; or the unexpected disconnection of one major item of transmission plant • non-credible contingency event is a contingency event whose occurrence is not considered "reasonably possible" in the circumstances. Typically a non-credible contingency event involves simultaneous multiple disruptions, such as the failure of several generating units at the same time.
Frequency control ancillary services (FCAS)	Those ancillary services concerned with balancing, over short intervals, the power supplied by generators with the power consumed by loads (throughout the power system). Imbalances cause the frequency to deviate from 50 Hz.
Interconnector	A transmission line or group of transmission lines that connect the transmission networks in adjacent regions.
Load	A connection point (or defined set of connection points) at which electrical power is delivered, or the amount of electrical power delivered at a defined instant at a

	connection point (or aggregated over a defined set of connection points).
Load shedding	Reducing or disconnecting load from the power system either by automatic control systems or under instructions from AEMO. Load shedding will cause interruptions to some energy consumers' supplies.
National electricity market (NEM)	The NEM is a wholesale exchange for the supply of electricity to retailers and consumers. It commenced on 13 December 1998, and now includes Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia, and Tasmania.
National Electricity Rules (NER)	The NER came into effect on 1 July 2005, replacing the National Electricity Code.
Network	The apparatus, equipment and buildings used to convey and control the conveyance of electricity. This applies to both transmission and distribution networks.
Operating state	The operating state of the power system is defined as satisfactory, secure or reliable, as described below. The power system is in a **satisfactory** operating state when: • it is operating within its technical limits (i.e. frequency, voltage, current etc are within the relevant standards and ratings) • the severity of any potential fault is within the capability of circuit breakers to disconnect the faulted circuit or equipment. The power system is in a **secure** operating state when: • it is in a satisfactory operating state • it will return to a satisfactory operating state following a single credible contingency event. The power system is in a **reliable** operating state when: •

	• AEMO has not disconnected, and does not expect to disconnect, any points of load connection under NER clause 4.8.9 • no load shedding is occurring or expected to occur anywhere on the power system under NER clause 4.8.9 • in AEMO's reasonable opinion the levels of short term and medium term capacity reserves available to the power system are at least equal to the required levels determined in accordance with the power system security and reliability standards.
Power system security	The safe scheduling, operation and control of the power system on a continuous basis.
Satisfactory operating state	Refer to operating state.
Secure operating state	Refer to operating state.
Transmission network	The high-voltage transmission assets that transport electricity between generators and distribution networks. Transmission networks do not include connection assets, which form part of a transmission system.
Transmission network service provider (TNSP)	An entity that owns operates and/or controls a transmission network.
Unserved energy (USE)	The amount of energy that is required (or demanded) by consumers but which is not supplied due to a shortage of generation or interconnection capacity. Unserved energy does not include interruptions to consumer supply that are caused by outages of local transmission or distribution elements that do not significantly impact the ability to transfer power into a region.

A AEMO REQUEST FOR PROTECTED EVENT DECLARATION

AEMO Request for Protected Event Declaration

November 2018

Potential Loss of Multiple Generators in South Australia

A request to the Reliability Panel

Executive summary

This is a request by AEMO to the Reliability Panel for a protected event declaration under clause 5.20A.4 of the National Electricity Rules (NER).

AEMO's request to the Reliability Panel

- AEMO requests the Reliability Panel declare a new protected event to manage risks relating to transmission faults causing generation disconnection and subsequent major supply disruptions during destructive wind conditions in South Australia.

Key Points

The current characteristics of the South Australian power system can present challenges for maintaining stability when multiple contingency events occur. These include its supply mix with substantial penetration of wind and solar PV, and a reliance on gas powered generation. With a predominantly radial network, the resilience of the region is susceptible to severe storms.

AEMO's analysis has found an increased risk to South Australian power system security during destructive wind conditions (faster than 140 km/h). Weather warnings for destructive winds in South Australia are issued by the Bureau of Meteorology on average 2.3 times per year.

In June 2018, AEMO released its first Power System Frequency Risk Review (PSFRR). In the 2018 PSFRR, AEMO noted its intention to formally request the Reliability Panel to declare a new protected event in South Australia.

AEMO considers the risk of transmission faults leading to the non-credible loss of multiple generating units during forecast destructive wind conditions should be managed as a "protected event". In these conditions, there is a heightened risk that the magnitude of generation loss will cause cascading failures leading to large-scale blackouts.

For the management of the proposed protected event, AEMO recommends:

- Initially maintain the current reduction of the maximum allowable flow towards South Australia on the Heywood interconnector to 250 MW, and review this limit as part of the SIPS upgrade studies, as well as in the regular PSFRR studies.
- Implementation of an upgrade of the System Integrity Protection Scheme (SIPS), as a protected event emergency frequency control scheme (EFCS). An enhanced SIPS will improve the resilience of the power system to manage the impacts of destructive winds.

AEMO estimates that the maximum annual market costs of managing the proposed protected event are between $0.7 million and $2 million – which includes the effects of limiting on the Heywood interconnector during destructive wind conditions and the annualised costs of upgrading the SIPS. These costs are significantly outweighed by the benefits of reducing the likelihood of a widespread blackout (between $3.4 million and $10.5 million per annum). The estimated net benefit of implementing the proposed protected event is between $1.5 million and $10 million per annum, depending largely on the value of customer reliability.

AEMO considers that the declaration and management of the proposed protected event will allow for more efficient operation of the power system, providing security and reliability benefits for consumers consistent with the national electricity objective.

Contents

Executive summary 2
1. Introduction 4
2. Background 6
3. Managing the Risk 7
3.1 Relevant historical events 7
3.2 Managing destructive wind conditions with a protected event declaration 8
3.3 Options for managing the proposed protected event 9
3.4 The Existing System Integrity Protection Scheme (SIPS) 11
3.5 SIPS upgrade options and target capabilities 12
4. Costs and Benefits 14
4.1 Estimated costs to manage the protected event 14
4.2 Estimated benefits of managing the protected event 15
5. Request for declaration 17
5.1 Management of the protected event 17
6. Consequences of not declaring a protected event 19
7. Conclusion 20

Tables

Table 1 Relevant power system security events in South Australia resulting from high flows on Heywood 7

1. Introduction

A key element of the NEM power system security framework is AEMO's obligation to maintain the system in a secure operating state. AEMO's power system security responsibilities generally do not extend to ensuring the system will remain in a satisfactory operating state following any non-credible contingency events, including multiple credible contingencies. The NEM cannot be operated economically to be resilient to all potential contingencies, most of which are extremely unlikely to occur.

However, recently there has been regulatory changes to provide AEMO with options to address some of these contingencies which could have a significant impact on the system. In particular, the AEMC's 2017 Emergency Frequency Control Schemes rule change[1] allows for the active management of potential high-impact non-credible contingency events through a 'protected event' mechanism.

Power System Frequency Risk Review

In June 2018, AEMO released a Power System Frequency Risk Review (PSFRR). The PSFRR must review non-credible contingency[2] events that could involve uncontrolled increases or decreases in frequency leading to cascading outages or major supply disruptions. The PSFRR can recommend:

- New or modified emergency frequency control schemes (EFCSs).
- Declaration of a protected event[3].
- Network augmentation.
- Non-network augmentation.

Protected Event Declaration

A protected event is a non-credible contingency event that the Reliability Panel has declared to be a protected event in accordance with clause 8.8.4 of the NER. If a protected event occurs, AEMO will seek to maintain power system security in accordance with the principles in the NER, including the frequency operating standard. Protected events can only be declared by the Reliability Panel after considering a request from AEMO.

In the 2018 PSFRR, AEMO noted its intention to formally request the Reliability Panel to declare a new protected event to manage risks relating to transmission faults causing generation disconnection and subsequent major supply disruptions during destructive wind conditions in South Australia.

As required by the NER, AEMO's request for the protected event declaration includes the following information:

- Nature and likelihood of the non-credible contingency event.
- Consequences for the power system if the event were to occur including AEMO's estimate of unserved energy.
- Options, and AEMO's recommended option, to manage the event.
- Additional costs for recommended management of the protected event (if declared) in accordance with the power system security principles.

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[1] Available at: https://www.aemc.gov.au/rule-changes/emergency-frequency-control-schemes-for-excess-gen

[2] Contingency events may be classified as either credible or non-credible. A credible contingency is an event which AEMO considers to be reasonably possible. Generally, such events would involve the loss of one generating unit or network element. A non-credible contingency is any other contingency, a sequence of credible contingencies within a five-minute period, or a further separation event in an island.

[3] From NER Clause 4.2.3(f): A protected event means a *non-credible contingency event* that the *Reliability Panel* has declared to be a *protected event* under clause 8.8.4, where that declaration has come into effect and has not been revoked. Protected events are a category of *non-credible contingency event*.

- Proposed target capabilities and estimated costs for the modified emergency frequency control scheme included in the recommended option for managing the proposed protected event.

2. Background

South Australia's power system has some key characteristics which are important to understand from a power system management perspective. In particular:

- Energy sources of the state – Reliance on gas powered generation (GPG) for system strength and inertia response, substantial penetration of wind generation and rooftop PV.
- Transmission network – Predominantly radial from the eastern states where load centres serviced by transmission elements connect generation in remote parts of the network with low system strength.
- Climate – South Australia's transmission backbone is prone to severe storms, destructive winds and tornadoes on occasion.

Historically, the stability of the South Australian power system has proven to be susceptible to the loss of a large amount of generation. When South Australia is importing significant levels of power from Victoria, such an event could lead to extreme flows, disconnection of the Heywood Interconnector, and a black system event (as occurred on 28 September 2016).

In destructive wind conditions that are between 125-165 km/h, a combination of many different events affecting transmission lines or plant can occur[4], which are unpredictable in terms of timing, location and impact. For example, AEMO has identified the following non-credible contingences that could occur in this situation which could result in a large loss of generation within South Australia:

- Trip or damage to multiple transmission lines due to high wind speed
- Trip of multiple transmission lines due to lightning strikes
- Trip of substation busbars due to flying debris (e.g. trip of the Mt Lock 275 kV busbar would disconnect up to 409 MW)
- Trip of multiple Torrens Island generating units
- Trip of other multiple synchronous generating units
- Trip of Torrens Island – Lefevre – Pelican Point 275 kV double-circuit line
- Multiple wind farms failing to ride through (that is, failing to remain connected) following severe high voltage faults.

During forecast destructive wind conditions in South Australia (which occur approximately twice a year[5]), AEMO considers this risk of transmission faults should be managed through the declaration of a "protected event" due to the heightened risk of multiple contingencies that have the potential to cause cascading failures leading to large-scale blackouts.

Managing this risk as a protected event will provide a firm, transparent and reviewable basis for AEMO to take reasonable operational action to maintain power system security in the declared conditions.

[4] ElectraNet has confirmed that all 275 kV transmission lines in South Australia are at risk of damage when wind gusts are >= 140 km/h, with some transmission lines in northern South Australia at risk even for wind gusts >106 km/h.

[5] In South Australia, the Bureau of Meteorology has issued 23 destructive weather warnings over the past 10 years (on average 2.3 times per year).

3. Managing the Risk

The resilience of the South Australian power system, its ability to remain connected to the remainder of the NEM and its ability to form a stable electrical island following loss of generation are all reduced during destructive wind conditions. This is due to the heightened risk of occurrence and potential greater magnitude of line failures and other transmission faults that could cause a sudden and significant loss of generation. Therefore, AEMO requests the Reliability Panel to declare a protected event allowing AEMO to take steps to maintain power system security when destructive wind conditions are forecast in South Australia.

3.1 Relevant historical events

The following table shows major power system security events since market start[6] in South Australia that posed a high risk to frequency stability.

Table 1 Relevant power system security events in South Australia resulting from high flows on Heywood

Date	Description	SA supply interrupted (MW)	Duration of separation	System inertia (MWs)	Peak Heywood flow during event (MW)	Time until separation (seconds)
2 December 1999	Trip of both units at Northern Power Station (520 MW)	1,130	26 minutes	10,693	950	2.8
8 March 2004	Runback of both units at Northern Power Station (480 MW)	650	43 minutes	7,617	825	1.7
14 March 2005	Runback of both units at Northern Power Station (465 MW)	580	22 minutes	11,127	900	2
16 January 2007	Cascade transmission line tripping in Victoria initiated by bush fires	100	38 minutes	14,612	700	3.9
28 September 2016	Extreme weather event caused loss of three transmission lines and loss of 456 MW of generation from nine wind farms.	1,895 (black system)	65 minutes	3,000	890	0.7
3 March 2017	Fault at Torrens Island switchyard	410 (in first 1.5 seconds) 610 (total)	No separation	8,590	963	No separation
25 August 2018	SA islanding following trip of QNI interconnector and islanding of Queensland	0	24 minutes	9,919	430	7

With the retirement of the Northern Power Station coal units, the risk of these two particular units tripping or running back no longer exists. However, this risk has been succeeded by the risk of disconnection of sizeable windfarms in the South Australian region. Changes in the supply chain in South Australia have led to:

[6] During the 1990s a number of South Australia transmission backbone 275 kV double-circuits tripped due to either lightning or fire.

- A lack of geographic diversity, with many wind farms being connected to transmission lines with design ratings below destructive wind speeds.
- A reduction in system strength and inertia[7].
- Exposure of wind farms to the operation of protection systems at common settings in response to power system events, or turbine over-speed protection during destructive wind conditions.

To date, there have not been any events where significant loss of load in the South Australia region has led to loss of synchronism and separation of the Heywood interconnector. For this reason, this protected event request only considers the loss of generation.

For the non-credible contingency scenarios noted in section 2, currently AEMO does re-classify the non-credible tripping of multiple transmission lines as credible when wind speeds are forecast to be above the wind design rating of the transmission lines affected. This reclassification action only covers the risk of loss of specific transmission lines, not the risk of loss of generation that is not connected to the reclassified lines. For this reason, further action is required to manage these risks.

3.2 Managing destructive wind conditions with a protected event declaration

Destructive winds cannot be sufficiently managed through traditional reclassification

The NER framework does not allow AEMO to reclassify the loss of multiple unspecified generating units as a credible contingency event in forecast destructive wind conditions. To reclassify an identified non-credible contingency event as credible, AEMO must determine that the occurrence of that event is 'reasonably possible' because of abnormal conditions such as destructive winds. The potential geographic impact of destructive wind conditions (other than weather systems like cyclones) cannot be forecast at a sufficiently localised level to enable AEMO or participants to identify specific power system equipment vulnerable to damage from those winds, or the potential generation response to damage to transmission infrastructure over a large geographic area.

Without taking some action to redefine the technical envelope for secure operation of the South Australian power system, the simultaneous loss of multiple generating units may lead to separation of South Australia from Victoria, and subsequent widespread load shedding in the South Australia network.

There has, to date, been only one occasion on which these wind conditions have resulted in widespread generation loss. As the specific protection parameters causing the previous generation response has subsequently been adjusted, AEMO cannot conclude that this event meets the 'reasonably possible' threshold. Nevertheless, given the heightened risk of transmission faults in these conditions from a range of different trigger events, and the uncertainty of operational responses across various power system technologies, AEMO considers the event should be managed within the power system security principles.

Current risk mitigation practices are an interim solution

After its investigation of the September 2016 black system event, AEMO implemented a practice of limiting flow into the South Australia region across the Heywood interconnector during forecast destructive wind conditions anywhere in the region to 250 MW. This action was taken in accordance with AEMO's power system security responsibilities under clause 4.3.1(v) of the NER – this allows AEMO to initiate an action plan, following a major power system incident, to manage situations that could reasonably threaten power system security.

As an outcome of the system wide blackout, an interim Emergency Frequency Control Scheme (EFCS) was implemented to reduce the impact of a similar event.

[7] Following installation of new synchronous condensers in the South Australian region, this risk is not expected to materially reduce as the additional system strength and inertia these units provide are expected to be offset by reducing the requirement of directions to synchronous generating units.

A protected event is the best way to manage this risk

The introduction of the protected events regime has provided a more transparent and reviewable basis for the ongoing management of these conditions, and allows AEMO's contingency management actions to be brought clearly within the NER power system security principles. In particular, the protected events regime allows for regular review by AEMO and the Reliability Panel with participant consultation. The need for, and level of management of this event may change over time as the characteristics of the power system change. Accordingly, the protected events regime provides the most fit-for-purpose mechanism to manage this risk.

3.3 Options for managing the proposed protected event

To manage the risk of multiple generation units tripping during forecast destructive wind conditions, AEMO reviewed the following options:

- Rely solely on the existing SIPS
- Incorporate more load and/or batteries into the existing SIPS
- Implement a high-speed post-separation tripping scheme
- Upgrade the SIPS
- Upgrade the SIPS and limit total import capacity during destructive wind conditions [Recommended].

3.3.1 Rely solely on the existing SIPS

Studies by AEMO and ElectraNet have shown that there are known conditions for which the existing SIPS fails to detect unstable power oscillations, even under system normal conditions, and therefore it is ineffective in managing the risk of separation for approximately 20 per cent of situations studied.

The SIPS has been shown to manage generation loss events up to approximately 500 MW in size, under system normal conditions only. For generation contingencies above this, it may not be effective (e.g. when Heywood is importing at high levels, and loss of generation includes synchronous units), and cascading failures leading to a potential black system may eventuate.

During destructive wind conditions where damage and tripping of transmission lines is more likely, the transient limits on the transmission network are expected to be lower. This means the existing SIPS effectiveness will be reduced further, meaning a system black could eventuate for even lower levels of generation loss. Section 3.4 provides more detail about current SIPS operation.

During destructive wind conditions, physical damage can impact both communications equipment and transmission infrastructure. Therefore, during these extreme conditions, a robust solution will reduce the risk of network separation through pre-emptive action and high-speed control schemes.

For these reasons AEMO considers this option would be insufficient to manage the proposed protected event in accordance with the power system security principles.

3.3.2 Incorporate more load and/or batteries into the existing SIPS

The amount of load armed for tripping currently at the upper level that can be managed without creating additional system security risks. Tripping large amounts of load can lead to excessively high system voltages, and subsequent cascade tripping of other load, generation or network elements.

There are currently no additional[8] utility scale batteries available in the South Australian region for inclusion in the scheme. If and when additional batteries come online, and their response can be demonstrated to be sufficiently fast to be included in the SIPS, then this option may warrant further investigation. This would also still rely on new hardware to enable real-time monitoring and selective arming of loads and batteries.

[8] ElectraNet are currently in the process of incorporating the Hornsdale Power Reserve battery, and the Dalrymple ESCRI-SA battery.

For these reasons, AEMO considers this option is currently not feasible to manage the proposed protected event in accordance with the power system security principles.

3.3.3 Implement a high-speed post-separation tripping scheme

If load tripping / battery injection were to be triggered post-contingency (i.e. post generation loss and subsequent Heywood tripping due to loss of synchronism) it is unlikely that such a scheme would be effective in returning the South Australia region to a satisfactory operating state. Loss of significant generation, and then import from the Heywood interconnector would result in rates of change of frequency which can be too high for under-frequency control schemes to operate effectively. Rates of change of frequency this high can also be above the capability of generation to remain online for. Such a scheme would cost similar amounts to the SIPS to implement, but not be as effective.

For these reasons AEMO considers this option would be insufficient to manage the proposed protected event in accordance with the power system security principles.

3.3.4 Upgrade the SIPS

As discussed in section 3.3.1, the existing SIPS cannot effectively mitigate the risk of a system wide black out during destructive wind conditions. The PSFRR recommended upgrades to the existing SIPS to improve its ability to respond more effectively to loss of generation events. This improvement will come from:

- A more robust method of detection of unstable power swings prior to loss of synchronism events, including during periods with additional transmission lines out of service.
- Real-time monitoring of batteries and loads available for tripping will mitigate loss of communications by automatically selecting loads / batteries that are available.
- Commensurate load tripping and battery injection that is matched to the size of the initiating event – preventing further cascade tripping due to other system issues (e.g. over-voltages).

Further detail on the SIPS upgrade proposal is provided in section 3.5.

The proposed upgraded SIPS will improve the effectiveness of the existing scheme to handle multiple loss of generation events that may eventuate under destructive wind conditions. However, during these extreme conditions, factors such as transmission lines being out of service, reduced available control action (loss of some ability to trip load or trigger batter injection), and higher levels of generation loss significantly increases the risk of major supply disruption. To manage this risk effectively, AEMO recommends additional head-room for limits on the interconnector flow (i.e. reduce transfer capability on Heywood during destructive wind conditions – as outlined in section 3.3.5).

For these reasons, AEMO considers upgrading the SIPS only would be insufficient to manage the proposed protected event in accordance with power system security principles.

3.3.5 Upgrade the SIPS and limit total import capacity during destructive wind conditions **[Recommended]**

An upgraded SIPS will reduce power system risks associated with loss of generation following transmission failure during destructive wind conditions in South Australia. To manage the proposed protected event in accordance with the power system security principles, AEMO considers that, under current system conditions, it would be necessary to also constrain Heywood interconnector flows into South Australia during destructive wind conditions.

During destructive wind conditions, AEMO currently manages the non-credible contingency risk by limiting the maximum flow into South Australia on the Heywood interconnector to 250 MW. Alternatives to implementing a 250 MW import limit were also considered but found to be less effective. A 250 MW import limit is a robust approach because it achieves a 600 MW headroom to the 850 MW satisfactory limit of the Heywood Interconnector, and caters to a range of historic generation contingency events (mostly 450-520

MW[9]). AEMO will continue to review this limit as part of the PSFRR or in the event of any changing power system conditions.

Operational experience indicates that a 250 MW import limit on the Heywood interconnector will rarely affect market operation during destructive wind conditions – when wind speeds are high, South Australia is likely to be exporting power. This limit of 250 MW was only reached for 1 per cent of the time it was invoked in 2017-18.

Combining interconnector limits with the proposed SIPS upgrade will deliver a robust and cost-efficient approach to managing power system risks associated with destructive wind speed conditions.

While the modified facilities comprising the upgraded SIPS will be active at all times, the additional capability arising from the modification is only needed to manage the proposed protected event as AEMO considers the existing SIPS is adequate to prevent or arrest uncontrolled decreases in frequency during a normal range of weather conditions.

AEMO considered implementing a second EFCS specifically for destructive wind conditions, but found the solution to be unnecessarily complex and costly. Although the proposed protected event will only arise at limited times, AEMO considers that the NER do not preclude the actions implemented to manage it from being effective at other times, where the Reliability Panel is satisfied that this is an efficient option.

3.4 The Existing System Integrity Protection Scheme (SIPS)

Existing operation

The SIPS is an EFCS designed to rapidly identify and respond to conditions that could otherwise result in a loss of synchronism between South Australia and Victoria. It is designed to correct these conditions by rapidly injecting power from batteries or shedding some load to assist in re-balancing supply and demand in South Australia, to prevent a loss of the Heywood Interconnector. Although the SIPS was installed and commissioned in December 2017, commercial negotiations are still being finalised to enable injection from the Hornsdale Power Reserve battery, and the Dalrymple ESCRI-SA battery.

The non-credible loss of multiple generating units in South Australia, at times of high import into South Australia, can lead to extreme flows on the Heywood Interconnector, causing it to trip – losing synchronism between South Australia and the rest of the NEM. This loss of multiple generators and import across the Heywood interconnector would result in rapid frequency decline and would pose a high risk of a state-wide blackout.

The SIPS incorporates three discrete progressive stages. The outcome of each stage is intended to defer or prevent the onset of the next stage:

- Stage 1 – Fast response trigger to inject energy from battery energy storage systems (BESS).
- Stage 2 – Load shedding trigger to shed approximately 200 MW of South Australian load.
- Stage 3 – Out-of-step trip scheme (islanding South Australia).

The operation and progression of each stage is discussed in detail in the 2018 PSFRR, at section 5.2.3.

[9] Additional headroom up to 600 MW, as opposed to just 520 MW, also caters for increases in interconnector flow due to items such as increase in system losses and additional tripping of embedded generation such as rooftop PV.

SIPS recommendation

The detailed modelling and studies conducted by AEMO to test the SIPS for a range of conditions are described in section 5.2.3 of the 2018 PSFRR. Based on the outcomes of those studies, AEMO recommended an investigation of technologies and solutions to upgrade to the existing SIPS, including:

1 Alternative mechanisms to detect unstable power swings, which left unchecked could lead to the onset of loss of synchronism between South Australia and the rest of the NEM (because the impedance-based Tailem Bend and South East loss of synchronism relays may fail to detect unstable power swings under some conditions).

2 Dynamic arming of load blocks, batteries, and potentially the Murraylink HVDC interconnector, based on real-time measurement and pre-processing of information for a number of different generation loss events (i.e. "Stage 2"). This is required because the current fixed load shed blocks may cause under or over-tripping and over-voltages, leading to trip of additional generation under some conditions. Detailed investigation of technologies and design is required due to the countless number of generation tripping events that could conceivably occur in the South Australia power system.

The technical envelope in which the existing SIPS has been shown to operate effectively is only with all transmission lines in the South Australian region in service. As the SIPS operates to prevent unstable transient power swings, not just thermal limitations, it currently may not be reliable with additional network elements out of service. During destructive wind conditions, damage and tripping of transmission lines is more likely, and could occur at the same time as generation tripping. This means a system black event could eventuate for even lower levels of generation loss.

Damage to transmission towers is likely to also result in damage to communication equipment incorporated along the transmission towers. Without reliable communications systems, required SIPS action may not be able to occur.

As static load tripping is currently installed, this may lead to over or under-tripping depending on system conditions at the time of an event occurring.

3.5 SIPS upgrade options and target capabilities

Following the 2018 PSFRR, ElectraNet and AEMO have commenced investigations into these two categories of solutions. For SIPS recommendation 1, the use of synchronised phasor measuring units (PMUs) is under investigation as a potential replacement for the current loss of synchronism relay detection. PMUs are able to measure the positive-sequence voltage angle measurements from two or more different locations on the power system. These PMU measurements are utilised to determine the angle difference between the buses, and identify power swings and out of step conditions, and are considered a more robust means to detect potential loss of synchronism conditions.

The use of PMUs in special protection systems is currently in limited application world-wide. For this reason, it is prudent for trials of the hardware to be progressed as a first stage to any SIPS upgrade to understand the reliability and accuracy of actual measurements over a period.

To address SIPS recommendation 2, real-time measurements of load points and batteries will be required. These measurements will then be required to be communicated back to the central real-time data management and response system, which will selectively arm battery injection and load tripping as required to reduce the probability of over or under tripping. The loads will also be selected to ensure that for any loss of communications, alternative available load tripping (as well as battery injection options) will be utilised.

The upgraded scheme will also use the three stages of action, as per the operation of the existing SIPS.

AEMO has estimated that the SIPS modification can be completed within two years. However, a number of uncertainties, stemming from the potential complexity of this protection scheme and the importance of performance monitoring and design accuracy before implementation, could delay its implementation beyond two years.

As discussed in section 3.3, AEMO requests the SIPS upgrade be considered as part of the solution for managing the proposed protected event. The modifications address the SIPS issues noted above and enhance AEMO's ability to manage the scheme under destructive wind conditions.

A request for an EFCS as part of a protected event request must include the target capabilities proposed to be included in the protected event EFCS standard. Noting that investigation and studies are ongoing, the following target capabilities are proposed.

- To be able to dynamically detect unstable power oscillations under a wide range of power system conditions, including for Heywood interconnector flows into the South Australian region up to 250 MW during destructive wind conditions.
- To be able to dynamically sense power system conditions, including Heywood interconnector flow, load available for tripping, and amount of battery response available.
- To be able to dynamically communicate the status of the scheme, including availability of battery or loads for tripping.
- As a first stage of action, be able to trigger responses from available batteries, with the size of response commensurate with the extent of the initiating event.
- As a second stage of action, trip up to 200 MW to 300 MW10 of load from separate load blocks across a number of sites, with the size of the response commensurate with the size of the initiating event. After tripping has occurred, load is able to be restored within an hour.
- As a third stage of action, separate and island the South Australian network from Victoria.
- Timeframes for action (tripping times and battery injection) to be less than 300 ms.
- The scheme should be able to operate for loss of generation within the South Australian Network of up to 500 MW (synchronous or non-synchronous), and to be able to cater for these contingencies whether tripped concurrently, or sequentially over a longer timeframe, for example 10 to 30 seconds.[11]
- To be able to operate and respond in a commensurate manner with additional transmission elements out of service.

[10] Range due to variance in load included in tripping blocks

[11] This is a target capability, with the actual capability to be determined following extensive studies. A requirement of concurrent loss of 500 MW of synchronous generation will be quite onerous and may not be able to be met under all system conditions.

4. Costs and Benefits

AEMO estimates that implementing the recommended option (see section 3.3.5) to manage the proposed protected event will result in an estimated annual net benefit between $1.5 million and $10 million.

4.1 Estimated costs to manage the protected event

To provide a more accurate understanding of the costs to manage the protected event, AEMO has calculated the costs of:

- Limiting interconnector import capability during destructive wind conditions
- The proposed SIPS upgrade

4.1.1 Limiting import capacity during destructive wind conditions

Over the past 10 years, there have been 23 instances of forecast destructive wind events issued by the BOM for the South Australian region. Each of these warnings lasted between 6 and 12 hours. Based on the information available, AEMO has estimated an expected duration of between 13.8 hours and 27.6 hours per year.

The increase in cost to operate the power system with reduced import capability of the Heywood interconnector into South Australia will depend on a number of initial conditions, such as:

- Demand in the South Australia region
- Output of wind and solar plant
- Availability of generation plant in the South Australia region
- The flow on the Heywood interconnector prior to, and during the event.

To estimate the maximum costs expected, a worst-case assumption is made that constraining import on Heywood to 250 MW results in displacement of coal plant in other NEM regions with gas plant within South Australia. This results in a change of generating costs from $10.5/MWh (brown coal plant SRMC) up to $120/MWh (gas plant SRMC)[12].

Using the estimated event durations and generating costs data, additional maximum annual costs are estimated to be between $75,000 and $1.2 million[13]. The lower end of the range represents a 13.8-hour event duration, with a low impact on Heywood flow[14], while the upper end represents an event duration of 27.6 hours with a maximum impact on Heywood flow (constrained down from 650 MW to 250 MW).

Analysis of the 2017-18 financial year data relating to the periods when AEMO constrained flows into South Australia to 250 MW for destructive wind conditions shows this limit was only restrictive for 1 per cent of the time it was in place. During destructive wind conditions, high output from wind generation within the South Australian region is expected, meaning high import on the Heywood interconnector is not usually required.

4.1.2 The proposed SIPS upgrade

Based on the information available, AEMO estimates that the SIPS upgrades will cost between $4 million to $5 million. This cost includes new communication systems, new central processing hardware, additional load

[12] AEMO. 2018 ISP Assumptions Workbook. Available at: http://aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/2018-Integrated-System-Plan--Modelling-Assumptions.xlsx

[13] AEMO also considered costs for implementing internal processes to manage a protected event but has not included these due to the costs being small in comparison to limiting the interconnector and SIPS upgrade and also that AEMO would consider these to be part of its operational costs.

[14] A low assumption of 50 MW change is used for this calculation. If there was no impact on Heywood flow (i.e. if the interconnector flow was already below the imposed limit), there would be no cost to the market.

tripping hardware, monitoring hardware (i.e. load measurement and PMUs), as well as the extensive system studies.

Where possible, existing hardware used in the current SIPS should be utilised (e.g. some communication assets and protection relays) to minimise costs. A separate control scheme could be developed for the protected event, but this would be inefficient and costlier for consumers. This augmentation and associated additional investment is not specifically needed for normal weather periods, with the primary value being its use during destructive weather events.

Ongoing annual maintenance costs are estimated at 1 per cent of the capital costs. Costs for any battery contracts have not been included in these estimates as these items will be subject to negotiation with proponents. Any subsequent costs for contracting for fast battery injection will need to be made on their own merit – based on reducing the total requirement for load shedding and provide a more economic outcome for consumers.

The hardware that is proposed for the protection scheme will also be able to be utilised or adapted if the proposed South Australia to New South Wales interconnector project[15] is approved.

The total annualised costs based on a 10-year lifetime and a weighted average cost of capital of 6 per cent[16] equate to $0.58 million to $0.73 million.

4.2 Estimated benefits of managing the protected event

The objective of managing the proposed protected event in accordance with the power system security principles is to minimise the risk of a black system condition. AEMO has developed these costs conservatively, as the costs of such an event will depend on the amount of load lost, the time it takes to restore the load, and the economic value of that load.

To estimate the cost of a South Australian black system, a number of reviews were examined to consider the economic cost of widespread load shedding:

1. Business SA survey estimates[17]– Using surveys of businesses impacted by the system black event, Business SA estimated a cost of $367 million to commercial load customers. This was noted by Business SA to be likely to be on the low side due to the event occurring at the end of the business day.
2. Similar Incidents – Estimates are available for incidents elsewhere in the NEM for similar levels of load shedding, such as an event in Victoria in 2007[18] where 7,100 MWh of load was shed. Costs of this incident were estimated at $300 million in direct costs, with a total impact of $500 million.

Using an average Value of Customer Reliability (VCR) value to estimate costs for a load loss of 7,100 MWh equates to approximately $270 million.

Using an average VCR is expected to underestimate cost of widespread outages[19]. For this reason, a sensitivity of 2 x VCR has been used to take this into account, which is a standard multiplier in assessing widespread or prolonged events. Results using this multiplier with VCR show similar estimates to the Business SA survey results, and the Victorian load shedding incident.

[15] ElectraNet. South Australia Energy Transformation. Available at: https://www.electranet.com.au/projects/south-australian-energy-transformation/.

[16] AEMO. 2018 ISP Assumptions Workbook. Available at: http://aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/2018-Integrated-System-Plan--Modelling-Assumptions.xlsx

[17] Business SA. September Blackout Cost State $367 Million. Available at: https://business-sa.com/Commercial-Content/Media-Centre/Latest-Media-Releases/September-Blackout-Cost-State-$367-Million.

[18] Victoria State Government. January Supply Interruptions. Available at: https://www.energy.vic.gov.au/safety-and-emergencies/past-energy-emergencies/january-supply-interruptions-executive-summary.

[19] AEMO. VCR Application Guide. Available at: http://www.aemo.com.au/-/media/Files/PDF/VCR-Application-Guide--Final-report.pdf

Given the significant uncertainty as to the amount of load lost and time for restoration, low (5,200 MWh) and high (7,800 MWh) range impacts would result in estimated blackout costs between $396 million and $595 million per event.

Although there are estimated to be 2.3 destructive wind warnings issued a year, existing data shows that there has only been one instance of multiple generating unit losses concurrent with a destructive wind warning over the past 10 years (i.e. approximately 4 per cent likelihood). The Bureau of Metrology (BOM) has not been able to ascertain the actual likelihood of the storm event that caused the South Australia black event[20]. It should be noted that anytime there are destructive wind conditions, the design rating of transmission elements is at risk of being exceeded, and there is a higher probability of multiple contingencies such as those described in section 2 and section 3.

Considering a range between 2 per cent and 4 per cent chance of a destructive wind event resulting in generation loss, the annual benefit expected of avoiding a blackout varies between $18 million and $55 million[21].

Considering the impact of SIPS load shedding to avoid the blackout (250 MW load tripped but restored within an hour) and the taking into account the annualised costs of upgrading the SIPS, gives an estimated net annual benefit between $1.5 million and $10 million.

[20] BOM. Severe Thunderstorm and Tornado Outbreak 28 September 2016. Available at: http://www.bom.gov.au/announcements/sevwx/sa/Severe_Thunderstorm_and_Tornado_Outbreak_28_September_2016.pdf

[21] As the SIPS upgrade investigations are ongoing and detailed system studies are yet to be completed, to ensure a conservative calculations of benefits the upgraded SIPS has also been assumed to at worse only improve upon the performance of the existing SIPS by 20%. For this reason, only 20% of the potential reliability benefits has been used.

5. Request for declaration

AEMO requests that the Reliability Panel declare a new protected event to manage risks relating to transmission faults causing generation disconnection and subsequent islanding and black system during destructive wind conditions in South Australia.

AEMO proposes the protected event be defined as the "loss of multiple transmission elements causing generation disconnection in the South Australia region during forecast destructive wind conditions."

AEMO proposes that this declaration would be in effect continuously. However, as the protected event is expressed by reference to conditions that arise only intermittently, it can be managed by a combination of permanent and event-based actions. AEMO would only need to take the event-based action during the conditions specified as part of the protected event.

5.1 Management of the protected event

The operational action to manage the protected event would be:

1) During periods for which destructive wind conditions are forecast in South Australia, limit flow towards South Australia on the Heywood interconnector to a level that will be likely to reduce the risk (based on AEMO's current modelling this would be to 250 MW). AEMO will review this number regularly through the PSFRR (which occurs every two years) or in the event of any power system conditions changing.
2) Utilise the SIPS to minimise the import constraint on the interconnector. To do this effectively, AEMO recommends an upgrade to the SIPS as a protected event EFCS, to operate in accordance with a protected event EFCS standard that provides for:

   - The ability to utilise new Phasor Measurement Units located throughout the 275 kV network in South Australia in order to detect unstable power oscillations resulting from loss of generation.
   - A centralised real-time data management and response system that monitors relevant power system conditions such as interconnector flows, load available for tripping, and battery injection available.
   - The ability to trigger battery injection or load shedding in sufficient time frames to prevent tripping of the Heywood interconnector occurring when unstable power oscillations are detected.

   This scheme will have the following target capabilities.

   - To be able to dynamically detect unstable power oscillations under a wide range of power system conditions, including for Heywood interconnector flows into the South Australian region up to 250 MW during destructive wind conditions.
   - To be able to dynamically sense power system conditions, including Heywood interconnector flow, load available for tripping, and amount of battery response available.
   - To be able to dynamically communicate the status of the scheme, including availability of battery or loads for tripping.
   - As a first stage of action, be able to trigger responses from available batteries, with the size of response commensurate with the extent of the initiating event.
   - As a second stage of action, trip up to 200 MW to 300 MW of load from separate load blocks across a number of sites, with the size of the response commensurate with the size of the initiating event. After tripping has occurred, load is able to be restored within an hour.
   - As a third stage of action, separate and island the South Australian network from Victoria.

- Timeframes for action (tripping times and battery injection) to be less than 300 ms.
- The scheme should be able to operate for loss of generation within the South Australian Network of up to 500 MW (synchronous or non-synchronous), and to be able to cater for these contingencies whether tripped concurrently, or sequentially over a longer timeframe, for example 10 to 30 seconds.
- To be able to operate and respond in a commensurate manner with additional transmission elements out of service.

6. Consequences of not declaring a protected event

If a protected event declaration is not implemented, there remains a material risk that, if significant generation is lost under some power system conditions, collapse of the South Australian network will not be prevented. Destructive wind conditions present an increased risk of multiple transmission and generation losses.

While AEMO is currently constraining interconnector flows under the action plan mechanism, the protected events regime provides a more transparent and reviewable basis for the ongoing management of these conditions. It also provides a more flexible mechanism under the Rules to manage additional power system conditions that may emerge with power system and NEM generation mix changes, and a requirement to review both the ongoing need for the protected event and whether the management actions remain appropriate.

Implementing the protected events regime allows for regular review by AEMO and the Reliability Panel with participant consultation. The need for, and level of, management of the event may need to change over time as the characteristics of the power system change. Accordingly, the protected events regime provides a more fit-for-purpose mechanism than current arrangements.

7. Conclusion

AEMO requests that during destructive wind conditions in South Australia (approximately twice a year), the risk of loss of large amounts of generation should be managed through the declaration of a "protected event". This will provide certainty and transparency to participants regarding AEMO's management of the heightened risk.

A Protected Event declaration and the modification of the existing EFCS to a Protected Events EFCS increases the likelihood that the Heywood Interconnector will remain connected, increases the ability of the SIPS to help manage the power system during destructive winds, and reduces the risk of a black system event following transmission failure and mass generation disconnection in South Australia. It also provides the market with a greater level of transparency of AEMO's contingency management actions. Under the protected events regime, this management is subject to greater review by AEMO, which is particularly important to meet the system's changing needs.

This proposal promotes the National Electricity Objective as the protected event classification allows for more efficient operation of the power system, providing security and reliability benefits for consumers. Under AEMO's economic assessment, the consequences of this event have been balanced with the costs associated with managing the event, reflecting an outcome that is in the long-term interests of consumers.

B AEMO'S COST BENEFIT ASSESSMENT FOR RECOMMENDED OPTION FOR MANAGING THE PROTECTED EVENT

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South Australia Protected Event - AEMO submission to the Reliability Panel
Supporting data for the Cost/Benefit Analysis

This supplement provides:

High level cost/Benefit analysis of the impact of managing a proposed protected event in the South Australian region.

Provided in order to assist with making a cost benefit assessment, and to allow review of sensitivities

Version History

Version Number	Date	Description
1.0	29/10/2018	First release

Worksheet Descriptions

Worksheet	Description
PE_Cost-Benefit	Assumptions and calculations relating to the cost/benefit assessment presented in the Protected Event recommendation
NPV	Net present value analysis of the benefits of the SIPS upgrade over the lifetime of the upgrade
VCR	Values and escalation of VCR calculations
SRMC	Calculations relating to generation costs used in estimation of the impact of applying constraints to the Heywood interconnector
BOM_Data	Data from the Bureau of Metrology relating to confirmed Destructive Wind Forecast events

Cost Benefit analysis

Breakdown of calculations shown in the Protected Event request report. Probabilities, Costs, weightings can be adjusted to see impact on outcomes.

Three scenarios with different ranges of input assumptions shown in order to give a view on best/worse case outcomes.

Scenario

	Worst	Neutral	Best		Description
Number of destructive wind events	23	23	23	recorded by BOM	
Period	10	10	10	years	
Frequency of PE	2.3	2.3	2.3	times / year	
Approximate duration of PE	12	10	6	hours	*Based on analysis of historical storm warnings and data in SA system black report* (see BOM_data worksheet)
Annual reclassification duration	27.6	23	13.8	hours	
Coal SRMC	$ 10.50	$ 10.50	$ 11.00		See SRMC worksheet for derivation of numbers
Gas SRMC	$ 120.00	$ 120.00	$ 120.00		
Heywood prior to reclass	-650	-500	-300	MW	
Heywood during PE	-250	-250	-250	MW	*Interconnector impact may be able to be mitigated with upgraded SIPS. Further studies/ confirmation of actual performance required.*
Impact on interconnection	-400	-250	-50		
Cost	$ 43,800	$ 27,375	$ 5,450	per hour	
Event cost	$ 525,600	$ 273,750	$ 32,700	per reclassification	
Annual cost of constraint	**$ 1,208,880**	**$ 629,625**	**$ 75,210**	per year	*With the SIPS upgrade in place, this cost may be able to be reduced. This reduced cost has not been assumed in these calculations*
VCR	$ 38,111.65	$ 38,111.65	$ 38,111.65		*See VCR worksheet. This is considered to underestimate the impact of wide-spread and prolonged outages*
VCR multiplier	2	2	2		*Used to cater for escalation of VCR for wide-spread outages*
Effective VCR	$ 76,223.31	$ 76,223.31	$ 76,223.31	$/MWh	
SA load	1300	1300	1300	MW	*50%POE for months forecasts are issued, noting blackouts more likely under higher demand conditions*
Interruption time	8	10	12	hours	*SA blackout took 8hrs to restore 90% of restorable load*
Restoration shape	0.5	0.5	0.5		*<-- to account for load being restored throughout the period*
AVG interruption time	4	5	6	hours	
Energy lost	5200	6500	7800	MWh	
Blackout cost (each event) using VCR	**$ 396,361,197**	**$ 495,451,496**	**$ 594,541,795**		
Likelihood of any destructive storm resulting in blackout	2%	3%	4%		*1 blackout /23 destructive wind events ~4% . Note: this should not just be probability of damage to lines, but also for other damage/ events leading to generation trips (e.g. busbar faults, lightning)*
Benefit per year	$ 18,232,615	$ 34,186,153	$ 54,697,845		
Effectiveness of existing SIPS	70%	70%	70%		*Studies show even under system normal, the existing SIPS is only 80% effective. This will be lower during protected event due to impacts of destructive winds (lines out of service, comms damaged). Considered a conservative estimate (i.e. likely lower probability).*
Effectiveness of upgraded SIPS	90%	90%	90%		*Improved detection mechanism, real-time monitoring of load/battery availability. Still assumes some possibility of not saving all events*
SIPS operates, sheds 250 MW for 1 hr. Cost of load shedding	$ 219,142	$ 328,713	$ 438,284		*Worst-case 250 MW, restored gradually within 1 hr*
Remaining benefit	$ 3,427,381	$ 6,508,518	$ 10,501,285		*i.e. benefit of reducing blackout probability by improvement in SIPS effectiveness*
Benefit per event	$ 1,490,166	$ 2,829,790	$ 4,565,776		
SIPS Total capital cost	$ 5,000,000	$ 4,500,000	$ 4,000,000		*2018/19 cost basis*
Annualised capital cost	$ 679,340	$ 611,406	$ 543,472		*10 year lifetime, 6% WACC (https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/2018-Integrated-System-Plan--Modelling-Assumptions.xlsx)*
Annual OPEX	$ 50,000	$ 45,000	$ 40,000		*1% of capital costs*
Annualised cost of SIPS upgrade	$ 729,340	$ 656,406	$ 583,472		
Annual cost of managing event	**$ 1,938,220**	**$ 1,286,031**	**$ 658,682**		*Cost of constraint and SIPS upgrade*
Net benefit per event	$ 647,461	$ 2,270,646	$ 4,279,393		
Annual Net benefit	**$ 1,489,161**	**$ 5,222,487**	**$ 9,842,603**		
Benefit / cost	2.84	10.34	139.63		
Weighting	25.0%	50.0%	25.0%		
Weighted annual benefit	**$ 5,444,185**				

Net Present Value analysis

Sample NPV calculation for the three scenarios previously considered, assuming the annualised costs and benefits do not alter over the lifetime of the upgraded SIPS scheme.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Net Benefit Worst			$ 1,489,161	$ 1,489,161	$ 1,489,161	$ 1,489,161	$ 1,489,161	$ 1,489,161	$ 1,489,161	$ 1,489,161	$ 1,489,161	$ 1,489,161	$ 1,489,161
Net Benefit Neutral			$ 5,222,487	$ 5,222,487	$ 5,222,487	$ 5,222,487	$ 5,222,487	$ 5,222,487	$ 5,222,487	$ 5,222,487	$ 5,222,487	$ 5,222,487	$ 5,222,487
Net Benefit Best			$ 9,842,603	$ 9,842,603	$ 9,842,603	$ 9,842,603	$ 9,842,603	$ 9,842,603	$ 9,842,603	$ 9,842,603	$ 9,842,603	$ 9,842,603	$ 9,842,603
Discounted benefits-Worst			$ 1,300,691	$ 1,215,599	$ 1,136,074	$ 1,061,751	$ 992,291	$ 927,375	$ 866,705	$ 810,005	$ 757,014	$ 707,490	$ 661,205
Discounted benefits-Neutral			$ 4,561,522	$ 4,263,105	$ 3,984,210	$ 3,723,561	$ 3,479,963	$ 3,252,302	$ 3,039,535	$ 2,840,687	$ 2,654,847	$ 2,481,166	$ 2,318,847
Discounted benefits-High			$ 8,596,911	$ 8,034,496	$ 7,508,875	$ 7,017,640	$ 6,558,542	$ 6,129,479	$ 5,728,485	$ 5,353,724	$ 5,003,480	$ 4,676,150	$ 4,370,234

Discount rate	7%
NPV-Worst	**$ 10,436,201**
NPV-Neutral	**$ 36,599,746**
NPV-Best	**$ 68,978,015**

Assuming 2 years before SIPS upgrade fully commissioned, and a 10 year lifetime

Costs in first 2 years same as 'do nothing' scenario. i.e. interconnector constraints already in place

Weighted result	**$ 38,153,427**

Value of Customer Reliability Escalation calculations

VCR numbers used in calculations of cost of blackout events in SA
Escalated from previous survey values using CPI

SA VCR for National Planning (including direct connects)

2014 VCR	2016 VCR	2018 VCR
34.06	34.965	38.112

National CPI

Mar-14	105.4	
Mar-16	108.2	*http://www.ausstats.abs.gov.au/ausstats/meisubs.nsf/0/A27604724363BBBFCA257FA10023195B/$File/64010_mar%202016.pdf*
Mar-18	117.9	*Estimate based on latest inflation rate here: http://www.abs.gov.au/ausstats/abs@.nsf/mf/6401.0*

SACOSS figure

$84.50	2.42	ratio

SRMC calculations used for estimation of Heywood constraint impact

SRMC calculation for gas vs coal, used in calculating market cost of constraining Heywood

Neutral coal price ($/GJ)

Generator	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37	2037-38	2038-39	2039-40	2040-41
	$ 2.03	$ 2.12	$ 2.28	$ 2.40	$ 2.45	$ 2.51	$ 2.57	$ 2.71	$ 2.82	$ 2.90	$ 3.05	$ 3.17	$ 3.31	$ 3.43	$ 3.48	$ 3.52	$ 3.57	$ 3.65	$ 3.70	$ 3.70	$ 3.70	$ 3.70	$ 3.70	$ 3.70
	$ 0.62	$ 0.62	$ 0.63	$ 0.64	$ 0.64	$ 0.65	$ 0.65	$ 0.65	$ 0.65	$ 0.66	$ 0.66	$ 0.66	$ 0.67	$ 0.67	$ 0.67	$ 0.68	$ 0.68	$ 0.69	$ 0.69	$ 0.70	$ 0.70	$ 0.71	$ 0.72	$ 0.72

Generator	Heat rate (GJ/MWh)	Efficiency
	9.73	37.0%
	15.32	23.5%

Generator	Variable OPEX ($/MWh)[1]
	$ 1.03
	$ 1.03

Sent-out SRMC ($/MWh sent-out)

Generator	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37	2037-38	2038-39	2039-40	2040-41
	$ 20.78	$ 21.66	$ 23.21	$ 24.38	$ 24.87	$ 25.45	$ 26.04	$ 27.40	$ 28.47	$ 29.25	$ 30.71	$ 31.87	$ 33.24	$ 34.40	$ 34.89	$ 35.28	$ 35.77	$ 36.54	$ 37.03	$ 37.03	$ 37.03	$ 37.03	$ 37.03	$ 37.03
	$ 10.53	$ 10.53	$ 10.68	$ 10.83	$ 10.83	$ 10.99	$ 10.99	$ 10.99	$ 10.99	$ 11.14	$ 11.14	$ 11.14	$ 11.29	$ 11.29	$ 11.29	$ 11.45	$ 11.45	$ 11.60	$ 11.60	$ 11.75	$ 11.75	$ 11.91	$ 12.06	$ 12.06

Neutral gas price ($/GJ)

Generator	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37	2037-38	2038-39	2039-40	2040-41
	$ 9.50	$ 9.50	$ 9.50	$ 9.50	$ 9.50	$ 9.21	$ 8.93	$ 8.64	$ 8.36	$ 8.38	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17	$ 9.17

Generator	Heat rate (GJ/MWh)	Efficiency
	12.00	30.0%
	11.25	32.0%

Generator	Variable OPEX ($/MWh)[1]
	$ 2.16
	$ 2.16

Sent-out SRMC ($/MWh sent-out)

Generator	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37	2037-38	2038-39	2039-40	2040-41
	$ 116.16	$ 116.16	$ 116.16	$ 116.16	$ 116.16	$ 112.74	$ 109.31	$ 105.89	$ 102.46	$ 102.74	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15	$ 112.15
	$ 109.04	$ 109.04	$ 109.04	$ 109.04	$ 109.04	$ 105.82	$ 102.61	$ 99.40	$ 96.19	$ 96.46	$ 105.28	$ 105.28	$ 105.27	$ 105.28	$ 105.27	$ 105.27	$ 105.27	$ 105.27	$ 105.27	$ 105.27	$ 105.27	$ 105.27	$ 105.27	$ 105.27

Source

https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/2018-Integrated-System-Plan--Modelling-Assumptions.xlsx

Bureau Of Meteorology data on Historic SA Destructive Wind Warnings

10 year period August 2007 to July 2017

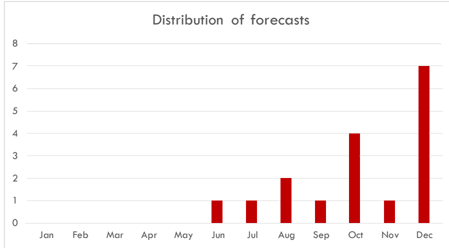
Data provided by BOM for confirmed destructive wind forecasts
Used to calculate the probability of destructive wind forecasts for SA, and the likely times of the year.

Severe Weather Warnings and Severe Thunderstorm Warnings that specifically mentioned the possibility of destructive winds

Adelaide Metro/Mid North/Flinders		Murraylands/Upper South East/Lower South East	
Severe Weather Warning	***Thunderstorm Warning***	***Severe Weather Warning***	***Thunderstorm Warning***
	19 Dec 2007		19 Dec 2007
	21 Dec 2007		
15 Sept 2008		15 Sept 2008	
	27 Nov 2008		
24 Aug 2009		24 Aug 2009	
	21 Sept 2009		21 Sept 2009
			31 Dec 2009
3 Sept 2010		3 Sept 2010	
	7 Dec 2010		7 Dec 2010
20 June 2011		20 June 2011	
	8 Nov 2011		
	9 Nov 2011		9 Nov 2011
	30 Nov 2012		30 Nov 2012
	31 Oct 2014		
		25 July 2015	
	3 Nov 2015		
	4 Nov 2015		4 Nov 2015
		25 July 2016	
28 Sept 2016	28 Sept 2016	28 Sept 2016	
	11 Nov 2016		11 Nov 2016
27 Dec 2016		27 Dec 2016	
	28 Dec 2016		28 Dec 2016
	19 Jan 2017		19 Jan 2017

Sum	Month
1	Dec
1	Dec
1	Sep
1	Nov
1	Aug
1	Sep
1	Dec
1	Sep
1	Dec
1	Jun
1	Nov
1	Nov
1	Nov
1	Oct
1	Jul
1	Nov
1	Nov
1	Jul
1	Sep
1	Nov
1	Dec
1	Dec
1	Jan

Row Labels	Count of Month
Jan	1
Jun	1
Jul	2
Aug	1
Sep	4
Oct	1
Nov	7
Dec	6
Grand Total	**23**



Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	1	2	1	4	1	7	6