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.

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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.

[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 MW[10] 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.

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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.

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[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.