DRAFT POWER SYSTEM FREQUENCY RISK REVIEW REPORT

NON-CREDIBLE LOSS OF MULTIPLE GENERATING UNITS IN SOUTH AUSTRALIA

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AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

The purpose of this publication is to review the potential non-credible loss of the Heywood Interconnector and the consequent islanding of the South Australian power system following the loss of more than one South Australian generating units, and options for future management of these events.

AEMO publishes this risk review report in accordance with clause 5.20A.3 of the National Electricity Rules (Rules). This publication is generally based on information available to AEMO as at 17 July 2017. More recent information may have been included where practical.

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EXECUTIVE SUMMARY

On 30 March 2017, the Australian Energy Market Commission (AEMC) made the National Electricity Amendment (Emergency frequency control schemes) Rule 2017. This requires AEMO, in collaboration with Network Service Providers (NSPs), to undertake an integrated, periodic review of power system frequency risks associated with non-credible contingency events through a Power System Frequency Risk Review (PSFRR).

Such a PSFRR must review non-credible contingency 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[1].
- Network Augmentation.
- Non-network augmentation.

This review considered specifically the non-credible loss of multiple generating units in the South Australian region when South Australia is importing energy from Victoria. Under such conditions (as occurred on 28 September 2016) the loss of multiple generating units could lead to the loss of the Heywood Interconnector, and islanding of South Australia from the rest of the NEM, followed by cascading loss of the remaining South Australian generating units and a black system. The recommendations in this review address this issue and mitigates/reduces the risk of this happening again.

This PSFRR recommends the implementation of an interim EFCS as the most efficient way to mitigate this risk. This interim EFCS is expected to evolve over time to be adaptive and progressively more sophisticated, by utilising the benefits from new technology as it is integrated into the power system over time.

The AEMO *Black System in South Australia - Final Integrated Report*[2] made a number of recommendations to reduce the risks to power system security in South Australia. One of the key recommendations studied and completed to date is the introduction of a minimum system strength requirement for the South Australian region by requiring a minimum quantity of synchronous generators to operate at all times. This establishes a strong base for the management of credible contingencies. It would also increase the inertia within the region and assist in limiting the resulting RoCoF following non-credible disconnection of Heywood Interconnector due to major loss of generation in SA. However, as indicated in the AEMO *Black System in South Australia - Final Integrated Report*, a viable island may not be possible under severe non-credible contingencies. The interim EFCS recommended here will assist in managing non-credible events by reducing the likelihood of separation occurring, hence increasing the likelihood of re-securing the system significantly.

The interim EFCS can be implemented quickly and cheaply to improve power system security. Early studies on the options of new interconnection into South Australia indicate that such infrastructure would also require an EFCS to ensure security, indicating the need for an EFCS even if longer term solutions, such as new interconnectors, are pursued.

The proposed interim EFCS will detect the imminent tripping of the Heywood Interconnector and trip load and, potentially, inject power from grid connected batteries, to stabilise the power system and

1 Clause 4.2.3 (f) of the rules defines a protected event as 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.

2 Power system incident report 28 March 2017. Available at: http://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

avoid a trip of the Heywood Interconnector and the consequential cascading generation trips that would likely follow.

The interim EFCS will use existing infrastructure, together with some additional hardware, to deliver the required outcomes.

AEMO and ElectraNet analysed the performance, costs, and benefits of the proposed interim EFCS. The estimated economic cost to South Australia of the black system event in 2016 is approximately $472 million. ElectraNet's preliminary estimate of the cost of the EFCS is $2 million. Based on experience over the last 18 years, South Australia is estimated to separate from the eastern states every 3.6 years. These figures would indicate a strong net benefit to consumers in South Australia from the implementation of the interim EFCS.

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1. INTRODUCTION

On 30 March 2017, the Australian Energy Market Commission (AEMC) made the National Electricity Amendment (Emergency frequency control schemes) Rule 2017, requiring AEMO, in collaboration with Network Service Providers (NSPs), to undertake an integrated, periodic review of power system frequency risks associated with non-credible contingency events.

Clause 11.97.3 of the National Electricity Rules (Rules) requires AEMO to undertake the first PSFRR within 12 months of the commencement date for the Rule, which is 6 April 2017.

AEMO has commenced work on that review, but the events of 28 September 2016, which resulted in a black system in South Australia, gave rise to an urgent need to undertake a more targeted risk review of the impacts of the loss of more than one generating unit in South Australia at times of high import from Victoria leading to a trip of the Heywood Interconnector and a subsequent cascading loss of the remaining South Australian generating units.

The Rules require a PSFRR to review non-credible contingency events that could involve uncontrolled increases or decreases in frequency leading to cascading outages or major supply disruptions, the current arrangements for the management of these events, and the options for future management.

The PSFRR can recommend:

- New or modified emergency frequency control schemes (EFCSs).
- Declaration of a Protected Event.
- Network Augmentation.
- Non-network augmentation.

This PSFRR is conducted under clauses 5.20A.1 and 5.20A.2, and published under 5.20A.3 of the Rules. The specific focus of the PSFRR is scenarios where the loss of multiple generating units in South Australia could lead to loss of the Heywood Interconnector. This work was foreshadowed in the AEMO *Black System in South Australia - Final Integrated Report*.[3] That report made a number of recommendations to reduce the risks to power system security in South Australia. One of the key recommendations studied and completed to date is the introduction of a minimum system strength requirement for the South Australian region by requiring a minimum quantity of synchronous generators to operate at all times. This establishes a strong base for the management of credible contingencies. It would also increase the inertia within the region and assist in limiting the resulting RoCoF following non-credible disconnection of Heywood Interconnector due to major loss of generation in SA. However, as indicated in the AEMO *Black System in South Australia - Final Integrated Report*, a viable island may not be possible under severe non-credible contingencies. The interim EFCS recommended here will assist in managing non-credible events by reducing the likelihood of separation occurring, hence increasing the likelihood of re-securing the system significantly.

AEMO will continue to work on management of power system security and will investigate future enhancements to the EFCS to further improve its operation.

The full PSFRR, due to be completed in early 2018, will consider a wider range of scenarios across the whole of the NEM (including further consideration of South Australia). That review will consider if additional actions are required to provide further protection for the South Australia region across a broader range of scenarios.

[3] Power system incident report 28 March 2017. Available at: http://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

2. BACKGROUND

2.1 General

On Wednesday 28 September 2016, tornadoes with wind speeds in the range of 190–260 km/h occurred in areas of South Australia. Two tornadoes almost simultaneously damaged a single circuit 275 kilovolt (kV) transmission line and a double circuit 275 kV transmission line, some 170 km apart.

The damage to these three transmission lines caused them to trip. As the number of faults on the transmission network grew, a number of wind farms in the mid-north of South Australia exhibited a sustained reduction in power following the activation of an unknown protection feature. A sustained generation reduction of 456 megawatts (MW) occurred over a period of less than seven seconds.

The reduction in wind farm output caused a significant increase in imported power flowing through the Heywood Interconnector. Approximately 700 milliseconds (ms) after the reduction of output from the last of the wind farms, the flow on the Victoria – South Australia Heywood Interconnector reached such a level that it activated a protection scheme that tripped the interconnector.

The South Australian power system then became separated (“islanded”) from the rest of the NEM. Without any substantial load shedding following system separation, the remaining generation in the region was much less than the connected load and was unable to maintain the islanded system frequency. As a result, all supply to the South Australia region was lost, resulting in a black system.

AEMO’s analysis shows that following system separation and frequency collapse, a black system was inevitable.

The AEMO report into the event, *Black System South Australia 28 September 2016 – Final Report*[4], highlighted the difficulties in forming a stable island in South Australia, and recommended development of special protection schemes that could:

1. Detect abnormal flows on the Heywood Interconnector or events within South Australia that would inevitably lead to separation.
2. Determine appropriate action.
3. Execute this action.

Recommendation 6 of this report (for completion by December 2017) was:

> *“In consultation with ElectraNet, AEMO to investigate the feasibility of developing a special protection scheme that would detect sudden excessive flows on the Heywood Interconnector or serious events within SA and initiate, if necessary, load shedding or generation response with a response time fast enough to prevent separation.”*

Chapter 5 of the 2016 *National Transmission Network Development Plan* (NTNDP)[5] further highlighted that with both the closures and decreasing availability of synchronous power stations, there is now an increased risk that a non-credible contingency will result in a state-wide blackout in South Australia.

2.2 Consultation

2.2.1 ElectraNet

AEMO and ElectraNet have worked extensively to consider the options available and to develop an EFCS to prevent the loss of the Heywood Interconnector following the non-credible loss of more than one generator in South Australia.

[4] AEMO, March 2017. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

[5] AEMO, December 2016. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan.

2.2.2 SA Power Networks and South Australian Jurisdictional System Security Coordinator

AEMO and ElectraNet have consulted with SA Power Networks (SAPN) to determine the suitability of the chosen loads that will form part of the proposed EFCS to provide the required response, while minimising the social and economic impacts of the load shedding. While the proposal is to trip the loads at a transmission connection point level, meaning that no SAPN assets will be utilised as part of the EFCS, SAPN customers will be impacted by the load shedding.

SAPN would also have a role in restoring the load following an event that triggers the EFCS, and appropriate procedures will be developed to ensure this happens in the quickest time, expected to be approximately 30 to 60 minutes.

AEMO and ElectraNet have consulted with the Jurisdictional System Security Coordinator on the details of the proposed EFCS settings and the risks and benefits of the proposed solution.

3. NON-CREDIBLE CONTINGENCY

3.1 Description of non-credible contingency

Following both the closures and decreasing availability of synchronous power stations, there is now an increased risk that a non-credible contingency event at times of high import into South Australia will result in a trip of the Heywood Interconnector and a rapid decrease in local frequency, leading to cascading generation trips within South Australia and a state-wide blackout.

South Australia has separated from the rest of the NEM due to non-credible contingency events five times since 1999, and the likelihood that a region-wide blackout might result from a non-credible separation event has increased as the amount of synchronous generation within South Australia has decreased and the capacity of the Heywood Interconnector has been increased.

In four of the five non-credible contingency events where South Australia has separated from Victoria since 1999, a sudden loss of generation (around 500 MW) in South Australia at times of high import from Victoria resulted in a rapid increase of imports before protection systems disconnected the Interconnector on detected loss of synchronism between South Australia and the remainder of the NEM. While the exact tripping conditions are complex, analysis of these events in the *Black System South Australia 28 September 2016 – Final Report* suggests that the Interconnector's protection will operate at approximately 900 MW[6], depending on system conditions.

AEMO analysis of the South Australian power system for the *Black System South Australia 28 September 2016 – Final Report* found there are a number of factors that influence the resilience of the system, its ability to remain connected to the remainder of the NEM, and its ability to form a stable electrical island following the loss of generation in South Australia. The three key factors are:

- Supply demand balance.
- System strength.
- Management of temporary over-voltages.

In the very short term following a separation event, the inertia of synchronous machines connected to the power system works to resist the change in system frequency if a generator trips from the network, however, if not quickly balanced by shedding of load loss of generation will lead to a significant drop in frequency. The inertia on the power system in South Australia will impact on the rate of change of frequency (RoCoF) following a separation event. A high RoCoF could cause a variety of undesirable consequences in the power system, including generators and load tripping, as well as failure of the under- frequency load shedding (UFLS) scheme to operate as designed.

As highlighted in the 2016 *Update to renewable energy integration in South Australia – Joint AEMO and ElectraNet report*[7], the RoCoF risk has increased with the upgrade of the Heywood Interconnector, increased renewable generation capacity in South Australia, and the closure of Northern Power Station. EFCSs in their current form (such as standard UFLS schemes that are based on pre-set relays that trigger on a specific frequency or RoCoF values) are increasingly unlikely to maintain the power system frequency. This could result in a black system across South Australia from a non-credible separation event during periods of high import from Victoria.

If the interconnector trips, and the South Australian region becomes separated from the rest of the NEM, South Australia no longer has access to online synchronous inertia from other regions. This means the level of RoCoF following a separation will depend on the amount of local inertia in the South Australian region. Depending on the interconnector flow at time of separation, the resulting flows on the

[6] Table 11 of AEMO, *Black System South Australia 28 September 2016 – Final Report*, available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports

[7] Available at: http://www.aemo.com.au/-/media/Files/PDF/Joint-AEMO-ElectraNet-Report_19-February-2016.pdf.

interconnector can be large (in comparison with the amount of synchronous inertia in South Australia), potentially causing a large contingency event with high RoCoF.

Due to online synchronous inertia from other regions, the frequency variations prior to system separation are not sufficient to activate the UFLS scheme.

The loss of generation can also lead to a reduction in the system strength and temporary over-voltages seen by remaining generators within the South Australian region, which will impact on their ability to remain connected.

3.2 Current arrangements for management of non-credible contingency events

In 2016, the South Australian Government introduced regulations to ensure the power system is operated so that there is sufficient synchronous generation online in South Australia such that following the non-credible loss of the double circuit Heywood Interconnector, the level of RoCoF does not exceed 3 Hz/s.

However, for a non-credible loss of more than one generator within South Australia leading to the trip of the Heywood Interconnector under loss of synchronism, AEMO's analysis for the 2016 NTNDP showed that the UFLS scheme is unlikely to protect the South Australian power system from extreme frequency events that could lead to rapid cascading trips of generating units and, ultimately, a black system.

3.3 Likelihood of occurrence

Three of the five non-credible separation events that have been observed to date involved the trip or fast runback of Northern Power Station, which is arguably no longer relevant as it closed in May 2016. However, this supply been replaced by large remote wind farms and changed operation strategies for remaining gas-fired generators, resulting in the South Australian system remaining susceptible to similar events.

Although there is no evidence to suggest that the likelihood of a separation event has increased in recent years, the likely impact of a separation event has significantly increased in severity, due to the changing energy mix and increased interconnector flow. The 2016 NTNDP estimated South Australia separating from the eastern states every 3.6 years (28% probability per year).[8]

3.4 Likely impact of non-credible contingency

In the event of a loss of synchronism separation, the South Australian power system must rely entirely on its own generation and automatic protection systems to balance supply and demand.

Chapter 5 of the 2016 NTNDP considered the issues around improving the South Australian power system's resilience. Based on a projection of historical events and an estimation of their impact, the 2016 NTNDP estimated the economic cost of a black system in South Australia to be approximately $472 million per event and could take 12 hours or more for full restoration of supply. Table 15 of the 2016 NTNDP estimated the probability weighted annual costs of the risk of a black system in South Australia. The 2016 NTNDP costs have been escalated for CPI, and are shown in Table 1.

Table 1 Probability weighted economic cost of blackout risk

Year	Likelihood of state-wide black system[a]	Probability weighted economic cost of blackout risk
2017–18	8%	$38 million
2022–23	8%	$40 million

8 Section 5.2.1, 2016 NTNDP, available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan.

Year	Likelihood of state-wide black system[a]	Probability weighted economic cost of blackout risk
2026–27	11%	$53 million
2032–33	11%	$55 million
2037–38	13%	$61 million

[a] This projection is based on a combination of historic and forecast data, and is intended for economic analysis only.

4. OPTIONS TO MANAGE NON-CREDIBLE CONTINGENCY

The 2016 NTNDP investigated a variety of proposals to improve the South Australian power system's resilience. This included assessment of additional interconnections, which primarily aim to reduce the risk of South Australia separating from the eastern states, and the installation of a number of high-inertia synchronous condensers to increase the resilience of the South Australia power system to events that include separation.

4.1 Constrain Heywood Interconnector

The risks that the trip of multiple generators in South Australia could lead to the trip of the Heywood Interconnector could be reduced through continually limiting the flow on the Heywood Interconnector. This would provide sufficient headroom to cover the loss of generation at all times.

Such a constraint would significantly reduce the efficiency of the wholesale market in South Australia and lead to higher prices to consumers.

4.2 New interconnectors

Two new interconnection paths were investigated in AEMO's 2016 NTNDP:

- An upgrade to the existing VIC–SA interconnector by adding a parallel link between Tungkillo in South Australia and Horsham in Victoria
- An interconnector from Robertstown in South Australia to Buronga in New South Wales.

These new interconnectors are expected to cost between $500 million and $1 billion, depending on length and capacity, and could be commissioned by around 2021 if approved quickly.

A new interconnection would also deliver fuel cost savings by increasing transfer capability between South Australia and the eastern states, thus supporting the growth of new generation in the regions with the best resources.

The 2016 NTNDP analysis showed that a new interconnector could deliver positive net market benefits of approximately $260 million.

Investigations into prospective new interconnectors highlighted that, to improve the South Australian power system's resilience, a key design criterion for any new interconnector is the ability to withstand a possible loss of the other AC interconnector.

To meet this criterion, the 2016 NTNDP suggested that a special protection scheme may be required to rapidly shed load or generation following the loss of one double circuit link.

4.3 Installation of synchronous machines

The 2016 NTNDP also reported that a local mitigation strategy could be designed to improve the resilience of the South Australian power system.

This could be achieved through the installation of suitably designed high inertia synchronous condensers or synchronous generators at strategic locations in South Australia or sourced by contracting with Generators with synchronous machines to remain in service at all times.

Such actions would provide the required levels of inertia and system strength to support the power system, such that:

- The loss of more than one generating unit in South Australia would be unlikely to lead to a loss of synchronism across the Heywood Interconnector.

- If the Interconnector tripped, there would be sufficient inertia within South Australia to give time for the UFLS to operate to prevent a black system.

The 2016 NTNDP estimated the cost of this option at approximately $455 million, and suggested that it could be cheaper if scheduled generation were bid into the market at a more economic price. It estimated the option to result in marginally positive net market benefits ($20 million).

The approximate cost of installing high-inertia synchronous condensers was estimated to be $350 million to $400 million, and, therefore, accounts for the majority of the cost of the local solution. It was estimated that the solution could be implemented by around 2021.

The 2017 South Australian Transmission Annual Planning Report[9] included an contingent project for increasing system strength through the installation of six synchronous condensers at selected locations across the 275 kV transmission network at approximately cost of $60 $80 million.

While the high inertia synchronous condensers required to mitigate the non-credible contingencies highlighted here could be more expensive than those needed to improve system strength, the much lower costs may indicate that this option would be built for a cheaper price.

4.4 New emergency frequency control scheme

As discussed in Section 3.1, AEMO's analysis in the *Black System South Australia 28 September 2016 – Final Report*, showed that because of the current difficulties in forming a stable electrical island in South Australia, it would be preferable to avoid islanding if at all possible. In section 7.2.4 of that report, AEMO recommended the development of a special control scheme that could:

1. Detect abnormal flows and power swings on the Heywood Interconnector, or events within South Australia, that would inevitably lead to separation.
2. Determine appropriate action.
3. Execute this action.

Such a scheme would avoid severe frequency disturbances in South Australia and the potential for cascading generation trips and black system events.

The operation of the control scheme would trip a number of circuit breakers to reduce the load in South Australia, potentially combined with injecting additional energy from grid connected batteries, to manage the loss of generation within South Australia and avoid the trip of the Heywood Interconnector. The load that is tripped could be quickly restored once the flow on the Heywood Interconnector has returned to acceptable levels and the power system is in a satisfactory operating state.

The reinstatement of the load within approximately 30 to 60 minutes, once the power system is in a satisfactory operating state, would limit the economic impact of the event and avoid the potential costs of a black system.

Further, the 2016 NTNDP also determined that a key design criterion for any new interconnector is the ability to withstand a possible loss of the other AC interconnector. To achieve this, AEMO suggested that a special protection scheme may be required to rapidly shed load or generation following the loss of one double circuit link. While the EFCS would need to be reconfigured, the infrastructure developed for the proposed EFCS could form part of this special protection scheme.

[9] 2017 South Australian Transmission Annual Planning Report; available at: https://www.electranet.com.au/wp-content/uploads/2017/06/2017-Transmission-Annual-Planning-Report.pdf

5. EXISTING PROTECTED EVENTS

There are no existing *protected events*.

6. ASSESSMENT OF EXISTING CONTROL SCHEMES

6.1.1 Under-frequency load shedding

There is an existing UFLS scheme in South Australia, designed to return system frequency to normal following multiple generation contingencies. The Rules require 60% of the total load of a region to be connected to under-frequency protection.

In section 3.1.1 of the *Black System South Australia 28 September 2016 – Final Report*, AEMO highlighted that under some conditions the sudden and large deficit of supply following a non-credible contingency event could cause system frequency to collapse more quickly than the South Australian UFLS scheme is able to act. Without any significant load shedding, the large mismatch between the remaining generation and connected load can lead to system frequency collapse, and consequently, a black system.

It is becoming increasingly foreseeable that the UFLS scheme will not work following the non-credible loss of multiple generating units leading to a separation event, such as the event on 28 September 2016. The UFLS did not work on that occasion because the frequency did not drop sufficiently to activate the UFLS scheme prior to system separation, and the low levels of synchronous inertia in South Australia following the separation meant that frequency dropped rapidly before the UFLS could operate. This is expected to be the case for future separation events, because, prior to the separation, system frequency, including that measured in the South Australian region, will be maintained by the whole of the interconnected NEM.

AEMO has reviewed the potential to improve the performance of the UFLS scheme, and concluded that the benefit of an improved UFLS scheme would be very marginal, considering the physical limitations of the network in terms of availability and capability of necessary circuit breakers and relays, and limited availability of higher percentages of operational demand for the UFLS scheme at a given time.

To maintain system stability following a major loss of generation in South Australia, AEMO has concluded there is a need for an EFCS to act on network parameters that reflect the ‘health’ of the power system more quickly than system frequency, and initiate as soon as conditions indicating instability are detected.

This rapid load shedding should avoid separation occurring and maintain supply to most of the South Australian network.

7. PREFERRED OPTION TO MANAGE NON-CREDIBLE CONTINGENCY

7.1 Emergency frequency control scheme

The AEMO *Black System in South Australia - Final Integrated Report*[10] made a number of recommendations to reduce the risks to power system security in South Australia. One of the key recommendations studied and completed to date is the introduction of a minimum system strength requirement for the South Australian region by requiring a minimum quantity of synchronous generators to operate at all times. This establishes a strong base for the management of credible contingencies. It would also increase the inertia within the region and assist in limiting the resulting RoCoF following non-credible disconnection of Heywood Interconnector due to major loss of generation in SA. However, as indicated in the AEMO *Black System in South Australia - Final Integrated Report*, a viable island may not be possible under severe non-credible contingencies. The interim EFCS recommended here will assist in managing non-credible events by reducing the likelihood of separation occurring, hence increasing the likelihood of re-securing the system significantly.

The proposed interim EFCS will detect the imminent trip of the Heywood Interconnector and send signals using ElectraNet's existing dedicated communications to trip loads from ElectraNet transmission connection points within South Australia and, potentially, instigate the injection of power from nominated grid connected batteries.

The relays will be set to trip the load and battery power injection prior to the Heywood Interconnector tripping and so avoid the need to attempt to form an electrical island in South Australia. AEMO and ElectraNet will investigate the technical potential for grid-connected batteries to be triggered earlier to avoid or reduce load shedding.

This load could be quickly restored once the flow on the Heywood Interconnector has returned to acceptable levels and the power system is in a satisfactory operating state.

The main challenge with such a scheme is ensuring secure operation of the scheme while still achieving the required response time for it to be effective in preventing a separation event.

The preferred scheme as currently proposed will detect the imminent trip of the Heywood Interconnector prior to the detection of loss of synchronism by relays in the South East Terminal Station in South Australia. To provide the required discrimination between the proposed EFCS and the loss of synchronism relays and to restore the system to a stable operating state, the interim EFCS will need to shed load, potentially along with power injected from batteries (if technically feasible), very rapidly (nominally within 200 ms).

The load tripped needs to be sufficient to avoid flows on the Heywood Interconnector rising to unsatisfactory levels that would cause it to suffer loss of synchronism and trip. Based on the initial studies, the scheme will be designed to trip approximately 200 MW of load (with a range of 140 MW to 250 MW), as well as potentially instructing a number of grid connected batteries to rapidly inject power into the grid.

ElectraNet and AEMO will investigate the technical feasibility of a future enhancement to the EFCS in which the early triggering of grid connected batteries could reduce the need for or the amount of load shedding required.

ElectraNet and AEMO are considering a number of options for the loads to be tripped, and evaluating these options against a range of selection principles including:

[10] Power system incident report 28 March 2017. Available at: http://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

- Ability to provide the required relief for different periods of the year.
- Ease of load disconnection of loads (number of circuit breakers to open).
- Ease of restoration of loads (avoiding complex and time consuming distribution switching).
- Loads further from the interconnection points provide additional relief as they include transmission losses.
- Loads connected to South East region and Riverland region will affect the transfer capacity via the interconnector paths and tripping of these loads needs to be avoided.
- Targeted loads, such as SA Water pumping loads or air-conditioning compressors, are not suitable as they not always online.

The South Australian Government has announced the results of its tender for the development of 100 MW of battery storage in South Australia, and said that 70 MW of this capacity will be reserved to provide grid stability and power system security. To the extent technically possible, the interim EFCS will include this and other grid-scale batteries into the scheme.

In the detailed design phase of project, AEMO and ElectraNet will investigate the potential for grid connected batteries to be instructed to inject power prior to the instructions to the circuit breakers to shed load.

Under some circumstances, this additional energy may be sufficient to reduce the flows on the Heywood Interconnector to acceptable levels and avoid the automatic tripping of the loads controlled by the interim EFCS. Such action would require the EFCS to detect the potential issue even faster, and for the batteries to respond in a very rapid timeframe.

AEMO is reviewing the proposed scheme and is conducting independent power system modelling studies for a range of potential scenarios to ensure:

- The interim EFCS will operate as designed to reduce the risk of trips of the Heywood Interconnector.
- The risk of false trips of the interim EFCS for conditions that would not, in practice, have led to the trip of the Heywood Interconnector is minimised.

The proposed interim EFCS will reduce the likelihood of the Heywood Interconnector tripping and cascading generation trips in South Australia leading to a black system. Such a scheme cannot protect against all events, however, and a residual risk will remain that events on the network could lead to cascading generation trips that blackout the South Australian region.

False triggering, where the interim EFCS operates for some events that would not have resulted in the trip of the Heywood Interconnector, would be very rare and the load shed would be restored between 30 to 60 minutes after the EFCS triggered.

The proposed interim EFCS is a simple scheme that is designed to initiate fixed load shedding and potentially battery injection.

AEMO and ElectraNet have identified that this interim EFCS contains a number of shortcomings:

- The method of detection of the imminent trip of the Heywood Interconnector is somewhat simplistic. Future work will investigate the benefits from the use of more sophisticated detection technologies, including the use of phasor measurements.
- The interim EFCS will shed load from fixed transmission connection points where the load shed will vary over a large range. An enhanced EFCS may be able to determine the amount of load required to be shed in real-time, and detect the actual load at the transmission connection points to trip the required amount of load.
- There will still be a residual risk that the interim scheme may not operate to avoid the islanding of South Australia and the potential black system. A more comprehensive scheme would further

reduce this residual risk. AEMO will also consider the costs and benefits of backup protection for the EFCS.

Following the implementation of the proposed interim design, AEMO and ElectraNet will assess whether there are benefits in adapting the interim EFCS to be smarter, adaptive, and more secure, with more detailed triggers and load shedding or potentially battery injection tuned, depending on the exact power system conditions and generation mix at the time.

7.2 Emergency frequency control scheme settings schedule

The proposed EFCS will detect the imminent trip of the Heywood Interconnector, and will issue signals to trip load prior to the trip of the interconnector.

At that time, the system frequency in South Australia would not have moved far from the *normal frequency operating frequency band*.

As distinct from the load shedding schedules for UFLS, the *EFCS settings schedule* will not specify the frequencies at which load would be shed, but rather would specify the transmission connection points to be shed, the priority of the loads and, potentially, batteries to be tripped to achieve this.

A number of alternative lists of transmission connection points that could be tripped have been identified, and are being used in the design of the project.

The detailed design will also consider the potential to trigger the use of batteries prior to the shedding of load to minimise the impacts on the South Australian economy.

The *EFCS settings schedule* will also specify the manner and order of the restoration of load following an event.

7.3 Time required to design, procure, and commission the scheme

ElectraNet has been working on the design of the interim EFCS and expects the initial design to be available by 1 September 2017. The settings for relays for the detection of the events will be determined by AEMO and ElectraNet to minimise the risk of false triggers while maximising its ability to avoid the trip of the Heywood Interconnector.

In parallel with ElectraNet's analysis, AEMO has started detailed power system simulation studies to confirm the veracity of the proposed scheme.

Following further consultation with both SAPN and the South Australian Jurisdictional System Security Coordinator, implementation is expected to be complete by 31 December 2017, subject to timely completion of the *EFCS Settings Schedule*.

The scheme will be implemented using new and existing infrastructure, such as protection relays, fibre optic communication cables, and circuit breakers.

The existing communications will need some reprogramming to perform the required tasks of the interim EFCS. ElectraNet believes that this is possible in the time allowed.

7.4 Costs and benefits of the emergency frequency control scheme

ElectraNet has prepared an initial design and cost estimate for the implementation of the interim EFCS, and estimates a total capital cost of approximately $2 million.

Using ElectraNet's current weighted cost of capital, this equates to an equivalent annual cost of approximately $0.5 million over the next five years.

With such a control scheme there always exists a very small possibility of false trips where load may be shed for an event that may not have resulted in a black system. Still, the overall benefit to system security warrants the EFCS and should a false trip occur, customers will be restored as soon as controllers are able to do so.

Using AEMO's latest state-wide South Australian Value of Customer Reliability[11] (VCR), escalated for changes in the consumer price index, the economic cost of limited load shedding following a false operation of the EFCS is estimated at $8 million. Further analysis would be needed to establish an estimate of the likelihood of such an occurrence.

As indicated in Table 1 in section 3.3, the annualised cost of a black system on the South Australian economy is around $38 million, rising to around $61 million over the next 20 years.

These estimates suggest there is significant consumer benefit from the installation of the proposed interim EFCS.

11 AEMO. *Value of Customer Reliability Report*, September 2014. Available at: http://www.aemo.com.au/-/media/Files/PDF/VCR-final-report--PDF-update-27-Nov-14.pdf. The VCR represents, in dollars per kWh, how willing consumers are to pay for reliable supply of electricity, and supports planners, regulators and asset owners to balance reliability and cost to consumers.