Level 22
530 Collins Street
Melbourne VIC 3000

Postal Address:
GPO Box 2008
Melbourne VIC 3001

T 1300 858724
F 03 9609 8080

13 September 2019

Mr John Pierce
Chair
Australian Energy Market Commission
PO Box A2449
Sydney South NSW 1235

AEMC Reference: EPR0057

Dear Mr Pierce

AEMO Submission to AEMC Discussion Paper: Mechanisms to enhance resilience in the power system

AEMO welcomes the opportunity to contribute to the Commission's discussion paper. The guiding principle in AEMO's assessment of key initiatives outlined in the Discussion Paper is whether the changes would help the power system to be more resilient to unknowns that can happen at any time.

AEMO advocates that any changes proposed through this review needs to holistically consider initiatives such as the mandatory primary frequency response rule change which if made, would increase system resilience by significantly helping the power system remain closer to equilibrium at all times.

AEMO supports the proposed extension of the existing power system frequency risk review to a broad range of potential events that may impact other aspects of power system security. This has been referred to as the general power system risk review. In extending the current review framework, with the experience of the initial frequency risk review, AEMO considers it would be beneficial to clarify the review's scope, expectations, sharing responsibilities and establishing implementation pathways.

AEMO considers that the Discussion Paper overstates the significance of cascading failure risk presented by interconnector variability. Monitoring variability of interconnector flows may provide one indicator of health of the NEM, but AEMO considers that a standard is unlikely to assist in addressing the underlying root causes which introduce operational uncertainty. A standard may inadvertently result in inflexible operation and inefficient dispatch outcomes.

AEMO believes until there is clarity about the extent of the issue and its causes and effects, it would be premature to regulate a standard, or impose monitoring and reporting requirements in relation to this single aspect of power system flows. To facilitate a full and considered assessment of the risk, AEMO proposes monitoring how interconnector flows track against applicable constraints, with a view to obtaining a fuller picture of any issues. This can then inform a problem definition, before determining whether any regulatory solution is required.

Australian Energy Market Operator Ltd ABN 94 072 010 327 www.aemo.com.au info@aemo.com.au
NEW SOUTH WALES QUEENSLAND SOUTH AUSTRALIA VICTORIA AUSTRALIAN CAPITAL TERRITORY TASMANIA WESTERN AUSTRALIA

AEMO does not support the n-1 (plus) proposal canvassed in the Discussion Paper. This concept is narrowly defined (limited to renewable generation variability); assumes an ability to forecast and quantify the consequences of indistinct risks on power system assets; and ultimately does not adequately address the most pressing threats to the system during normal operations.

AEMO instead proposes that the modified ‘protected operations’ framework be applied to indistinct risks that present as reasonably possible (indistinct credible risks) rather than the application of a n-1 (plus).

AEMO welcomes the opportunity to discuss our submission further with the Commission. Should you have any questions on the matters raised in our submission, please contact Kevin Ly, Group Manager - Regulation at Kevin.Ly@aemo.com.au

Yours sincerely

Peter Geers
Chief Strategy and Markets Officer

Submission to AEMC Discussion Paper: Mechanisms to enhance resilience in the power system

September 2019

Executive summary

The NEM transition to a de-centralised, de-carbonised and digital power system, together with more diverse commercial influences on generation and demand behaviour, have resulted in a decline in the resilience of the power system to withstand large, sudden changes in frequency, voltage, or other properties. The causes of declining resilience are many, varied, and interdependent, as are the solutions needed to address those causes. These issues are being experienced internationally, as grids worldwide transform to new technologies.

AEMO acknowledges that the scope of the AEMC's review of the South Australia black system event is limited by its terms of reference. However, it must be recognised that if improved power system resilience is the desired outcome, the priorities for regulatory change must focus on, and address, the underlying causes of the decline of inherent resilience in the power system. The measures proposed in the discussion paper alone cannot efficiently improve power system resilience, because they seek to address the symptoms rather than causes of low resilience. The NEM power system needs to be more resilient to unknowns that can happen at any time. Initiatives such as mandatory primary frequency response are necessary to make that happen, by helping the power system remain closer to equilibrium at all times.

AEMO urges caution in considering incremental regulatory change limited to individual aspects of the whole interconnected issue of supply and demand uncertainty. It is important any such changes are flexible and discretionary.

AEMC discussion paper proposals

The AEMC's staff discussion paper *Mechanisms to enhance resilience in the power system – Review of the South Australia Black System Event*, proposes measures to expand the way in which AEMO manages power system security risk from two sources of uncertainty, described in the paper as:

- 'Credible indistinct risks' – the range of variability associated with forecasting uncertainty for weather-dependent renewable energy resources.
- 'Non-credible indistinct risks' – focusing on 'high impact low probability' events.

The paper proposes measures for identifying and managing the impact of these risks:

- For 'credible indistinct risks', adding a variable margin to the largest single credible contingency for which AEMO maintains a secure operating state.
- For 'non-credible indistinct risks', three measures:
  - Expanding the existing power system frequency risk review beyond events that have an impact on frequency, to consider the full range of risks to the power system arising from indistinct non-credible contingencies.
  - Expanding the protected events framework to allow ad hoc protected operation, allowing AEMO to manage 'non-credible' risks emerging in real time.
  - Monitoring interconnector flows against a standard.

AEMO acknowledges the intent of the proposals in the discussion paper is to enable AEMO to take positive action to reduce the likelihood that cascading failures will result either from high levels of variability within dispatch intervals or a large, simultaneous and widespread event. However, AEMO considers there is a simpler and more effective way to improve NEM contingency risk management.

An alternative approach to contingency risk management

There are threats to the power system that are not clearly addressed in the existing contingency framework, yet need to be managed in operational timeframes. In contrast with the categorisation in the AEMC's discussion paper, AEMO considers these as threats that:

- Could cause sudden, large, and (from a timing perspective) unexpected variations in supply or demand that cannot be accounted for in AEMO's forecasting and dispatch systems.
- Are indistinct in the sense that it is not possible to identify which power system assets could be impacted.
- Are nevertheless **credible**, in the normal sense of the word, in the operational time horizon being considered (credible in normal operating conditions, or become credible in abnormal conditions).

A contingency risk management framework that appropriately and effectively incorporates these threats to the power system should:

- Be capable of broad application across a range of sources of uncertainty that can create such risks, including as yet unknown risks.
- Operate within a simple and transparent governance framework, allowing AEMO as the independent system operator to address real-time conditions within and external to the power system, apply professional judgment drawn from experience, and account for the actions it takes as a result.
- Where possible, be implemented through adapting existing regulatory frameworks to be fit for purpose for the power system of today and tomorrow.

With these principles in mind, AEMO suggests a preferable approach as follows.

AEMO proposal

- Redefine and expand the existing concept of a contingency event beyond the failure or removal from service of generation or transmission equipment, to cover any unplanned event that causes a sudden change in the balance of available supply and demand.
  - Most importantly, it must be clear that contingency events can impact identified assets or be distributed across multiple assets, including load. This would be subject to the proviso that under normal conditions AEMO is to keep the power system secure for the largest loss of supply or demand that AEMO considers would result from a single credible contingency event in the NEM (or any region) at any time.
- Revise the concepts of credible and non-credible contingencies, moving away from an example-based approach to definitions focusing on the probability of occurrence. In abnormal conditions, AEMO will assess and if necessary reclassify a non-credible contingency as credible, whether it relates to identified assets or a heightened threat of sudden supply or demand changes over a broad area.
  - With these revised contingency concepts, the reclassification criteria will allow AEMO to apply different types of measures to manage non-credible events that have become credible in abnormal conditions, depending on the nature of the risk:
    - For credible distinct (identifiable and quantifiable) events, by applying traditional constraint-based measures such that the power system is expected to remain in a satisfactory operating state in accordance with the power system security principles should that event occur.
    - For credible indistinct (dispersed and non-quantifiable) events, by taking steps within AEMO's control to increase the resilience of the power system to those events, such that the power system is expected to remain in a satisfactory operating state should those events occur.
- Notify reclassification and contingency management measures to the market close to real time, with regular reviews and transparent reporting.
- Retain a more limited protected events regime, limited to high impact events that are foreseeable but remain non-credible at all times, with identifiable control measures that could economically reduce the impact. The operational management of a protected event will be limited to the measures approved as part of the declaration process. These may or may not ensure the power system remains satisfactory.

Response to remaining proposals

In respect of the discussion paper proposals not directly relating to operational contingency risk management, AEMO:

- Agrees with the need for a broader review of power system risks beyond frequency, with an appropriate scope and greater involvement from network service providers in risk identification and quantification.
- Proposes monitoring how interconnector flows track against applicable constraints, with a view to obtaining a fuller picture of any issues. This can then inform a problem definition, before determining whether any regulatory solution is required.

1. Observations on power system operation

1.1 The black system event

The AEMC's terms of reference for this review require it to build on findings from both the AER and AEMO event reports. AEMO's report concluded that the cause of the black system was a loss of synchronism following a sudden reduction in generation due to a control system response to a series of transmission faults experienced by many inverter-controlled generators simultaneously over a wide area.

The power system events that led directly to the black system on 28 September 2016 were non-credible in terms of the current framework. Objectively, however, the conditions on that day presented a credible but not definable threat of multiple impacts on power system equipment across large areas within the South Australia region. With that came a heightened risk of unidentifiable failures, with unknown consequences.

Using the terminology of the AEMC discussion paper, these were 'indistinct, non-credible' events. If we step away from the existing NEM contingency management rules, AEMO suggests they could more appropriately be considered as indistinct but **credible** events in the prevailing conditions.

In the three years since the black system event, the NEM has fundamentally changed in terms of:

- Quantity and technology type of generation normally online.
- Physical and commercial behaviour of generation.
- Significantly greater understanding (through observation and modelling) of the impact of phenomena like low system strength, low inertia, and declining frequency control.
- Mechanisms to identify and control system strength, inertia, and frequency control.

Limiting the focus of the AEMC's black system review to pre- and post-event observations is artificial. The significance of uncertainty resulting from issues like wind feathering and interconnector flow variability is marginal in the broader context of the power system in 2019 and beyond.

1.1.1 Extreme wind cut-out

Wind feathering, or extreme wind cut-out (EWC) was not a material contributor to variability during the storm prior to the South Australia black system, and is not a focus area in the context of resilience.

EWC settings at individual turbines and across wind farms are known. They are established in a way that minimises the reduction in output across an entire wind farm. Many wind turbine control systems are set to respond differently at increasing wind speeds sustained for a decreasing period[1], as experienced at individual or clustered turbines, typically dispersed over a wide area (sometimes tens of square kilometres) at various elevations.

Forecasts for EWC are factored into AEMO's Australian wind energy forecasting system (AWEFS), and AEMO has tools that monitor and manage EWC in dispatch to the extent practicable and override processes that operators can use if necessary.

This contrasts sharply with less predictable variability that occurs more frequently and on a much larger scale from all sorts of weather conditions (both common and extreme), price-related or technical output changes, demand variation, unexpected behaviour of non-scheduled generation, and dispatch non-conformance.

[1] Typically starting at 90 km/h sustained for 10 minutes on average.

1.1.2 Interconnector flows

Under the current NEM design, interconnectors will often exceed their constraint levels at times during a dispatch interval, sometimes materially, because they absorb changes in generation and demand within the two interconnected regions. That is expected and normal and does not of itself indicate the power system is not secure. AEMO's NEM dispatch engine (NEMDE) solves this for the next dispatch interval where it dispatches generators either side of the interconnector accordingly. The flow across the interconnector is a function of economic dispatch. Where there are price differentials between the regions, central dispatch will seek to maximise flows of cheaper electricity into the more expensive region.

The speed and frequency of changes in output of electronically-connected generation could be causing interconnector flow changes to become more volatile. The extent and impact of any increased volatility is yet to be established, however. To avoid unintended outcomes of changes to the regulation of interconnector flows, it is essential to first understand the extent of any issues and their impact in the overall context of variability in NEM dispatch.

1.2 Impacts of the energy transformation

Australia is undergoing an unprecedented transformation of generation technology and operation as new clean generation technologies are installed at world-leading rates. This is occurring both across the consumer base as distributed energy resources (DER) and as large-scale generation on transmission and distribution networks. The power system will change more in a technical, operational and market sense over a decade than it has in the last century, driving a rapid need for new principles and guidelines for managing uncertainty and risk in a very fast changing system and market context.

Modern power systems across the world are entering unchartered territory with rapidly evolving technical, planning and forecasting risks, as more power is supplied by distributed, de-centralised and digital equipment. These risks magnify uncertainty, challenging system and network operators' ability to maintain secure operations under both normal and abnormal operating conditions. Most recently:

- A routine credible contingency on the UK grid on 9 August 2019 (lightning strike resulting in the loss of approximately 500 MW embedded generation) saw the almost simultaneous loss of a further 1,378 MW of generation at two geographically and technologically separate plants. Interim reporting[2] indicates reduction of about 740 MW of generation at an offshore wind farm due to successive protection system responses to a system voltage fluctuation likely associated with the lightning. About 640 MW of generation tripped at a gas-fired power station, initiated by discrepancies on three independent safety critical speed measurement signals to the generator control system. Automatic under-frequency load shedding (UFLS) was activated (about 1.1 million customers representing 5% of load). Frequency and voltage collapse were avoided in this case, as the load shedding successfully stabilised frequency.
  - It is worth noting that in the NEM, the availability of automatic UFLS can vary significantly in some regions depending on the time of day. In periods of high rooftop solar output, the impact of UFLS is reduced and could be insufficient to arrest a frequency drop after a very large generation event. During the current period of transition for the NEM, AEMO is unable to rely solely on UFLS as the resilience measure to prevent cascading failures. As a result, when abnormal conditions make contingencies more likely than normal, it will often be prudent to operate the system more conservatively.
- A black system on most of the Argentinian grid on 16 June 2019 was reportedly initiated by a short circuit disconnecting a 500 kV transmission line, and at the same time an automated system disconnecting a

[2] National Grid ESO, *Interim Report into the Low Frequency Demand Disconnection (LFDD) following Generator Trips and Frequency Excursion on 9 August 2019*, 16 August 2019. A review by the UK's Energy Emergencies Executive Committee and an Ofgem investigation are also underway.

second 500 kV line[3]. No cause has been reported for the second disconnection, and official investigation results are yet to be released.

AEMO is contributing to and collaborating with a range of GO15 and CIGRE members in international working groups and information exchanges dedicated to understanding resilience in the context of modern power systems. In collaboration with international counterparts and drawing on vast experience, AEMO is exploring concepts of operational resilience (broader than the system security risks covered within this review), the relationship between reliability and resilience, characteristics of resilient power systems, and how resilience can be enhanced within regulatory frameworks.

It is important to feed learnings from these forums into the future design of mechanisms and policy positions which enhance overall power system resilience.

1.3 Concepts of resilience

Power system resilience is a multidimensional concept, spanning both physical and temporal scales. The time taken to transition between power system states, the severity of the physical impacts to the system, and the ability of the system to return to satisfactory operation reflect a power system's resilience to sudden shocks.

AEMO's internal work exploring frameworks for power system resilience draws on similar source material to the AEMC in this review[4]. However, AEMO has been able to take a broader view than NEM concepts of power system security, which are the focus of the AEMC's review.

AEMO's starting point is that a resilient power system not only exhibits 'operational resilience' by resisting and responding to a known or unknown event, but is also inherently resilient. This means power system resilience under normal operating conditions is enhanced and optimised, such that the ability to resist the initial onset of disturbances is prioritised.

A theoretical resilience curve can be used to characterise key phases of a power system's performance in response to a disturbance[5]. These phases are:

- Robustness – the ability to anticipate conditions and withstand the initial shock. Preventative operational flexibility is key.
- Post-degraded state – system resourcefulness, redundancy, and adaptive self-organisation help the system adapt to evolving conditions.
- Operational restoration – the response and recovery of the system to a resilient and acceptable state as soon as possible.
- Post-restoration resistance – maintenance of the system in an acceptable state.
- Infrastructure recovery – returning the system and infrastructure to its robust state.

When considered under a temporal lens, operational resilience (the focus of this review) is only one part of the broader resilience landscape for power systems.

To select the most efficient measures to enhance underlying resilience in a way that improves the system's ability to withstand disturbances from the outset, it is necessary to consider the entire landscape, including:

- Planning and investment resilience – embedding resilience into decision-making processes supporting resource adequacy (such as generation and transmission) planning, investment, and asset development. Methods include concepts of 'least worst regret' and value at risk approaches.

[3] Amy Nordrum, *Transmission Failure Causes Nationwide Blackout in Argentina*, published in IEEE Spectrum, 18 June 2019. Article cites an initial review by CAMMESA as the source of this information.

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

[5] Ibid.

- Infrastructure and value chain resilience – resilience of the entire supply and value chain that supports the electricity system including fuel and logistics. Interlinkages and exposures across each of these separate components must be considered in terms of their potential to impact the system.
- New frameworks for 'insuring the system' – insurance reflects the level of financial protection sought by participants in a system. Currently, the physical and financial loss impacts of interruptions to supply are borne predominantly by consumers who go uncompensated. By exposing electricity sector participants and institutions to loss consequences, natural incentives can be created which improve resilience. Participants are incentivised to act proactively and comprehensively in their measure and management of market risk, shifting away from the predominantly reactive and prescriptive approaches to risk management currently in place.

1.4 NEM resilience initiatives

Since the black system event, and on an ongoing basis, AEMO has initiated or contributed to measures to enhance power system resilience across AEMO's operational, forecasting, and planning responsibilities, deliverables, and decision-making. Progressing from the implementation of the recommendations in AEMO's black system event report[6], some of the significant initiatives and activities intended to enhance resilience in the NEM are listed in Table 1[7] .

Table 1 Implemented, ongoing, and future work to enhance NEM resilience since 28 September 2016

Implemented	Ongoing and future
System strength System strength is a localised ability of the power system to maintain the voltage waveform at any given location, with and without a disturbance. This includes resisting changes in the magnitude, phase angle and waveshape of the voltage. The system strength services framework introduced in 2017[8] requires all new and modified connections to remediate any adverse impacts to system strength that they cause, using three-phase fault levels as a proxy for system strength. Where AEMO declares a system strength shortfall, TNSPs are required to procure the services required to meet the prescribed minimum fault levels. In the interim, AEMO may frequently direct synchronous machines into operation to maintain system strength.	**Review of contingency and regulation FCAS volumes and management** Commencing in March 2019, AEMO adopted a policy of increasing base volumes of Regulation FCAS procured for the mainland in small increments as required after monthly reviews. These reviews are ongoing, and may result in increases up to an initial maximum volume of 250 MW[9]. Monthly updates on the review outcomes are published on AEMO's website[10]. Other frequency management actions are under way or being explored, including review of the volumes and regional allocation of regulation and contingency FCAS; and further AGC tuning.
Inertia The power system requires the presence of sufficient inertia to resist changes in response to a disturbance, allowing for FCAS and ultimately load shedding mechanisms to operate in time to arrest the decline. The *National Electricity* Amendment *(Managing the rate of change of power system frequency) Rule 2017* introduced a similar shortfall framework as for system strength, under which TNSPs must procure inertia services in response to any identified inertia shortfall declared by AEMO.	**Primary frequency response** One of the major improvements to power system resilience in international jurisdictions has been the introduction or tightening of primary frequency response. In 2018, the Federal Electricity Reliability Council of the USA (FERC) mandated primary frequency response for all types of new generation, excluding nuclear and co-generation. The FERC action followed similar requirements in Texas which realised significant improvements in regulation of frequency (balance of supply and demand). AEMO has recently submitted two rule change proposals to remove disincentives to the provision of primary frequency

[6] Relevant recommendations from AEMO's Final Integrated Report on the black system event, March 2017.

[7] Excludes work undertaken and ongoing to improve system restart procedures, processes, and service testing.

[8] Under the *National Electricity Amendment (Managing power system fault levels) Rule 2017*.

[9] See AEMO, Regulation FCAS Changes, March 2019, at https://aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Ancillary_Services/Frequency-and-time-error-reports/Regulation-FCAS-factsheet.pdf.

[10] See AEMO, Frequency and Time Deviation Monitoring, April 2019, at https://aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Ancillary-services/Frequency-and-time-error-monitoring.

Implemented	Ongoing and future
	response under normal operating conditions; and to require all capable scheduled and semi-scheduled generating units to respond to changes in frequency outside a specified dead-band.
Generator technical standards The technical performance standards for connection of generation and the associated negotiation framework in NER chapter 5 were extensively reviewed and amended in 2017-18, drawing heavily on the experience of the black system event. This resulted in the *National Electricity Amendment (Generator technical standards) Rule 2018.*	**Improved forecasting of intermittent generation** Large scale VRG is moving to self-generated, advanced, short-term forecasting for dispatch alongside AEMO's ASEFS and AWEFS systems. In many cases, technological improvements mean that a high degree of correlation between forecast dispatch and actual output can be observed. One of the questions in the ESB's September 2019 Issues Paper on Post 2025 Market Design is how to effectively manage the commitment and dispatch of generation with a much greater proportion of VRG.
Forecast Uncertainty Measure (FUM) for lack of reserve (LOR) conditions AEMO developed the FUM to recognise uncertainty in its assessment of the level of capacity reserves required to maintain reliability and security. This was implemented in early 2018. Since then AEMO has continued to improve the FUM, retraining the underlying Bayesian Belief Network (BBN) models on a quarterly basis, incorporating the use of back cast functionality when analysing and reporting on retraining[11].	**Review of control schemes** AEMO will engage with TNSPs to review the interactions of control schemes in the context of the operating regimes and parameters experienced with new technologies and markets. There has been a considerable increase in the number and complexity of control schemes in the NEM to accommodate new generation and technologies into vast areas of the NEM. The operation, unintended consequences and interactions of both new and old control schemes are being reviewed.
	Planning The Integrated System Plan (ISP) will continue to assess the potential benefits from transmission development and increased interconnection to improve the reliability and resilience of the system and to allow the efficient use of existing and new generation and storage resources. Facilitated by evolving planning models and approaches, AEMO's key focus is on the assessment of how various candidate system plans may build grid resilience to disruptive events such as extreme weather, wind or hydro droughts, fuel supply chain issues and the withdrawal of synchronous generation from the market.
	Understanding the impacts of climate change on the electricity sector In partnership with the Bureau of Meteorology (BoM) and CSIRO, AEMO is developing an approach to value measures that enhance the resilience of the power system and electricity sector to climate change risks, through the adoption of improved climate and extreme weather information which will be incorporated into AEMO's demand and supply forecasting and planning activities.

Notwithstanding these initiatives, a robust contingency risk management framework and protection measures are, and will remain, essential for the secure operation of the power system under normal and abnormal operating conditions. These are complementary to the ongoing need for broad-based, economically efficient enhancements and uplifts in the underlying strength and resilience of the system to withstand sudden and unexpected large-scale changes.

[11] Lack of Reserve Framework reports, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Power-system-operation/NEM-Lack-of-Reserve-Framework-Quarterly-Reports.

1.5 A framework for contingency management

A framework for operational resilience, or contingency management, can take many forms but should be principles-based and outcome-focused. The breadth of the framework will depend on:

- The identification of which risk conditions are foreseeable and manageable.
- The level of risk willing to be accepted.
- The allocation of risk and risk controls to those best placed to manage them.

As underlying resilience of the power system increases or decreases in response to a rapidly evolving operating environment, it is expected that the number, nature, and extent of operator interventions to maintain or restore power system security will change, as will the anticipated risks for which pre-emptive measures are reasonable and prudent.

With these objectives in mind, any contingency management framework needs to allow a suitable level of:

- Flexibility to be adapted and applied proportionately as the underlying level of power system resilience to contingencies changes and additional responses become available.
- Discretion to accommodate quick decision-making by the system operator in the face of both known and uncertain operating conditions and emerging, unencountered, risk conditions which cannot be pre-defined.

A robust contingency management framework will allow for mechanisms which will improve the system's overall ability to withstand disturbances under a variety of known and unknown risk conditions and events without seeking to identify such threats in advance and predefine the potential consequences and the appropriate response. That is an impossible task, and if attempted would quickly become redundant. Knowledge will always be partial, and the existence of 'unknown unknowns' will change and potentially grow in line with the energy transition, climate change, random space weather events, threats associated with coordinated cyber or physical attacks, and digitisation of the electricity supply chain.

1.6 High impact low probability risks/events

The probability of an event occurring, and the magnitude of its consequence, rapidly changes as operating and environmental conditions evolve. For example:

- A low impact high probability (that is, almost certain) event can very quickly become a high impact high probability event in response to unforecastable externalities such as commercial responses to pricing, operation of non-scheduled generation, unexpected variability in load, or weather irregularities.
- A high impact low probability event (such as a tornado impacting transmission lines) can quickly become a high impact high probability event in the space of minutes in response to an unforecast change in wind direction, bringing previously out-of-range assets within its path.

The discussion paper characterised the storm in South Australia and the resulting unforeseen tornadoes and super cells that impacted transmission assets just prior to the 28 September 2016 black system event as an example of a 'High Impact Low Probability' (HILP) event. These were further described as '*more severe disturbances…which occur much less frequently than credible contingency events…and are generally difficult to model. This means their impact is much less predictable, while their probability of occurrence is much less known*'. Section 4 of the AEMC's paper proposes a framework for enhancing resilience to these types of 'non-credible' indistinct events, presenting a range of policy positions intended to address the '*increasing severity of an event*' in Figure 4.3.

While AEMO agrees that HILP events are of increasing operational concern, the suggested nominal categorisation of risks and events based on their 'increasing severity' or supposed probability of occurrence is unlikely to be a workable or robust basis for operational security decision-making into the future. Events or circumstances that may previously have had a low probability of occurring, may now have periods of significantly increased probability due to changes that have occurred in the power system, particularly with dispersed, weather-dependent generation.

In all but a few cases, it is not practical to attempt to pre-identify types of indistinct non-credible events, model their potential impact, and determine mitigation measures in advance. Compartmentalising events and pre-determining assessments of consequence will always be inaccurate, and in many cases will materially over- or underestimate the actions that a reasonable and prudent operator would determine in real time, presented with the actual threat in all the market and system conditions at the time.

In a complex and fast-moving operating environment, as the system operator, AEMO needs to be able to apply its reasonable judgment and experience to the circumstances, to determine the actions necessary to position the power system to withstand credible threats in abnormal conditions, with appropriate transparency and reporting of those decisions. AEMO strongly supports the concept of 'protected operations' in this regard, as further described in Section 3.3 of this submission.

1.7 Distinct vs indistinct risks/events

The distinction between risks and events is often blurred, but important.

In the context of power system management, the aim is to minimise the adverse consequences of **events** impacting the operation of power system equipment. Any number of **risks** can give rise to those events. Some of those risks may be more or less probable at any time, depending on circumstances, conditions, or threats. Others will be constant, such as latent defects, and things that just happen 'out of the blue'.

A risk may threaten an identifiable set of equipment, in which case it will often be possible to quantify the impact of any resulting event and take steps to enable the power system to absorb an impact of that size and location. AEMO understands this to be what is meant by a 'distinct' event, as described in the AEMC discussion paper.

Other risks may threaten the power system, or part of it, more generally. These risks may result in one or multiple events at an unknown location or over a more widespread area. In this case, it will not be possible to quantify the potential impact of resulting events. However, where the risk poses a credible threat of such events, it will be prudent to take measures to increase the resilience of the power system to withstand them. AEMO understands these to be 'indistinct' events, as described in the AEMC discussion paper.

2. Managing credible indistinct events

2.1 AEMC characterisation of the issue

Section 3 of the AEMC's discussion paper seeks to address risks to power system security associated with indistinct events which could be considered reasonably possible and therefore credible. In progressing the design of this mechanism, the AEMC has a particular focus on risks arising from increased generation variability due to distributed weather conditions[12].

[12] The discussion paper does recognise that 'distributed weather conditions are not the sole source of such variability which can include load variability and generator non-conformance with dispatch instructions.' However, the initial policy position and mechanism design is limited to renewable generation variability.

2.2 AEMC proposal to manage variability arising from indistinct events

The AEMC outlines a proposal to maintain a level of headroom, such that the power system is continuously maintained in a secure operating state for a determined 'credible' level of forecast variability from renewable energy resources, to be held in some cases standalone or in addition to the largest credible contingency in a region. The AEMC is considering:

- Adjusting the criteria for AEMO to operate the system in a secure state, to account for the consequences of different forms of variability arising from indistinct events.
- Providing for the use of a probabilistic approach to characterising variability arising from indistinct events relevant to system security settings.
- Setting thresholds for the variability arising from indistinct events requiring management through system security frameworks.

This is described in the discussion paper as an 'n-1 (plus)' power system security criterion.

2.3 Uncertainty during normal operation

The operating reality of the NEM is inherently uncertain, and is becoming increasingly so. Significant variations in power system supply and demand are inevitable in a system characterised by high penetrations of variable renewable generation (VRG) and distributed energy resources (DER).

Fundamentally, AEMO supports mechanisms which assist in the management of risks that introduce uncertainty during normal operation, including, but not limited to, weather contingencies.

A wide range of factors can influence overall supply-demand imbalances which require adjustment in operational timeframes.

VRG variability is only one source of supply-side variability. Table 2 lists common supply and demand side sources of variability and uncertainty.

Table 2 Common sources of variability or uncertainty in operational timeframes

Supply-side	Demand-side
• Unscheduled generation from exempt and non-scheduled systems • Semi-scheduled generation (not required to achieve dispatch forecasts) • Non-conformance of scheduled generation with dispatch instructions • DER output • Generation and portfolio response to market prices, particularly from electronically controlled sources with near-instantaneous response capability • Common protection or control system responses to power system events • Abrupt unforecast weather changes	• 'Normal' residential and industrial operational demand variability, including in response to DER changes in output • Sudden shutdown of large load • Demand behavioural response to market prices • Embedded energy storage system behaviour

For some of these sources, variability can be forecast and built into AEMO systems and processes to inform dispatch. Others are more uncertain. Not all sources of uncertainty are weather-dependent, and not all will present a magnitude of variability which is likely to present a risk to system security. However, the changing dynamics of the power system and complex interactions of external influences mean that greater uncertainty is a reality of power system operation.

While it is true to say that weather-related variability is inevitable, the ability to predict the probability or magnitude of variability occurring from a given set of weather conditions depends on those specific conditions, all of which have multiple permutations[13.]

2.4 AEMO's views on the n-1 (plus) proposal

The NEM will continue to operate with increasing levels of variability and uncertainty. AEMO agrees with the conceptual intent to improve resilience in real time power system security management and operations though does not agree that the proposed design of the n-1 (plus) mechanism is an effective or practical solution to achieve this.

AEMO considers that the n-1 (plus) proposal canvassed in the discussion paper is narrowly defined (limited to renewable generation variability); assumes an ability to forecast and quantify the consequences of indistinct risks on power system assets; and ultimately does not adequately address the most pressing threats to the system during normal operations.

Beyond relatively straightforward weather-dependent variability, there is also increasing risk for a variety of interdependent or coincident responses of power system equipment, which means a high degree of variability could reasonably be expected all the time. The combinations of conditions that produce that variability are not readily predictable, therefore it is also impossible to specify parameters that would enable AEMO to determine an appropriate 'plus'. Even if we consider probabilistic weather forecast variability alone, it is only at the extremes of weather conditions that we experience very steep increases in forecast uncertainty, and at these points there is little statistical data to rely on. In other words, a 'plus' is difficult to pre-determine at the times when it is most likely to be needed.

Where there are specific threats that increase the likelihood of coincident responses, such as a credible cyber-attack, or approaching weather front, AEMO proposes that a more effective and efficient tool for managing operational uncertainty in those conditions is a modified and extended version of the 'protected operations' framework outlined in the AEMC discussion paper.

With respect to the AEMC's assessment principles, AEMO considers the conceptual n-1 (plus) design is not aligned with the principles of efficient framework design, proportionality and technology neutrality.

- *Efficient framework design*:[14] Due to the scope demarcation and focus on EWC, the resultant mechanism design accounts for only one source of variability affecting power system security and reliability of supply. As such, it is impossible to wholly identify and balance all costs and benefits of the mechanism in its current form in order to determine whether procurement of additional reserves under an n-1 (plus) regime will address the most pressing risks and subsequently result in the most efficient outcome. Narrowly defined risk conditions may result in the over- or under-provision of services, inefficient dispatch of services out of merit order, or uneven allocation of risks and responsibilities across the supply chain.
- *Proportionality and materiality*:[15] The conceptual design does not adequately consider whether the intended outcomes can be delivered under existing NEM frameworks. i.e. whether these risks can be addressed through amending the reclassification framework or reviewing FCAS volumes.

[13] Examples of weather contingencies include one or a combination of: Cyclones, storms, wind troughs and fronts, cloud fronts, scudding cloud, lightning, tornadoes, high ambient temperatures, rapid cool changes and warm fronts, sea breezes, wind draughts, sunrise and sunset, solar eclipse, dust storms or density, and solar irradiance.

[14] Definition from Issues Paper: *When assessing new regulatory frameworks [the AEMC] consider whether these frameworks will be able to identify and balance all costs and benefits to determine the most efficient outcome.*

[15] Definition from Issues Paper: When considering the development of new regulatory frameworks, the materiality of current and potential issues must be assessed, including whether issues can be adequately managed under existing frameworks. In doing so, potential changes under-way in the NEM and the ability of current frameworks to adapt and address the consequences of those changes are considered.

- *Technology neutrality*:[16] As mentioned above, the proposed mechanism design targets generation variability associated with VRG technology, ignoring other sources of variability within operational timeframes.

Initiatives which enhance power system resilience have been delivered, or are in the process of being implemented, since the SA black system event as described in section 1.4.

FCAS is currently the primary market tool to manage reasonably anticipated, or credible, variation in the balance of supply and demand. AEMO has recently reviewed and increased regulation FCAS reserves across the NEM in response to a broader range of variations increasing breaches of the normal operating frequency band. A combination of improved primary frequency response and appropriate volumes of regulation FCAS reserves will provide greater resilience to variability at all times. At this stage, AEMO considers that adding a category of 'plus' to a contingency level would introduce additional complexity, and potential costs, without improving operational resilience to the power system.

AEMO recognises that there are new and emerging risks around credible and unknown variability, and several initiatives are being investigated by AEMO, the ESB, and the AEMC to address power system resilience to uncertainty in 'business as usual' ways. The proposed n-1 (plus) operation cannot cater for common sources of uncertainty that present a more critical risk to power system security than the normal range of variability resulting from weather-related causes.

For these reasons, AEMO considers that the n-1 (plus) proposal in its current form is too narrowly scoped and adds unnecessary complexity to the problem (weather-dependent VRG uncertainty) which it seeks to address. Currently, measures to address the consequences of variability in VRG are being addressed by AEMO's review of regulation FCAS volumes and improvements to AEMO's forecasting processes, both of which are practical and transparent. It will never be possible to pre-identify all uncertainties, much less to forecast the extent to which resulting contingency events could impact the power system. New ways of working must anticipate an almost infinite variety of coincidental contingencies of many types that are managed on a 'business as usual' basis. For the time being, and in conjunction with continuous improvement and investment in the accuracy of forecasting techniques, this requires an operational regime that allows the operator the freedom to respond appropriately to the uncertainty and variability in the NEM.

AEMO proposes that the modified 'protected operations' framework be applied to indistinct risks that present as reasonably possible (indistinct credible risks) rather than the application of a n-1 (plus). This is further described in section 3.3 of this submission.

2.5 Further work

AEMO supports future developments which would improve how we understand, quantify, value and ultimately procure additional reserves or system security services that will efficiently support the maintenance of power system security in a transitioning power system. Further work for future system service needs and changes to the NEM design should:

- Provide transparency on the pricing and procurement of these services; and
- Consider the most economically efficient way to value, optimise, procure, dispatch and remunerate these services (i.e. through market or regulatory mechanisms).

Considerations for these objectives must include how the regulatory framework:

- Values, models, quantifies and procures reserves
- Values, models, quantifies and procures system security services (e.g. system strength; inertia)
- Defines these services and reserves (e.g. operating reserves; ramping services; fast frequency services)

[16] *Regulatory arrangements should be designed to take into account the full range of potential solutions. They should not be targeted at a particular technology, or be designed with a particular set of technologies in mind. Technologies are changing rapidly and, to the extent possible, a change in technology should not require a change in regulatory arrangements. Equally, however, regulatory frameworks should not form a barrier to new technologies, to the extent that the use of those technologies is consistent with the physical safety and security requirements of the NEM.*

- Explores market delivery of services (e.g. in or out of market; adjusting existing markets; introduction of new markets)
- Balances operator interventions (e.g. curtailing generation or interconnectors; directing units).

In collaboration with the Energy Security Board (ESB) 2025 market initiative and through reviews such as the AEMC Co-ordination of Generation and Transmission Investment (COGATI) review, AEMO is exploring the short and long-term implications of these fundamental market design challenge.

3. Managing non-credible indistinct events

3.1 Extending the Power System Frequency Risk Review

AEMO supports the proposed extension of the existing power system frequency risk review to a broad range of potential events that may impact other aspects of power system security. In extending the current review framework, with the experience of the initial frequency risk review, AEMO considers it would be beneficial to clarify the review's scope, expectations, sharing responsibilities and establishing implementation pathways.

3.1.1 Benefits and considerations of a general power system risk review

In determining the framework for a general power system risk review (GPSRR), it is important to reflect expectations of what can, and cannot, be practicably scoped within such a review. Alignment on scoping principles will allow a GPSRR to prioritise a recognised or emerging gap within existing risk frameworks supporting power system security and operational resilience.

Initial considerations include:

- The framework should be flexible enough to allow new risk categories to be included or scope-limited at AEMO's discretion as identified through experience.
- A process to enable prioritisation of risks to be considered 'in-scope' for each review being conducted would promote efficiency and value. This would allow the risk review to indeed be 'general' yet focused on the most pressing risks requiring coordinated attention.
- A GPSRR cannot substitute for network service provider (NSP) network planning standards[17], or for broad-based resilience uplifts.
- It may not be practical to combine the minimum inertia and minimum fault level requirements processes with the GPSRR initially, as they focus on specific credible contingency risks and are risks in system normal. The GPSRR considers non-credible contingencies.
- There are significant modelling limitations when it comes to simulation of non-credible contingencies. Existing modelling tools have been designed to cater for simulating credible contingencies, rather than non-credible contingencies, which are vastly more complex. Until advances in modelling tools are available, a GPSRR cannot be expected to be a comprehensive risk review.
- Given the rapid pace of change and evolving uncertainty observed within operational timeframes, the ability to identify all resiliency measures to prevent cascading failure will continually be challenged in the real-time by aspects such as modelling capability, future power system operation, evolution of the

[17] NER S5.1.8 requires that NSPs must consider non-credible contingencies when planning their network and implement schemes to significantly reduce the probability of cascading failure. The GPSRR should not be a substitute for this.

generation fleet, new technology performance characteristics, and interactions between plant and control schemes.

- It should also be noted that changes to operational practices can significantly change the validity of modelling for a risk review. For example, if mandatory primary frequency response were initiated, then analysis performed beforehand will be invalidated. Therefore, some flexibility in terms of the publishing cycle for a GPSRR would be useful, so analysis can be deferred where there is a reasonable prospect of material change. The current PFSRR requirement of "at least every two years" offers some flexibility.

3.1.2 Shared responsibilities

Given the pace of change in the power system, a GPSRR should be able to be completed in a relatively short space of time, but with a relatively high degree of confidence in its results.

This requires an adjustment of expectations on scope and depth, as suggested above, and clarity of the roles and requirements of AEMO and NSPs:

- NSP participation in the GPSRR process may need to be more active, with clear obligations to assist as requested by AEMO.
- Greater cooperation between NSPs may be required, to review the action and interaction of control schemes on different networks.
- AEMO's ability to model distribution networks is currently limited, but in principle AEMO supports the engagement of distribution network service providers (DNSPs) in a GPSRR. DNSP contributions are likely to be particularly relevant in assessing DER response and the efficacy of automatic UFLS schemes.

3.1.3 Implementation pathways

Clear linkages between the GPSRR and planning processes should be drawn in the Rules, including the Integrated System Plan (ISP) where appropriate.

For example, risks identified that cannot be adequately addressed through an emergency frequency control scheme could be incorporated in the ISP as a sensitivity to the least regrets model. This would enable AEMO to assess the impact of the occurrence of the risk under different development paths, and then allow stakeholder consultation to indicate the preference of incurring additional investment costs to mitigate the risk. Depending on the outcome of stakeholder consultation, the additional investment would then be included in the optimal development path that is ultimately selected through the ISP process.

3.2 Enhancing the protected events framework

In principle, AEMO supports the proposal to consider options for streamlining the process and reducing the timeframe between a recommendation for a protected event and its declaration.

However, in view of AEMO's alternative contingency management framework proposed in this submission, and the experience of the recently-completed protected event declaration process, AEMO has identified a number of concerns with the protected events regime that warrant further consideration[18]:

- The protected events framework should only be employed for HILP events where the likely resultant consequences can (a) be confidently **identified**; and (b) be confidently **quantified**, for the economic assessment to be effective. If the event is uncertain or the majority of resultant consequences cannot be confidently identified at the risk assessment phase (for example, random, unforeseeable system or network behaviours resulting in disconnection of plant or line outages), the framework should defer to the 'protected operations' scheme described in Section 3.3 below.

[18] The Protected Events Framework currently allows AEMO to identify one (or more) non-credible contingency events which we consider may be economically efficient to manage using existing ex-ante operational measures. The framework requires AEMO to submit a request to the Reliability Panel to have the event declared to be a "protected event", allowing AEMO to operate the power system in a way that limits the consequences of the declared event.

- Protected events should be limited to high impact events that are foreseeable but will always remain non-credible, with identifiable control measures that could economically manage the outcomes. Events that can become credible in changing conditions cannot readily be accommodated within the protected events framework and should defer to the 'protected operations' scheme described in Section 3.3 below.
- The operational management of a protected event is limited to the measures approved as part of the declaration process. AEMO considers the Rules need amendment to clarify that those measures (having been determined based on a cost-benefit analysis) will not necessarily mean the system will remain in a satisfactory operating state for the occurrence of that protected event. In other words, the Rules should not require AEMO to maintain the system in a secure operating state for protected events as well as credible contingency events.
- Noting the speed with which the power system is changing and new interactions are becoming apparent, consideration should be given to the possibility of recommending the declaration (or cessation) of a protected event by the Reliability Panel outside of a GPSRR process.
- The AEMC discussion paper proposes removing one round of consultation from the Reliability Panel's process for declaring a protected event. Noting that (at present) AEMO is already required to undertake consultation before recommending a declaration, an option for the Reliability Panel to move to an interim declaration in appropriate urgent circumstances could also be considered. Any material capital expenditure on operational management measures would be deferred until a final determination, after consultation.

The difficulties involved in defining an 'indistinct' event as a protected event and applying operational measures within pre-defined limits were starkly illustrated on the first occasion that AEMO invoked the first protected event declared for South Australia, on 8 August 2019, as described in Table 3.

Table 3 Protected event in South Australia, 8 August 2019

Date/Time	Conditions and operational actions
8 Aug 11:02	BoM issues destructive wind warning forecast for multiple areas in South Australia and Victoria.
8 Aug 12:00	After issuing a market notice of protected event, AEMO implements constraint limiting Victoria-South Australia flow to 250 MW.
8 Aug 19:45	Destructive wind forecasts remain current for parts of Victoria and South Australia. Interconnector flows are towards Victoria, therefore the protected event constraint on Victoria-South Australia flow was not binding. AEMO invokes additional constraint limiting South Australia-Victoria flow to 250 MW, given non-credible events (potential impact of abnormal conditions on multiple transmission elements) are more likely. Market notice issued.
8 Aug 23:05	BoM issues revised wind warning with destructive winds still forecast in Victoria and damaging winds in South Australia and New South Wales.
8 Aug 23:55	Conditions for protected event no longer met. Market notice issued. However, AEMO decides to maintain the Victoria-South Australia constraint, given the combination of actual observed wind conditions, varying EWC at large wind farms, damaging wind forecasts across wide areas of all three regions, and expected interconnector flows present heightened risk of impact on multiple transmission elements. 250 MW South Australia-Victoria constraint also remains in place. Market notice issued.

In practice, there are significant limitations on the ability to predict the consequences of a proposed protected event (that is, the amount of unserved energy), determine the probability of occurrence (particularly if it is an event that has never happened before, and noting that subsequent changes in the market can materially impact flow paths), or estimate the costs and benefits of a solution. All these assessments involve a high degree of uncertainty with very wide error margins. This forms a barrier to justification for protected events, making it an impractical tool to manage risks associated with non-credible contingency events in all but the simplest and most severe examples.

The main defences against cascading outage risk are broad-based resilience uplifts that are not event-specific (for example, primary frequency control rule changes, increasing the amount of inertia, maintaining system strength, and frequency droop control) and operator flexibility to respond to abnormal conditions.

3.3 Protected operation

AEMO strongly supports the concept of protected operation proposed in the discussion paper, but considers it should be developed as a framework that allows a proportionate operational response to increased threat levels due to abnormal conditions – essentially, **credible** threats to the power system that could result in indistinct events. Conceptually, it would be an option available to AEMO to respond to identified risks that increase the probability of 'indistinct' events impacting the power system, but cannot be managed by existing reclassification constraints because it is not possible to identify specific assets at risk.

AEMO considers this should be a flexible, ongoing measure, and not only for as yet unidentified risks or as an interim measure pending declaration of protected events.

It is neither practical nor desirable to prescribe a complete list of risk circumstances or response measures, or a maximum permitted level of response. Such limits, while an interesting economic exercise, are more likely to cause system failures by preventing operators applying professional judgment drawn from experience and observation of current conditions.

In short, an inflexible set of parameters removes part of the essential role of the independent operator. Power system controllers are then placed in the position of going against their professional judgment or disregarding the Rules.

3.3.1 Recommended resilience measures

AEMO has recently completed a review of the reclassification criteria, which has been workshopped with the NEM Power System Security Working Group (PSSWG). The review specifically included consideration of dispersed events, and recommended a risk-based approach to network resilience.

The draft proposal endorsed by the PSSWG is summarised in Table 4.

Table 4 PSSWG-endorsed approach to managing distributed risk

Risks to the power system that cannot be managed by reclassification
Risks of a wider geographic nature do not lend themselves to [a reclassification] approach. Such risks might include: • Several transmission lines in the same easement, currently being threatened by a bushfire. Reclassifying all the lines as a single contingency would be operationally impractical (perhaps requiring widespread pre-contingent load shedding). It would be unusual to lose all the circuits simultaneously. • Severe weather (for example, wind speeds >100 km/h) affecting a significant part of a network, where no single reclassification would manage the whole risk. • Widespread pollution on insulators (e.g. salt on coastal lines, soot from bushfires). • Impacts of protection or control system malfunction (including SCADA degradation). • Solar storms and geomagnetic disturbances (due to severe space weather). • Solar eclipse. • Weather forecast uncertainty. • Other "emerging risks" (as yet unappreciated) which may impact power system security. Certain risks mentioned above affect a wider geographical area that cannot be effectively managed solely by the reclassification of a non-credible contingency to a credible contingency. Under such circumstances, AEMO shall adopt a risk-based approach through the application of measures specifically intended to increase network resilience, rather than just a single constraint. Such measures could include (but are not limited to): • Reducing interconnector flows. • Increasing FCAS. • Increasing reactive reserves. • Restoring transmission equipment on outage;

Risks to the power system that cannot be managed by reclassification
• Reducing the largest generation loss in the affected part of the network. • Reducing flows on heavily-loaded lines. • Any other measures agreed with the TNSP for increasing resilience (e.g. sectionalising the network to increase the probability of a viable power island remaining post-contingency). It is appreciated that such measures will not necessarily protect the power system against every possible contingency, and that different measures will be required to manage different circumstances. The main intention is to reduce the probability of a more widespread system incident.

3.3.2 Governance and reporting

AEMO recognises and commits to transparency in operational decision-making.

AEMO already issues market notices whenever it identifies abnormal conditions that have the potential to impact the power system, even if no particular assets at risk can be identified.

In PSSWG discussions about the measures proposed in Table 4, it was proposed that:

- AEMO would issue a market notice if it initiates general resilience measures. The notice would identify the measures put in place and the circumstances giving rise to the need to increase system resilience.
- AEMO would report on the reasons for all such decisions every six months. The report would include an explanation of the factors that AEMO considered relevant, and how effective the measures proved to be.

These transparency measures are commensurate with existing notice and reporting provisions for reclassifications.

3.3.3 Implementation

The regulatory framework necessary to implement this outcome could be achieved by expanding the definition of a contingency event to be capable of applying to any unplanned event that causes a sudden change in the balance of available supply and demand, whether it impacts identified assets or is distributed across multiple assets, including load.

The concept of credible and non-credible contingencies should also be reviewed, moving away from an example-based approach to a definition that is more closely focused on the probability of occurrence. This would be subject to the proviso that under normal conditions AEMO is to keep the power system secure for the largest loss of supply or demand that AEMO considers would result from a single credible contingency event in the NEM (or any region) at any time.

With these revised contingency concepts, it would be possible for the Rules to allow the reclassification criteria (contained in the power system security guidelines) to deal with both distinct and indistinct contingency events that are normally non-credible, but become credible based on abnormal conditions. Once reclassified as credible, the difference would be in the measures applied by AEMO to manage each subset of credible contingency event:

- For credible distinct (identifiable and quantifiable) events, by applying traditional constraint-based measures such that the power system is expected to remain in a satisfactory operating state in accordance with the power system security principles should that event occur.
- For credible indistinct (dispersed and non-quantifiable) events, by taking steps within AEMO's control to increase the resilience of the power system to those events, such that the power system is expected to remain in a satisfactory operating state should those events occur.

This proposal represents a step change away from the way in which contingencies are recognised and addressed in the Rules, but AEMO considers it is a logical step and one that better reflects power system reality. Acknowledging that the changes may present some rule drafting challenges, ultimately AEMO envisages that the outcome could be a relatively simple yet effective regulatory framework for managing power system security.

3.4 Managing interconnector flows

Variability of interconnector flows is a normal operational outcome in the NEM because, under current market and system design, interconnectors themselves cannot be dispatched. Flows will naturally be more variable in an operating environment characterised by growing VRG.

AEMO considers that the discussion paper overstates the significance of cascading failure risk presented by interconnector variability. Interconnector flows are currently managed by dynamic constraint equations that reflect both maximum physical limitations for the interconnecting transmission assets themselves, and current power system conditions in the regions on both sides of the interconnector. There are multiple built-in margins that recognise the potential for variability within a 5-minute dispatch interval, including automated constraints that effectively overcompensate for excess flows above a defined margin.

Monitoring variability of interconnector flows may provide one indicator of health of the NEM, but AEMO considers that a standard is unlikely to assist in addressing the underlying root causes which introduce operational uncertainty. A standard may inadvertently result in inflexible operation and inefficient dispatch outcomes.

Until there is clarity about the extent of the issue and its causes and effects, it would be premature to regulate a standard, or impose monitoring and reporting requirements in relation to this single aspect of power system flows. To facilitate a full and considered assessment of the risk, AEMO will commit to gather interconnector flow data over an appropriate period of time, and identify any observed correlations and trends.